Geology and Ground-Water Resources of Dougherty County Georgia

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1539-P

Prepared in cooperation with the Georgia Department of Mines, Mining, and Geology

Geology and Ground-Water Resources of Dougherty County Georgia

By ROBERT L. WAIT

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1539-P

Prepared in cooperation with the Georgia Department of Mines, Mining, and Geology

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

[Plates 2-6 are in pocket]

TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGY AND GROUND-WATER RESOURCES OF DOUGHERTY COUNTY, GEORGIA

By Robert L. Wait

ABSTRACT

Dougherty County has abundant ground-water resources in beds of limestone and sand, ranging in age from Late Cretaceous to late Eocene. Wells range in depth from about 150 to 1,200 feet.

The Lower Cretaceous series consists of red, bluish-green, and black claystone and siltstone, and white to red to bluish-green sand and sandstone. Some of the Lower Cretaceous sediments are nonmarine.

The Upper Cretaceous rocks consist of a series of alternating sand, gravel, clay, and limestone, which attain a thickness of more than 2,500 feet in Dougherty County. The entire section of Upper Cretaceous sediments was penetrated by two oil-test wells. Several of the Albany city wells penetrate the upper part of the Upper Cretaceous series and obtain water from these rocks. The upper part of the Upper Cretaceous series consists of silty sand underlain by coquina.

The Clayton formation of the Midway group is divided into three units. The basal unit consists of arkosic fine to coarse sand and pebble gravel. The middle or limestone unit is pure, firmly cemented, slightly recrystallized limestone. The upper unit consists of very fine to medium calcareous silty quartz sand. The Midway group ranges in thickness from about 180 to 220 feet.

The Wilcox group consists of the Tuscahoma sand, which is fine to medium glauconitic quartz sand, and silt. The Bashi marl member of the Hatchetigbee formation has been recognized only in city well 15. It was identified from its microfauna.

The Claiborne group includes the Lisbon and Tallahatta formations. The Tallahatta formation consists of three units—siliceous limestone about 20 feet thick, which is overlain by fine to medium sand about 120 feet thick, and coquina about 120 feet thick. The Lisbon formation consists of fine-grained sandy limestone and calcareous sandstone. It may be as much as 100 feet thick.

The Ocala limestone of the Jackson group is exposed in the valley of the Flint River and along Muckalee and Kinchafoonee Creeks. The Ocala ranges in thickness from 70 feet in western Dougherty County to 250 feet in the eastern part. It is a pure limestone, containing as much as 98 percent calcium carbonate.

The Flint River formation is confined to southeastern Dougherty County and is represented mostly by siliceous boulders and residuum.

Terrace deposits of sand and gravel along the Flint River are of Pleistocene age. Dune sand of Pleistocene age is present east of the Flint River, opposite the city of Albany. As much as 30 feet of sand is exposed in road cuts along U.S. Highway 82.

The Upper Cretaceous and Tertiary rocks dip gently to the southeast. The dips range from about 22 feet per mile in the rocks of the Upper Cretaceous series to about 5 feet per mile in the rocks of the Claiborne group. Thickening of the Midway and Claiborne groups downdip accounts for the decrease in dip of the younger rock units.

Upper Cretaceous rocks yield water to wells throughout the county, although no water wells completely penetrate these formations. Yields of as much as 300 gallons per minute have been obtained. The water is of a soft, sodium bicarbonate type, low in dissolved solids, and may contain excessive amounts of iron. The temperature of the water ranges from 72° to 78°F. Saline water is believed to be present at a depth of 2,850 feet, as indicated by the electric log of the J. R. Sealy 1 oil-test well. Flowing wells can be obtained from the Upper Cretaceous rocks except in the immediate Albany area.

Yields as great as 300 gpm can be obtained from the Clayton formation in Dougherty County; yields of 1,700 gpm have been obtained from it in nearby Clay County. Water levels in the Clayton formation have declined as much as 70 feet in Dougherty County since 1881. Water from the lower unit of the Clayton is of the sodium bicarbonate type. Water from the limestone unit of the Clayton is of the calcium bicarbonate type, as is the water from all succeeding younger formations in Dougherty County.

The Tuscahoma sand is not important as an aquifer in Dougherty County.

The Tallahatta formation is one of the important aquifers in Dougherty County and in the surrounding counties; yields of as much as 1,400 gpm have been obtained from it. The city wells in Albany and the wells at the U.S. Marine Corps Supply Center obtain water from this formation. The water is of the calcium bicarbonate type.

The Lisbon formation may yield ground water to wells in other areas, but it is not an important aquifer in Dougherty County.

The Ocala limestone is the principal source of rural domestic and irrigation water throughout the county, as much as 1,700 gpm having been obtained from it. The water is of the calcium bicarbonate type and is moderately hard to hard. The temperature of the water is 69°F.

Recharge to the Ocala limestone occurs from local rainfall and from changes in stage of the Flint River. Water levels in the Ocala are highest during the late winter and early spring, and lowest during the summer and early fall, when pumpage and evapotranspiration are the greatest.

Total pumpage in Dougherty County is estimated to be about 9 million gallons per day, about two-thirds of which is obtained from wells that penetrate rocks of the Claiborne, Wilcox, and Midway groups and the Upper Cretaceous series, and the remaining one-third from the Ocala limestone.

INTRODUCTION

In 1881, Colonel John Porter Fort completed the first flowing artesian well in Georgia, on his Hickory Level plantation about 20 miles west of Albany. This was a significant contribution to the development and history of southwestern Georgia. Colonel Fort, who was an amateur geologist, was convinced that previous unsuccessful attempts to obtain flowing wells in Georgia were by no means conclusive evidence of a lack of water but were due to improper well construction. Flowing wells had been drilled in Charleston, S.C., about 1848.

Colonel Fort believed that geologic conditions in southwestern Georgia were similar to those at Charleston, and in February 1881 he began to drill his first well. Amid derisive remarks of friends and neighbors, many of whom referred to the attempt to obtain water as "Fort's Folly," drilling continued, and in August, nearly 7 months later, the first water flowed from the well. A depth of 450 feet had been reached, and the flow amounted to about 5 gpm (gallons per minute). The drilling was halted at a depth of 547 feet. The flow had increased with depth, and the water level rose at least 10 feet above the land surface. Colonel Fort achieved what previously had been considered impossible, and people came a great distance to view this new wonder of the world. The road which ran past the plantation was renamed "Artesian Well Road," a name it still bears. Later, the well site and one-quarter acre of land were deeded to the perpetual care of Dougherty County, and a plaque was installed to commemorate the event.

Today we take for granted the water we drink; we turn on the faucet and fill the glass. However, it required the courage and perseverance of men like Colonel Fort to open up new frontiers and make the discoveries that later led to the development of the State's water resources.

After Colonel Fort's success in obtaining a flowing artesian well, the city of Albany decided to avail itself of this new-found resource, and money was appropriated to drill a well. The first city well was completed in 1882, in the intersection of Broad Avenue and Jefferson Street. An iron fence was placed around it, and the water flowed freely from a fountain (McCallie, 1898, pl. 4). After the successful completion of these two wells, many of the citizens of Albany had wells drilled. One of the best known of these was drilled in 1903 by Cornelius Coffey. It was located at 201 Commerce (now Broad) Street, and it supplied water to a public bath house and furnished drinking water as well.

The knowledge that a supply of ground water was available brought tourists to Albany and planters to southwestern Georgia. Albany became known as the "Artesian City." By 1907, three flowing artesian wells had been drilled at the city waterworks, on Roosevelt Avenue between Jackson and Jefferson Streets. The deepest of these was 1,320 feet, nearly 200 feet deeper than any of the present city wells. Wells 1 and 2 were used until after 1941.

Today Albany has a modern waterworks consisting of 12 wells that range in depth from 700 to 1,027 feet and are capable of producing a total of more than 15,000 gpm. Each well is in a brick house, and shrubs and trees are planted to help it blend with the landscape of the residential area. The abundant supply of ground water available in the Albany area and in southwestern Georgia is an extremely valuable resource.

PURPOSE AND SCOPE OF INVESTIGATION

This investigation was made to determine the depth, thickness, areal extent, and water-bearing properties of the principal aquifers in Dougherty County and to determine the chemical quality of the water in them.

Dougherty County was the first county to be studied in southwestern Georgia, partly because of the relative abundance of geologic and hydrologic data available. From 1939 to 1957, much geologic information was compiled from drill cuttings and electric logs gathered from Dougherty and surrounding counties. From 1940 to 1950, Albany was one of the fastest growing cities in the United States, and, in order to meet the demand for water, the city drilled 8 new wells in 9 years. Drill cuttings were obtained from all these wells, and electric logs were obtained from five.

Included in this report are geologic data from wells in Lee, Webster, Calhoun, and Mitchell Counties. (See pls. 3 and 4, sections *A–A′* and *B–B′*.) These sections show changes in the lithologic character and water-bearing properties of the rocks underlying the area. Such information is useful in that part of southwestern Georgia where water is obtained from the limestone and sand aquifers.

LOCATION AND EXTENT OF AREA

Dougherty County is in southwestern Georgia between long 84°00′ and 83°30′ W. and lat 31°25′ and 31°40′ N. Albany, the county seat, is 176 miles south of Atlanta, 90 miles southeast of Columbus, 109 miles southwest of Macon, and 90 miles north of Tallahassee, Fla. (fig. 1). It is the largest city in southwestern Georgia and the center of trade for the area.

Dougherty County is bounded on the east by Worth County, on the north by Lee and Terrell Counties, on the west by Calhoun County, and on the south by Baker and Mitchell Counties. It measures approximately 27 miles from east to west and 13 miles from north to south.

WELL-NUMBERING SYSTEM

In order to facilitate the location of wells, springs, and other features, a well-numbering system based on geographic coordinates is used in this report. In previous reports on Georgia, wells and springs have been numbered serially within each county. The numbering system used here is based on the 5-minute longitude and latitude grid.

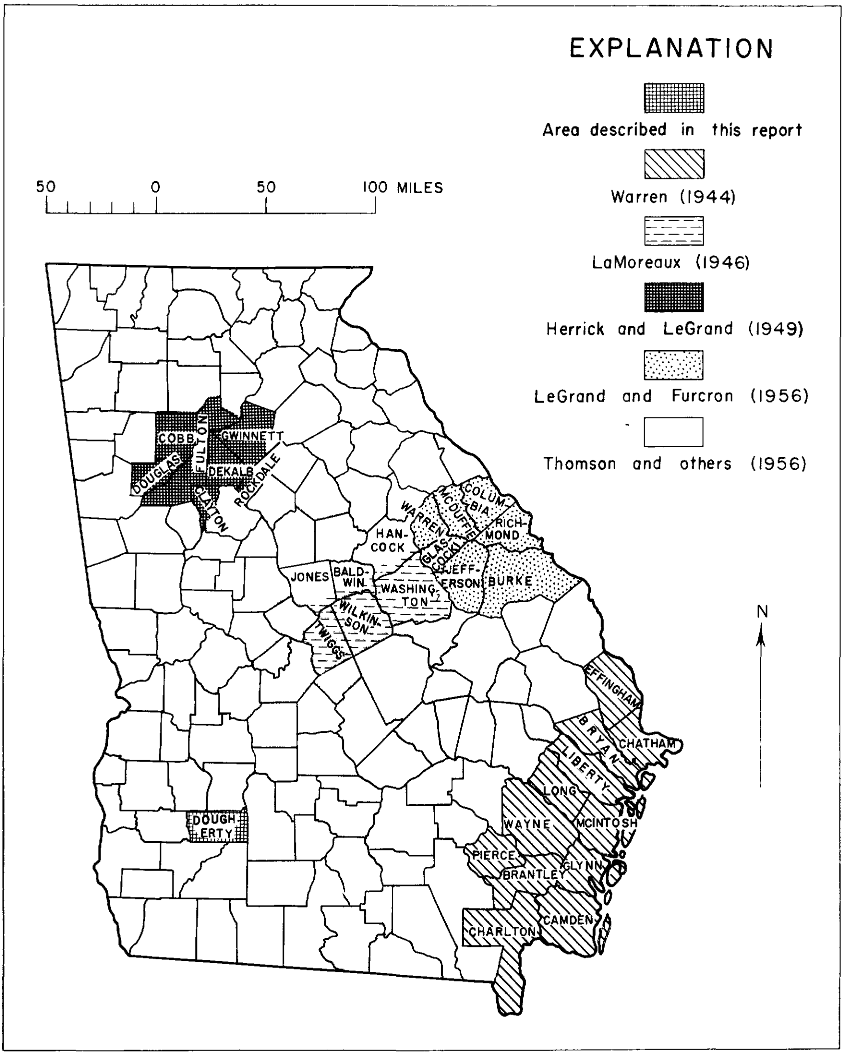


FIGURE 1.—Map of Georgia showing Dougherty County and areas described in previous reports.

Each well is given two 4-digit numbers, separated by a dash, which represent the longitude and latitude, respectively, of the southeast corner of the quadrangle in which the well is located. The final digit, separated by a dash, is the serial number of the well within that quadrangle. Accordingly, the number 8410–3125–1 represents the first well located within the quadrangle bounded on the east by long 84°10′ W. and on the south by lat 31°25′ N. (pl. 2). Thus, the number locates the well to the nearest 5 minutes of longitude and latitude and makes it possible to plot the well on maps of various scales.

Information on the wells referred to in the report may be found in the following tables on file in the Atlanta office:

1. Records of ground-water supplies in Dougherty County.
2. Logs of wells in Dougherty County and adjacent counties.

PREVIOUS INVESTIGATIONS

The first ground-water investigation in Georgia was that of J. W. Spencer (1891). S. W. McCallie in 1898 reported on the artesian well system of Georgia, discussing ground water in the coastal plain. In 1908 he wrote a preliminary report on the underground water of Georgia, in which he discussed the occurrence of ground water in all parts of the State. Both these bulletins contained well logs and chemical analyses of water from several wells in Dougherty County.

Stephenson and Veatch (1915) wrote what is the most comprehensive report to date on the ground-water resources of the coastal plain of Georgia, in which they discussed in detail the geology of the coastal plain and the occurrence of ground water in that area. Logs of wells, chemical analyses of water, and other data concerning wells in Albany are contained in that bulletin. Warren (1944, p. 18a, fig. 2) included the eastern part of Dougherty County in a piezometric map of the coastal plain of Georgia.

Other reports about the ground-water resources of Georgia include bulletins of the Georgia Geological Survey by LaMoreaux (1946), Herrick and LeGrand (1949), LeGrand and Furcron (1956), and Thomson and others (1956). (See fig. 1.)

Previous geologic work includes that of McCallie (1908, p. 32), of Veatch and Stephenson (1911), and of Stephenson and Veatch (1915).

Cooke and Shearer (1918) included a geologic map of the coastal plain of Georgia in their study of deposits of Claiborne and Jackson ages.

In 1939, in commemoration of the 50th anniversary of the Georgia Geological Survey, a geologic map of the State was published. Principal authors were C. Wythe Cooke, Geoffrey Crickmay, and Charles Butts. A later report by Cooke (1943) also contained a geologic map of the coastal plain of Georgia.

MacNeil (1947), in his preliminary gas and oil map, included several revisions and generalizations of the Tertiary and Quaternary formations of Georgia.

ACKNOWLEDGMENTS

This investigation is a part of the appraisal of the ground-water resources of the State of Georgia being made by the U.S. Geological Survey in cooperation with the Georgia Department of Mines, Mining, and Geology, Garland Peyton, Director. Work was done under the direct supervision of J. T. Callahan, district geologist of the Geological Survey.

From the U.S. Geological Survey, Stephen M. Herrick, identified the Foraminifera listed and illustrated in the report and assisted in the geologic correlations, Mrs. Doryand Drake drew the figures of the Foraminifera, and Vaux Owen, Jr., described the drill cuttings and made many valuable suggestions.

The author is indebted to Messrs. John M. David and Jack Carlson of the Layne-Atlantic Co. for drill cuttings and for the opportunity to make electric logs of many wells drilled by that company throughout Dougherty and adjacent counties. Mr. William Peebles of the Southeastern Drilling Co., Americus, Ga., furnished the drill cuttings of several wells in Lee and Webster Counties. Mr. F. P. Wuller of Merck & Co., Flint River Plant, furnished pumpage data and water-level measurements from the firm's observation wells. Major G. W. Torbert, USMC, allowed installation of recording gages and furnished data on wells and pumpage from the U.S. Marine Corps Supply Center. Messrs. E. B. Adams and J. L. Davis of the Albany City Water Department supplied information concerning the city wells and extended courtesies during the investigation. The assistance of those specifically mentioned and the many citizens of Dougherty County who allowed water-level measurements to be made in their wells is gratefully acknowledged.

The rock-color chart prepared by the National Research Council (Goddard, 1948) has been used in the well logs of this report in describing the drill cuttings.

PHYSICAL GEOGRAPHY

That part of Georgia south of the Fall Line, a line from Columbus through Macon and Milledgeville to Augusta, is known as the Coastal Plain. The Coastal Plain has been subdivided (Cooke, 1925, p. 17, fig. 2) into six topographic divisions. (See fig. 2.) The topographic division known as the Dougherty Plain includes an area of about 7,000 square miles. Several smaller plains are included within its boundaries but have not been accurately defined owing to lack of topographic maps. (See Cooke, 1925.) The Dougherty Plain extends from near the junction of the Flint and Chattahoochee Rivers in the southwest corner of the State, northward along the Chattahoochee River as far as Blakely, and then northeastward to the Oconee River. It is bordered on the north by the Fall Line Hills and Fort Valley Plateau. The southeast border of the Dougherty Plain follows approximately the outcrop area of the Tampa limestone, which

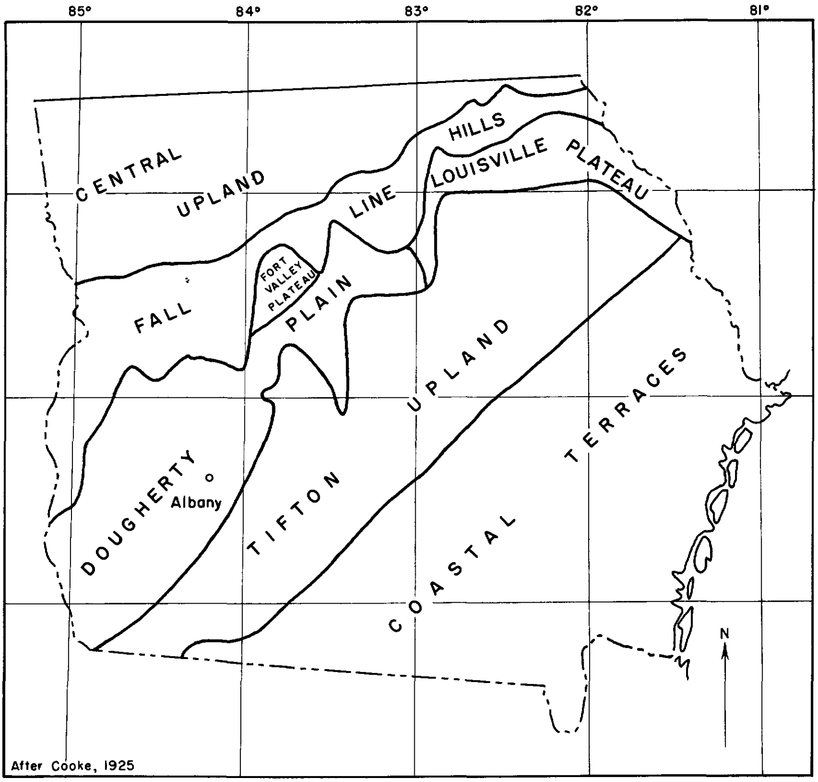


FIGURE 2.—Topographic divisions of the Coastal Plain of Georgia

crops out east of and nearly parallel to the Flint River, from a point north of Cordele in Crisp County southwestward to the junction of the Flint and Chattahoochee Rivers in Decatur County. The Dougherty Plain slopes southeastward from a high point of about 600 feet in the northwestern part of the plain to about 50 feet above sea level at the lowest point near the mouth of the Flint River.

Locally the Dougherty Plain is nearly level, sloping gently to the southward and southwestward on the west side of the Flint River. East of the Flint River, the slopes are slightly steeper and are toward the west and northwest. Altitudes are generally higher along the north border of the county than along the south border, with the exception of the southeast corner of the county near the Worth-Mitchell County line, where the altitude is about 330 feet. This is the highest point in the county and is on the edge of the Tifton Upland.

Altitudes along Chickasawhatchee Creek, which is the west border of the county, range from about 170 feet at the south county line to about 220 feet at the north county line.

The altitude along Cooleewahee Creek, which is about 6 miles east of Chickasawhatchee Creek, is about 165 feet at the south county line. The upland area between these creeks rises to more than 220 feet near Salem Church, slightly northwest of Ducker. Along the south county line from Cooleewahee Creek east to Flint River, about 8 or 9 miles, the land surface rises from an altitude of 180 to more than 200 feet before descending rather sharply into the Flint River valley, where the river is entrenched from 60 to 75 feet. In the city limits of Albany west of Flint River, altitudes are as much as 220 feet above sea level.

Percosin Creek, which flows from the vicinity of the Seaboard Air Line Railroad crossing of U.S. Highway 19 north of Albany southwestward to Cooleewahee Creek, south of Lockett Crossing, lies in a slight depression, altitudes ranging from 175 to 190 feet. This area is marked by many sinkholes.

Along the Flint River, altitudes range from about 225 feet above sea level in the northern part of the county above the Georgia Power Co. dam to about 165 feet at the south border of the county.

From Flint River eastward to the county line, about 14 miles, the elevation increases slightly from about 200 feet just east of the river to about 250 feet in the area of the Marine Corps Supply Center and northward to the county line. From the Supply Center to the southeast corner of the county, the altitude increases to over 330 feet. This gradual ascent, ranging from 8 to 16 feet per mile, increases more rapidly toward the southeast, beyond the east border of the county, as the Tifton Upland is approached.

GEOMORPHOLOGY

Dougherty County is an area of karst or sinkhole topography. Certain conditions must exist for the development of karst topography. The area must be underlain by a soluble rock, such as limestone. The rock must be jointed and bedded so that solution proceeds along restricted channels. The region must have been uplifted sufficiently to cause downcutting of major streams and to allow underground drainage to occur at a rapid rate. Also the area must have sufficient rainfall to dissolve the soluble rock.

Dougherty County is underlain throughout by the Ocala limestone, which is a nearly pure limestone containing about 98 percent calcium carbonate (Brantly, 1916, p. 133). The Ocala limestone is jointed, probably the major jointing pattern is northwest-southeast, although there is very little substantiating surface evidence. Some sinkholes are alined slightly west of south and slightly north of west, as noted on topographic maps of the area. Streams throughout southwestern Georgia follow this general directional pattern. Uplift in southwest Georgia has occurred along the Chattahoochee River (Veatch and Stephenson, 1911, p. 62–65). This structural feature trends north–south, and the axis may be just east of the Chattahoochee River. As evidence of the uplift, Stephenson points out that streams adjacent to the Chattahoochee River are deeply downcut and have short deep courses, and that streams which flow to the Flint River have long shallow courses.

Dougherty County has an average of about 50 inches of rainfall a year, sufficient for solution of the limestone.

Sinkholes in both old age and youthful stages of development are present in Dougherty County. The old-age sinkholes are the more easily recognized of the two. They are nearly circular, with steep sides and nearly flat bottoms, and are about 20 to 25 feet deep and 500 to 1,000 feet wide. The altitudes of the bottoms of several prominent sinkholes southwest of Albany and west of the municipal airport are 170 to 175 feet. This type of sinkhole is thought to be the result of solution that has proceeded for a long enough time to weaken the roof of a cavern and cause it to collapse because of the weight of overlying sediments. These sinkholes are filled with sand, silt, and clay. Water collects in them and stands for several months. In the spring of 1947, several of the sinkholes southwest of Albany were filled with rainwater and remained filled for several months, necessitating rerouting of traffic along Georgia Route 62.

The youthful sinkholes are far more numerous. They are smaller than the old-age sinks, irregular in shape and size, and are areas of interior drainage. Limestone may crop out in them, or a thin covering of residuum 1 to 10 feet thick may be developed in the bottoms. These sinkholes appear to be the result of solution along joints, where solution has not been sufficient to form the caverns necessary to produce the older sinkholes.

Residents report that caverns occasionally collapse. Chimneys of a house on Broad Avenue between Jefferson and Jackson Streets disappeared into caverns beneath the house on two occasions.

In Albany, an attempt was made to construct a lake at the site of a large sink between Harding and Davis Streets and north of Second Avenue. Clay was hauled in to make an impervious bottom, and logs and tree stumps were placed near the center in an attempt to plug the sink. Water was pumped into the hole for several days, and it became partly filled with water; but apparently either the wetting action of downward percolating water loosened the central plug or the added weight of water caused the sinkhole to collapse further. Water and filling material including tree stumps fell into the hole.

Terraces are present along the Flint River in Dougherty County. Prominent terraces are developed along the Flint River north and south of Albany. One terrace lies at an altitude of about 175 feet. The terrace is developed most prominently on the west side of the Flint River south of Albany, between Viola Bend and Radium Springs. Abandoned meanders in these two areas have been filled with cross-laminated sand and gravel deposits. Immediately along the edge of and parallel to the river are a series of disconnected longitudinal bars, which appear to be remnants of a natural levee. This levee is discontinuous, having been breached in many places. Between the natural levee and the old riverbank to the west are several abandoned meanders, which sometimes become flooded. Altitudes in this low area are about 165 feet or slightly less. Excavation has shown that the terrace deposits attain a thickness of 30 feet or more. Thus, the surface upon which the sand and gravel was deposited probably lies at an altitute of 140 to 145 feet. Terrace deposits are being mined just below the confluence of Muckafoonee Creek and the Flint River by the Dawes Silica Co. Similar deposits have been mined immediately across the river.

From the Georgia Power Co. dam to the north boundary of the county, the 175-foot terrace is concealed by ponded water, but a second terrace lies at an altitude of about 195 feet. This terrace is developed prominently on the south bank of the river between Piney Woods Creek and Mercer Grove Church. Examination of the cut banks of an unnamed stream running westward across the terrace shows about a foot of alluvial material, consisting of gray sand. Immediately across the river, deposits of sand and gravel are piled in a crescent shape concave away from the river. These deposits lie at about the same altitude as the terrace on the south side; thus, it appears that cutting and deposition may have occurred at the same time.

East of the Flint River and south of U.S. Highway 82 is a small area covered by dune sand. Road cuts expose about 20 to 30 feet of wind-deposited sand, known locally as the Fossil Sand Dunes. Similar deposits of wind-blown sand have been noted on the east side of several other rivers flowing across the Coastal Plain of Georgia; however, none are as prominent or as isolated as those in Dougherty County. Subaerial deposition of sand of Pleistocene age along the east side of rivers indicates the great length of time that the area has been subjected to westerly winds.

DRAINAGE

The Flint River (fig. 2) is the principal stream in Doughtery County, and all the streams that flow through the county eventually flow into it, some beyond the border of the county. The minor streams

654863 O—63——2

are Kinchafoonee, Muckalee, Chichasawhatchee, and Cooleewahee Creeks. Drainage is toward the south and southeast.

The Flint River flows southward through the eastern part of Dougherty County, dividing Albany from east Albany. Kinchafoonee Creek which flows southward from Lee County, enters Dougherty County near U.S. Highway 19 north of Albany, turns eastward, and flows nearly parallel to the north county line until it joins Muckalee Creek. Muckalee Creek flows southward from the eastern part of Lee County and enters Dougherty County about 2.5 miles east of U.S. Highway 19. Muckalee and Kinchafoonee Creeks join about 1 mile west of the Flint River. From the confluence of these creeks to the Flint River, the stream is called Muckafoonee Creek.

The Flint River is dammed by the Georgia Power Co. hydroelectric plant near the north county line, about 1 mile upstream from the confluence of Muckafoonee Creek and the Flint River. A spillway at the head of Muckafoonee Creek prevents outflow from this creek.

East of Flint River, the drainage is westward and northwestward from the scrap at the west edge of the Tifton Upland. Two small streams, Dry and Piney Woods Creeks, drain the part of Doughtery County that is east of Flint River. Dry Creek originates in the high area in the southwest corner of the county. It flows nearly due west for most of its course and is just north of and parallel to the Dougherty-Mitchell county line. It enters Flint River about half a mile north of the south county line.

Piney Woods Creek flows northward from the vicinity of the U.S. Marine Corps Supply Center and joins the Flint River northeast of Turner Air Force Base.

On the west side of the Flint River, the drainage is southward. No streams enter the Flint River in Dougherty County from the western part of the county.

Chickasawhatchee Creek flows nearly due south and forms the border between Dougherty County and Calhoun County, which lies to the west. It is the main drainage in the western part of Dougherty County. Kiokee Creek, whose two main tributaries are Mud and Tallahassee Creeks, joins Chickasawhatchee Creek about 1 mile north of the Dougherty-Baker county line. These creeks drain the area from Pretoria on the east to a point about 3 miles west of Ducker Station, including the northwest corner of Dougherty County.

Cooleewahee Creek flows southward through Dougherty County slightly east of Pretoria and joins the Flint River near Newton in Baker County. This creek heads about 2 miles south of the Lee-Terrell-Dougherty county line. It is joined by Percosin Creek near Walker Station. Percosin Creek heads in the vicinity of U.S. Highway 19 north of Albany.

CLIMATE

Dougherty County has a mild climate and abundant rainfall. Summers are warm and winters are mild and open.

The average annual rainfall for Albany is 49.29 inches, according to records of the U.S. Weather Bureau (1953). Figure 3 shows the

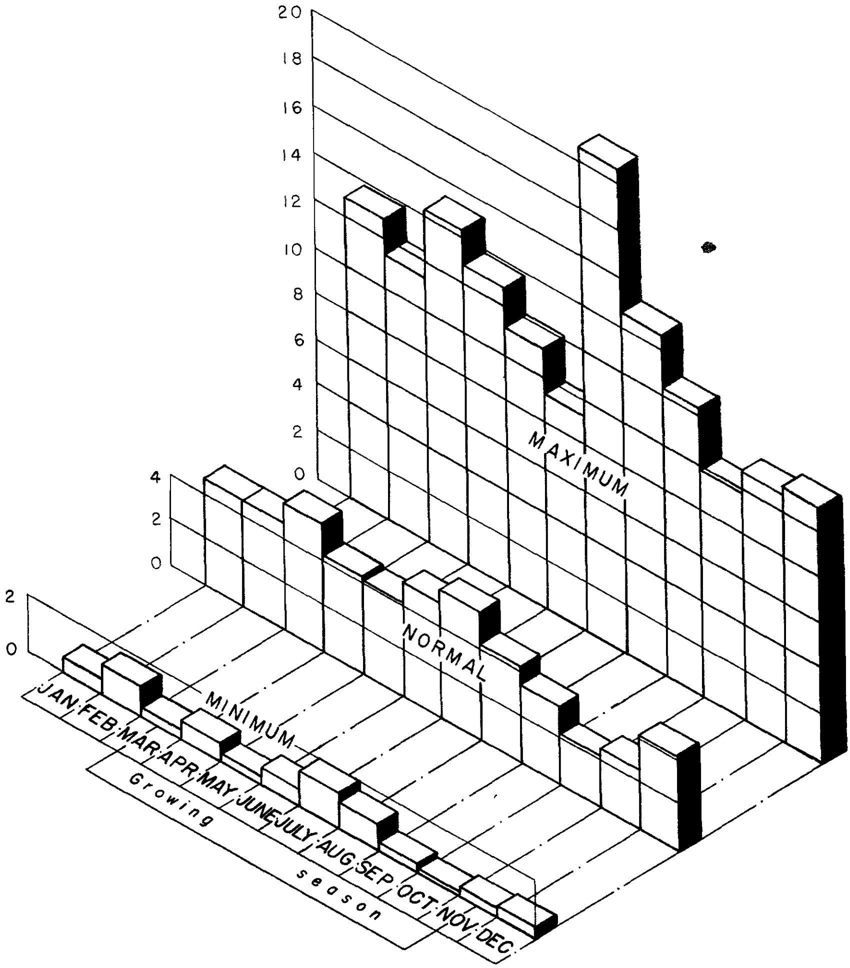


FIGURE 3.—Maximum, normal, and minimum rainfall, 1900–53, Albany, Ga.

maximum, normal, and minimum rainfall by months for the 54-year period, 1900–53. The greatest average rainfall occurs in March, July, and August—5.46, 5.44, and 5.13 inches, respectively. The driest months are October and November, which average 2.09 and 2.37 inches of rainfall, respectively. The maximum rainfall in any 24-hour period was 7.60 inches, on April 12, 1928. The wettest year on record was 1948, when 66.72 inches of rain fell and the driest year on record was 1954, when 31.73 inches of rain fell.

Monthly precipitation and average monthly temperature for the period 1953–57, the period of investigation for this report, are shown in figure 4. During that time, greater than normal rainfall occurred only in 1953 and 1957.

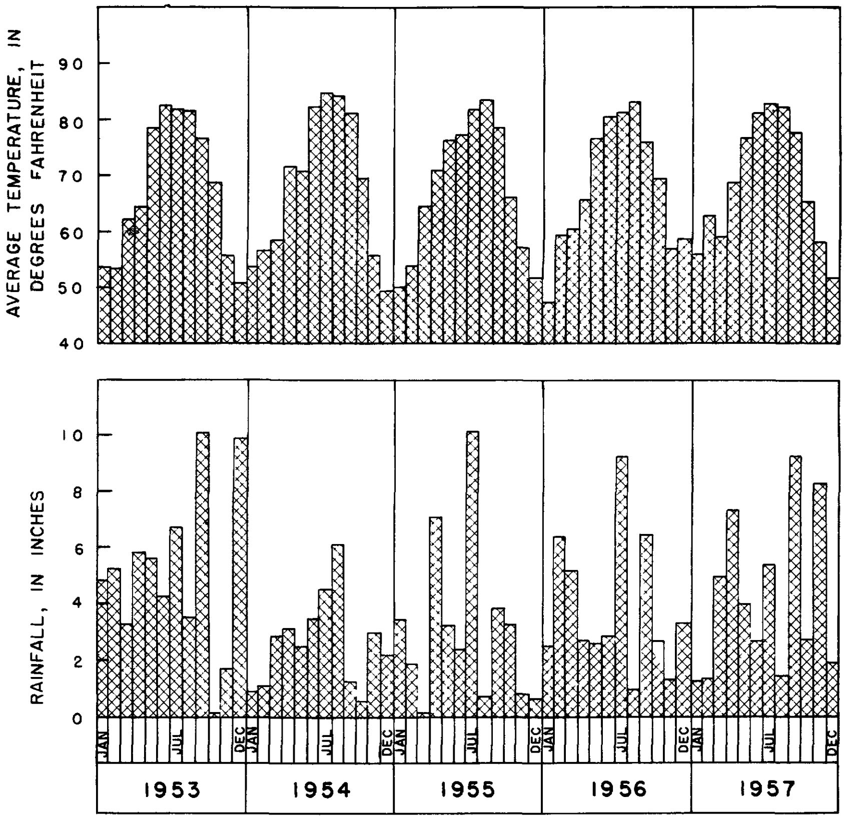


FIGURE 4.—Monthly rainfall and temperature, 1953–57.

Rain falls on an average of 108 days per year. Rainfall totaling 1 inch or more occurs on an average of 15 days per year. Rainfall of 1 inch or more occurred on 9 days during 1957, amounting to 16.45 inches or 35 percent of the annual total.

Snow is uncommon in Dougherty County; it was recorded in measurable amounts only 4 times between 1910 and 1953, ranging from 0.2 to 1.0 inches. The maximum snowfall, according to the Albany Herald, occurred on February 13, 1899, when 4 inches fell.

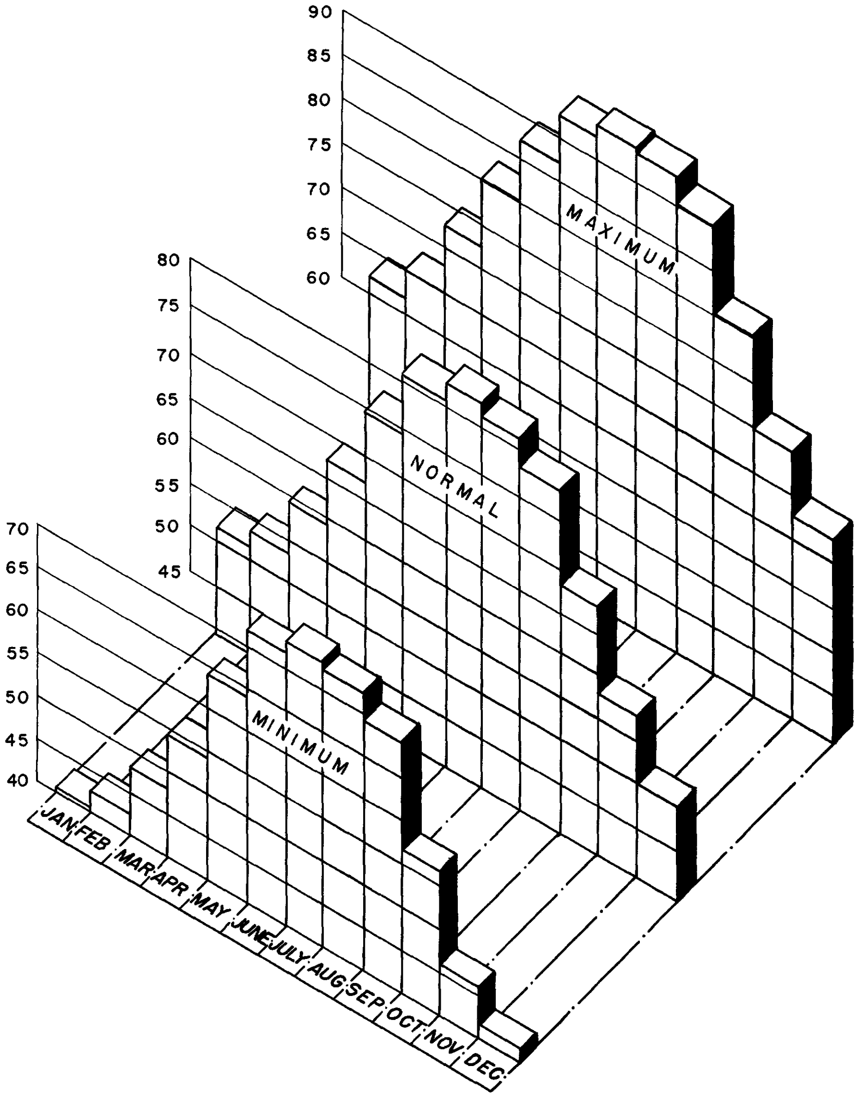


FIGURE 5.—Monthly maximum, normal, and minimum temperatures, in degrees Fahrenheit, Albany, Ga.

The mean annual temperature at Albany is 67.4°F. Average maximum temperature is 78.8°F, and average minimum temperature is 55.9°F, based on records from 1921 to 1950. During the winter, the average daily maximum temperature is 63°F, and the average daily minimum temperature is 41°F. Figure 5 shows the monthly maximum, normal, and minimum temperatures for Albany, based on weather-bureau records for the period 1920–53.

The earliest killing frost on record was October 21, 1913, but the average date for the first killing frost is November 16. The average date for the last killing frost is March 12; the latest on record was April 26, 1910. The average growing season is 249 days per year (fig. 5).

Prevailing wind directions vary throughout the year. The prevailing winds are from the northeast during September, October, and November; the east during April and August; the south during January and March; the southwest during July and May; the west during June; and the northwest during February and December. Wind velocities as high as 60 miles per hour have been recorded. Occasional windstorms and tornadoes occur in this area. On February 10, 1940, a tornado destroyed part of the city of Albany, resulting in $5 million property damage and the death of 19 people.

DEVELOPMENT

Dougherty County is primarily an agricultural area. Chief crops are peanuts, pecans, cotton, livestock, pulpwood, and lumber. Many small industries are located in Albany. Coats and Clark, Inc., which has a thread and yarn mill in east Albany, is the largest industry in the county, the Flint River Cotton Mill is the second largest.

The mineral industry in Dougherty County is represented chiefly by sand companies. In 1954, Albany Lime and Cement Co., Garrett Base Materials Products, Musgrove Sand Co., and Quick Service Sand Co. produced 127,000 tons of sand valued at $119,000 (Vallely and Peyton, 1954, p. 11).

The population of Dougherty County was 28,521 in 1940 and 43,617 in 1950, according to the U.S. Bureau of Census. This represents a 43-percent increase in population during the 10-year period. The population of Albany, the only city and the county seat, increased from 19,055 in 1940 to 31,155 in 1950, according to the U.S. Bureau of Census—an increase of 62.5 percent. The 1956 estimate of the population of Albany was 43,600, according to the local Chamber of Commerce.

TRANSPORTATION

Albany is the transportation center of southwestern Georgia. It is served by 5 railroads, 2 airlines, and State and Federal highways. The railroads serving Albany include the Atlantic Coast Line, Central of Georgia, Seaboard Air Line, Georgia Northern, and the Albany and Northern. U.S. Highway 19 leads north toward Atlanta and south toward Florida. U.S. Highway 82 is the main east-west highway from Albany to Waycross, Ga. Five State highways also radiate from Albany to the smaller southwestern Georgia cities. Eastern Airlines and Southern Airways provide air transportation to and from Albany.

GEOLOGY

The Coastal Plain province in Georgia is underlain by rocks ranging in age from Paleozoic to Recent. (See table 1.) Rocks of Late Cretaceous age and younger crop out in northeastward-trending zones nearly parallel to the Fall Line. The oldest (Late Cretaceous) rocks crop out at the Fall Line, and successively younger rocks crop out to the south. The rocks of the coastal plain dip slightly to the south and southeast, usually at less than 100 feet per mile. Thus, the older rocks are deeply buried south of the outcrop area.

The older rocks must be studied by an examination of drill cuttings and from electric logs of wells. A systematic collection of drill cuttings and electric logs was undertaken in Georgia several years ago. Through the cooperation of the many drillers in the State, a library has been established that contains drill cuttings from more than 500 water wells and oil-test wells drilled throughout the coastal plain. A study of the drill cuttings from wells in Dougerty and surrounding counties has yielded information concerning the depth, thickness, areal extent, and water-bearing properties of rocks in the area.

Dougherty County is underlain by a succession of sand, clay, and limestone to a depth of at least 5,000 feet. Tertiary sediments range in thickness from about 500 feet in the northwestern part of the county to more than 1,000 feet in the southeastern part. Sediments of Late Cretaceous age underlie the Tertiary throughout the county. Data from 2 oil-test wells indicate that the Upper Cretaceous rocks attain a thickness of more than 2,500 feet, below which are sedimentary rocks of Early Cretaceous and Triassic(?) age.

TABLE 1.—*Generalized section of geologic units underlying Dougherty County, Ga., and their water-bearing properties*

System	Series	Group	Stratigraphic unit	Thickness (feet)	Lithologic composition	Water-bearing properties
Quaternary	Pleistocene		Dune sand	0–35	Fine to coarse well-sorted angular to subangular quartz sand. Windblown deposit in small area east of Flint River.	No wells are known to obtain water from these sands; probably not water bearing.
			Terrace deposits	0–20	Gravel, sand, and clay deposits on banks of Flint River.	No wells are known to obtain water from these sands; probably not water bearing.
Tertiary	Oligocene		Flint River formation		Light-gray to yellowish-gray cherty limestone and chert. Occurs as disarranged boulders in residuum. Limited to higher elevations in southeastern Dougherty County. Not recognized in subsurface in Dougherty County.	Not known to be water bearing in Dougherty County.
	Eocene	Jackson	Ocala limestone	130–300	White to very light pink pure to sandy aphanitic oolitic and crystalline limestone. Contains bones of zeuglodonts. Abundant Foraminifera, macroshells, and bryozoa. Overlain by residuum of red to reddish-brown sandy clay and silt, containing abundant chert derived mostly from Ocala limestone but in part from Flint River formation.	Major aquifer. Yields as much as 1,700 gpm to wells. Principal source of domestic, industrial, and irrigation water supplies. Water of calcium bicarbonate type.

Tertiary	Eocene	Claiborne	Lisbon formation	75–100	Yellowish-gray to olive-gray fine-grained calcareous sand and sandstone, arenaceous limestone, and bryozoan limestone. Macroshells, bryozoa, and Foraminifera common. Glauconite and phosphate rare to common.	Sand and limestone, water bearing. Not an important aquifer in Dougherty County.
			Tallahatta formation	214–258	Yellowish-gray to light-olive-gray sandy pelycepod coquina; very light gray phosphatic sand contains fish teeth; basal limestone silicious, glauconitic.	Major aquifer in Dougherty County. Yields of wells as much as 1,400 gpm. Both massive sand and coquina limestone yield water of calcium bicarbonate type.
		Wilcox	Hatchetigbee formation, Bashi marl member	0–24	Light-gray fine calcareous glauconitic sand, containing some "green" quartz; Foraminifera abundant. Recognized only in city well 15.	Recognized from microfauna in city well 15 only. Water-bearing properties not known.
			Tuscahoma sand	90–152	Light-gray, olive-gray, and greenish-gray glauconitic silt and sand. Contains Foraminifera, macroshells, pyrite, and abundant "green" quartz. Lower part is predominantly silt with very fine to fine sand.	Basal sands are water bearing. Several city wells obtain water from this formation.
	Paleocene	Midway	Clayton formation (Upper unit)	32–70	Light-gray very fine to fine calcareous sand with thin beds of foraminiferal limestone. Contains abundant *Operculinoides* and other large Foraminifera.	Thin limestone beds are water bearing. Water of calcium bicarbonate type. Little used in Dougherty County.

TABLE 1.—*Generalized section of geologic units underlying Dougherty County, Ga., and their water-bearing properties*—Continued

System	Series	Group	Stratigraphic unit		Thickness	Lithologic composition	Water-bearing properties
Tertiary	Paliocene	Midway	Clayton formation	Limestone unit	100–110	White to light-gray aphanitic slightly recrystallized limestone. Pure in most of Dougherty County but locally contains abundant sand. Contains small amounts of glauconite and pyrite. Poorly preserved macroshells, chiefly gastropods, abundant.	Excellent aquifer throughout southwestern Georgia. Yields of 250 to 1,700 gpm have been obtained. Water of calcium bicarbonate type. Source of municipal supply in many towns.
				Lower unit	30–50	Light-gray conglomeratic feldspathic glauconitic sand. Locally cemented with calcium carbonate. Contains fragments of macroshells.	Probably poorly water bearing owing to cementing. Water of sodium bicarbonate type.
Cretaceous	Upper Cretaceous undifferentiated				>2, 500	Light- to olive-gray sandy marl and fine to coarse feldspathic calcareous glauconitic sand. Contains abundant Foraminifera, ostracods, and macroshells. Pelecypod coquina near top.	Yields of several hundred gallons per minute are probable. Coquina near top an excellent aquifer. Water is of sodium bicarbonate type, with a slightly high iron content. Wells flow in western Dougherty County.
Lower Cretaceous and Triassic(?)	Pre-Upper Cretaceous					Includes Lower Cretaceous red beds, dark-red and greenish - gray micaceous shales, and white, red, and gray sandstones.	Contains saline water. Oil-test wells drilled into these rocks should be plugged to prevent contamination of overlying aquifers by saline waters.

PALEONTOLOGY

Abundant and well-preserved Foraminifera were obtained from well cuttings. These microfossils are very useful as aids in determining the formational boundaries in the subsurface. Although the large fossils are easily recognized in outcrop samples, they are useless in drill cuttings because they are broken into small pieces by the drill bit. Only the microfossils are usable as guides in drill cuttings, and the more diagnostic fossils for this part of Georgia are listed below, together with the formations in which they occur. The following list of Foraminifera and the illustrations in plate 1 were prepared by Mr. S. M. Herrick, U.S. Geological Survey. The specimens shown in plate 1 have been deposited with the U.S. National Museum.

Stratigraphic unit	*Genus and species*
Flint River formation	*Rotalia mexicana* Nuttall var.
	Quinqueloculina sp.
	Pyrgo sp.
Ocala limestone	*Amphistegina pinarensis* Cushman and Bermudez var.
	Camerina cf. *C. vanderstoki* (Rutten and Vermunt)
	Operculina mariannensis Vaughan*
	barkeri Vaughan and Cole
	Gypsina globula (Reuss)
	Eponides jacksonensis (Cushman and Applin)*
	Lepidocyclina ocalana Cushman
Lisbon formation	*Lepidocyclina (Polylepidina) antillea* Cushman
	Discocyclina (Asterocyclina) monticellensis Cole and Ponton
	Operculinoides sp.
	Asterigerina lisbonensis Cushman and Todd*
	Cibicides westi Howe*
	pseudoungerianus (Cushman) var. *lisbonensis* Bandy*
Tallahatta formation	*Valvulineria danvillensis* (Howe and Wallace) var.*
	jacksonensis Cushman var.
	Reussella subrotundata (Cushman and Thomas)
	Cibicides blanpiedi Toulmin
	tallahattensis Bandy*
Wilcox group (undifferentiated)	*Valulineria wilcoxensis* Cushman and Ponton*
	scrobiculata (Schwager)
	Globorotalia wilcoxensis Cushman and Ponton
	Alabamina wilcoxensis Toulmin*
	Eponides dorfi Toulmin*
	Cibicides howelli Toulmin
Clayton formation	*Robulus midwayensis* (Plummer) Cole and Gillespie*
	degolyeri (Plummer) Bandy
	Discorbis midwayensis Cushman
	midwayensis Cushman var. *trinitatensis* Cushman and Renz

* Illustrated on plate 1.

Stratigraphic unit	*Genus and species*
Upper Cretaceous series, Providence sand.	*Anomalina midwayensis* (Plummer) Cushman
	Cibicides newmanae (Plummer) Cushman
	Eponides lotus (Schwager) Cushman and Ponton*
	Gaudryina rudita Sandidge
	Loxostoma plaitum (Carsey) Cushman
	Anomalina clementiana d'Orbigny *pseudopapillosa* Carsey*

* Illustrated on plate 1.

PRE-UPPER CRETACEOUS ROCKS

Mesozoic rocks of Early Cretaceous age and older may underlie Dougherty County. Applin (1951), Applin (in Reeside, 1957) discussed Triassic(?) sediments taken from wells in Calhoun, Mitchell, and Early Counties. Sowega Minerals Exploration Co., J. W. West 1, at the west edge of Calhoun County about 40 miles west of Albany, penetrated Triassic(?) diabase at depths between 5,190 and 5,265 feet. In Mitchell County about 25 miles southeast of Albany, the Stanolind Oil and Gas Co. J. H. Pullen 1 penetrated Triassic(?) diabase sills or dikes at depths between 6,550 and 6,620, 7,070 and 7,090, and 7,350 and 7,470 feet. A third well, the Mount Warren and others, A. C. Chandler 1, about 60 miles southwest of Albany in southern Early County, penetrated rocks identified as early Paleozoic age at a depth of 6,950 feet.

Applin and Applin (1947) list the following criteria for the recognition of the Lower Cretaceous in wells:

1. Very fine, highly micaceous red clay-shale, having gritty or finely granular texture.
2. The presence of pink sandy limestone nodules at or near the top of the Lower Cretaceous. . . . These may be absent in some wells or below the top of beds.
3. Multicolored sands in the Lower Cretaceous compared to white sands in the lower Atkinson. In southeastern Georgia the sand has pink and amber feldspar; in west Georgia and east Alabama, pink and yellow quartz. It is more even grained than the Atkinson formation.
4. Fragments of fine-even grained pink or bluish-green sand, and occasionally a shale of an unusual bluish-green color.

UPPER CRETACEOUS SERIES

Rocks of the Upper Cretaceous series crop out in a wide northeastward-trending band across the State near the Fall Line. Along the Chattahoochee River, the outcrop area is about 60 miles wide, extending from Columbus southward almost to Fort Gaines. Toward the northeast, the outcrop area narrows and is only about 30 miles wide at Macon, 90 miles east-northeast of Columbus. From Macon eastward to Augusta, the Upper Cretaceous outcrop area becomes even narrower. At places it is scarcely more than 10 miles wide where it is overlapped by the Tertiary formations.

The Upper Cretaceous series in Georgia consists of sand, clay, and a few thin beds of limestone—all of which are of sedimentary origin. Cooke (1943) divided the Upper Cretaceous into six formations; in ascending order they are, the Tuscaloosa, Eutaw, and Blufftown formations, the Cusseta sand, the Ripley formation, and the Providence sand. Eargle (1955) also used this classification in a more detailed study of the Upper Cretaceous rocks in Georgia. LaMoreaux (1946) and LeGrand and Furcron (1956) also studied the Upper Cretaceous series in connection with ground-water studies in eastern Georgia. Warren and Thompson (1943) studied the kaolin-producing area of the Upper Cretaceous series in eastern Georgia. Applin and Applin (1947) studied the Upper Cretaceous rocks in the subsurface in Alabama, Georgia, and Florida.

In this report the Upper Cretaceous series has not been divided into the six formations of Cooke and Eargle. It is not possible to subdivide the Upper Cretaceous rocks in Dougherty County on the basis of information available, as only two wells completely penetrate these rocks. Correlations from the outcrop area are doubtful because of a lack of subsurface data in the intervening area.

Lithology.—Two oil-test wells, Reynolds Brothers J. R. Sealy 1 (8415–3130–1) and Reynolds Brothers J. R. Sealy 2 (8420–3125–1) completely penetrate the Upper Cretaceous rocks in Dougherty County. Sealy 1 penetrated the Upper Cretaceous series between depths of 760 and 3,209 feet. The rocks consist of sand, clay, and some gravel and become progressively finer grained toward the top of the section. The sands are feldspathic and range in color from gray to white. The interbedded clay or shale is gray, pink, purple, and green. Several of the city of Albany wells and one well at the U.S. Marine Corps Supply Center penetrated the uppermost beds of the Upper Cretaceous series. (See pl. 3, section A–A′.) The Upper Cretaceous rocks in the order penetrated by these wells consist of a calcareous silty sand, light olive gray (5*Y* 6/1) [1] to light gray (*N* 7), or an arenaceous marl, light gray (*N* 7), and very fine to fine subrounded to subangular well-sorted quartz sand. Glauconite and pyrite are abundant. The uppermost bed may be as thick as 40 feet. Beneath the marl is a bed of shell limestone, or coquina, light gray (*N* 7), containing very fine to fine subrounded well-sorted clear quartz sand. Pyrite and glauconite are common accessory constituents. The shell-limestone unit appears to persist throughout the county, and it is easily identified on electric logs of wells as the first large "kick"

[1] Number refers to "Rock Color Chart" (Goddard and others, 1948).

below the finer grained material underlying the limestone of the Clayton formation.

Thickness.—The Upper Cretaceous rocks in Dougherty County are 2,538 feet thick in the J. R. Sealy 1 oil-test well in western Dougherty County. From the Fall Line southward, most of the formations in the Coastal Plain thicken. Therefore, it is probable that in southeastern Dougherty County the Upper Cretaceous may be somewhat thicker than in western Dougherty County.

Structure.—Figure 6 is a structure-contour map of the top of the Upper Cretaceous series. It is based on data from wells in Dougherty, Calhoun, Terrell, Lee, and Mitchell Counties. These beds dip gently southeastward at the rate of about 22 feet per mile. It is possible that the dip may increase southeast and south of Dougherty County.

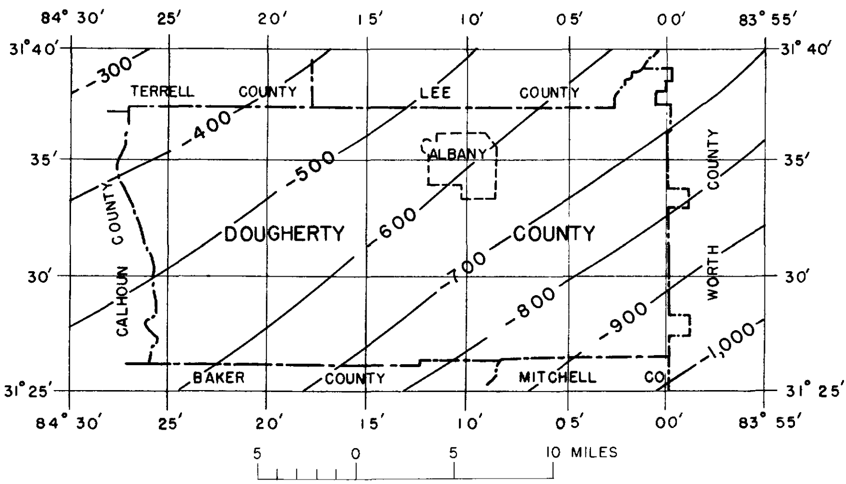


FIGURE 6.—Structure-contour map of the top of the Upper Cretaceous series.

PALEOCENE SERIES

The term "Paleocene series" was used for many years in Europe before it was accepted in the United States for beds formerly designated earliest Eocene. Cooke (1943) was the first to apply the term in Georgia. He referred deposits of the Midway group to the Paleocene series. Previously these beds had been considered lowermost Eocene in Georgia. Cooke (1943, p. 39) stated, "The justification for classifying the Paleocene as a series apart from the Eocene lies in its fauna, which is, perhaps, as individual as that of any other series of the Cenozoic era." Cooke's assignment of the Midway group as being of Paleocene age is followed in this report.

MIDWAY GROUP

The term "Midway" was first used by Smith (1886, p. 14) to describe exposures at Midway Landing on the west bank of the Alabama River in Wilcox County, Ala. It was used then in a restricted sense to refer to a zone now known as the Clayton formation of the Midway group. Harris (1894, p. 303–304) included the Matthews Landing marl, Black Bluff clay, and Midway clay and limestone in the Midway group. Midway group is now used in this broad sense and includes three formations in Alabama. They are the Clayton, the Naheola, and the Porters Creek formations.

CLAYTON FORMATION

Langdon (1891, p. 589–605) used the term "Midway or Clayton group" to describe exposures near Clayton, Barbour County, Ala. He was referring to the same zone as Smith, the zone now regarded as the Clayton formation. Langdon described the Clayton as consisting of

> 8 feet of massive coarse-grained sandstone, almost a conglomerate, 10 feet of light-yellow siliceous limestone with large *Ostrea* and many obscure casts; 200 feet of white calcareous sand containing a few casts of *Ostrea* sometimes irregularly indurated, and containing in the upper 10 feet pockets of white sand enclosed in black clay.

Veatch and Stephenson (1911, p. 216–226) mapped and described the "Midway formation" in Georgia. The Midway formation of their report is the same as the Clayton formation of present terminology. They recognized the presence of the Naheola formation and Porters Creek formation in Alabama but stated that these upper zones were apparently missing in Georgia. Cooke (1943, p. 39) recognized only the Clayton formation of the Midway group.

The Clayton formation overlies the Upper Cretaceous series unconformably and is unconformably overlain by the Wilcox group.

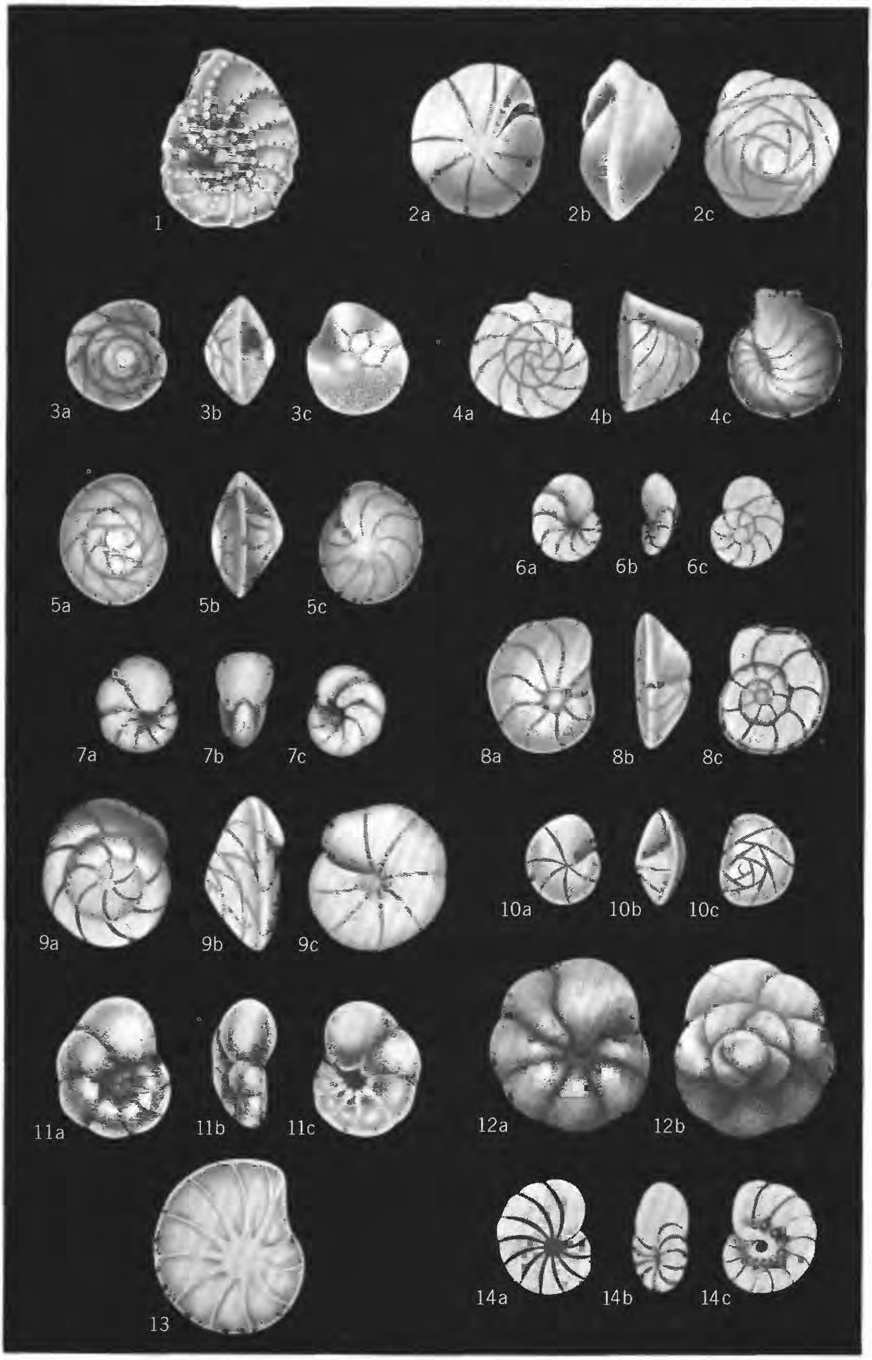
Lithology—The Clayton formation is the only part of the Midway group thought to be present in Dougherty County. In this report the Clayton formation is divided into three units: a lower calcareous sand, a limestone, and an upper calcareous sand.

The lower unit is composed of a firmly cemented calcareous arkosic fine to coarse sand and pebble gravel. This unit is more calcareous in some wells than in others. Color ranges from very light gray (*N* 8) or light gray (*N* 7), to light olive gray (5*Y* 6/1). Feldspar, glauconite, and pyrite are common accessory constituents, and silt may be present. Microfossils are rare, but fragments of macrofossils are common. It is possible that part or all of this lower unit, here placed in the Paleocene, may properly belong to the underlying Upper Cretaceous. However, paleontologic evidence needed to determine the position of the boundary is lacking.

EXPLANATION OF PLATE 1

[Microfossils enlarged ×50 unless otherwise indicated]

1. *Operculina mariannensis* Vaughan.
   Side view; ×12½; Ocala limestone.
2. *Eponides jacksonensis* (Cushman and Applin).
   a, Ventral view; *b*, apertural view; *c*, dorsal view; ×25; Ocala limestone.
3. *Asterigerina lisbonensis* Cushman and Todd.
   a, Dorsal view; *b*, apertural view; *c*, ventral view; ×25; Lisbon formation.
4. *Cibicides westi* Howe.
   a, Dorsal view; *b*, apertural view; *c*, ventral view; Lisbon formation.
5. *Cibicides pseudoungerianus* (Cushman) var. *lisbonensis* Bandy.
   a, Dorsal view; *b*, apertural view; *c*, ventral view; Lisbon formation.
6. *Valvulineria jacksonensis* Cushman var. *persimilis* Bandy.
   a, Ventral view; *b*, apertural view; *c*, dorsal view; Tallahatta formation.
7. *Valvulineria danvillensis* (Howe and Wallace) var. *gyroidinoides* Bandy.
   a, Ventral view; *b*, apertural view; c, dorsal view; Tallahatta formation.
8. *Cibicides tallahattensis* Bandy.
   a, Ventral view; b, apertural view; *c*, dorsal view; Tallahatta formation.
9. *Eponides dorfi* Toulmin.
   a, Dorsal view; *b*, apertural view; *c*, ventral view; Hatchetigbee formation, Bashi marl member.
10. *Alabamina wilcoxensis* Toulmin.
    a, Ventral view; *b*, apertural view; *c*, dorsal view; Hatchetigbee formation, Bashi marl member.
11. *Valvulineria wilcoxensis* Cushman and Ponton.
    a, Dorsal view; *b*, apertural view; *c*, ventral view; Hatchetigbee formation, Bashi marl member.
12. *Eponides lotus* (Schwager) Cushman and Ponton.
    a, Ventral view; *b*, dorsal view; Clayton formation.
13. *Robulus midwayensis* (Plummer) Cole and Gillespie.
    Side view; ×25, Clayton formation.
14. *Anomalina pseudopapillosa* Carsey.
    a, Dorsal view; *b*, apertural view; *c*, ventral view; Providence formation.



GUIDE MICROFOSSILS FOR DOUGHERTY COUNTY

654863 O—63——3

The limestone unit is a pure firm aphanitic to slightly recrystallized limestone. The color ranges from white (*N* 9) to light gray (*N* 7). Fragments of poorly preserved macrofossils are abundant, particularly pelecypods and gastropods, which are usually represented by casts and molds. Glauconite and pyrite are common accessory constituents. Fine to coarse quartz sand may also be present. Glauconitic sand is abundant in wells in the western part of the county, and thin beds of fuller's earth are also present. Drill cuttings from wells in counties west and north of Dougherty County contain greater amounts of glauconitic sand and fuller's earth. The basal contact of the limestone of the Clayton formation with the sandy lower unit is generally sharp. However, where the limestone is sandy, the contact with the lower unit may be determined by the first appearance of feldspar grains.

That part of the Clayton formation above the limestone and below the Wilcox consists of very fine to medium calcareous weakly to firmly cemented silty quartz sand. Thin beds of foraminiferal limestone and glauconitic limestone also are present. The color ranges from light gray (*N* 7) to light olive gray (5*Y* 6/1). Glauconite, pyrite, and muscovite are common accessory constituents. The upper unit contains an excellent microfauna, including two large Foraminifera which were described by Cole and Herrick (1953).

Thickness.—The Clayton formation in Dougherty County ranges in thickness from 160 to 220 feet. It is thickest in the city well 7 but probably thickens to the south and east. In U.S. Marine Corps Supply Center 3 well, 202 feet of limestone of the Clayton formation was penetrated.

Structure.—The Clayton formation dips gently southeastward. (See fig. 7.) The rate of dip is about 20 feet per mile. The thickness of the Clayton formation appears to be uniform throughout the county, although the formation may thicken slightly to the southeast.

Paleontology.—Two species of large Foraminifera from the Clayton formation—*Operculinoides georgianus* Cole and Herrick and *Pseudophragmina* (*Athecocyclina*) *stephensoni* Vaughan—were described by Cole and Herrick (1953). The Foraminifera occur in a thin bed of white glauconitic arenaceous fossiliferous limestone. These Foraminifera were found in city wells 10, 11, 13, and J. R. Sealy 1. These same species subsequently have been found in city well 16. The first appearance of these large microfossils is used to determine the top of the Clayton formation in Dougherty County.

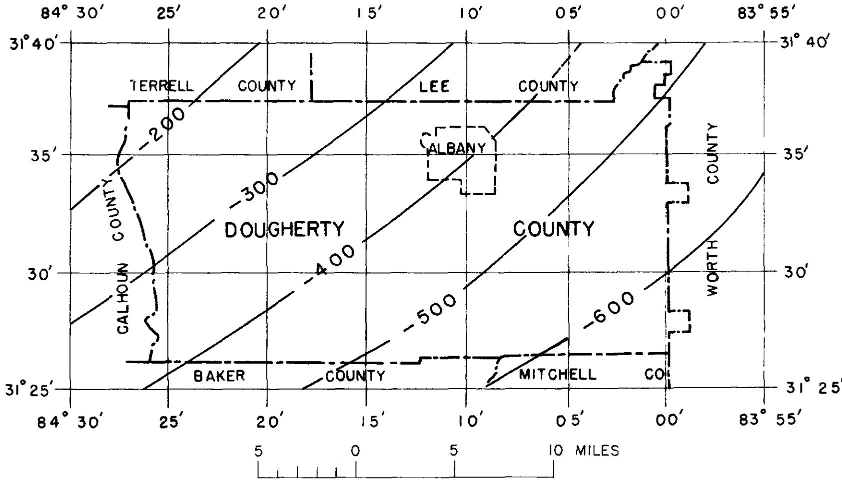


FIGURE 7.—Structure-contour map of the top of the Clayton formation.

EOCENE SERIES

The Eocene series in Georgia consists of the Wilcox group (lower Eocene), the Claiborne group (middle Eocene), and the Jackson group (upper Eocene). All three groups have been identified in the subsurface in Dougherty County.

WILCOX GROUP (LOWER EOCENE)

The name "Wilcox" was first used by E. A. Smith in an unpublished report that described beds at Wilcox, Ala., which had previously been called "Lignitic" by Hilgard. Crider and Johnson (1906, p. 5, 9) were the first to use the term "Wilcox formation" in a published report. The name as adopted was used to designate beds between the Porters Creek clay below and the Tallahatta buhrstone above. The term "Wilcox group" as used today refers to deposits overlying the Midway group and underlying the Claiborne group. The type locality is in Wilcox County, Ala.

In Alabama, the Wilcox group is divided into the Hatchetigbee, Tuscahoma, and Nanafalia formations. Veatch and Stephenson (1911) and Cooke (1943) recognized only the Wilcox formation in Georgia. However, Cooke (1943) noted that equivalents of the Nanafalia, Tuscahoma formations, and Bashi marl member of the Hatchetigbee formation are represented in Georgia. MacNeil (1947) mapped the Nanafalia, Tuscahoma, and Hatchetigbee formations as a unit, stating the Hatchetigbee was present only west of southeastern Stewart County.

The Wilcox in Georgia usually consists of fine sand and gray laminated clay (Cooke, 1943). It unconformably overlies the Midway group and in turn is unconformably overlain by the Claiborne group. Along the Chattahoochee River, sinkholes in the Clayton formation are filled with dark-gray sandy micaceous clay of the overlying Wilcox group.

The Wilcox group crops out in a narrow band from Fort Gaines, Clay County, where it is exposed on the Chattahoochee River, northeastward to Muckalee Creek, northwest of Americus in Sumter County.

The Wilcox group in Dougherty County is represented by the Tuscahoma sand except in city well 15, where 27 feet of sand and limestone was assigned to the Bashi marl member of the Hatchetigbee formation.

TUSCAHOMA SAND

"Tuscahoma sand" was the name used in 1888 by E. A. Smith for beds between the Bashi marl above and the Nanafalia below. The name was applied to deposits at Tuscahoma, on the Tombigbee River, Choctaw County, Ala., which had previously been called "Bells Landing series" by Smith and Johnson (1887). Cooke (1943, p. 50) tentatively assigned some beds in an outcrop on Colomokee Creek, Early County, to the Nanafalia formation. Sand beds exposed in Randolph County, 4 miles southwest of Cuthbert along Hog Creek, were assigned to the Tuscahoma sand. Fossil mollusks from a weathered yellow clay about 5 feet above the level of a spring (USGS Loc. 12097) in Randolph County, about 1 mile north-northwest of Crittenden Mill, were identified by Julia Gardner and tentatively assigned by Cooke (1943, p. 52) to the Bashi marl member of the Hatchetigbee formation.

Lithology.—The Tuscahoma sand in Dougherty County consists of a fine to medium abundantly glauconitic quartz sand, overlain by silt which contains fine quartz sand and is abundantly glauconitic. The silty upper part of this formation also contains thin beds of glauconitic limestone at some places. Color ranges from light olive gray (5*Y* 6/1) to greenish gray (5*GY* 6/1), or dark greenish gray (5*GY* 4/1). A prominent constituent of all beds is glauconite. Pyrite, muscovite, and fine-grained ferromagnesian minerals are accessory constituents. Quartz grains stained green are also present. The contact of the Tuscahoma with the underlying sandy upper unit of the Clayton formation is somewhat difficult to establish because the lithologic characteristics are similar. However, a definite paleontologic break exists, and the differing faunas can be clearly distinguished. Also, thin hard limey beds at the top of the upper unit of the Midway group cause both increased resistivity and spontaneous potential on the electric logs, in contrast to the silty sands of the Tuscahoma, which have a low resistance and spontaneous potential and are nearly featureless except for the occasional increase in resistance caused by the glauconitic limestone beds in the upper sandy silt.

In city well 15, the interval from 445 to 468 feet is assigned to the Bashi marl member of the Hatchetigbee formation. In this well, the Bashi consists of 8 feet of very fine to fine subrounded fair-sorted clear quartz sand, underlain by 115 feet of light-olive-gray (5*Y* 6/1) very fine to fine subangular to subrounded silty sand. Fine-grained, sandy glauconitic limestone is present throughout the interval. The abundant foraminiferal fauna has been identified by S. M. Herrick as belonging to the Bashi.

Thickness.—The Wilcox group ranges in thickness from 90 to 152 feet in Dougherty County, thickening slightly to the south and southeast.

Structure.—The Wilcox group dips southeastward at the rate of about 20 feet per mile (fig. 8) throughout Dougherty County.

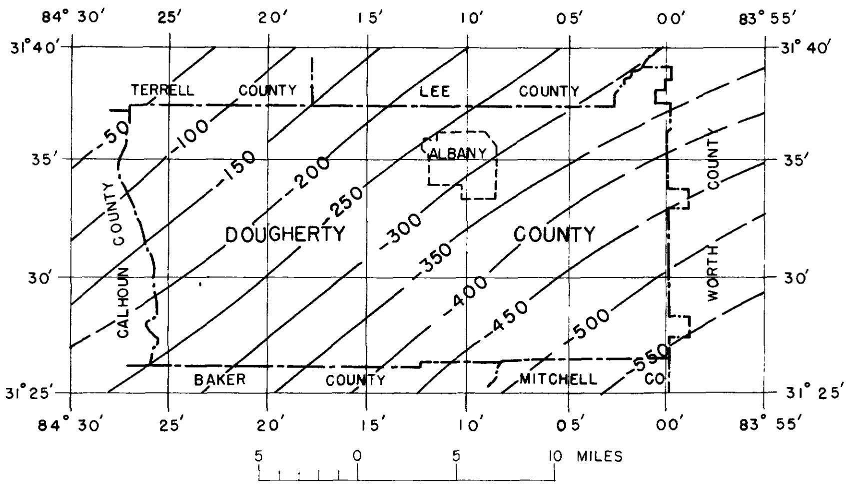


FIGURE 8.—Structure-contour map of the top of the Wilcox group.

CLAIBORNE GROUP (MIDDLE EOCENE)

Conrad (1847) first proposed the name "Claiborne" for Eocene rocks in the vicinity of Vicksburg, Miss., from which he described 105 new fossil species. He divided the Eocene into the "Upper or Newer Eocene" and "Lower or Older Eocene" and assigned the Vicksburg group to the "Newer Eocene" and the "Claiborne sands" to the "Older Eocene." Neither the Vicksburg group nor the Claiborne sands were described at that time. Hilgard (1860) reported that the Claiborne group consisted of the "Calcareous Claiborne group," "lignitic clays and sands," and the "Siliceous Claiborne group"; in 1867 he assigned the "Claiborne group proper" to his "Calcareous Claiborne," thereby excluding the "Siliceous or Buhrstone group." Harris (1894) included the "Buhrstone" in his "Lower Claiborne stage." Vaughan (1900) included the lower siliceous beds in his "Claiborne stage." The Geological Survey has included the siliceous beds of the Tallahatta in the Claiborne group since 1906. The Claiborne group, as now recognized, is overlain by the Jackson group and underlain by the Wilcox group. In Alabama, the Claiborne is divided into the Tallahatta formation, the Lisbon formation, and the Gosport sand, in ascending order. The Claiborne group is named for exposures at Claiborne Bluff and Claiborne Landing on the Alabama River, Monroe County, Ala. The Tallahatta formation is not exposed at this locality but is exposed several miles up the river.

Veatch and Stephenson (1911, p. 235–296) described the middle Eocene of Georgia, stating it was inappropriate to use the threefold division recognized in Alabama. They divided the Claiborne into the Barnwell sand and the McBean formation, which contained the "Congaree clay member." The McBean was defined as the equivalent of the Tallahatta and Lisbon formations and the lower part of the Gosport sand. Subsequent work in Georgia has shown that the Barnwell formation is the equivalent of the Ocala limestone (Cooke and Shearer, 1918, p. 41–81), and the "Congaree clay member" is now known as the Twiggs clay member of the Barnwell formation—all are upper Eocene, Jackson group (LaMoreaux, 1946, p. 51–65).

Cooke and Shearer (1918) restricted the McBean formation to deposits of Lisbon age exposed along the Savannah River.

Cooke (1943, p. 54) described the Claiborne of Georgia, naming all deposits McBean, but with the qualification that deposits west of the Flint River might be somewhat older than the typical McBean formation. In this report, deposits regarded as Claiborne in age are assigned to the Lisbon and Tallahatta formations. If any Gosport sand is present, it has been included with the Ocala limestone of the Jackson group, which it closely resembles in the subsurface.

Rocks of the Claiborne group crop out in a discontinuous belt across the State. They are overlapped at places by the younger Barnwell and Flint River formations.

The Claiborne group lies unconformably on the Wilcox group and at some places the Clayton formation. In Dougherty County it is unconformable upon the Wilcox group and is overlain unconformably by rocks of the Jackson group.

Thickness.—In Dougherty County the Claiborne group ranges in thickness from 350 feet in the southeast to 270 feet in the northwest, thinning updip. It is thinnest in the Dixie Pines well (pl. 4) in Lee County, northwest of which it has not been recognized in the subsurface. The Tallahatta formation also thins updip to the northwest. However, it is present in Webster County in the Negro High School and Elementary School well. (See pl. 4)

Structure.—The Claiborne group dips about 11 feet per mile to the southeast. Because of thickening of the Tallahatta formation downdip, the Claiborne group dips more gently than underlying older formations. Figure 9 shows structure contours of the top of the Claiborne group. The strike is northeast in most of Dougherty County but appears to be somewhat more toward the east in the southwestern part of the county, where the dip increases slightly.

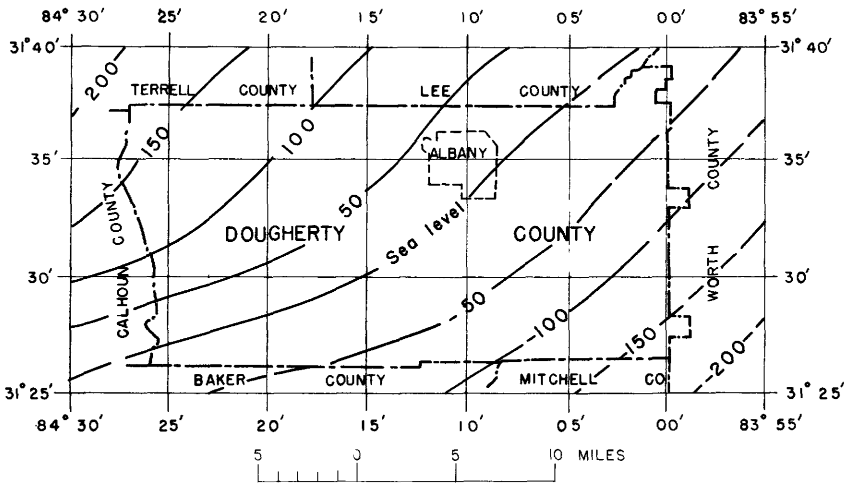


FIGURE 9.—Structure-contour map of the top of the Claiborne group.

TALLAHATTA FORMATION

The name Tallahatta, first used by Dall (1898), was suggested by E. A. Smith from the name of the hills in Choctaw County, Ala., where the rocks are exposed. This formation previously had been called the "Buhrstone," because of the rough siliceous nature of the rocks.

In Dougherty County, the Tallahatta formation consists of a siliceous, abundantly glauconitic, somewhat micaceous limestone at the base, overlain by fine to medium, well-rounded well-sorted phosphatic sand with interbedded thin calcareous clay layers, above which is a very sandy shell limestone or coquina that also contains some thin clay beds.

The siliceous limestone at the base of the formation ranges in color from light gray (*N* 7) to light olive gray (5*Y* 6/1). Where this bed is highly siliceous, it appears to consist mainly of clear irregular detrital quartz grains, dark gray chert, limestone, and glauconite. In some wells, it contains much muscovite and silt. Although it is somewhat difficult to recognize in cuttings, the siliceous limestone bed is more readily recognized on an electric log by the increase in spontaneous potential and resistivity.

The overlying sand is very light gray (*N* 8) to yellowish gray (5*Y* 8/1). It is a clean well-sorted abundantly phosphatic quartz sand with thin calcareous clay layers. Garnet and ferromagnesian minerals are accessory constituents. Rounded fragments of pelecypods are abundant. The thin clay layers contain Foraminifera. Fish teeth are a characteristic of this sand. The sand is firmly cemented in some wells and is weakly cemented in others.

The shell limestone or coquina ranges in color from yellowish gray (5*Y* 8/1) to light olive gray (5*Y* 6/1). It is composed mostly of pelecypod fragments, with minor amounts of fine to medium well-rounded well-sorted quartz sand. Phosphate and garnet are common accessory constituents. A few thin beds of calcareous clay are present. The coquina appears to grade into the massive sands below.

The basal limestone is generally about 20 feet thick. The massive sands range from about 100 to 120 feet in thickness, and the coquina bed at the top of the formation may be as much as 100 feet thick.

LISBON FORMATION

The Lisbon formation is named for exposures at Lisbon Bluff on the Alabama River, Clarke County, Ala. The name "Lisbon" was first applied by T. H. Aldrich in 1886.

In Dougherty County, the Lisbon formation consists of fine-grained sandy limestone and fine-grained calcareous sandstone. The color ranges from yellowish gray (5*Y* 8/1) to light olive gray (5*Y* 6/1). Glauconite and finely disseminated ferromagnesian minerals are common accessory constituents. Bryozoan remains are abundant, and shells of macrofossils are common.

Electric logs of wells penetrating the Lisbon formation are characterized by a high negative spontaneous potential. (See pl. 29, section *A–A′*.)

The Lisbon formation ranges in thickness from 70 to 100 feet in Dougherty County.

JACKSON GROUP (UPPER EOCENE)

The Jackson group was first named by Conrad (1856), when he divided the Eocene into "Newer Eocene Vicksburg," "Older Eocene

Jackson," and "Older Eocene Claiborne." Conrad placed the Jackson group in the "Older Eocene," stating, "I believe the group to be newer than Claiborne deposits and certainly older than that at Vicksburg." Hilgard (1860, 1867) described deposits assigned to the Jackson group in Mississippi. Cooke (1915) described the Jackson formation of Mississippi and divided it into the Yazoo clay member above and the Moodys marl member below. The Jackson group is named for deposits at Jackson, Miss., along the Pearl River and Moodys Branch. In eastern Georgia, the Jackson group consists of the Ocala limestone; the Barnwell formation, which probably is a shoreward facies of the Ocala; and the Cooper marl. In western Georgia, only the Ocala limestone is present.

OCALA LIMESTONE

Dall and Harris (1892) first described the "Ocala limestone" from deposits exposed near Ocala, Fla. He assigned it to the "Eocene or Oligocene." Veatch and Stephenson (1911) placed a part of the Ocala limestone in the Vicksburg formation, with which the Ocala limestone of Florida was then correlated, and part in the Jackson formation. Cooke (1915) established the Jackson age of the Ocala limestone and first applied the name in Georgia to rocks exposed near Bainbridge, Decatur County. Cooke and Shearer (1918) described the Ocala limestone in Georgia.

Area of outcrop.—The Ocala limestone crops out in a wide area in western Georgia, including most of the Dougherty Plain. The area of outcrop continues as far east as Okmulgee River, beyond which it merges laterally with the Barnwell formation. The Ocala limestone is present in southern and southeastern Georgia in the subsurface.

The Ocala limestone is the principal outcropping rock in Dougherty County. Because of the lack of relief, the slight dip of the formations, and the thick cover of residual material developed on the Ocala limestone, there are few outcrops in Dougherty County. The best exposures of the limestone are along the Flint River and Kinchafoonee and Muckalee Creeks, where the streams have eroded channels as much as 60 feet in depth. Veatch and Stephenson (1911, p. 316) described the following outcrop of limestone on Kinchafoonee Creek, about 2 miles north of Albany.

	Thickness (feet)
4. Pleistocene sand, flint fragments at the base, Vicksburg formation	10
3. Limestone	5
2. Flint, nodular, discontinuous	2
1. Massive limestone	8

The following section was measured by the author on the east side of the Flint River just below the Georgia Power Co. dam.

	Thickness (feet)
Pleistocene series:	
5. Sand, light-gray, argillaceous, medium to very coarse, poorly sorted; contains boulders of flint and jasper as much as 2 feet in diameter. May include some artificial fill	10
Eocene series, Jackson group:	
Ocala limestone:	
4. Limestone, gray on fresh surface, dark gray to black where stained by water; contains silicified nodules as in bed 2; forms pitted ledge and is cap rock of exposure	2
3. Limestone, light-gray to light-yellow if fresh; weathers gray; abundantly fossiliferous; contains pelecypods and echinoids	3
2. Limestone, light-yellow, fresh; gray, weathered; fine-grained; fossiliferous; weathers pitted; contains flint nodules as much as 3 feet long and 6 inches thick; irregular basal contact	2
1. Limestone, white if fresh; weathers gray, massive; forms ledge at edge of river; pocketed by solution and erosion of river; abundantly fossiliferous; contains bryozoa and casts of pelecypods. (Base of unit in river)	6
Total Ocala exposed	13
Total thickness	23

The Ocala limestone crops out along most of the length of the Flint River in the county. At low flow, 4 to 6 feet of limestone is exposed in a nearly vertical bank along the river. Few exposures are above this level, as terrace material masks the limestone. Boulders of silicified limestone crop out in several road cuts along Georgia Route 62 between Albany and Leary. Foraminifera have been identified from several of these outcrops. One notable exposure of the Ocala limestone is outside Dougherty County at the quarry of the Albany Limerock Co., about 10 miles northwest of Albany. About 40 feet of limestone has been exposed by recent quarrying. An older quarry, now filled with water, is just north of the present one. At the new quarry, the contact of the Ocala with the overlying residuum is exposed. Large blocks of slightly weathered limestone protrude into residuum as much as 20 feet, presenting an uneven surface. At lower levels, quarrying has exposed solution cavities filled with dark-brown fine-grained sandy clay. One such solution cavity approximately 30 feet below land surface was examined in February 1958. The cavity was about 5 feet high, 20 feet wide, and 40 feet long. Stalactites as long as 6 inches were hanging from the roof. The sides of the cavity were fluted. The bottom was covered with dark-brown sandy silt, and water flowed through the cavity.

Radium Springs, on the east bank of the Flint River about 4 miles south of Albany, flows from a large solution cavity.

Lithology.—The Ocala limestone in Dougherty County is pure, much recrystallized, aphanitic to fragmental to oolitic limestone. It is abundantly fossiliferous, some zones being made up mostly of pelecypods and bryozoan remains. Rhombs of calcite indicate that much secondary deposition has occurred. The Ocala limestone is predominantly very pale orange (10*YR* 8/2), and the color varies little. The contact of the Ocala with the underlying Lisbon formation is distinguished in drill cuttings by a change in color as well as a change in lithology. The Lisbon is sandier than the Ocala, and it is usually some shade of gray.

Brantly (1916, p. 136) analyzed two samples of limestone from an outcrop on Muckafoonee Creek. They contained 95.64 and 95.06 percent calcium carbonate.

Residuum, developed from the Ocala limestone and from the Flint River formation, overlies the Ocala throughout Dougherty County. The residuum varies in color but mostly is red to reddish brown. It is sandy, silty clay and contains boulders, some of which are several feet in diameter. The boulders are much weathered siliceous limestone, the silica consisting of chert, flint, and locally jasper.

Solution action of ground water has caused the formation of caverns—many of which have collapsed to form sinkholes—and has also caused the overlying sediments to be mixed with the Ocala residuum. Therefore, no age determination of the residuum is possible, nor is it always possible to determine with certainty the source of the residual material. The contact of the residuum with the Ocala limestone is sharp at most places.

Thickness.—The Ocala limestone ranges in thickness from 70 feet in the State Fish and Game well (8420–3125–1) in western Dougherty County to 260 feet in eastern Dougherty County in the U.S. Marine Corps well 2 (8400–3130–10). The variation in thickness of the Ocala limestone is caused by the development of the overlying residuum and the cover afforded by the Flint River formation in eastern Dougherty County. The residuum overlying the Ocala may range in thickness from 40 to 70 feet.

Structure.—No structure-contour map has been prepared for the Ocala limestone. The weathered surface of the Ocala precludes determination of the dip of the formation top. The dip of the Ocala does not exceed that of the Claiborne group in Dougherty County, which is about 5 feet per mile southeast.

Paleontology.—The right mandible of the archaeocete *Zygorhiza kochii* (Richenback) was recovered during quarrying operations at

Armena in Lee County. The specimen jaw was identified by Dr. Remington Kellogg, Director, U.S. National Museum, Smithsonian Institution, Washington, D.C. (written communication, 1957). This primitive whale was common during the late part of the Eocene epoch (Jackson age). The specimen is now on display in the Georgia Department of Mines museum. Bones of an archaeocete were previously identified (Kellogg, 1936) from the Ocala limestone near the mouth of Cedar Creek, Crisp County, Ga.

The Foraminifera, *Operculinoides* sp. and *Lepidocyclina ocalana* were identified by S. M. Herrick from an outcrop of much weathered silicified fossiliferous limestone about one-eighth of a mile west of the Pretoria fire tower. Another outcrop about 300 yards east of Ducker Station contained molds of pelecypods, bryozoan remains, and Foraminifera. Herrick has tentatively identified an *Operculinoides*, probably *O. mariannensis* or *ocalana*, from this outcrop.

OLIGOCENE SERIES

According to Cooke (1943, p. 77), the lower boundary of the Oligocene has been well established at the top of the Jackson group, but the upper boundary has been variously placed at the top of the Hawthorn formation and at the base of the Tampa limestone. As currently recognized by the Geological Survey, the Oligocene series includes all rocks younger than the Cooper marl and older than the Tampa limestone.

FLINT RIVER FORMATION

The Flint River formation is the only Oligocene formation in Dougherty County. The Flint River formation was named by Cooke (1935, p. 1170–1171) for exposures of chert and flint overlying the Ocala limestone along the Flint River between Hales Landing and Red Bluff, Decatur County, Ga. Veatch and Stephenson (1911) previously had placed these beds in the Chattahoochee formation (of former usage). Cooke (1923) correlated them with the Glendon limestone (middle Oligocene) but later abandoned this correlation when it was determined (Cooke, 1935, p. 1162–1172) that macrofauna of the younger Chickasawhay marl (upper Oligocene) is closely associated with the Antigua limestone of British West Indies, with which the Flint River had been correlated. The Flint River is thought to be late Oligocene in age and to be equivalent to the Suwannee limestone, although the Suwannee may contain some beds younger than the Flint River formation, according to Cooke.

The Flint River formation crops out in southwestern Georgia in two northeastward-trending bands, which merge in Dooly County. One outcrop area is to the west of the Flint River, extending from northern Early County eastward to Dooly County. The other extends from southern Seminole County northeastward, east of and parallel to the Flint River, to Dooly County, where the two areas merge and continue eastward to northern Laurens County. East of Laurens County, the Flint River formation is overlapped by the Hawthorn formation and coastal terrace deposits, except for a small area in southern Burke and northern Screven Counties along the Savannah River.

On the geologic map of Georgia by Cooke and others (1939), that part of Dougherty County east of the Flint River has been mapped as Flint River formation. Because of the thickness and nature of residuum and the presence of silicified boulders, it is extremely difficult to determine where the contact between the Ocala limestone and the Flint River formation should be placed. The Flint River formation crops out only in the southeastern part of Dougherty County. It has not been recognized in well samples anywhere in Dougherty County. Cooke (1943, preface) states, "Much of the mapping of the Coastal Plain was based on rapid reconnaissances * * * and without satisfactory base maps. The resulting boundary lines therefore lack detail and are subject to modification." The contact between the Flint River formation and the Ocala limestone presumably falls in that category. As presently mapped, one must assume that the position of the Ocala limestone on the west side of the Flint River and the Flint River formation on the east side, both at the same elevation, is a result of faulting. However, no evidence of faulting has been found.

Paleontology—Silicified limestone crops out along the east County Line Road. Three of these localities were sampled and examined for Foraminifera. A weathered outcrop of silicified limestone in a matrix of red sandy clay at the junction of Flemming Road and County Line Road (locality 1) yielded no Foraminifera. A white much calcitized, somewhat cherty fossiliferous limestone was observed at locality 2, about 1 mile south of locality 1.

The following Foraminifera of Oligocene age were identified from locality 2 by S. M. Herrick:

Discocyclina sp.
Lepidocyclina sp.
Rotalia mexicana var (common)
Siphonina advena
Asterigerina subacuta

The following Oligocene Foraminifera were found at locality 3 about one-eighth of a mile north of Flat Springs Road, on the east side of County Line Road:

Rotalia mexicana var.
Pyrgo sp.
Quinqueloculina sp.
Asterigerina subacuta
Discocyclina sp.

Localities 2 and 3 are at altitudes of about 250 and 270 feet, respectively. Locality 4, at the junction of Johnson and Spring Flats Road, was not sampled. Several large boulders more than 6 feet long are exposed at this locality. They consist of fossiliferous cherty limestone containing casts and molds of pelecypods. Residuum from the Flint River, consisting of mottled and white sandy clay, caps several of the knolls to the northwest along Johnson Road.

The Flint River formation in Dougherty County is restricted to the extreme east edge and the southeast corner of the county, where it appears to be in place.

PLEISTOCENE SERIES

It is estimated by geologists that the Pleistocene epoch started about a million years ago. Dating is based on the rate of decay of radioactive substances (carbon–14) and on the rate of deposition of certain types of clay.

During the Pleistocene, several advances and retreats of continental ice sheets, one of which came as far south as Kansas, took place in the United States. The sea stood at different levels that correspond to the advances and retreats of the glaciers, and the old shorelines are still visible on the Georgia Coastal Plain. Seven terraces have been recognized in Georgia (Cooke, 1943). Rivers cut and scoured deeper channels during the retreat of the sea and deposited terrace materials along the sides of streams during the advance of the sea. Terrace deposits exist along nearly all the rivers in Georgia and have been described along the Flint River from the Fall Line southward to Bainbridge in Decatur County.

RIVER-TERRACE DEPOSITS

River-terrace deposits of sand and gravel are present in Dougherty County, north of U.S. Highway 82 and along both sides of the Flint River. South of the highway, the terrace deposits are present east and west of the river and between the river and River Road. The deposits along the west bank of the river north of the highway are being mined [1957] by the Dawes Silica Co. The following section was measured in a sand pit at the Dawes Silica Co., near the confluence of Muckafoone Creek and the Flint River.

	Thickness (feet)
4. Sand, quartz, very fine, yellowish gray (5*Y* 7/2), argillaceous, subangular to subrounded; ferromagnesian minerals rare	7
3. Sand, quartz, fine to medium, very pale orange (10*YR* 8/2), subangular to subrounded, well-sorted; grains show chatter marks; iron staining rare; ferromagnesian minerals rare; fine sand contains red mineral, possibly garnet	2

2. Gravel, quartz, medium to coarse, moderate yellowish brown (10*YR* 5/4), angular; weakly argillaceous; ferromagnesian minerals rare; iron staining rare; cross laminated; poorly sorted; ferruginous cement at upper contact; lower contact sharp, even	4
1. Sand, quartz, fine to medium, yellowish-gray (5*Y* 7/2), very angular; some frosting on larger grains; phosphate rare, muscovite rare; weakly argillaceous, iron staining rare	2
Total thickness	15

Limestone and chert boulders as much as 2 feet in diameter were noted in the bottom of the pit.

The following section was measured in a pit about one-fourth mile southeast of section 1.

	Thickness (feet)
2. Sand, quartz, yellowish-gray (5*Y* 7/2), very fine, argillaceous, subangular to subrounded; ferromagnesian minerals rare; bedding massive; lower contact irregular	5
1. Sand, quartz, dark yellowish orange (10*YR* 6/6), to grayish orange (10*YR* 7/4), medium-grained; subangular to subrounded; about 30 percent of grains iron stained, ferromagnesian minerals rare; cross laminated	15
Total thickness	20

Terrace deposits also are present immediately across the river and have been mined extensively. The deposits south of Albany are known to be at least 30 feet thick, and they consist of cross-laminated sand, some gravel, and clay.

DUNE SAND

Dune sand, known locally as the Fossil Sand Dunes, is present east of the Flint River and south of U.S. Highway 82. The sand is brown to tan, fine to coarse well-sorted angular to subangular quartz. Some grains show frosting and chatter marks. Ferromagnesian accessory constituents are rare, as is muscovite. In road cuts and sand pits where the sand is freshly exposed, bedding is discernible. These beds are as much as half an inch thick and consist of alternating fine and medium sand. The fine-grained sand stands out as slight ridges. The dunes rest unconformably on residuum.

The dune sand supports a vegetation of long-stemmed grasses, scrub oak, and a few pine trees—all of which prevent migration and erosion. However, in road cuts and quarries where the vegetation has been removed, the sand migrates eastward.

Another small area of dune sand is present along the east boundary of the U.S. Marine Corps Supply Center. This deposit has been mined for road fill.

GROUND-WATER RESOURCES

Ground water is one of the most valuable resources of the Coastal Plain of Georgia. The need for water by industry, especially the pulp and paper and the chemical industries, is great. Rapidly growing cities must drill new wells to keep pace with ever-increasing demands for water. Irrigation of farmland to increase production and to sustain crops during minor as well as extended drought has increased in Georgia since 1950. It is expected that the use of ground water for irrigation will increase even more. An attraction to industrial development, a necessity to cities, a boon to agriculture—water is vital in our complex modern civilization.

HYDROLOGIC CYCLE

The source of all water is the ocean. Water is evaporated from the ocean by the heat of the sun. This moisture moves upward and forms clouds that drift to other areas, where the moisture condenses and falls to earth as rain. Most rainfall runs off in rivers and returns to the ocean, where it is again evaporated by the sun.

Part of the water that falls on the earth is evaporated and returned to the atmosphere. Part of the rainfall enters the ground. Some is used by plants, and some is held in the open spaces in the soil zone. Water held in the soil zone is called soil moisture. Part of the water that enters the ground moves downward to be stored as ground water. Water is removed from the ground-water reservoir by man, or it is returned to the land surface through springs and then is returned to the ocean to begin the cycle again.

OCCURRENCE OF GROUND WATER

Permeable rocks that lie below a certain level in the ground are generally saturated with water. The water is contained in the pore spaces of the rocks, and the rocks are said to be in the zone of saturation. The top of the zone of saturation is called the water table. That part of the earth between the water table and the land surface is called the zone of aeration.

The pore spaces of rocks may be extremely small, as are the minute pores between grains of clay or silt; or they may be large, as are pore spaces between pebbles in coarse uncemented well-sorted alluvium. Water also occurs in the solution cavities of limestones and in the joints and fractures of rocks. Rocks in which water is stored are called aquifers, which means water bearing. Aquifers in Dougherty County yield water readily to pumping wells and to springs. Rocks that are considered to be aquifers in Dougherty County include sand, gravel, and limestone. Some rocks are nearly impermeable and yield water to wells very slowly or not at all. Where they occur above or below aquifers, they are called confining beds. Clay, silt, cemented sandstone, and some recrystallized limestone are confining beds in Dougherty County.

WATER-TABLE CONDITIONS

Ground water that is in contact with the atmosphere through the zone of aeration is said to be unconfined and to occur under water-table conditions. In the southeast corner of Dougherty County, ground water occurs under water-table conditions in the residuum of the Flint River formation, above the zone of artesian water in the Ocala limestone. At one place, a difference of about 60 feet was recorded in the depth to water in 2 adjacent wells. One was a dug well 27 feet deep, in the residuum, and the water level was 15 feet below the land surface. The other was a drilled well, 340 feet deep, in the Ocala limestone, and the water level was 75 feet below the land surface. Differences of a lesser magnitude were recorded in other wells in this area.

Dug wells, ranging in depth from about 20 to 50 feet, are used to obtain water from the residuum in Dougherty County. The yield may range from less than 1 gpm to as much as 15 gpm. Dug wells are usually not curbed and are open at the top. The shallow ground water in the residuum is subject to pollution from outdoor privies, barns, and debris which might fall into the well.

Few dug wells are in use in Dougherty County. A drilling program conducted by the County Health Department made possible the drilling of many domestic wells to replace dug wells.

ARTESIAN CONDITIONS

Ground water that occurs in an aquifer bounded above and below by less permeable rocks and therefore is under pressure is called artesian water. Should a well be drilled into an artesian aquifer, the water level will rise in the well above the point at which it was first struck. If the pressure is sufficient to cause the water level to rise above land surface, the well will flow. Thus, an artesian well is one in which the water level rises above the top of the zone in which the water was first found, and it may flow if the artesian pressure is great enough.

Artesian water occurs in sand, gravel, and limestone in Dougherty County. The amount of water that can be obtained from the artesian aquifers in Dougherty County is many times the amount that can be obtained from water-table aquifers.

654863 O—63——4

Artesian aquifers are recharged mainly in outcrop areas. Thus, a part of the recharge area of the Ocala limestone is in Dougherty County, where this rock is at or near the land surface. Other artesian aquifers in Dougherty County are recharged where they crop out north and northwest of the county.

Ground water moves in response to gravity in the direction of the hydraulic gradient, and thus is toward areas of lower pressure. The areas of lower pressure may be manmade, such as those caused by pumping from wells, or they may be natural, such as discharge areas at the land surface or on the ocean floor.

CAUSES OF WATER-LEVEL FLUCTUATIONS

The water level in an artesian aquifer may fluctuate in response to many outside influences. One of the chief causes of water-level fluctuations is withdrawal of ground water through wells. When water is pumped from a well, the pressure in the aquifer is decreased and a cone of depression is established around the well. The cone of depression may be large or small, depending upon the amount of water removed, the rate at which it is removed, and the ability of the rock to transmit water. If large amounts of water are pumped for a long period of time, the resulting cone of depression may be extensive; for example, the cone of depression at Savannah, Ga., is more than 60 miles in diameter.

The water levels in artesian wells usually respond to changes in atmospheric pressure. An increase in atmospheric pressure causes the water level in wells to decline; a decrease in pressure causes the water level to rise.

The movement of heavy loads over an artesian aquifer, such as the passage of a train, may cause a momentary rise in water levels, owing to the added pressure on the aquifer. Earthquake shocks may cause momentary changes in water levels many thousands of miles from the epicenter of the quake.

WATER-BEARING ROCKS OF DOUGHERTY COUNTY

The water-bearing rocks of Dougherty County include the Ocala limestone, the Claiborne and Midway groups, and the Upper Cretaceous series. These rocks underlie all the county. Two fence diagrams (pls. 5, 6) show the geology and water-bearing rocks that underlie the immediate Albany area.

Plate 5 shows the geology of the Albany area, as determined by examinations of drill cuttings. Each well was plotted at its location on the Albany East and Albany West topographic quadrangles. Plate 6 shows the position of the well screens and open hole in each well, plotted on the same base as plate 5.

UPPER CRETACEOUS SERIES (UNDIFFERENTIATED)

The uppermost beds of the Upper Cretaceous series in Dougherty County consist mainly of silty limestones and calcareous sandy marls which range in thickness from about 20 to 45 feet and which yield little or no water to wells. Beneath them is weakly cemented porous coquina or shell limestone, as much as 70 feet thick, that is a good aquifer. The silty limestones and marls above the coquina probably act as a confining bed. City wells 7, 11, 15, and 16 obtain water from the coquina limestone. Beneath the coquina are beds of calcareous sand and sandstone from which water is also obtained. These sands are composed chiefly of quartz and plagioclase feldspar.

Several wells in Dougherty County obtain water from rocks of the Upper Cretaceous series. (See table 2.) City wells 7, 10, 11, 14, 15, and 16, well 8415–3130–3, and two oil-test wells obtain water from rocks of the Upper Cretaceous series.

City well 7 penetrates Upper Cretaceous rocks below a depth of 830 feet. Screens were set in the coquina at depths of 865 to 895 and 905 to 920 feet and in the calcareous sand below the coquina at depths of 948 to 973, 982 to 997, and 1,007 to 1,022 feet. In city well 11, coquina is screened from 865 to 875 feet and 910 to 915 feet, and calcareous sandy marl is screened from 850 to 855 feet. In city well 15, calcareous sandy marl and coquina is screened from 770 to 820 feet, and coquina is screened from 825 to 830 and 860 to 865 feet. In city well 16, coquina is screened from 820 to 840 feet.

City well 2, now abandoned and plugged, obtained water from Upper Cretaceous sediments. This well was drilled in 1904–06 (Stephenson and Veatch, 1915, p. 241) to a depth of 1,320 feet. At least four water-bearing formations were penetrated. Water was obtained from shale at 350 feet, limestone from about 660 to 790 feet, and sand from 920 to 930 feet and 1,300 to 1,320 feet.

Analyses of water from the second and fourth zones show the waters to be calcium bicarbonate and sodium bicarbonate waters, respectively. The depth at which the water was obtained and the quality of the water indicate that water was obtained from the Midway group from 660 to 790 feet and from the Upper Cretaceous series from 1,300 to 1,320 feet. Upon completion of drilling, the water level in this well was about 30 feet above the land surface (McCallie, 1898, p. 180).

A well (8415–3130–3) owned by the St. Joe Paper Co. is 795 feet deep and is cased to 542 feet with 6-inch casing. The well flowed about 270 gpm in 1942, and the pressure head was about 26 feet above the land surface. This well probably derives water from the lower unit of the Midway group and from the Upper Cretaceous sand. The

TABLE 2.—*Water-bearing zones, developed in drilled wells in Dougherty County*

[In feet below land surface]

Geologic unit	City of Albany well—												USMC Supply Center well—		
	6	7	8	9	10	11	12	13	14	15	16	17	1	2	3
Ocala limestone													240–250 275–285		
Lisbon formation					260–	245–250						200–205	325–330 375–380 400–405	380–400	240–250 340–350
Tallahatta formation	365–395 412–432 470–	411–450	319–329 374–404	330–345 357–362 370–410 425–465	265 295–305 315–325 350–360 380–420 440–460 480–485	265–270 285–295 325–335 355–365 385–390 400–405 430–435 450–460	230–245 260–270 295–310 360–375 385–405 415–435	270–275 290–300 312–322 335–345 373–378 400–420 430–460 480–	275–295 330–350 385–395 420–440 480–	270–280 285–295 335–355 360–370 385–395 440–	280–320 330–350 430–440	300–305 415–420 435–445 460–470	420–430 440–450 485–500 515–535 605–615 635–	445–455 475–495 520–530 550–560 585–595 610–620 645–655	400–410 420–430 460–470 500–510 520–530 535–545 580–590 595–605
Wilcox group	490	520–530 540–550 575–585 595–605	416–426 599–609				475–480	490	490	450			640		
Upper unit	[1]640–	615–625 635–645 665–675											850–		
Limestone unit of Clayton formation.		695–705 725–735 755–765 785–	[1]653–768	[1]695–	[1]680–	670–680 690–700 720–740 750–760	[1]635–725	[1]676–	[1]657–750	[1]605–700	[1]628–720		940	920–997	800–900
Lower unit		795 815–825		795		780–790		800							
Upper Cretaceous series	955	865–895 905–920 948–973 982–997 1007–1022			868	850–855 865–875 910–915			835–855	790–810 825–830 860–865	820–840				

[1] Open hole in limestone; all other intervals screened.

well flowed about 20 gpm in 1957, but no water-level measurement was possible.

Two oil-test wells drilled in Dougherty County is 1942 probably obtain water from the Upper Cretaceous series. Reynolds Brothers J. R. Sealy 1 (8415–3130–1) was drilled to a depth of 5,012 feet. The well has 10-inch casing from the land surface to an unknown depth. Water flowed from the well at the rate of about 2 gpm in 1957. The second oil-test well, Reynolds Brothers J. R. Sealy 2 (8420–3125–1) was drilled to a depth of 5,500 feet. According to the driller, this well is cased with 6-inch casing to about 1,200 feet. In August 1942, the well had a pressure head of 83 feet above the land surface. Because the casing was rusted, it was not possible to measure the pressure in the well in 1957. Both of the oil-test wells yield sodium bicarbonate water, which is typical of ground water from the rocks of the Upper Cretaceous series in Georgia.

Wells drilled in Upper Cretaceous rocks in western Dougherty County and in Calhoun County to the west may flow, but little is known of the water-bearing properties of the sediments because few wells penetrate these rocks. No wells east of the Flint River in Dougherty County are known to obtain water from the Upper Cretaceous series. Ground water available from the Upper Cretaceous rocks represents a large and as yet little developed source of ground water in Dougherty County. Yields of wells may range from 100 to 300 gpm.

CLAYTON FORMATION

Ground water may be obtained from rocks of the Clayton formation throughout Dougherty County. The first flowing artesian well in Georgia, drilled in 1881 by Colonel John P. Fort, obtained water from limestone of the Clayton formation of the Midway group. (See pl. 3.) Since 1881, many wells in the southwestern part of Georgia have obtained water from limestone of the Clayton formation. The city wells of Cuthbert in Randolph County; Dawson and Bronwood in Terrell County; Edison, Morgan, Leary, and Arlington in Calhoun County; Fort Gaines in Clay County; Blakely in Early County; and Albany in Dougherty County obtain water from rocks of the Midway group.

The Midway group in Dougherty County has been divided into three units in this report. The upper unit consists of calcareous sand and thin sandy limestone beds and ranges in thickness from 32 to 70 feet. The middle unit or limestone unit is massive somewhat recrystallized fossiliferous limestone. Internal casts and molds of macroshells are abundant in well cuttings. The pore space resulting from solution of the shells contains much ground water. This limestone bed ranges in thickness from 100 to 110 feet. The lower unit consists of 30 to 50 feet of weakly to firmly cemented poorly sorted sands. The sand is composed mostly of quartz and feldspar. The principal water-bearing bed in the Midway group is the limestone of the Clayton formation. The sand and arenaceous limestone units above and below the limestone unit appear to be well cemented throughout and probably furnish little water to wells.

In 1957, the Walter F. George Lock and Dam was under construction by the U.S. Army Corps of Engineers at Fort Gaines, Clay County, Ga. The dam foundation is seated in the Clayton formation. On the basis of test-drilling records, the limestone in that area was divided into three units by the Corps of Engineers. The upper "earthy" unit consists largely of bryozoan remains and calcareous clay. The middle "shell" unit consists mostly of large pelecypod shells and casts and molds of pelecypods and gastropods. It is much recrystallized, very firm but very porous. The "lower unit" is sandy limestone. Relief wells, drilled by the cable-tool method, were used to lower the artesian water level during excavation for the dam footing. These relief wells obtained water from the middle "shell" limestone. One well was pumped at the rate of 1,750 gpm. It is probable that the upper part of the Clayton formation, also, contains little water in Dougherty County and that most of the water is obtained from the limestone.

The first well drilled by the city of Albany was in the intersection of Broad Avenue and Jefferson Street. No record is available regarding the construction of this well, but the well flowed (McCallie, 1898, pl. IV). An analysis of water from the well shows it to be a calcium bicarbonate water, typical of water from the Clayton formation. City wells 1, 2, and 3, listed by Stephenson and Veatch (1915, p. 236), also obtained water from the Clayton formation. Some city wells have screens opposite all water-bearing beds, including the Clayton formation. Others are unscreened opposite the Clayton formation. In constructing city well 7, screens were used throughout. Eight screens totaling 80 feet are set in the Clayton formation: 3 totaling 30 feet in the upper unit, 4 totaling 40 feet in the limestone unit, and one 10-foot screen extending from the limestone unit into the lower unit. Screens also were used throughout city well 11, where, of 5 screens totaling 60 feet that were placed in the Clayton formation, 4 were in the limestone unit. Other city wells and those of the U.S. Marine Corps Supply Center were constructed without screens in the Clayton formation. Construction without screens is cheaper than with screens and eliminates frictional losses, which occur when water passes through a well screen. However, excessive pumping rates can pull limestone fragments and sand into wells that do not have screens. Such material may accumulate in the bottom of the well and decrease the effectiveness of the lower part of the well, or it may be pumped into distribution lines.

An 8-inch well (8410–3135–17) owned by Spencer Walden was drilled to a depth of 180 feet in December 1949 and was deepened to 823 feet in January 1950 in an attempt to obtain a flow. From 176 to 620 feet, 4-inch casing was installed, and 6-inch casing extended from the land surface to 179 feet. The slight overlap afforded a seal so that water would be pumped only from the bottom part of the well. The well was uncased from 620 to 823 feet. The lower part of the well produced 250 gpm of water from the Midway group and Upper Cretaceous series. The static water level in the well was 17 feet below the land surface. Because a flow was not obtained from the bottom part, the 6-inch casing was removed in order to obtain water from both the Clayton formation and Ocala limestone. Upon removal of the 6-inch casing, the well produced 700 gpm. The water level remained at 17 feet.

A well (8405–3135–3) formerly owned by the Artesian Water Co. penetrates the Midway group. According to the driller's log, this well penetrated limestone from 695 to 806 feet. The 8-inch casing extended to 713 feet. On October 22, 1957, an electric log was made of the uncased part of the well. The electrode would not go beyond 760 feet. The bottom of the 8-inch casing was determined to be at 714 feet. When tested at completion, the well yielded 250 gpm with a 147-foot drawdown. This well penetrates only about 45 feet of the Clayton formation, which probably accounts in part for the low yield and excessive drawdown.

WATER-LEVEL FLUCTUATIONS

A well (8405–3135–6), owned by the Atlantic Ice and Coal Co. was drilled in 1885 to a depth of 710 feet. It was recased to 660 feet in 1901. The water level in the well was 26 feet above the land surface (Stephenson and Veatch, 1915, p. 238) at the time it was drilled, and the flow was 125 gpm. By 1896 the flow had decreased to 75 gpm, owing to the interference of other nearby wells. On August 10, 1955, the water level was 72.1 feet below the land surface. Figure 10 shows a hydrograph of the water-level fluctuations in the well for the period April through December 1957. Water levels fluctuated between 50 and 70 feet below the land surface. The chief cause of the seasonal decline is the increase in pumpage by the city of Albany during the summer.

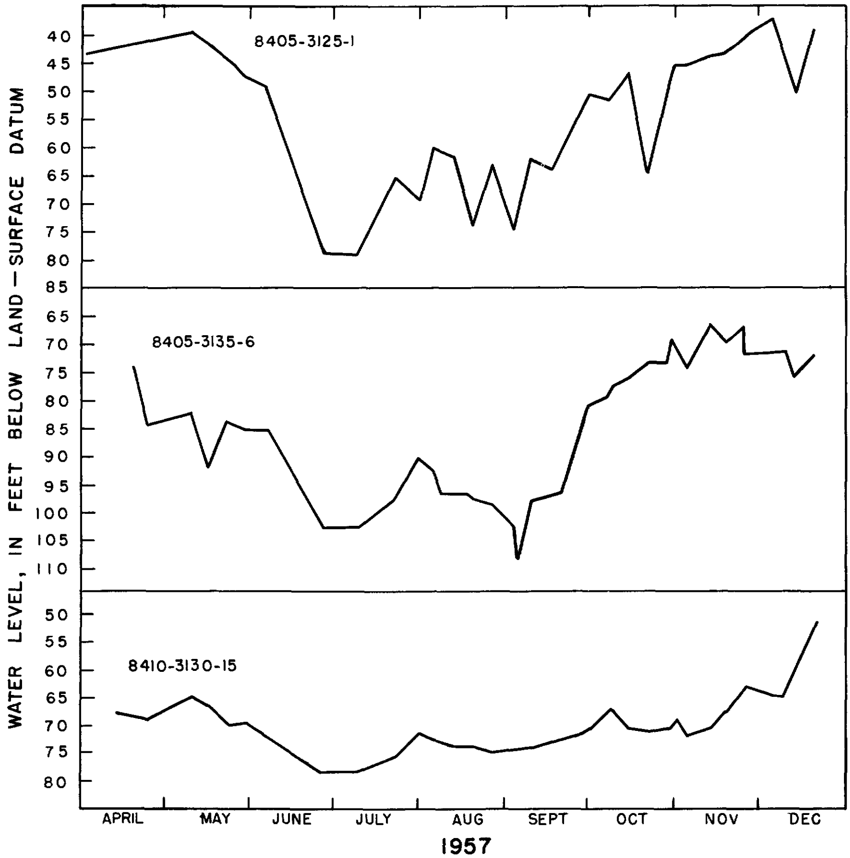


FIGURE 10.—Hydrographs of three wells penetrating rocks of the Midway group, Dougherty County.

Well 8410–3130–15 is owned by Virginia-Carolina Chemical Co. It is not known when this well was drilled nor to what depth. The measured depth in 1957 was 594 feet. Dark-gray micaceous silt, similar to that of the Wilcox group, was found on the sounding weight. It is probable that the casing had rusted and collapsed at that depth. According to records furnished in 1941 by the plant manager, the well flowed 55 gpm in 1918. Flow stopped in 1931 when city well 5 was put into use. City well 5, now plugged and abandoned, was 812 feet deep and was screened in the interval 658 to 815 feet. The well is about 1,000 feet southeast of the Virginia-Carolina well. The Virginia-Carolina well was probably drilled into the Clayton formation to obtain a flow. No flowing wells are recorded at lesser depths in the Albany area. The water level in well 8410–3130–15 was 99.8 feet below the land surface in August 1955. Figure 10 shows a hydrograph of this well from April through December 1957. The water level fluctuated between 66 and 102 feet below the land surface, or a total of 36 feet during the period of record.

A well (8405–3135–8) owned by Swift and Co. was drilled in 1913 to a depth of 1,000 feet, according to reports, but no record of its construction is available. A jet pump installed in the well prevented sounding to determine the present depth. The water level was 60 feet below the land surface on August 10, 1955. Weekly water-level measurements are shown in fig. 10. The total fluctuation was 42 feet for the period April through December 1957. This well is near city well 16, which is screened in the Upper Cretaceous series, and has open hole from 628 to 720 feet in the Clayton formation. The occasional low water-level readings obtained from the well probably are due to the interference caused by pumping in city well 16.

Declines in head ranging from 70 to 95 feet have occurred in the rocks of the Midway group in Albany since the first well was drilled. Water levels have declined from about 30 feet above the land surface to more than 50 feet below. Chief cause of the decline has been pumping. However, some leakage to overlying formations can occur in abandoned wells and in gravel-packed wells.

TUSCAHOMA SAND

The Tuscahoma sand consists of light-gray micaceous silt and sand underlain by fine to medium glauconitic sand. The sand is unconsolidated to weakly cemented. A sand unit near the base of the formation ranges in thickness from 40 to 50 feet in eastern Dougherty County and thins toward the west, where it grades laterally into sandy silt at Morgan, Calhoun County, about 25 miles west of Albany. The city of Albany wells 6, 7, 8, 10, 12, and 14 (table 2) are screened opposite the basal sand. Owing to its silt content, the sand probably yields only small quantities of water to wells.

No well in Dougherty County is known to obtain ground water exclusively from the Tuscahoma sand, and data are not available regarding the yield, static head, or quality of water to be expected from it. This formation is of minor importance as an aquifer in Dougherty County.

CLAIBORNE GROUP

TALLAHATTA FORMATION

The Tallahatta formation in Dougherty County consists of dark siliceous to silty glauconitic limestone, at the base, overlain by about 120 feet of unconsolidated to weakly cemented phosphatic sand and a few beds of calcareous clay. Above the sand is about 100 feet of sandy shell-limestone or coquina, which contains a few beds of calcareous clay. Abundant ground water is obtained from sand and the shell limestone of the Tallahatta formation. The city wells and the three U.S. Marine Corps Supply Center wells have screens set in the Tallahatta formation (table 2).

City well 6 has approximately 60 feet of screen in the Tallahatta formation, of which 50 feet is near the top, opposite sand. The remaining 10 feet is near the base of the formation.

City well 7 has 39 feet of screen in the sand of the Tallahatta formation, and city well 8 has 2 screens totaling 40 feet near the top of the formation. Samples are not available from well 8, but the 10-foot screen probably is in the coquina and the 30-foot screen in the sand.

City well 9 has 100 feet of screen in the Tallahatta formation. All the screens in this well are in sand. The 15-foot screen from 330 to 345 feet is in sand which is weakly to firmly cemented.

City well 10 has 100 feet of screen set in the Tallahatta formation. The top screen, from 260 to 265 feet, is in sand; two 10-foot screens from 295 to 305 feet and from 315 to 325 feet are in calcareous sand. A 10-foot screen from 350 to 360 feet is in arenaceous marl. A 40-foot screen from 380 to 420 feet is in sand, and a 5-foot screen from 480 to 485 feet is in siliceous limestone.

City well 11 has 55 feet of screen in the Tallahatta formation. The top screen, from 265 to 270 feet, is in arenaceous limestone, 1 screen from 285 to 290 feet is in calcareous sand, and 5 screens totaling 35 feet in the interval from 325 to 435 feet are in the coquina. A 10-foot screen from 450 to 460 feet is in arenaceous marl.

City well 13 has 100 feet of screen set in the Tallahatta formation. Screens set between 270 and 345 feet are in the coquina; those in the interval from 373 to 460 feet are in unconsolidated sand. One 10-foot screen, from 480 to 490 feet, is set in the basal siliceous limestone and extends downward into the upper part of the underlying Tuscahoma formation.

City well 14 has 80 feet of screen set in the Tallahatta formation. Screens set from 275 to 295 feet and from 330 to 350 feet are in arenaceous limestone. Screens set from 385 to 395 feet and from 420 to 440 feet are in sand. The screen from 480 to 490 feet is in siliceous limestone at the base of the formation. City well 15 has 70 feet of screen set in the Tallahatta formation. Two screens from 270 to 280 feet and 285 to 295 feet are in the coquina. Screens from 335 to 355 feet, 360 to 370 feet, and 385 to 395 feet are in the unconsolidated sand. The screen from 440 to 450 feet is in arenaceous limestone.

City well 16 has 80 feet of screen in the Tallahatta formation; 2 screens from 280 to 320 feet and from 330 to 350 feet are set in the coquina, 1 screen from 430 to 440 feet is in the unconsolidated sand.

City well 17 has 35 feet of screen set in the Tallahatta formation. No drilling samples are available from this well, but the driller's log describes the following beds in the screened intervals:

Description	*Depth (feet)*	*Screen setting (feet)*
Limerock, white, and brown sand	190–218	200–205
Shells, brown, and limerock	265–322	300–305
Sand, fine, gray, with marl	385–462	415–420 435–445
Sand, soft, fine, gray, with shell	462–478	460–470

The three U.S. Marine Corps Supply Center wells also obtain water from the Tallahatta formation. The screen settings in these wells are given in table 2. Water is obtained from both the massive sand and the coquina.

LISBON FORMATION

The Lisbon formation consists of firmly cemented very fine to fine, fossiliferous glauconitic sandstone overlain by sandy glauconitic firmly cemented shell limestone. Few wells are screened in the Lisbon formation. City wells 9, 11, and 17 and U.S. Marine Corps Supply Center wells 1, 2, and 3 have screens set opposite the sandstone of the Lisbon formation. Domestic supplies of water probably could be obtained from the Lisbon formation in areas to the north and west of Dougherty County. No well in Dougherty County is known to obtain water from this formation exclusively; hence, data are not available concerning the yield of the aquifer.

YIELD OF CLAIBORNE GROUP

City well 14, drilled in the winter of 1953–54, was tested in February 1954. After the well was cased, the bottom part of the well from 865 to 657 feet was filled with sand. Water from the Midway group and from the Upper Cretaceous series flows through screens and open hole in this part of the well, and water from the Claiborne and Wilcox groups flows through screens set between the depths of 275 and 490 feet.

For the development test, a pump consisting of 200 feet of column, 7 feet of bowls, and 20 feet of suction pipe was installed. The well was pumped for 12 hours at 825 gpm. The static water level was 46 feet, pumping level 227 feet, and drawdown 181 feet.

The following day the well was pumped at the rate of 925 gpm. The static and pumping water levels were the same as on the previous day. On the third day, the well was pumped at 950 gpm, with the static and pumping water levels still the same. Development had increased the capacity of the well from 825 to 950 gpm.

The test pump was then removed, and the sand was cleaned from the well. To determine the amount of water that could be pumped from the entire well, the same test pump was reinstalled, and the well was pumped at the rate of 1,440 gpm. The static water level was 51 feet, the pumping water level 208 feet, and drawdown 157 feet. The well was pumped for 16 hours the following day. The pumping rate was varied, but near the end of the test the well was pumped at the rate of 1,319 gpm. Before the test, the static water level was 64 feet, the pumping water level 230 feet, and drawdown 166 feet, or 9 feet greater than that of the previous day when the pumping rate had been about 120 gpm greater. This test indicated that the well produced from 825 to 950 gpm from the Claiborne and Wilcox groups combined and from 360 to 625 gpm from the Midway group and the Upper Cretaceous series combined.

City well 15 was tested in a similar manner. The bottom part of the well from 865 to 600 feet was filled with sand. The same test pump used in well 14 was installed. This well produced only 450 gpm from the Claiborne and Wilcox groups combined. Static and pumping water-level measurements were not recorded. The sand was then cleaned from the well, the test pump was reinstalled, and the well was pumped at the rate of 1,550 gpm for 24 hours. At the end of that time, the pumping level was 138 feet. Static level had been 31 feet before the test, and thus the drawdown was 107 feet. This test indicated that the Claiborne and Wilcox groups combined produced 450 gpm and that the Midway group and the Upper Cretaceous series combined produced 1,100 gpm.

These tests show the variation in the amount of water that can be pumped from each aquifer but give little positive evidence as to which is most productive.

City well 17 produces water from only the Claiborne group. A 5-foot screen is set in the Lisbon formation, and 30 feet of screen is set in the Tallahatta formation. This well has been pumped at the rate of 1,400 gpm with about 150 feet of drawdown.

The aquifers of the Claiborne group are capable of furnishing from about 500 to 1,400 gpm between depths ranging from about 500 feet in western Dougherty County to about 850 feet in eastern Dougherty County. Pumping levels may be as much as 250 feet below the land surface. The Claiborne group is utilized only in the city wells and U.S. Marine Corps Supply Center wells. This aquifer would be an excellent source of ground water for irrigation.

WATER-LEVEL FLUCTUATIONS

No wells, except city well 17, are known to derive water exclusively from the aquifers of the Claiborne group, hence data are lacking regarding water levels in this formation. All other city wells and the U.S. Marine Corps Supply Center wells are constructed as multiple-aquifer wells and are gravel packed. Water-level measurements in these wells, therefore, are not indicative of the true water levels in the Claiborne group.

OCALA LIMESTONE

Ground water occurs in the Ocala limestone throughout Dougherty County. Most domestic supplies and a few irrigation and industrial supplies are obtained from wells that penetrate the Ocala limestone. Yields obtained usually depend upon the depth and diameter of the well and the size of the pump installed. Most domestic wells range in depth from 100 to 200 feet and are 3 inches in diameter. The wells are usually equipped with a small-capacity jet pump; consequently small amounts of water are pumped from the wells. However, several deeper wells of larger diameter have been drilled. A 10-inch well (8405–3125–11), 215 feet deep, owned by Merck and Co., produces about 1,000 gpm. An irrigation well (8415–3130–1) at the Nilo plantation has reportedly been pumped at the rate of about 1,700 gpm. Thus, the amount of water produced by a single well is not indicative of the amount of water that can be obtained from the Ocala limestone.

In two areas east of the Flint River, the limestone appears to be cavernous. This is discussed more completely in the section "Piezometric surface." Wells drilled in these areas may yield larger quantities of water than wells in other areas. However, if the water is for domestic use, a careful check should be made of the sanitary quality of the water. Supply wells at an apartment house near Radium Springs have become polluted when the Flint River was in flood stage. These wells obtain water from the Ocala limestone. Polluted water could be avoided by drilling wells to greater depths and utilizing the underlying coquina or sand in the Tallahatta formation.

WATER-LEVEL FLUCTUATIONS

Figure 11 is a hydrograph of Merck and Co. observation well 1 (8405–3125–14) and shows rainfall and pumpage from August 1953 through 1957. Weekly water-level measurements were furnished by the company until a recording gage was installed in May 1957. The hydrograph from May through December 1957 shows weekly averages of daily noon readings taken from the recorder charts. Water levels are highest in the period from November through March of each year. The high for the period of record was in January 1954, and the low was in September 1957. A poor degree of correlation appears to exist between the rainfall recorded in Albany and the water level in this well. In July 1955, 10 inches of rainfall raised the water level about 1 foot in this well. In July 1956, 9 inches of rainfall raised the water level less than half a foot. In September 1957, about 9.2 inches of rain fell, and the water level in the well was at a record low of

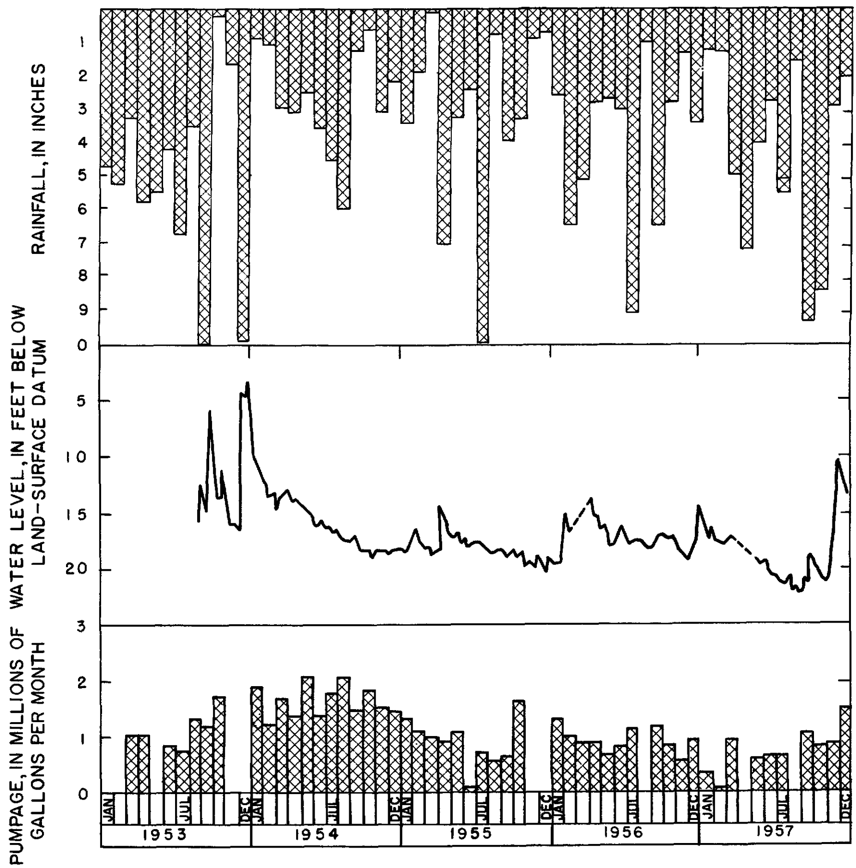


FIGURE 11.—Hydrograph of well 8405–3125–14 showing lack of correlation with local pumpage and rainfall.

about 23 feet below the land surface at the end of September. The high for the year 1957 occurred in November and December, after 17.6 inches of rain fell during September and October. Rainfall durng the summer, when evapotranspiration is high, appears to have only a slight effect on the water level in this observation well. Much of the rainfall during this period is used by vegetation.

The water level in this well probably responds more rapidly to changes in stage of the Flint River than to local rainfall. The stage of the Flint River is affected by local rainfall, by rain that falls in the Flint River drainage system above Albany, and by the regulation of the Crisp County power dam and the Georgia Power Co. dam, which are upstream from the observation well. Ground-water levels in wells near the Flint River vary with the stage of the river.

Figure 12 shows hydrographs of five wells which penetrate the Ocala limestone in Dougherty County.

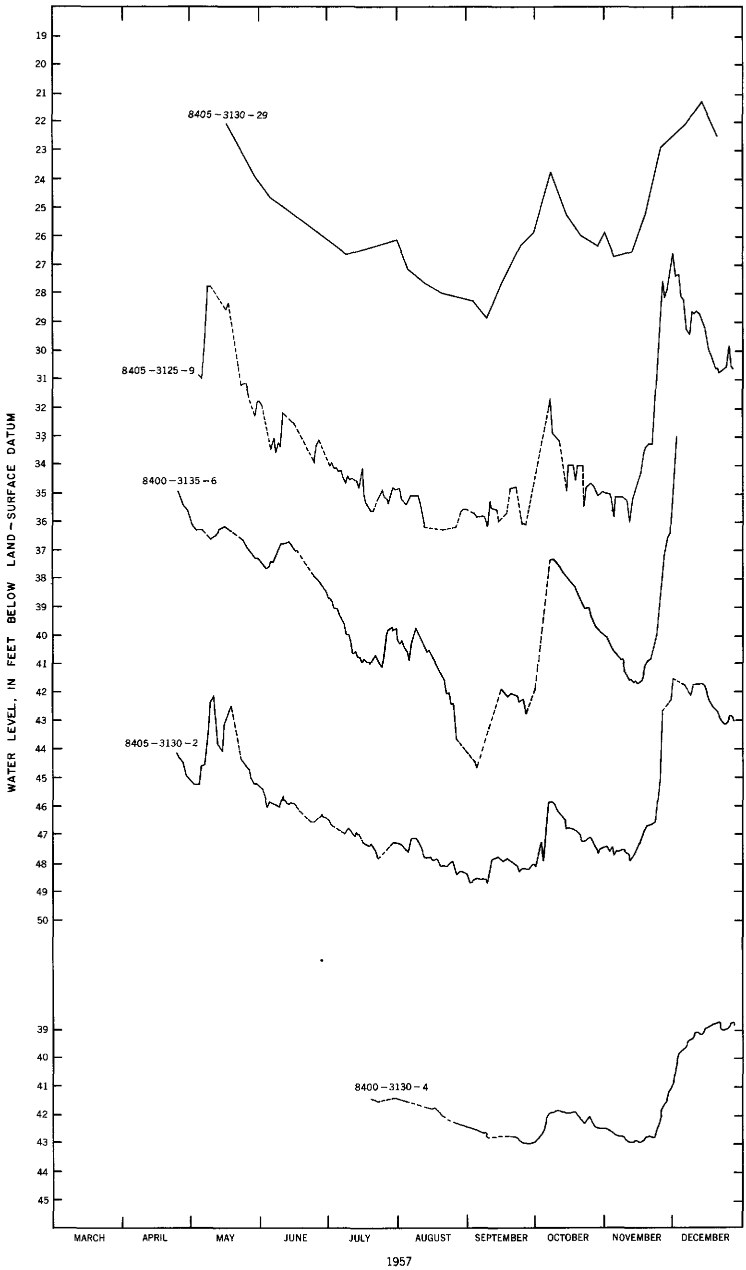


FIGURE 12.—Hydrographs of wells penetrating Ocala limestone in Dougherty County.

Well 8405–3130–29 is a 6-inch well, 138 feet deep, and cased to an unknown depth. It is south of the old U.S. Highway 82 bridge and about 200 feet east of the Flint River. Water levels are affected by the stage of the Flint River. Well 8405–3125–9 is a 4-inch well 151 feet deep and cased to an unknown depth. It is about 0.8 mile east of the Flint River and is affected by the stage of the river. This well responds to the noon rise in water level in the river (p.60–63) most rapidly of the wells shown. Well 8405–3130–2 is a 6-inch well, 193 feet deep and cased to 103 feet. It is about 40 feet from U.S. Marine Corps Supply Center well 3 and responds to changes in stages of the Flint River as well as to pumping of the nearby Supply Center well. Well 8400–3130–4 is a 6-inch well, 243 feet deep and cased to 206 feet. It is near the east end of the U.S. Marine Corps Supply Center.

The water levels are high in the spring and decline during the summer and early fall. The decline is due to increased use of water by vegetation and to increased pumpage. Water levels rise in the late fall and winter in response to heavier rainfall and decreased use of water from wells. The yearend water levels in all the wells are higher than those in April, the beginning of the period of record for most of the wells. Rainfall was above normal in October and December 1957.

SPRINGS

All known springs in Dougherty County issue from the Ocala limestone. Radium Springs (8405–3130–S1), formerly called Blue Springs (Stephenson and Veatch, 1915, pl. XX, opposite p. 240), is the largest and best known spring in the county. It is about 4 miles south of Albany on U.S. Highway 19 and about 200 yards east of the Flint River. The spring emerges from an opening about 3 feet in diameter, in the bottom of a 15-foot depression. (In May 1955 an amateur skin diver was drowned while exploring the spring, and the body was recovered during a subsequent search by Navy frogmen from Charleston, S. C. The searchers described a cavern about 300 feet wide, 150 feet long, and 80 feet deep below the entrance to the spring.) Flow from this spring has been measured at rates of from 87 to 2.6 mgd. The measured flow from the spring on various dates is given in table 3. Measurements were made by the Surface Water Branch of the Geological Survey.

No attempt was made to locate other springs along the river, although they are numerous. Several springs, visible during low water, have been reported in the bottom of the river between Radium Springs and the U.S. Highway 82 bridge. Because most of the springs are along the bank of the river and are covered during high stages of the river, they cannot be developed as sources of ground water.

TABLE 3.—*Discharge of water from Radium Springs*

(Measurements by U.S. Geological Survey)

Date of measurement	Discharge: Cubic feet per second (cfs)	Discharge: Million gallons per day (mgd)	Date of measurement	Discharge: Cubic feet per second (cfs)	Discharge: Million gallons per day (mgd)
4-19-04	135	87	8-25-53	45.1	29.2
9-23-04	44	28	9-7-53	37.6	24.3
11-16-04	26.4	17.0	9-7-53	26.0	23.3
4-20-05	69	45	9-14-53	24.3	15.7
6-22-37	69.3	44.7	9-21-53	23.5	15.2
9-13-51	25.5	16.5	10-23-53	43.0	27.8
11-15-51	29.8	19.3	11-16-53	38.5	24.9
11-21-51	42.8	27.6	11-17-53	41.5	26.8
11-28-51	32.0	20.7	11-23-53	33.3	21.6
12-12-51	39.3	25.4	2-3-54	76.9	49.7
1-8-52	62.0	40.1	2-7-54	18.0	11.7
1-21-52	47.3	30.6	10-19-54	[1]4.09	2.6

[1] Leakage through weir; not entire flow at spring outlet.

PIEZOMETRIC SURFACE

A piezometric or pressure-indicating surface is shown on plate 2. This is the elevation above sea level to which water would rise in tightly cased wells that penetrate only the Ocala limestone. During the period August 5–9, 1957, 125 wells were measured by the wetted-tape method to obtain data for the construction of this map. Some well elevations were obtained by instrumental leveling; others were obtained from topographic maps of the area.

The contour lines indicate the direction of movement of ground water, which is generally perpendicular to the contour lines. The contours of this piezometric map show that ground water moves toward the Flint River from the east and west. The contour lines swing to the north or upstream and parallel the river before crossing it at right angles. This upstream displacement of the contour lines indicates that the Flint River is fed by ground water. Springs along the bank of the Flint River and in the bed of the river indicate that water is discharging to the river from the Ocala limestone. Thus, the river is shown as a trough in the piezometric surface. Ground water moves nearly parallel to the Flint River in the area south of the U.S. Marine Corps Supply Center.

A ground-water trough between Radium Springs and the U.S. Highway 82 bridge extends eastward from the Flint River to the central part of the Supply Center. A similar trough lies to the south along the river and about 4 miles north of the Mitchell County line. These troughs probably indicate areas in which the limestone is cavernous.

654863 O—63——5

A perched water table, not shown on the piezometric map, is present in the southeast corner of the county. Here, on the highest hill in the county, water is obtained from several dug wells. Water-level measurements in dug wells indicate a great disparity in depth to water as compared to water levels in the drilled wells in the area. The dug wells tap unconfined ground water in the residuum of the Flint River formation, and the drilled wells tap artesian ground water in the Ocala limestone.

In the northeast part of Dougherty County, in the area above the Georgia Power Co. dam, the ground-water levels were generally below the elevation of the ponded water. Recharge to the ground-water body from the lake probably occurs in this area.

West of Flint River, ground water in the Ocala limestone moves southeastward toward the river. In the western part of the county, it appears that the piezometric surface is at the land surface in several creeks and swamps. A ground-water mound may exist between Kiokee and Cooleewahee Creeks, and recharge may occur from large sinkholes in the interstream area. Ground water is discharged into these creeks from the Ocala limtstone. However, Cooleewahee and Kiokee Creeks were dry in October 1954. Several other minor tributaries also were dry during this severe drought. (See Thomson and Carter, 1955, table 3, p. 74.) Water levels in several of the sinkholes in the southwestern part of the county may coincide with the piezometric surface. The sinks and the ground-water body may be connected in this area.

The creeks and the Flint River are effluent or gaining streams in Dougherty County. Ground water is discharged into these streams from the Ocala limestone. Because of ground-water discharge, the flow of the streams continues throughout the year.

A comparison of the piezometric surface for 1957 with that of Warren (1944, fig. 2, p. 18a) shows that water levels have declined about 10 feet along the Flint River in the southern part of Dougherty County and slightly less than 10 feet in the northern part of the county along the river. The decline probably was caused by the increased domestic and industrial use of ground water and subnormal rainfall for most of the period 1950–57.

INFLUENCE OF THE FLINT RIVER

Changes in stage of the Flint River cause changes of lesser magnitude in the ground-water levels in the Ocala limestone. Figure 13 shows the stage of the Flint River plotted in feet above gage height; water levels of wells 8405–3125–9, 8405–3130–2, and 8400–3130–4; and the flow from Radium Springs from September 3 through September 9,

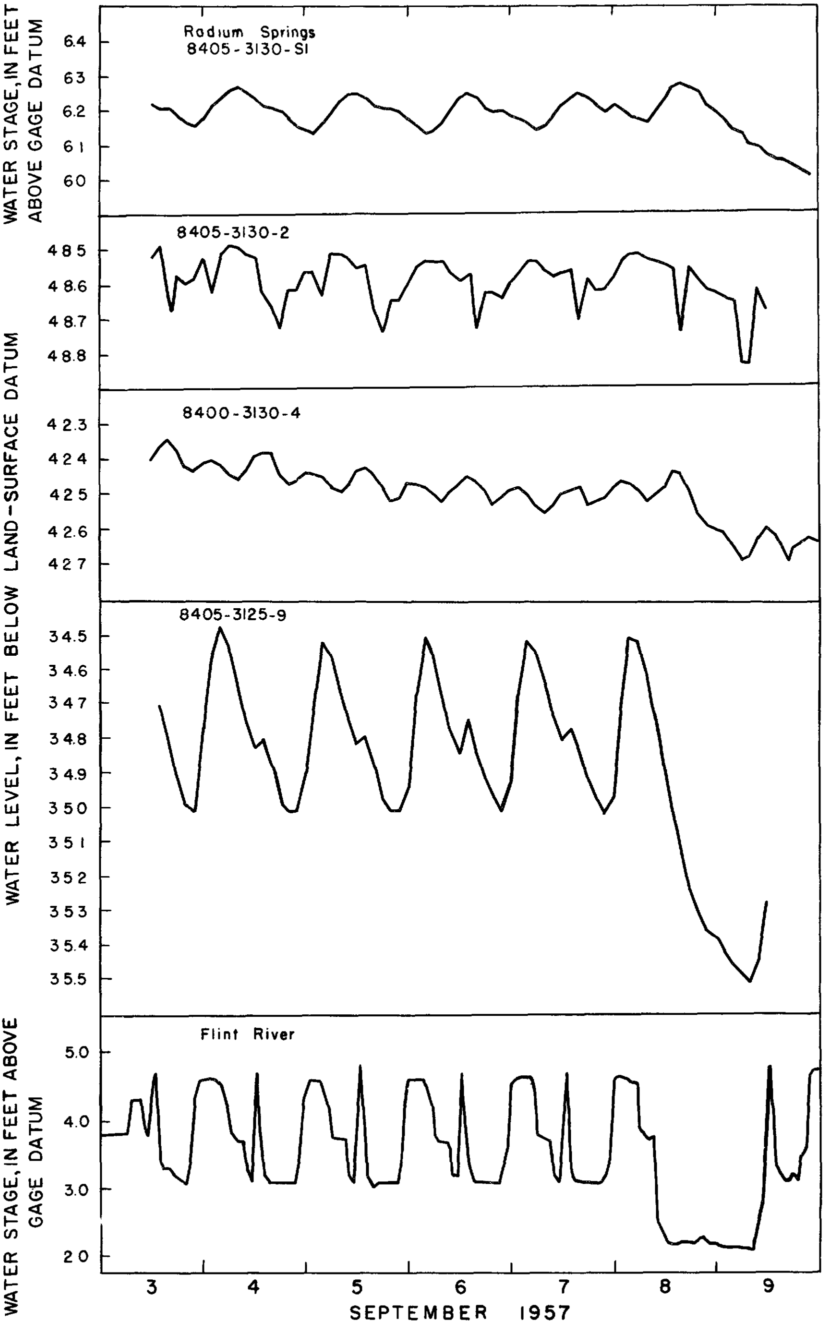


FIGURE 13.—Fluctuations in water level in the Ocala limestone caused by changes in stage of the Flint River, Albany, Ga.

1957. The gaging station is on the Georgia Northern Railroad bridge 1.3 miles upstream from the U.S. Highway 82 bridge in Albany. Radium Springs is 4.6 miles south of the gaging station. The outflow from the spring is measured at the junction of the outflow with the Flint River, 0.6 mile below the spring. Well 8405–3125–9 is about 8 miles downstream from the gaging station, 3 miles below Radium Springs and 0.8 mile east of the river. Well 8405–3130–1 is 4.5 miles southeast of the gage, and well 8400–3130–4 is 4.7 miles southeast of the gage and 2.7 miles east of the river.

Water is released from the Georgia Power Co. dam for about an hour, beginning slightly before noon to accommodate the peak electric load, and again throughout the night.

The release of water at noon causes a rise in ground-water level of about 0.02 foot in well 8405–3125–9. This rise is not clearly discernible on records from the other wells. An increase in river stage caused by release of water at night appears to reach a peak at about midnight, ground-water levels in well 8405–3125–9 peak about 4 hours later; and the flow of Radium Springs peaks about 16 hours later. Part of the lag at Radium Springs may be explained by the location of the gage, which is 0.6 mile below the spring. Peaks are somewhat masked in well 8405–3130–2 but appear to be about 6 hours later. The diurnal water-level fluctuations in well 8400–3130–4 are caused by changes in barometric pressure.

The distance of a well from the river appears to have little relation to the elapsed time between a peak in river stage and a peak in the water level of the well. There may be several explanations for this lack of correlation. Two troughs in the piezometric surface east of the Flint River, one in the vicinity of well 8405–3135–9 and one in the vicinity of the U.S. Marine Corps Supply Center, indicate possible rapid drainage of ground water from these areas as compared to surrounding areas and may indicate caverns in the limestone. In cavernous areas, water-level fluctuations caused by changes in river stage would be transmitted more rapidly than in less permeable rocks. Changes in stage in the Flint River are reflected by changes in ground-water levels as much as 3 miles from the river in Dougherty County. The change in ground-water levels in some parts of the county may be due to a damming effect by the river. As the depth of the water in the river increases, the flow of river-bottom springs or of bank springs decreases because they must discharge against increased head. This in turn causes water to be stored temporarily in the Ocala limestone. However, because Radium Springs is above the level of the river and does not become submerged except by flooding, the decrease in discharge from river-bottom springs causes ground-water levels to rise, and, when sufficient water is stored in the Ocala limestone to reach the level of Radium Springs, the overflow from the springs increases.

MINOR WATER-LEVEL FLUCTUATIONS

Figure 14 shows a hydrograph for well 8405–3130–2, a 6-inch drilled well, 160 feet deep, that penetrates the Ocala limestone. This well is about 40 feet east of U.S. Marine Corps Supply Center well 3, which is 900 feet deep and obtains water from sands of the Claiborne group and limestone of the Midway group. (See table 1.) Well 3 was constructed in a manner similar to city well 15. (See fig. 16.) The top screen is at a depth of 240 to 250 feet, or 80 feet below the bottom of well 8405–3130–2. When well 3 is pumped at the rate of 1,350 gpm, the water level in well 8405–3130–2 declines 0.2 foot. The decline may be due to a release of pressure on the Ocala limestone, when a cone of depression is created around the pumping well. Release of pressure causes the forces supporting the Ocala limestone to be lessened and allows the Ocala limestone to expand slightly. The decline also could be attributed to leakage from the Ocala into the pumping well around imperfectly sealed casing.

Fluctuations caused by passing railroad trains (fig. 4) were noted in well 8400–3130–4, a 6-inch well, 259 feet deep, penetrating the Ocala limestone. This well is about 100 feet south of the Atlantic Coast Line Railroad near Acree. Fluctuations of this kind were first noted by Jacob (1939). On September 2, 1957, a train consisting of 9 cars and diesel engine, traveling west at a speed estimated to be 20–25 mph, produced a rise in water level of 0.04 foot in the well. Rises of greater and lesser magnitude also have been recorded. This phenomenon is due to loading of the aquifer, in this case the Ocala limestone. The added weight of the train in the vicinity of the well causes the aquifer to become slightly compressed and decreases the storage space available for water. When the storage space is decreased, water is forced out of the limestone in the area where the weight is applied. The added pressure causes the water to rise in the well as the limestone adjusts itself to the added weight. As the train moves away from the vicinity of the well, the load is removed, and the water level declines to its former position.

Earthquakes.—On July 28, 1957, an earthquake of magnitude 7.5 (Pasadena scale) occurred at Guerrero, Mexico. Water-level fluctuations caused by the shock waves from this earthquake were recorded in three wells in Dougherty County. Earthquake fluctuations in wells are the result of compression of the earth and, later, expansion after the shock wave of the earthquake has passed the locality of the well. When the aquifer is compressed, water is released from the containing

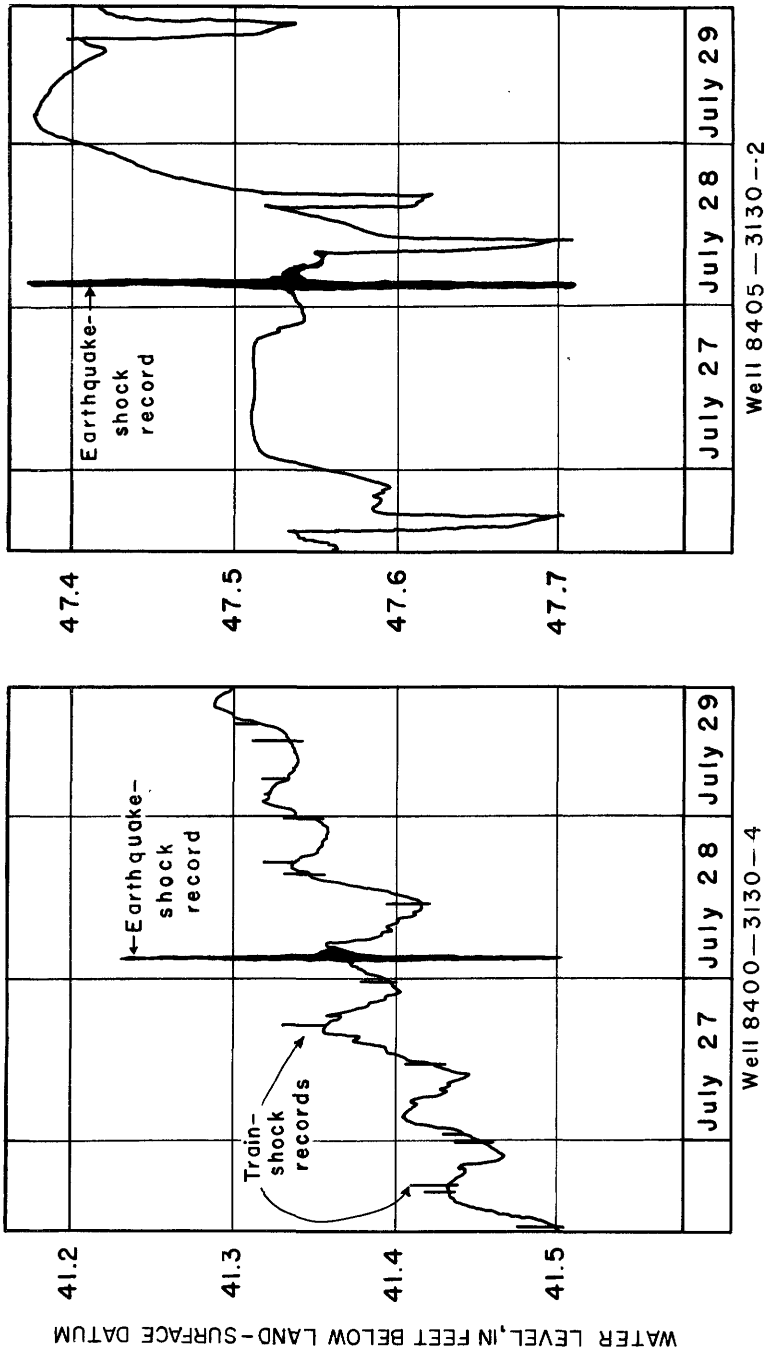


FIGURE 14.—Hydrographs showing water-level fluctuations caused by the Guerrero, Mexico, earthquake, 1957.

rocks instantaneously, causing the water level to rise in wells. When the shock wave has passed, the stress is removed and the water level declines.

The Guerrero earthquake caused the water level in well 8400–3130–4 to fluctuate a total of 0.27 foot; in well 8405–3130–2, 0.34 foot. Figure 14 shows the fluctuations that occurred in wells 8405–3130–2 and 8400–3130–4.

RECHARGE

The ground-water body in the Ocala limestone is recharged through sinkholes and areas of interior drainage. Recharge may be very rapid or exceedingly slow. In a study of the hydrology of ponds in limestone in Baker County, Hendricks and Goodwin (1952) showed that the pond levels lowered most rapidly after a pond exceeded its usual limits and spilled onto the adjoining areas of residuum. This is to be expected in old established ponds such as were studied, because the ponds have been partly filled with sediments carried by storm runoff. (The transporting power of a stream varies as the sixth power of velocity, and fine particles settle out when water loses its velocity. Thus, when water enters the pond, the fine sediment, clay and silt, is deposited in the pond.) According to Hendricks (1954, p. 800), the permeability of disturbed bottom materials was found to be 0.005 inch per day under a gradient of 1 foot per foot. Such a low permeability is typical of clay or silt. Thus, when the pond is within its usual confines, recharge to the ground-water body may be exceedingly slow, but when the pond fills beyond its usual limits and spills onto the surrounding area of coarser grained material, recharge is more rapid.

Many areas of interior drainage exist in Dougherty County. Some of them are easily recognizable as sinkholes, but others are merely lowland areas of interior drainage. The two types of sinkholes are described on page 10. Recharge probably is more rapid in youthful sinkholes than in the old-age sinkholes that have a considerable thickness of silt and clay accumulated in the bottoms. One sinkhole observed had an opening in its bottom nearly 1 foot in diameter. This would allow water to recharge the ground-water body at an extremely rapid rate.

Recharge from rainfall.—The Ocala limestone in this area is recharged chiefly from local rainfall. Figure 15 shows hydrographs of wells 8405–3130–2 and 8400–3130–4 for September and October 1957. Rainfall is plotted at the bottom of the graph. These two wells appear to be least affected by changes in stage of the Flint River.

Although 0.53 inch of rain fell during the period August 17 to 20 and 0.48 inch fell on August 27, sufficient time had probably elapsed for the effect of this rainfall to have dissipated before the first rain

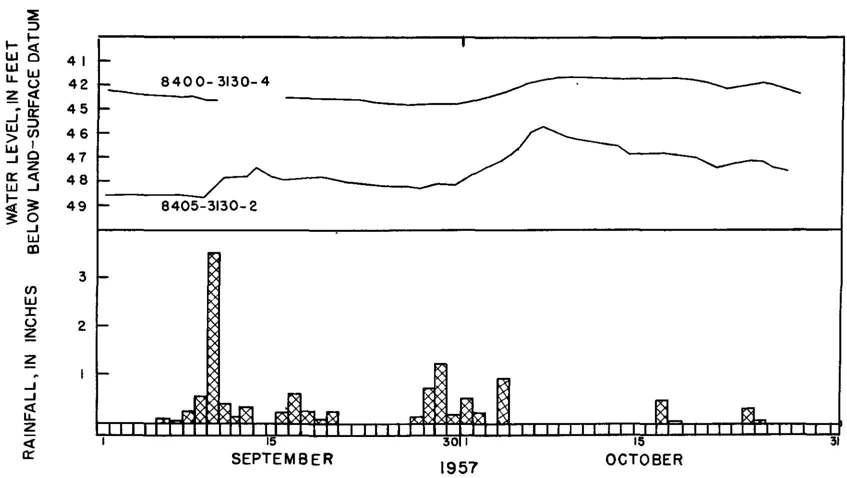


FIGURE 15.—Hydrographs showing effect of rainfall on wells penetrating Ocala limestone in Dougherty County.

on September 5, when 0.10 inch fell. Rainfall continued on September 5–13, totaling 5.41 inches, including 3.55 inches of rain on September 10. Rises in water level were noted, starting on September 10. Rain did not fall on September 12 and 14. From September 16 through 20 rainfall amounted to 1.48 inches; the heaviest rainfall for this period, 0.62 inch, occurred on September 17. No appreciable changes in water levels were noted as a result of these rains. Rain began again on September 27 and continued through October 4, amounting to 4.07 inches, which included 1.24 inches on September 29 and 0.95 inch on October 4. Rises in water levels were noted on September 30.

Although a part of the rise in ground-water levels may be attributed to increased flow in the Flint River, the effect of rainfall on the water levels in the Ocala limestone usually occurs within 4 or 5 days.

RESIDUUM

Residuum overlies the Ocala limestone and Flint River formation throughout Dougherty County. It consists of brown to red mottled sandy clay that contains chert boulders. Small quantities of ground water are obtained from the residuum throughout the county by dug wells. The wells are usually 3 to 4 feet in diameter and are dug to relatively shallow depths by hand tools. Hard material, such as siliceous boulders or limestone, usually restricts the depth to less than 70 feet. Some of the wells are dry; others yield as much as 15 gpm.

Water obtained from dug wells is unconfined, and rainfall causes the water table to rise. The water table may decline below the bottom of the well during drought.

Dug wells are subject to pollution because they are usually not covered. Pollution may also occur from nearby privies. A drilling program carried out by the County Health Department has nearly eliminated dug wells as a source of water supply.

WATER-LEVEL FLUCTUATIONS

In several dug wells in the grid rectangle, 8400–3125, water levels range from 5.1 to 47.1 feet below the land surface and from about 27 to 70 feet above the water level in drilled wells in this area. The difference in water levels indicates that the dug wells obtain water that is perched above the artesian water of the underlying Ocala limestone. The perched water body is dependent on local rainfall for recharge. Water levels are usually highest in the spring and lowest in the late fall or early winter.

WELL CONSTRUCTION

Two types of well construction are used in Dougherty County. The type of construction depends on the type of rock from which water is to be obtained.

The simplest type of construction is used to obtain water from limestone. A hole is drilled to a depth slightly below the top of the water-bearing limestone and casing installed from this point to the land surface. Below the bottom of the casing, the hole is drilled to the desired depth and left uncased. The open hole does not cave because the limestone is firm. If a rotary drill is used, casing is sometimes cemented in place. If a cable tool (percussion) is used, the casing usually is driven into the top of firm rock. Either of these methods will serve to seat the casing firmly in place, but the cementing method will better seal out water from the rocks above the open hole. Well construction of this type is used to obtain water from the Ocala limestone and Clayton formation.

Occasionally, well owners report that their well pumps sand for a long time after completion. This usually can be prevented by proper development of the well. Each well should be developed by pumping or bailing at a greater rate than that at which it will be pumped when placed in service. Rapid movement of water through the water-bearing formation will cause sand or silt deposited in the cavernous parts of the limestone to be moved into the well bore, from which it can be removed by bailing. When the well is pumped at a lesser rate by the permanent pump, little sand will be drawn into it.

The second well-construction method used in Dougherty County is somewhat more complicated. If water is to be obtained from the deeper lying sands and coquina limestones of the Claiborne group or the Upper Cretaceous series, screened gravel-packed wells are constructed. The well screens are bronze or stainless steel pipe with horizontal louver slots or keystone-shaped vertical slots. Holes are sometimes punched in the pipe, and wire gauze is then wrapped around the pipe; then wire shaped like a keystone is wrapped around the gauze. The narrow part of the keystone slot is placed toward the outside of the casing to allow sand grains to be drawn into the well and prevent the slots from being clogged.

The type of screen used depends upon the preference of the contractor. Screens must be placed opposite the water-bearing sands to obtain the maximum amount of water. A large-diameter hole is drilled to a depth of 180 to 240 feet and 18- to 20-inch casing is cemented in place. The purpose of the casing is to prevent caving of the decomposed Ocala limestone.

A small-diameter test hole is then drilled inside the large-diameter casing to the desired depth, and drill cuttings are taken at 10-foot intervals. An electric log can then be made of this uncased test hole. By examining the electric log and drill cuttings, the water-bearing zones are determined. The test hole is then reamed to a diameter large enough to accommodate the screens and to allow pea-sized gravel to be inserted in the annular space between the screens and wall of the reamed hole. Screens are carefully positioned opposite the water-bearing sands. If water also is to be obtained from the Clayton formation, the casing is extended to a point slightly below the top of the limestone, and that part of the hole in the limestone is left uncased.

City wells 14, 15, and 16 were constructed in a unique manner. The construction features of city well 15 are shown in figure 16. The test hole was drilled into the Upper Cretaceous sediments. Water-bearing zones were determined; the part of the hole in the Upper Cretaceous rocks was under-reamed, screens set in place, and gravel placed in the annular space between the screens and wall of the hole. Cement was then inserted on top of the gravel to prevent caving of the material above the screened zone. The limestone unit of the Clayton formation was left uncased. Screen and casing were extended upward from the top of the limestone unit of the Clayton to overlap the large-diameter casing, and the upper part of the well was gravel packed.

The large-diameter casing at the top of the well allows installation of a large-diameter pump and provides additional storage space from which water can be drawn during pumping.

The wells are developed by swabbing and surging and are tested to determine the rate at which they can be pumped.

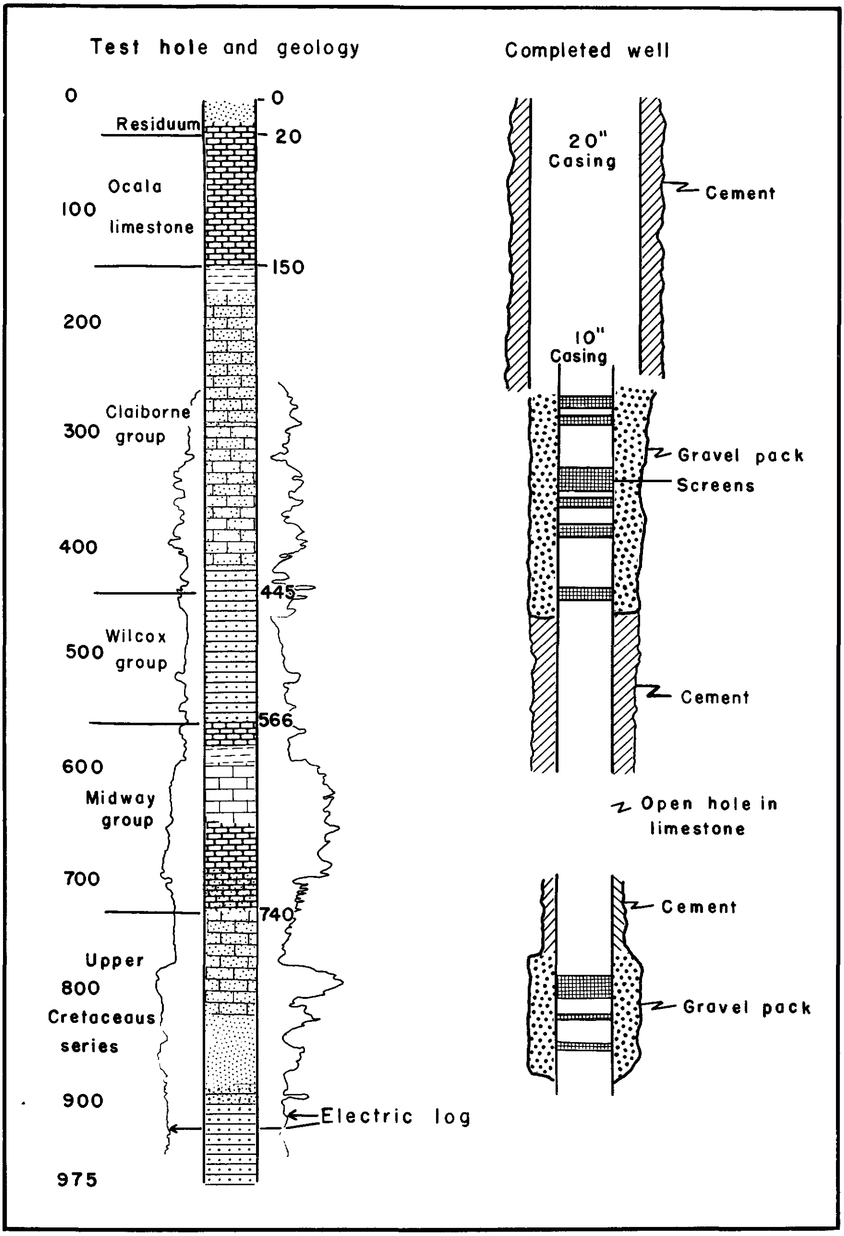


FIGURE 16.—Sketch of city well 15.

PUMPAGE

The total use of ground water in Dougherty County in 1957 was estimated to be 8.94 mgd, of which 6.57 mgd was derived from the Claiborne, Wilcox, and Midway groups and Upper Cretaceous series, and 2.37 mgd from the Ocala limestone.

Estimates of the total amount of ground water pumped in Dougherty County based on the metered pumpage of the city, Marine Corps Supply Center, and others, plus estimates by per capita consumption of water in gallons per day in rural areas, give the best evaluation of the total consumption of ground water in the area.

CITY OF ALBANY

Pumpage for the city of Albany from 1939 through 1957 is shown in figure 17. McCallie (1898, p. 151) estimated the use of water in Albany in 1898 to be 25,000 gpd. In 1915 the city had 3 wells at the waterworks capable of producing a total of about 1,000 gpm: wells 1 and 3 were pumped by air lift at the rate of 450 gpm each; well 2 flowed 125 gpm. A fourth well, the Coffey well, flowed about 40 gpm. Privately owned wells supplied many residents of Albany.

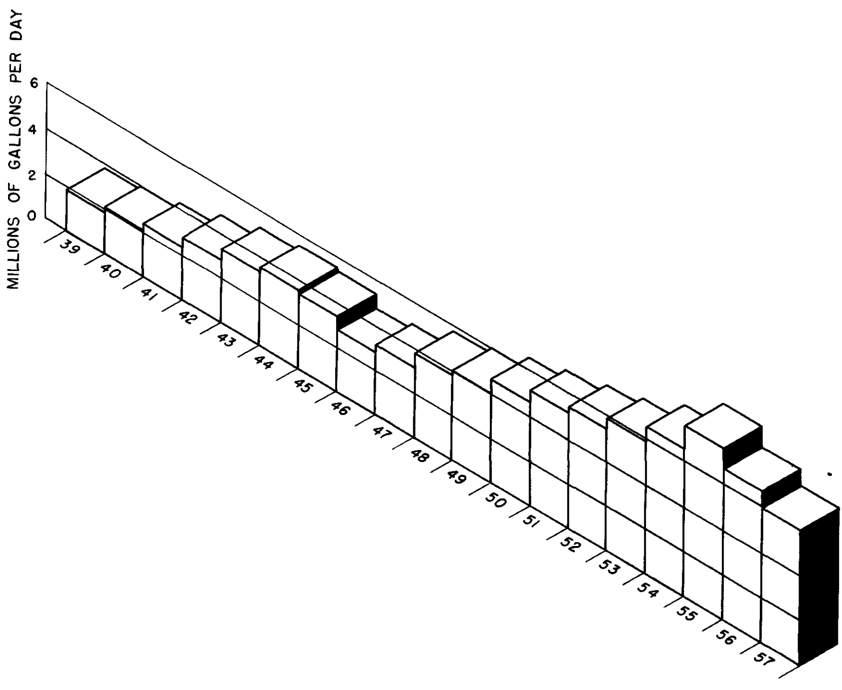


FIGURE 17.—Average daily pumpage at Albany, 1939–57.

During the last 10 months of 1939, the metered pumpage for the city of Albany was 539,942,000 gallons, an average of 1.96 mgd. In 1940 the average daily metered pumpage had increased to 2.05 mgd. In 1950, pumpage had increased to 4.77 mgd, and in 1956, to 6.26 mgd. During 1955, the peak year, pumpage of water averaged 7.41 mgd. Per-capita consumption of water for the urban area of Albany cannot be calculated from this figure, as it includes water sold to industrial users, at least one of whom uses nearly 1 mgd. Figure 18 shows the monthly metered pumpage of the city of Albany during 1957.

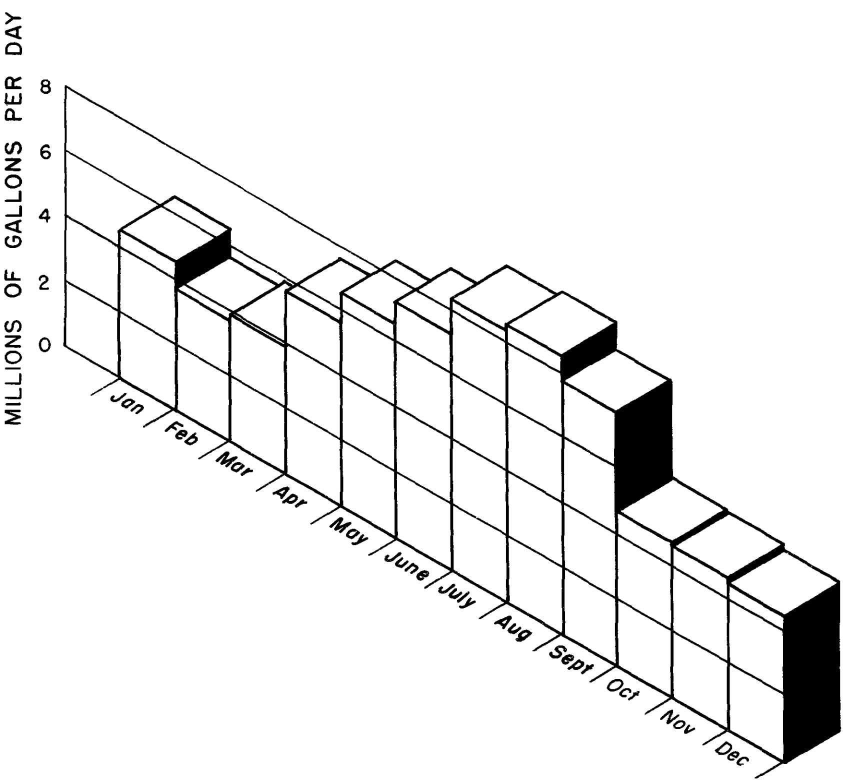


FIGURE 18.—Monthly pumpage at Albany, 1957.

MERCK AND CO.

Merck and Co. obtains water from two wells, both of which are developed in the Ocala limestone. The plant operation began in 1953, and pumpage records are available from March 1953 through 1957. Well 1 supplies water for sanitation, cooling, and manufacturing, and is used most of the time. This well was pumped at the rate of 980 gpm in 1957. Well 2, a 6-inch well equipped with a smaller pump, is used to supply additional water required during plant operation; on weekends the well is used to fill a 100,000-gallon elevated water tower, which provides water for manufacturing processes and for fire protection. Monthly pumpage for the period of record and average daily pumpage based upon the number of days for which data are available are shown in table 4. Average daily pumpage ranged from 0.51 mgd in 1957 to 0.87 mgd in 1954.

TABLE 4.—*Pumpage, Merck and Co., Flint River Plant*

[Million gallons]

Month	1953	1954	1955	1956	1957
January	--------	28. 4	23. 3	23. 3	13. 6
February	--------	21. 9	21. 0	20. 2	10. 7
March	20. 4	26. 9	19. 9	19. 1	19. 3
April	20. 4	23. 5	19. 2	19. 0	10. 0
May	7. 0	30. 7	20. 6	16. 6	16. 0
June	18. 2	23. 7	10. 3	18. 1	16. 6
July	17. 3	27. 8	17. 0	21. 7	9. 0
August	23. 0	30. 4	15. 4	10. 5	7. 5
September	21. 7	25. 5	16. 5	21. 1	20. 7
October	27. 2	28. 8	26. 8	18. 3	18. 6
November	--------	25. 2	--------	15. 4	19. 3
December	--------	24. 7	--------	19. 7	25. 3
Total Annual	155. 2	317. 5	190. 0	223. 0	186. 6
Daily average	[1] . 63	[2] . 87	[3] . 62	[2] . 61	[2] . 51

[1] 245 days.
[2] 365 days.
[3] 305 days.

U.S. MARINE CORPS SUPPLY CENTER

The U.S. Marine Corps Supply Center wells were placed in operation in 1953. Pumpage data are available from October 1954 through 1957. The average daily consumption is about 0.5 mgd. Average daily metered pumpage in 1955 was 0.46 mgd; in 1956, 0.52 mgd; and in 1957, 0.57 mgd.

The total pumpage of the center includes water for all purposes, including industrial, domestic, and sanitary. Per-capita consumption cannot be calculated, as there is no metering for the different uses of water. Table 5 shows the pumpage for the last 3 months of 1954 and for the period 1955–57.

TABLE 5.—*Pumpage, U.S. Marine Corps Supply Center, Albany*

[Million gallons]

Month	1954	1955	1956	1957
January	----------	6. 8	16. 1	13. 7
February	----------	6. 8	11. 9	12. 8
March	----------	13. 1	15. 9	13. 2
April	----------	13. 6	14. 5	14. 1
May	----------	15. 5	17. 4	16. 4
June	----------	18. 7	15. 9	20. 5
July	----------	16. 8	15. 3	25. 1
August	----------	20. 4	19. 2	26. 9
September	----------	15. 0	18. 7	20. 6
October	7. 7	13. 7	15. 2	17. 4
November	6. 3	13. 5	13. 6	15. 4
December	6. 8	15. 7	12. 0	13. 3
Daily average	----------	0. 46	0. 51	0. 57

MORNINGSIDE SUBDIVISION

Wells 8405–3130–26 and 8405–3130–28 furnish water to the Morningside subdivision. The wells are located in East Albany, south of Georgia Route 133. These wells obtain water from the Ocala limestone and are capable of producing a combined total of 550 gpm. Probably not more than 0.4 mgd is used from these wells.

TURNER CITY

The Artesian Water Co. was set up as a subsidiary of the Layne-Atlantic Co. in 1952 to supply the housing area near Turner Air Force Base. Two wells, 8405–3135–3, supplied water to this area. In 1957 these wells were purchased by the city of Albany, and well 8405–3135–4 was put into operation as city well 17. Pumpage of the Artesian Water Co. was metered separately for Turner City and for the Sylvandale and Rolling Grove subdivisions. Well 8405–3135–3 is presently used as an observation well in the permanent observation network being established in Georgia by the Geological Survey. Table 6 lists pumpage by years for the Artesian Water Co.

TABLE 6.—*Pumpage, Artesian Water Co.*

Year	Annual (mg)	Daily
1952	22. 2	0. 06
1953	29. 3	. 08
1954	38. 1	. 10
1955	44. 9	. 12
1956	51. 6	. 14
1957 (half year)	13. 8	. 03

IRRIGATION

Irrigation use is calculated on the basis of 1 acre-foot of water per acre per year. Total irrigated land reported in Dougherty County in the 1954 agriculture census was 200 acres. Accordingly, water used for irrigation would amount to 60 million gallons per year, about 0.16 mgd.

RURAL USE

In 1954, the rural use of water in Dougherty County was estimated (Thomson and others, 1956, fig. 2) to be about 1,000 to 2,000 gpd per square mile or 0.3 to 0.6 mgd. This estimate was based on a per-capita consumption of 50 gpd for population served with running water and 10 gpd for those without running water.

The water requirements of animals is given in table 7 in gallons per day. The animal population of Dougherty County is taken from the 1954 census of agriculture (U.S. Dept. Agriculture, 1956).

TABLE 7.—*Water requirements and estimated use of water by domestic animals in Dougherty County, 1954*

[Requirements and numbers of domestic animals from U.S. Dept. Agriculture, 1956, v. 1, pt. 17]

Animal	Requirement (gpd)	Number	Water used (gpd)
Milk cows	20	747	14, 440
Other cattle	10	16, 226	160, 226
Mules and horses	10	626	6, 260
Hogs	3	4, 485	13, 260
Sheep and goats	2	----	----
Chickens	. 04	26, 521	1, 060
Turkeys	. 06	1, 279	77
Total	----	----	196, 000

The 1954 census of agriculture reported a total of 534 farms in Dougherty County. Of this number, 233 farms had hot and cold water inside, 105 had cold water only inside, and 116 had cold water only outside; the remainder did not report. According to U.S. Census estimates, the American family averages four persons. If it is assumed that the per-capita use of water in Dougherty County is 100 gpd, per person where hot and cold running water are available, 50 gpd, where cold water is available inside the house, and 10 gpd where cold water is available outside the house, the total rural farm use would be about 118,000 gpd. Of the total of 2,058 rural nonfarm dwellings reported in Dougherty County, 1,043 reported hot and cold water inside, 274 reported cold water only inside, and 204 reported cold water only outside; the remainder did not report. Using the same basis for rate of use, the total rural nonfarm use would be about 480,000 gpd. Accordingly, rural and domestic use of water in

Dougherty County probably exceeds 700,000 gpd, which is in excess of the estimate of Thomson by about 14 percent. Table 8 lists the estimate of total water used in Dougherty County during 1957.

TABLE 8.—*Estimated use of water in Dougherty County, 1957*

User	*Million gallons per day*	*User*	*Million gallons per day*
City of Albany [1]	6.0	Dawes Silica Co.[2]	0.15
Merck and Co.[1]	.51	Atlantic Ice and Coal Co.[2]	.3
U.S. Marine Corps Supply Center [1]	.57	Musgrove Sand Co.[2]	.1
Morningside subdivision [2]	.40	Plant Mitchell [2]	.02
Rural domestic and animal [2]	.70	Total	8.94
Irrigation [2]	.16		

[1] Metered.
[2] Estimated.

SOURCES OF GROUND WATER FOR IRRIGATION

Very little land was irrigated in Dougherty County during 1957. However, sufficient ground water is available for supplemental and probably full-scale irrigation. The lack of development of ground water for irrigation is probably due in part to the lack of knowledge concerning the availability of this resource.

The Ocala limestone is an excellent aquifer throughout Dougherty County. Wells that are 8 to 10 inches in diameter and 200 to 250 feet deep yield 1,000 to 1,700 gpm from this aquifer. Figure 19 shows the depth to water below the general land surface in wells that penetrate the Ocala limestone—approximately the depth to static water level in wells. The depth to water ranges from about 20 feet below the land surface in western Dougherty County to more than 50 feet in the eastern part. The pumping level in a well at any locality depends upon several factors, but chiefly upon the rate at which the well is pumped. Drawdown increases when the pumping rate increases.

Additional ground-water supplies for irrigation may be obtained from sand and coquina of the Claiborne group, limestone of the Midway group, or sand of the Upper Cretaceous series. Sections *A–A′* and *B–B′* show the relation of these aquifers to each other and their approximate depth below the land surface.

The approximate depth to these water-bearing formations can be determined also with the aid of the structure-contour maps. The depth to the water-bearing zones is the difference in elevation at any place between the land surface and the top of the formation or group, as shown on the structure-contour map.[2]

[2] Topographic maps of the Dougherty County area are available from the Georgia Department of Mines, Mining and Geology, 19 Hunter St. SW, Atlanta 3, Ga., and the U.S. Geological Survey, Washington 25, D.C.

654863 O—63——6

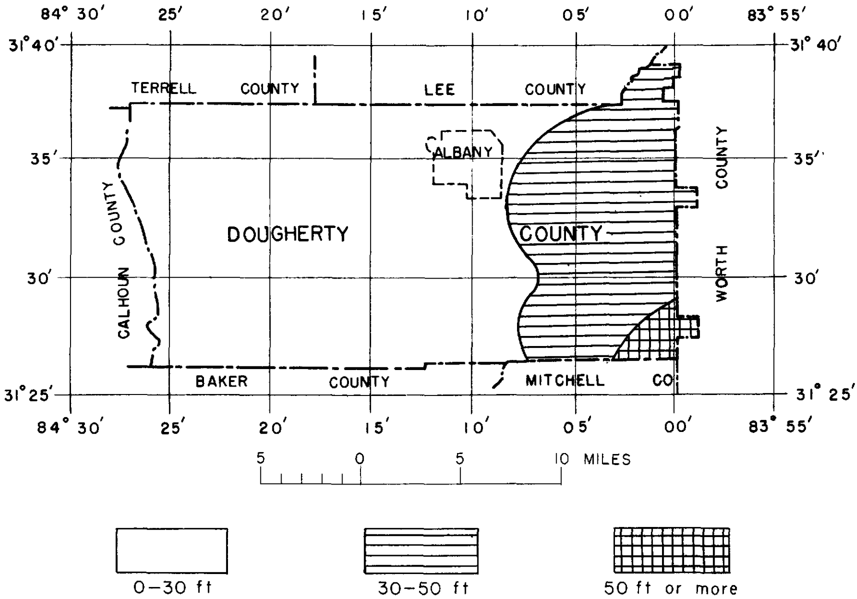


FIGURE 19.—Depth to water in the Ocala limestone, Dougherty County.

Yields of as much as 1,400 gpm can be obtained from the Claiborne group, and yields of as much as 300 gpm can be obtained from the Midway group. Water from the Upper Cretaceous series also can be used for irrigation, although water from 1,200 feet and deeper appears to contain considerable amounts of sodium and chloride. If this water is applied to land for long periods of time, the results might be detrimental to the soil. According to the U.S. Department of Agriculture (U.S. Salinity Laboratory Staff, 1954, p. 81) "high sodium water * * * will require special soil management—good drainage, high leaching, and organic matter additions." However, if wells are constructed to obtain water from the Claiborne or Midway groups, which contain calcium bicarbonate water, and from the Upper Cretaceous series, which contains sodium bicarbonate water, it appears (fig. 26) that sufficient mixing occurs to dilute the sodium to a level that is permissible for irrigation.

QUALITY OF WATER

The water samples taken during this investigation were collected in 1-gallon Pyrex bottles; an additional 6-ounce sample was taken in a separate bottle for determination of iron.

SAMPLING PROCEDURE

Well construction, diameter of the well, and the number of aquifers penetrated dictated the sampling procedure. Wells producing from more than one aquifer, such as those of the city of Albany and U.S. Marine Corps Supply Center, yield water that is a mixture of the types of water in each aquifer. The water is mixed in the proportion of the yield of the aquifers at that particular well, and pumping at that particular rate. Pumping at a greater or lesser rate may change the mixture of the water yielded by the well. It has been shown (Piper and Garrett, p. 41; Sayre and Livingston, 1945, p. 81–83) that changes in quality of water depend upon the number of aquifers penetrated, the head in each of the aquifers, and the length of time and rate at which the well is pumped. A well that penetrates several aquifers, or is gravel packed, may give varying results in the quality of water yielded. When such a well is idle, the zones having the highest head cause the water to be circulated into and to recharge the zones of lower head. When a well is pumped after being idle for a long period, the first water discharged is nearly the same as that which was being discharged when the well was last pumped, as the water stands in the pump column, and little or no circulation occurs. The quality then changes, and the next water discharged is typical of water from the zone of highest head, which has furnished much water to the zones of lower head. When this water, typical of the zone of highest head, is discharged from the zones of lower head, the zones of lower head begin to yield water that is native to them. After pumping has continued for a sufficient period of time to be producing water native to all aquifers, the mixture obtained from a well is in the proportions of the productivity of those several aquifers under the given pumping rate and head in the aquifer. Therefore, before the water sample is taken, the constructional features of the well should be known as well as the time since the well was last pumped and the length of time it was pumped.

The water samples from city wells 9, 11, and 13 were collected after the wells had been pumping for several hours, and the water obtained probably represents a mixture of waters from the various zones penetrated. Other city wells and the two U.S. Marine Corps Supply Center wells were pumped the length of time necessary to replace completely the water standing in the well bore with water from the formations. U.S. Marine Corps Supply Center well 2 was pumped 35 minutes, and well 3 was pumped 45 minutes. These samples also are thought to be representative of the mixture of waters produced by the well. Wells penetrating the Ocala limestone were pumped for a period of time sufficient to replace water in the well bore. Wells 8415–

3130–2 and –3 and the two oil-test wells were flowing at the time the samples were taken. The samples were taken from the point of overflow. These samples probably are representative of the zones of highest head in these wells. The sample from the dug well was obtained by bucket.

Where it was necessary to obtain water for analysis from a storage tank, no temperature is listed as such temperatures are not representative of the temperature of the ground water being sampled. Mineral constituents are reported in parts per million. (See tables 9 and 10.)

MINERAL CONSTITUENTS

The following description of the mineral constitutents has been adapted from Collins and others (1934, p. 5–37). Silica (SiO_2) is dissolved from practically all rocks. Although its state in natural water is not known, it is assumed to be in the colloidal state and takes no part of the equilibrium between acids and bases. The amount of silica in ground water depends upon the character of the water and the time of contact of the water with the rocks, as well as the rock type. Silica may be objectionable in boiler-feed water, if present in large amounts; it forms a hard scale, which prevents rapid transfer of heat. Other than contributing to the formation of hard scale in boilers, silica probably is of little importance in ground water.

Iron (Fe) is dissolved from all soils and rocks, and from iron pipes and iron storage tanks in the distribution system. Soft water which has a low mineral content, and water of low pH will dissolve iron, particularly from hot-water lines and boilers. Water furnished to customers should not contain more than 0.3 ppm (parts per million) of iron. In water containing more than this amount of iron, a reddish-brown sediment may occur as a result of the oxidation of the iron. Iron in water will stain white porcelain, enameled fixtures, and white goods. Several industries require water that is practically free of iron. Iron may be removed by aeration, coagulation, and filtration. Adjustment of pH to prevent corrosion can be made by the addition of lime or soda ash.

Calcium (Ca) and magnesium (Mg) are dissolved from many rocks. Calcium may be dissolved in large quantities from limestone, which is composed largely of calcium carbonate. Although calcium carbonate is only very slightly soluble in pure water, much of the water flowing through calcareous deposits contains carbon dioxide, which readily dissolves calcium carbonate. Gypsum (calcium sulfate also may be the source of calcium in much water.

TABLE 9.—*Chemical analyses of water, Dougherty County*

Well or spring	Date of collection	Aquifer	Parts per million: Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25 °C)	pH
8400-3125-5	5/3/57	Residuum	69	6.4	0.80	4.8	5.4	14	10	25	0	1.2	27	0.1	9.7	145	34	14	176	6.2
8400-3125-6	5/3/57	Ocala limestone	----	9.5	.40	56	1.9	1.7	.4	184	0	.8	2.0	.1	.1	167	148	0	285	7.5
Flint River	1/19/38	Discharge: 3,910 cfs[1]	----	9.8	.16	7.0	1.2	3.6	.6	30	0	1.7	3.0	.0	.4	43	22	0	----	----
8400-3130-10 USMC Supply Center 2.[2]	4/24/52	Claiborne and Midway groups	78	34	.25	28	11	16		170	0	2.4	5.5	.0	----	655	115	----	----	7.8
Do.	10/16/57	do	73	37	.34	27	9.4	21	3.1	176	5	7.0	4.0	.0	.4	----	106	0	292	7.8
8405-3125-11 Merck and Co. 1.	5/2/57	Ocala and Lisbon formations	69	11	.08	47	1.1	2.2	.2	150	0	.2	2.0	.0	1.3	143	122	0	239	7.7
8405-3130-10 USMC Supply Center 3	10/16/57	Claiborne and Midway groups	71	30	.04	42	5.6	12	2.0	178	4	4.0	3.5	.0	.5	188	128	0	292	7.8
8405-3130-11[3] City of Albany 6.	4/37	Tallahatta formation, Wilcox and Midway groups.	----	11	.07	26	5.7	35		178	0	7.8	4.5	----	----	192	88	----	----	----
8405-3130-12[4] City of Albany 9.	12/22/47	Tallahatta formation	----	5.0	.14	58	1.0	1.5		166	0	2.0	9.8	----	----	216	149	13	----	7.5
Do.[5]	12/1/51	Tallahatta formation and Midway group.	72	32	.11	32	6.5	24		176	0	8.6	3.2	.2	.2	194	107	0	297	7.8
Do.[5]	5/15/57	do	----	34	.07	31	5.5	24	2.4	178	0	6.8	2.8	.2	.3	192	100	0	287	8.0
8405-3130-13 City of Albany 7.	9/15/39	Tallahatta formation, Wilcox and Midway groups, and Upper Cretaceous series.	76	24	.01	21	5.2	43	2.3	194	0	8.3	2.9	.2	.1	202	74	0	----	----
Do.	12/1/51	do	72	28	----	----	----	----	----	203	0	----	----		----	----	77	----	334	7.8
8405-3130-13 City of Albany 7.	10/22/57	do	74	24	.02	18	4.6	57	2.1	216	0	6.4	4.5	.0	.6	223	64	0	334	7.9
8405-3130-14 City of Albany 13.	5/15/57	Tallahatta formation, Wilcox and Midway groups.	73	26	.06	24	9.2	45	2.0	221	0	9.5	6.8	.4	.3	238	64	0	362	8.0
8405-3130-32[6] City of Albany 5.	5/2/28	Tallahatta formation and Midway group.	----	18	.70	24	4.6	30	1.8	156	0	11	5.2	----	----	173	79	0	----	----
8405-3130-33[7]	----	Clayton formation	----	9.3	[8]2.6	46	1.9	2.4		140	----	7.1	3.6	----	.2	160	123	8	----	----

City of Albany 2.																				
Do.[1]	----------	Upper Cretaceous series	78	14	[8]1.8	4.3	1.8	463	29	-----	576	1.4	69	-----	-----	1,160	18	0	------	----
8405-3130-S1	4/5/11	Ocala limestone	----	12	.4	48	2.4	3.8	-----	178	0	2.0	3.5	-----	1.5	139	130	0	------	----
Radium Springs.																				
Do	6/22/37	do	69	9.6	.01	45	1.1	1.7	.2	140	0	1.3	2.2	.0	1.4	136	117	2	------	----
Do	5/13/57	do	69	12	.00	45	1.3	1.8	.4	143	0	.0	3.2	.4	1.6	139	118	0	232	7.7
8405-3135-3	8/16/55	Clayton formation	----	21	.60	11	5.7	40	2.8	149	0	12	2.5	0.2	0.4	169	50	0	256	7.6
8405-3135-4, City of Albany 17.	10/22/57	Claiborne group	71	32	.06	43	6.4	6.3	2.2	174	0	4.0	5.2	.0	.3	178	134	0	277	7.9
8405-3135-6[7]	4/ 1/11	Midway group and Upper Cretaceous series.	----	16	1.0	13	6.8	41		178	0	2.0	3.5	-----	1.5	139	60	0	------	----
8405-3135-10	5/14/57	Ocala limestone	----	9.2	.37	39	1.6	1.0	.3	127	0	.2	2.0	.0	.4	121	104	0	200	7.8
8410-3130-14[5]	12/ 1/51	Claiborne and Midway groups and Upper Cretaceous series.	73	26	.11	26	7.7	28		173	0	11	2.9	.2	.3	188	96	0	295	8.0
8410-3130-14	5/15/57	do	73	28	.08	28	7.8	24	2.6	179	0	8.8	2.5	.3	.3	185	102	0	290	8.0
8415-3130-1	5/21/42	Upper Cretaceous series	74	11	.02	2.9	.9	74	1.0	171	15	7.2	2.5	.4	.0	203	11	0	------	----
Do	5/14/57	do	74	15	.14	2.0	.5	74	1.2	186	8	6.5	2.5	.5	1.0	203	7	0	325	8.8
8415-3130-2	5/14/57	do	74	16	.09	9.2	3.6	46	1.4	156	0	9.8	3.2	.5	.4	170	38	0	263	8.2
8415-3130-3	5/14/57	do	74	15	.07	3.6	1.6	70	1.3	178	6	8.0	4.5	.5	.1	196	16	0	313	8.6
8415-3130-7	5/14/57	Clayton formation	72	26	.06	16	6.3	28	2.2	140	0	11	1.8	.4	.3	159	66	0	241	8.0
8420-3125-1	8/30/42	Upper Cretaceous series	----	------	------	51	-----	------	-----	727		3	432				21			
Do	10/15/57	do	72	15	.81	5.2	2.3	586	5.6	820	10	0	435	2.6	7.6	1,470	22	0	2,490	8.4
8420-3130-4	10/23/57	Ocala limestone	69	12	.00	65	3.4	2.0	.2	216	0	0	3.8	.0	.9	193	176	----	337	7.7

[1] Cubic feet per second.
[2] L. H. Turner, analyst.
[3] U.S. Geol. Survey Water-Supply Paper 912, p. 32.
[4] Law and Co., analyst.
[5] U.S. Geol. Survey Circular 269, p. 33.
[6] U.S. Geol. Survey Water-Supply Paper 658, p. 55.
[7] U.S. Geol. Survey Water-Supply Paper 341, p. 242.
[8] Iron and aluminum oxides.

TABLE 10.—*Chemical analyses of water, Clay County*

Well	Date of collection	Aquifer	Temperature (°F)	Parts per million														Specific conductance (micromhos at 25° C)	pH
				Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$			
																Total	Noncarbonate		
City of Fort Gaines 2	8/ 5/57	Clayton formation	71	24	3.3	50	3.4	7.5	1.8	164	16	3.2	0.2	0.1	190	139	4	293	7.5
U.S. Corps of Engineers 15A.	5/28/57	do	69	12	.03	43	1.6	4.1	.7	128	14	2.2	.1	.0	143	114	9	235	8.0

Magnesium is dissolved from dolomite and dolomitic limestone. Sea water contains large quantities of magnesium, and if fresh ground water is contaminated by sea water an increase in magnesium content will result. Magnesium also may be derived from beds of salts that were deposited from sea water.

Calcium and magnesium cause hardness in water. Hardness is discussed later in this section.

Sodium (Na) and potassium (K) are dissolved from practically all rocks and soils. Sea water, which is composed to a large extent of common salt (sodium chloride), may contribute large amounts of sodium to ground water. The effect of sodium on the suitability of ground water for irrigation is discussed in another section.

Bicarbonate (HCO_3) results from the action of carbon dioxide, dissolved in water, on carbonate rocks. Little natural ground water contains carbonate, but 4 water samples from the Upper Cretaceous series and 2 from the Claiborne and Midway groups, combined, in Dougherty County contained carbonate.

Sulfate (SO_4) is dissolved from rocks and soils. Gypsum may be the source of much sulfate in ground water. Some sulfate may be derived from oxidation of sulfides. Sulfate combined with calcium forms a hard adhering boiler scale.

Chloride (Cl) is dissolved in small quantities from rocks. Sewage and industrial waste may contribute chloride to ground water. Ground water that becomes contaminated with sea water may have a high chloride content. Appreciable amounts of chloride increase the corrosiveness of water.

Fluoride (F) is dissolved in small quantities from rocks. The quantity of fluoride in most natural ground water is much less than that of chloride. Deep-well water and sodium bicarbonate water are more likely to contain significant amounts of fluoride than is calcium bicarbonate water, the principal type of water in the Dougherty County area. The sample of water from the J. R. Sealy 2 well had the greatest amount of fluoride, 2.6 ppm. The average content of fluoride in water in Dougherty County is 1.0 ppm from the Upper Cretaceous, series, 0.1 ppm from the Ocala limestone, 0.3 ppm from the Midway group, and 0.1 ppm in mixtures of water from sediments of the Claiborne and Midway groups and the Upper Cretaceous series.

According to Dean (1941), fluoride in drinking water in concentration of about 1.0 ppm inhibits dental decay in the teeth of children. The value of this inhibitory effect has been recognized by health authorities. The addition of about 0.5 ppm of fluoride to the Albany city water has been found to be beneficial to children's teeth. Excesses of fluoride may cause mottling of the tooth enamel, the severity of the mottling being proportionate to the excess. Fuoride has no effect on the teeth of adults for the enamel portion of the third molar, the wisdom tooth, is complete when a person is 12 to 16 years of age.

Nitrate (NO_3) is usually a product of the final oxidation of organic matter. Its presence may indicate contamination by organic matter. Nitrate may also result from solution of beds of nitrate. None of the deep-well water analyzed from the Dougherty County area contained excessive amounts of nitrate. Excessive amounts of nitrate in water may cause methemoglobinemia or "blue babies" (Waring, 1949).

Dissolved solids, the residue remaining after evaporation, represents the dissolved mineral matter in water. Water containing less than 500 ppm of dissolved solids is suitable for domestic and public supplies, according to drinking-water standards of the U.S. Public Health Service (1946).

Hardness is largely caused by calcium and magnesium in water. It is reported as calcium carbonate ($CaCO_3$) equivalent to calcium and magnesium. The hardness caused by calcium and magnesium equivalent to the bicarbonate and carbonate is known as carbonate or temporary hardness and may partly be removed by boiling the water. The remainder of hardness is called noncarbonate or permanent, and this hardness is not removed by boiling. Hard water is objectionable, because it forms sticky insoluble compounds with soap. Hard water also causes scale in boilers.

Water is classified, with respect to hardness, by the Geological Survey as follows:

Class	*Hardness (ppm)*
Soft	0–60
Moderately hard	61–120
Hard	121–180
Very hard	>180

The water in the Dougherty County area ranges from soft to hard. Water from the Upper Cretaceous rocks is soft; that from the Tertiary rocks is moderately hard to hard.

Hydrogen ion concentration is expressed in terms of pH units and is related to the acidity or alkalinity of water. The pH of water is the logarithm of the reciprocal of the hydrogen ion concentration in moles per liter. Water with a pH of 7.0 is said to be neutral; that with a pH greater than 7.0, alkaline; and a pH less than 7.0, acidic.

UPPER CRETACEOUS SERIES

Four water samples were taken during this investigation (table 9) from wells that penetrate rocks of the Upper Cretaceous series.

Water from these rocks ranges from sodium bicarbonate water to sodium chloride water. It is very soft, has a low dissolved-solids content, is moderately alkaline, and in some areas may contain excessive amounts of iron. The water usually has a slightly sulfurous odor and taste.

Water from the four wells sampled and water analyzed and reported by McCallie (1908) are considered typical of water from the Upper Cretaceous series in Dougherty County. Wells sampled were 8415–3130–2, 8415–3130–3, J. R. Sealy 1 (8415–3130–1), and J. R. Sealy 2 (8420–3125–1). One sample listed (McCallie, 1908, p. 99) was taken at a depth of 1,300 to 1,320 feet. The waters from three of the wells are characterized by carbonate alkali—that is, are composed primarily of sodium and bicarbonate. The water from J. R. Sealy 2 and city well 2 contain the most dissolved solids. Carbonate was detected in water from well 8415–3130–3, both oil-test wells, and city well 2. Values for bicarbonate and carbonate reported in the analyses and those in the samples at the time of collection probably differ slightly because of elapsed time and changes in temperature and pressure betwen the times of collection and analysis. The water from well 8415–3130–2 is similar in chemical composition to the water from wells penetrating Upper Cretaceous sediments. The temperature of the water was 71°F in 1941 and 74°F in 1957. The reported depth of the well is 585 feet. This well is about 100 feet south of well 8415–3130–3, which obtains water from the interval 540 to 795 feet.

Water from J. R. Sealy 2 contained 2.6 ppm of fluoride, the maximum found during this investigation. Fluoride was not reported at the time the analysis was made on city well 2.

When the electric log was made of the J. R. Sealy 1 oil-test well, an interpretation of the log, made by the operator at the request of Dr. A. S. Furcron, State Geologist, revealed brackish water at a depth of 2,850 feet, with salinity increasing at depth. In 1957 this well flowed 3 to 5 gpm of water of excellent quality. Temperature of water from rocks of the Upper Cretaceous series ranged from 72°F to 78°F.

Figure 20 shows the water samples from five wells, plotted in equivalents per million.[3] Dissolved solids appear to increase with depth. J. R. Sealy 2 is reported to be cased to 1,200 feet, and the water has 435 ppm of chloride. Water from this well is of the sodium bicarbonate-chloride type.

---

[3] An equivalent per million is an expression of the concentration of a constituent in terms of chemical equivalents or combining weights.

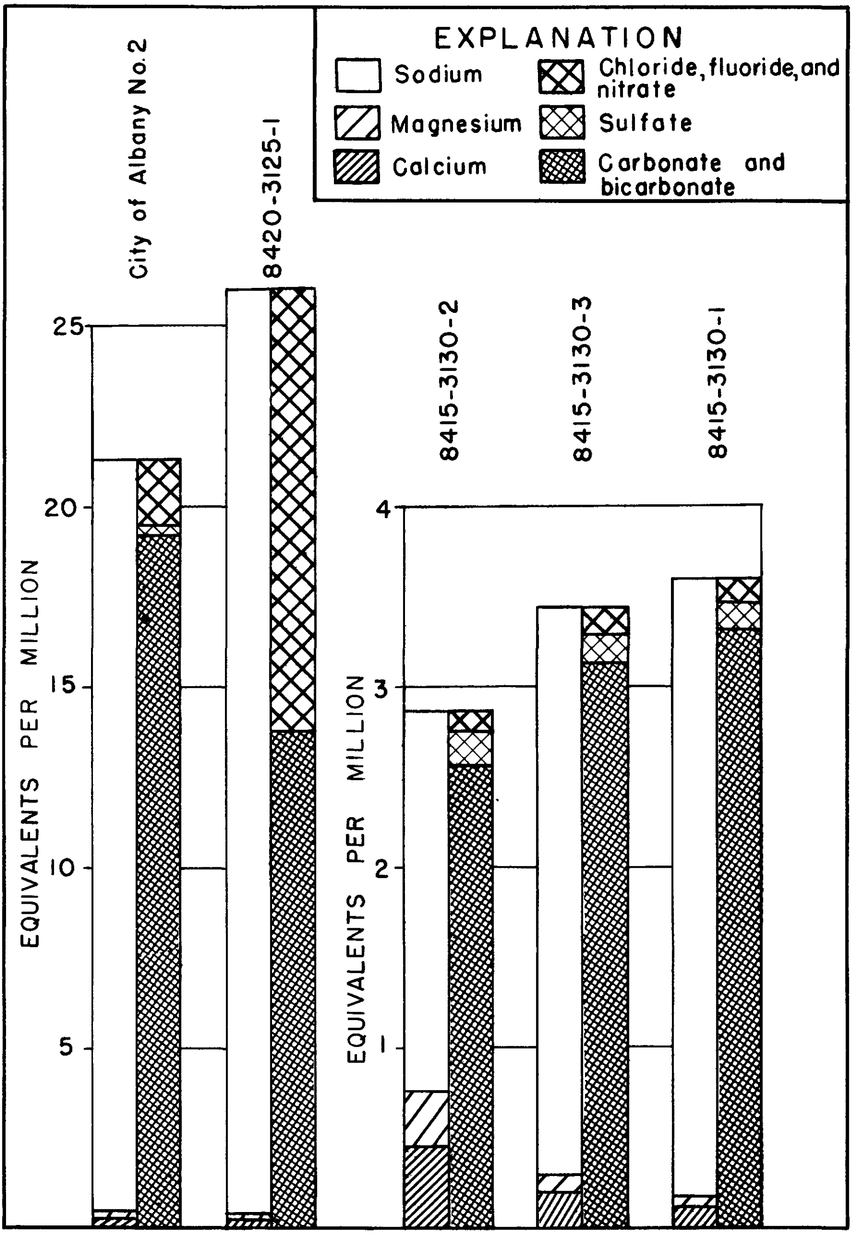


FIGURE 20.—Composition of water from Upper Cretaceous series, Dougherty County.

MIDWAY GROUP

Water from rocks of the Midway group (fig. 21) is of two types, calcium bicarbonate and sodium-calcium bicarbonate. Analyses of two water samples from wells at Fort Gaines, Clay County, Ga., which penetrate the limestone of the Clayton formation, show the water to be a calcium bicarbonate type that is moderately hard. Well 2, city of Fort Gaines, obtains water from the Clayton formation. It is 455 feet deep, penetrates the Clayton formation from 310 to 455 feet, is cased to 313 feet, and produces water from the interval 313–455 feet. Well 15A obtains water from the "shell limestone" of the Clayton formation. Both waters are of the calcium bicarbonate type; however, the water from city well 2, Fort Gaines, contains a greater amount of dissolved solids. Well 8405–3135–4, formerly owned by the Artesian Water Co., was drilled to a depth of 803 feet and cased to 714 feet. The well originally penetrated the top of the Upper Cretaceous series at 803 feet. The sample from this well is a soft sodium-calcium bicarbonate water. The increased sodium may be due to leakage through the bore of the well even though it is now filled. That part of the hole from 714 feet to 760 feet is in the interval of the upper unit and the limestone of the Clayton formation.

A water sample from city well 2, (McCallie, 1898, p. 181) is from the Clayton formation. This water agrees essentially in chemical character with water from the Clayton formation at Fort Gaines. The sample was taken from the interval 660–710 feet, which is shown as the upper unit of the Clayton formation and the middle or limestone unit on the log of city well 13. City well 2, near city well 13, has been abandoned and plugged.

Well 8415–3130–7, drilled by Colonel John P. Fort in 1911 (Veatch and Stephenson, 1911, p. 241) to a depth of 725 feet, is cased to 500 feet. The well probably taps the Clayton formation, including the lower unit. The water is of the sodium-calcium bicarbonate type. Temperature of water from the Midway group ranges from 71°F to 73°F.

CLAIBORNE GROUP

Two water samples are available from the Claiborne group. One sample, from city well 9 (8405–3130–12), was taken in December 1947 during the drilling of the well. The sample is from the interval 350 to 465 feet, from sands of the Tallahatta formation. The water is of the calcium bicarbonate type, similar to water from the Ocala limestone. The water is hard and has an iron content of 0.14 ppm. The temperature of water from this zone was not recorded. The other sample is from city well 17 (8405–3135–4), which is 700 feet deep and

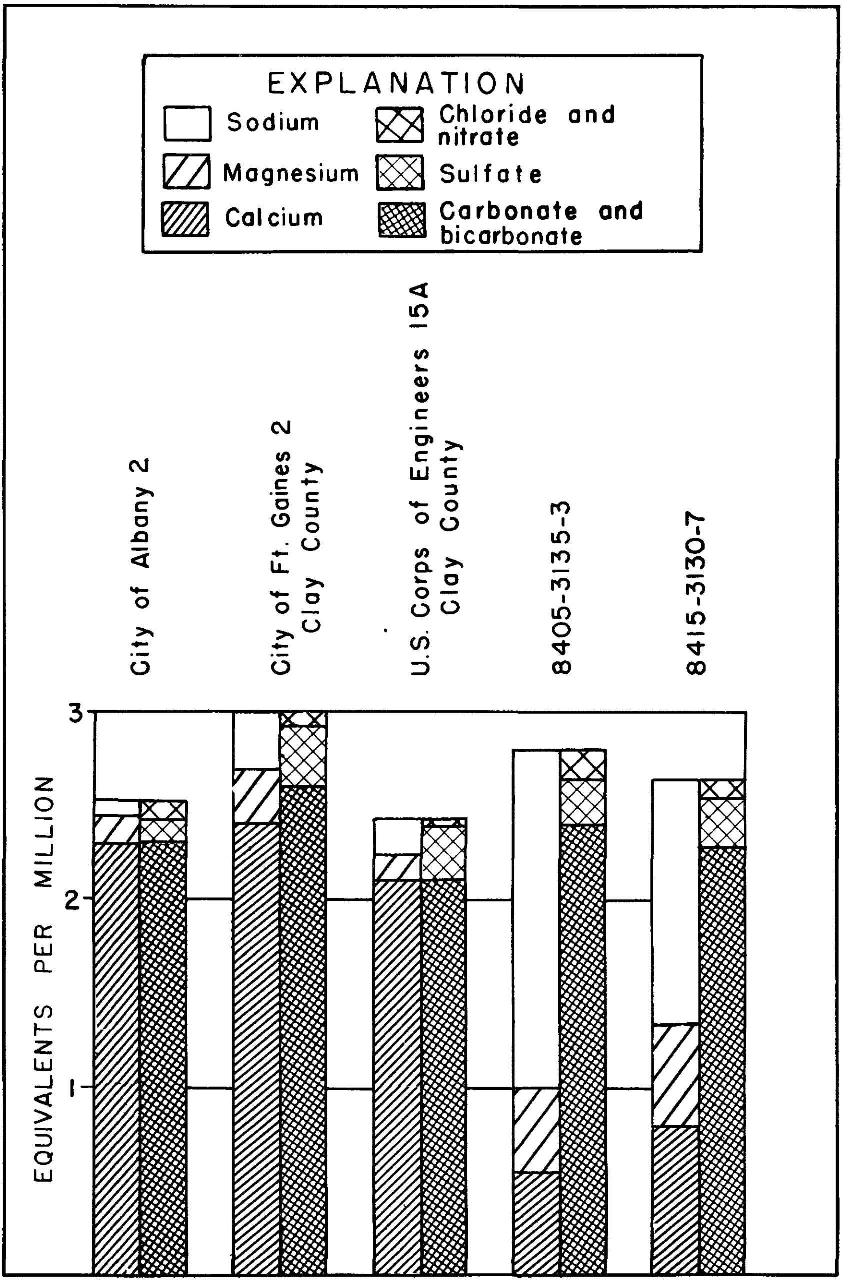


FIGURE 21.—Composition of water from Midway group, Dougherty County.

has screens set in the Lisbon and Tallahatta formations (table 11). This well yields hard calcium bicarbonate water with a moderate amount of dissolved solids. The temperature of the water was 71° F. These two analyses are shown in figure 22 plotted in equivalents per million.

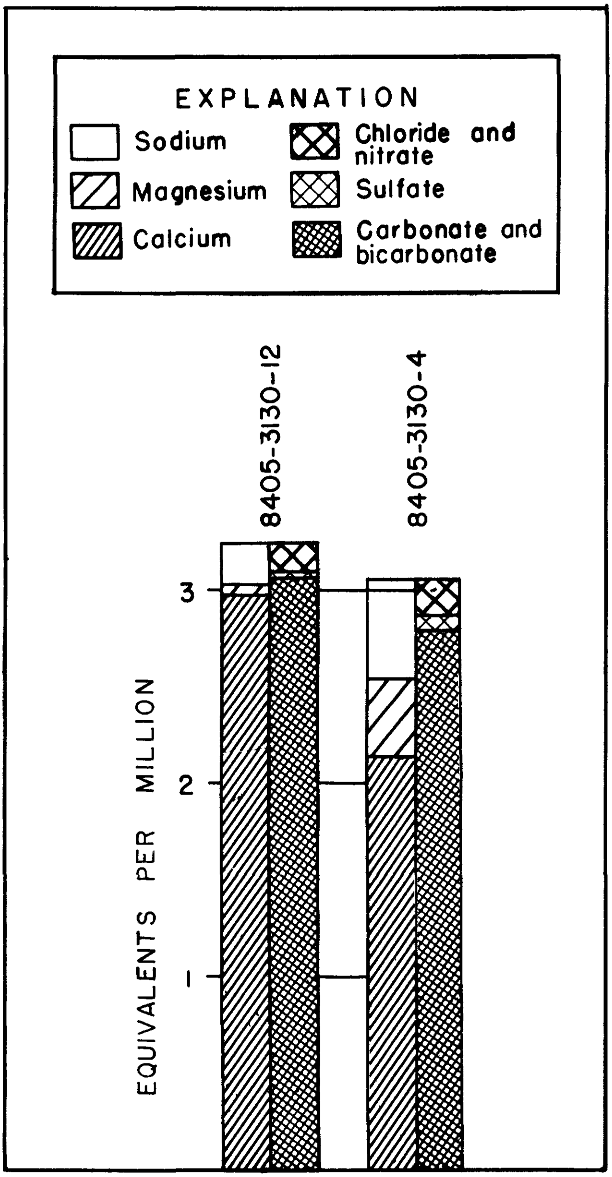


FIGURE 22.—Composition of water from Claiborne group, Dougherty County.

OCALA LIMESTONE

Water samples were taken from the Ocala limestone from 4 drilled wells, 1 dug well, and 1 spring (Radium Springs). The water is of a calcium bicarbonate type, moderately hard to hard, with a low to moderate amount of dissolved solids. The water has a pH ranging from 7.5 to 7.8. Merck and Co. well 1 (8405–3125–11) penetrates the Ocala limestone and a few feet of the Lisbon formation. The water from this well is of the same type as that from wells penetrating only the Ocala limestone.

One notable feature of water from the Ocala limestone in Dougherty County is the small quantity of sulfate. The sulfate content is extremely low, ranging from 0.0 to 0.8 ppm in 5 samples. The fluoride content of the water also is low, being reported as 0.0 ppm in 3 of the 4 wells sampled, 0.1 ppm in the other well, and 0.4 ppm in Radium Springs.

Water from well 8400–3125–5 in the residuum (a dug well) is soft, slightly acid, and contains excessive nitrate, probably from decayed organic matter. This well was uncovered, and weeds were growing on the wall of the well when it was sampled. The temperature of water from the Ocala limestone is 69°F in Dougherty County.

Figure 23 shows diagrams of analyses of samples from four drilled wells and from Radium Springs, plotted in equivalents per million.

MIXTURES OF WATERS

The city wells and those of the U.S. Marine Corps Supply Center produce water that is a mixture of the types of water in the aquifers penetrated by these wells. Five mixtures of water are shown in fig. 24. The sodium content in the mixture is greatest in the water obtained from Upper Cretaceous rocks. Well 7 has 110 feet of screen in the Upper Cretaceous series, and the water contains the greatest amount of sodium of these 3 wells. City well 13 has about 10 feet of open hole in the lower unit of the Midway group. It is located at the city waterworks near old city wells 1, 2, and 3. These wells were abandoned and plugged but were not filled with concrete from bottom to top. Water probably leaks from rocks of the Upper Cretaceous series to the rocks of the Midway group through the unplugged part of the bore of well 2. City well 9 has about 5 feet of open hole in the lower unit of the Clayton formation, and the analysis shows the least amount of sodium of the 3 wells shown. The water from the city wells is of the calcium-sodium or sodium-calcium bicarbonate type, and moderately hard. Temperature may range from 71°F to 74°F. The mixtures of waters from five wells from which samples were obtained range from a sodium bicarbonate water (well 8405–3130–13) to a calcium-sodium bicarbonate water (well 8400–3130–10).

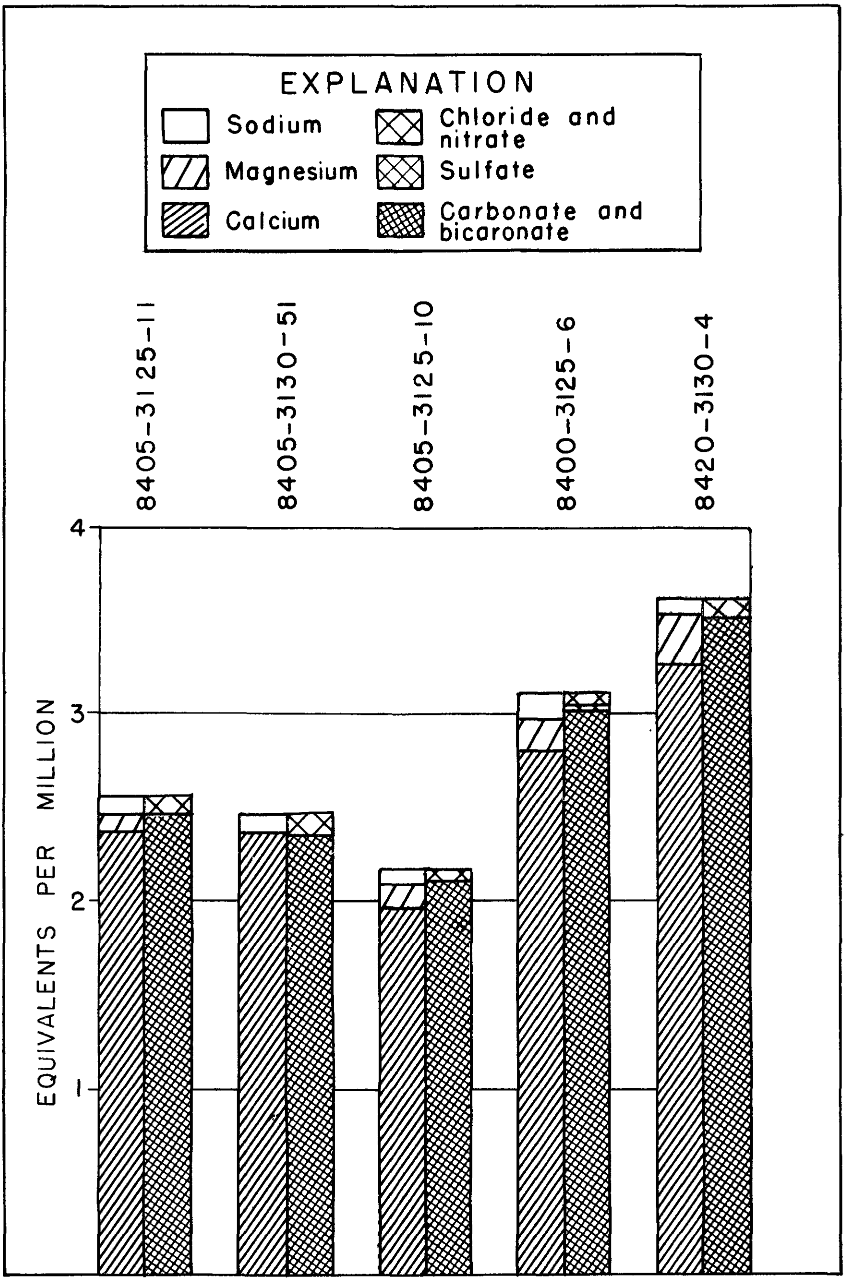


FIGURE 23.—Composition of water from Ocala limestone, Dougherty County.

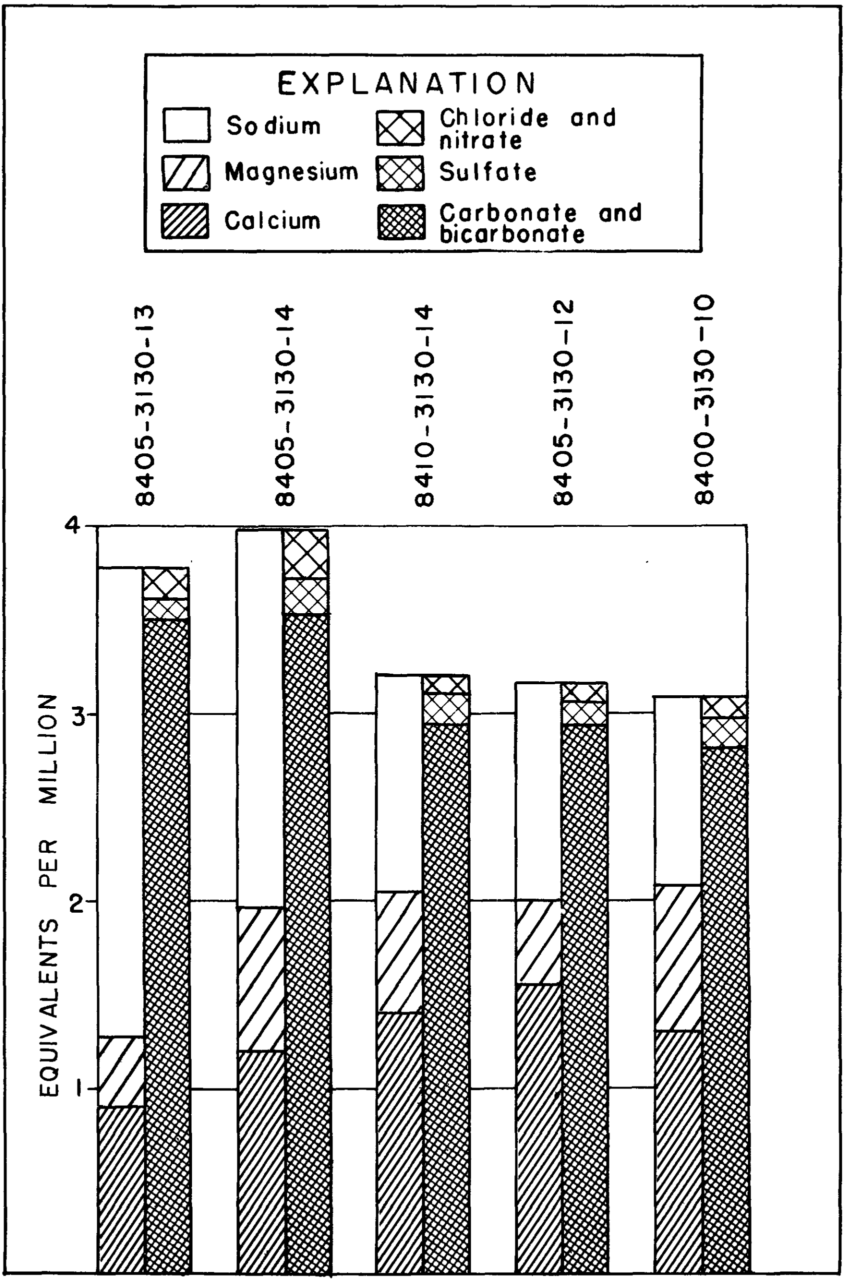


FIGURE 24.—Composition of mixtures of water from two or more aquifers, Dougherty County.

CHANGES IN QUALITY OF WATER WITH DEPTH

Figure 25 shows analyses of water from the Ocala limestone, Tallahatta formation, Clayton formation, Upper Cretaceous series, and mixtures of these waters from city wells 7, 9, and 13. The analyses are plotted according to the percentage by weight of chemical equivalents of each of two groups of the major cations and anions. The size of the circle indicates the amount of dissolved solids. The waters range from hard calcium bicarbonate type in the Ocala limestone, Tallahatta formation, and Midway group, to a soft sodium bicarbonate type in the Upper Cretaceous series. The waters from the three city wells are mixtures of these waters. The water becomes softer with depth because of the decreasing amount of calcium in the water from th Upper Cretaceous rocks. The hardness in a mixture of waters varies according to the amount of water obtained from the lower unit of the Midway group and from the Upper Cretaceous series.

SUITABILITY OF GROUND WATER FOR IRRIGATION

The suitability of water for irrigation can be determined by means of the sodium-adsorption ratio (SAR) and the conductivity of the water. The sodium-adsorption ratio is defined according to the following formula:

$$SAR=\frac{Na^{+}}{\sqrt{\frac{Ca^{+2}+Mg^{+2}}{2}}},$$

where values for all the constituents are given in equivalents per million (U.S. Salinity Laboratory Staff, 1954, p. 72). If the proportion of sodium is high with respect to calcium plus magnesium, the sodium (alkali) hazard is high. If the proportion of sodium is low with respect to calcium plus magnesium, the sodium hazard is low.

Electrical conductivity is a measure of the amount of solids dissolved in the water. As the amount of solids dissolved increases, the conductivity of the water increases.

Figure 26 shows a classification of 16 analyses of ground water from Dougherty County and 2 analyses of ground water from Clay County, using the sodium-adsorption ratio and the conductivity of the water. The water samples are from the Ocala limestone, the Claiborne group, the Clayton formation, and rocks of the Upper Cretaceous series. Of these water samples, 6 are mixtures of water obtained from wells that utilize two or more aquifers, and 3 samples were from wells (city wells 7, 11, and 13) that in addition utilize the Upper Cretaceous.

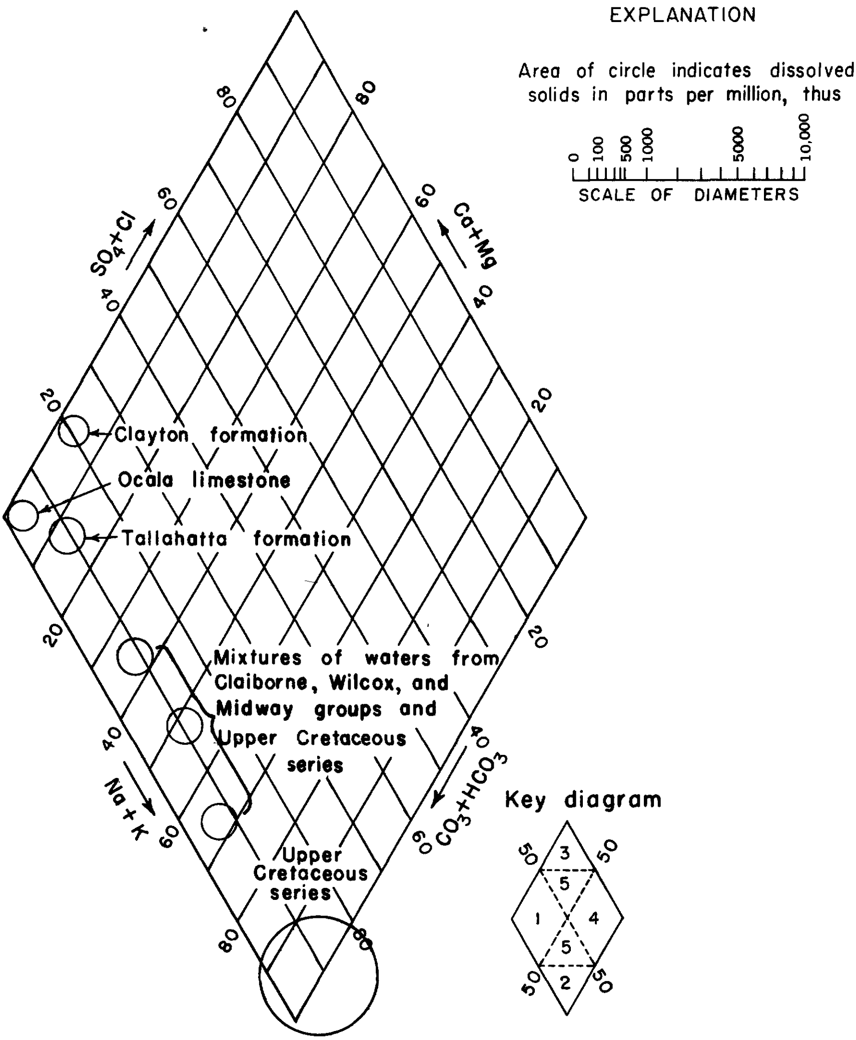


FIGURE 25.—Changes in quality of water with depth.

Area 1, carbonate hardness (secondary alkalinity exceeds 50 percent of all the dissolved solids in terms of chemical equivalents).
Area 2, carbonate alkali (primary alkalinity exceeds 50 percent).
Area 3, noncarbonate hardness (secondary alkalinity exceeds 50 percent).
Area 4, noncarbonate alkali (primary salinity exceeds 50 percent).
Area 5, no one of the preceding four characteristics is as much as 50 percent.

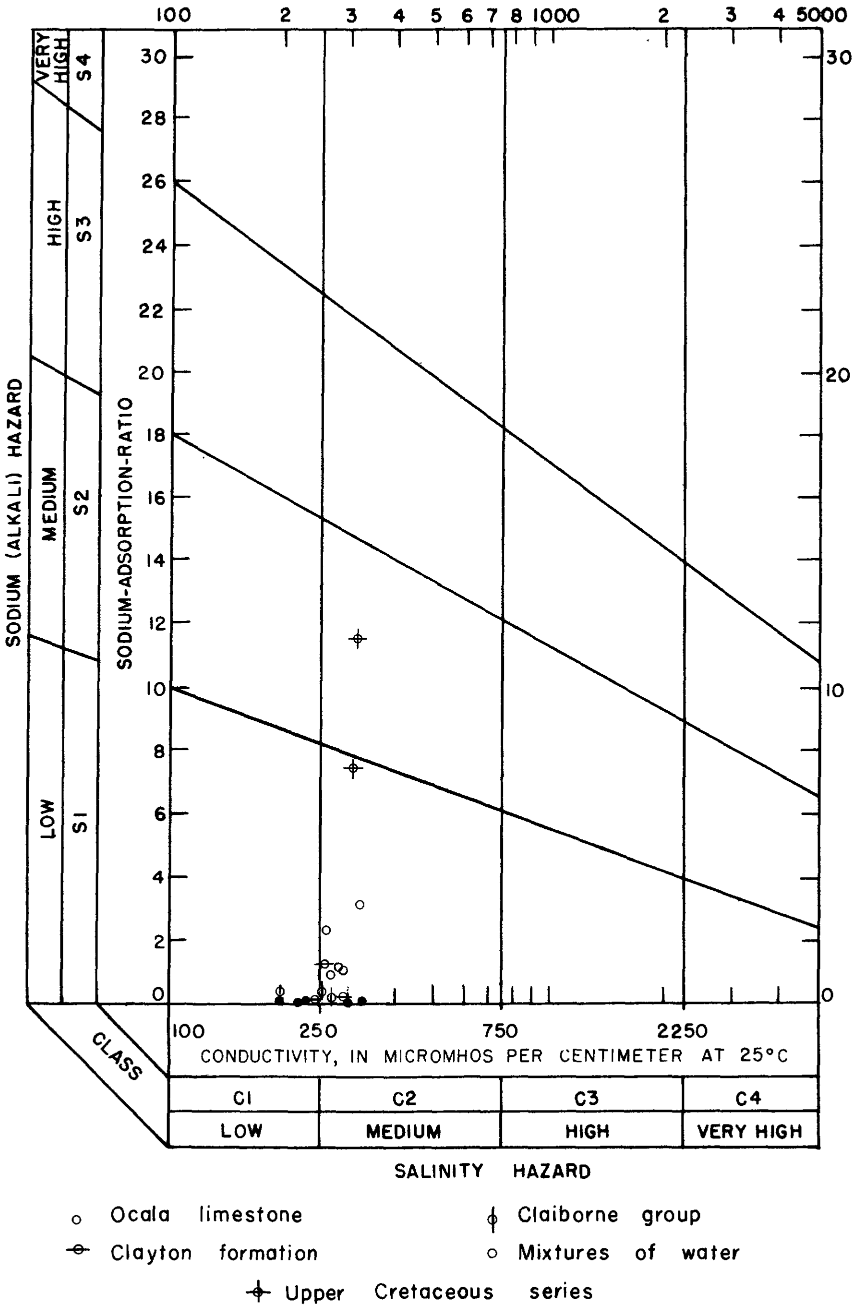


FIGURE 26.—Suitability of ground waters for irrigation.

The water from the Ocala limestone, the Claiborne group, and the Clayton formation have a low to medium salinity hazard and a low sodium hazard. The two water samples from the Upper Cretaceous have a medium salinity hazard, but one sample has a low and the other a medium sodium hazard. A third sample of water obtained from the Upper Cretaceous series (J. R. Sealy 2) is not plotted on the diagram. The sodium-adsorption ratio of this water is 60.6, and the conductivity is 2,490 micromhos, placing it in the very high salinity- and sodium-hazard class—so high, in fact, that it cannot be plotted within the limits of the diagram. The excess of sodium in the water would cause black alkali to form in poorly drained soils, and the salts would damage or kill crops that are not salt tolerant. This water was obtained from a depth of 1,200 feet, which probably is too deep to be economically feasible as a source of irrigation water at this time.

The mixtures of water are within the range of waters suitable for irrigation. The high-sodium water from the Upper Cretaceous series is mixed with the high calcium-magnesium water from the overlying formations, and the proportion of sodium with respect to the calcium plus, magnesium is reduced.

All ground water in Dougherty County that is within economical depths is well suited for irrigation. Also mixtures of water from the Upper Cretaceous and any of the overlying formations are suited for irrigation because the relative amount of sodium is low and the salinity content is low to medium.

SUMMARY

Abundant ground water is available in Dougherty County. The Ocala limestone, the sand and coquina of the Claiborne group, and the limestone unit of the Clayton formation of the Midway group are the principal aquifers in the county. Much ground water for irrigation and industry could be developed from the Ocala limestone, especially in the eastern part of the county where wells yield from 300 to 1,000 gpm. Water from wells near the Flint River that tap the Ocala limestone should be checked for sanitary quality, if the water is for domestic use.

Yields of as much as 1,400 gpm can be obtained from wells tapping the Claiborne group at depths ranging from 500 to 850 feet. Yields of as much as 300 gpm can be obtained from the Clayton formation. Insufficient data are available to determine accurately the yield from the Upper Cretaceous series. However, yields of several hundred gallons per minute are possible. Gravel-packed wells that utilize several aquifers may yield as much as 1,600 gpm. Additional water

supplies can be obtained from the deeper lying rocks of the Upper Cretaceous series.

The ground water in the Ocala limestone, the Claiborne group, the upper unit of the Clayton formation, and the limestone unit of the Clayton are of the calcium bicarbonate type. The water is moderately hard to hard, alkaline, and contains moderate amounts of dissolved solids. Sulfate is low or absent in water from the Ocala limestone. Water from the lower unit of the Clayton formation is of a calcium-sodium bicarbonate type. Water from the Upper Cretaceous series is of a sodium bicarbonate to sodium chloride type that is soft and may contain excessive amounts of iron. Saline water is present at depths of 2,800 feet and greater.

The annual pumpage in Dougherty County was estimated to be about 9 mgd in 1957, two-thirds of which is pumped from aquifers in the Claiborne and Midway groups and Upper Cretaceous series and the remaining one-third from the Ocala limestone.

Although little irrigation is practiced, irrigation is feasible from ground-water sources throughout the county. The ground water is well suited chemically for irrigation.

Dougherty County is part of the recharge area for the Ocala limestone, a unit of the principal artesian aquifer and the most important single source of water in the Georgia Coastal Plain. The Ocala is recharged from rainfall through the residual soil. Water levels in the Ocala are affected approximately 4 days after rainfall except in the immediate vicinity of Flint River, where the river stage effects the water levels. Many millions of gallons of water flow daily from the Ocala, maintaining the base flow of the Flint River in this area.

REFERENCES

Aldrich, T. H., 1886, Preliminary report upon the Tertiary fossils of Alabama and Mississippi: Alabama Geol. Survey Bull. 1, p. 44–60.

Applin, P. L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent States: U.S. Geol. Survey Circ. 91, 28 p.

Applin, P. L., and Applin, E. R., 1947, Regional subsurface stratigraphy, structure, and correlation of middle and early Upper Cretaceous rocks in Alabama, Georgia, and north Florida: U.S. Geol. Survey Oil and Gas Inv. (Prelim.) Chart 26.

Brantly, J. E., 1916, A report on the limestone and marls of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 21., 289 p., 18 pls., 1 map.

Cole, W. S., and Herrick, S. M., 1953, Two species of larger Foraminifera from Paleocene beds in Georgia: Bull. Am. Paleontology, v. 35, no. 148, p. 3–14, pls. 4, 5.

Collins, W. D., Lamar, W. L., and Lohr, E. W., 1934, The industrial utility of public water supplies in the United States, 1932: U.S. Geol. Survey Water-Supply Paper 658, 135 p.

Conrad, T. A., 1847, Observations on the Eocene formations, and description of one hundred and five new fossils of that period, from the vicinity of Vicksburg, Miss.: Philadelphia Acad. Nat. Sci. Proc., v. 3, p. 280–299.

Conrad, T. A., 1856, Observations on the Eocene deposit of Jackson, Mississippi, with descriptions of thirty-four new species of shells and corals: Philadelphia Acad. Nat. Sci. Proc., v. 7, p. 257–258.

Cooke, C. W., 1915, The age of the Ocala limestone: U.S. Geol. Survey Prof. Paper 95, p. 107–117.

——— 1923, The correlation of the Vicksburg group: U.S. Geol. Survey Prof. Paper 133, p. 1–9.

——— 1925, Physical geography of Georgia—the Coastal Plain: Georgia Geol. Survey Bull. 42, p. 19–54.

——— 1935, Notes on the Vicksburg group: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 1170–1171.

——— 1943, Geology of the Coastal Plain of Georgia: U.S. Geol. Survey Bull. 941 (1944), 121 p., 1 pl.

Cooke, C. W., and Shearer, H. K., 1918, Deposits of Claiborne and Jackson age in Georgia: U.S. Geol. Survey Prof. Paper 120–C, p. 41–81.

Cooke, C. W., Crickmay, Geoffrey, and Butts, Charles, 1939, Geologic Map of Georgia: Georgia Geol. Survey.

Crider, A. F., and Johnson, L. C., 1906, Summary of the underground-water resources of Mississippi: U.S. Geol. Survey Water-Supply Paper 159, 86 p.

Dall, W. H., 1898, A table of North American Tertiary horizons, correlated with one another and with those of western Europe, with annotations: U.S. Geol. Survey 18th Ann. Rept., pt. 2, p. 323–348.

Dall, W. H., and Harris, G. D., 1892, Correlation papers; Neocene: U.S. Geol. Survey Bull. 84, 349 p.

Dean, H. T., Jay, Philip, Arnold, F. A., Jr., and Elvove, Elias, 1941, Domestic water and dental caries: U.S. Public Health Repts., v. 56, p. 761–792.

Eargle, H. D., 1955, Stratigraphy of the outcropping Cretaceous rocks of Georgia: U.S. Geol. Survey Bull. 1014 (1956), 101 p.

Goddard, E. N., chm., and others, 1948, Rock-color chart: Washington, D.C., Natl. Research Council; Washington, D.C. repub., 1951, Geol. Soc. America.

Harris, G. D., 1894, On the geological position of the Eocene deposits of Maryland and Virginia: Am. Jour. Sci., p. 301–304.

Hendricks, E. L., 1952, Water-level fluctuations in limestone sinks in southwestern Georgia: U.S. Geol. Survey Water-Supply Paper 1110–E, p. 157–245.

———1954, Some notes on the relation of ground-water levels to pond levels in limestone sinks of southwestern Georgia: Am. Geophys. Union Trans., v. 35, no. 5, p. 796–804.

Hendricks, E. L., and Goodwin, M. H., Jr., 1952, Observations on surface-water temperatures in limesink ponds and evaporation pans in southwestern Georgia: Ecology, v. 33, no. 3., p. 385–397.

Herrick, S. M., and LeGrand, H. E., 1949, Geology and ground-water resources of the Atlanta area, Georgia: Georgia Geol. Survey Bull. 55, 124 p.

Hilgard, E. W., 1860, Report on the geology and agriculture of the State of Mississippi: 391 p.

——— 1867, On the Tertiary formations of Mississippi and Alabama: Am. Jour. Sci., p. 29–41.

Jacob, C. E., 1939, Fluctuations in artesian pressure produced by passing railroad trains as shown in a well on Long Island, New York: Am. Geophys. Union Trans., pt. 4, p. 666–674, August.

Kellogg, A. R., 1936, A review of the Archaeceti: Carnegie Inst. Washington Pub. 482, p. 20, 105, 256.

Lamar, W. L., 1942, Industrial quality of public water supplies in Georgia: U.S. Geol. Survey Water-Supply Paper 912, 83 p.

LaMoreaux, P. E., 1946, Geology and ground-water resources of the Coastal Plain of east-central Georgia: Georgia Geol. Survey Bull. 52, 173 p.

Langdon, D. W., 1891, Variations in the Cretaceous and Tertiary strata of Alabama: Geol. Soc. America Bull. 2, p. 589–605.

LeGrand, H. E., and Furcron, A. S., 1956, Geology and ground-water resources of central-east Georgia; with a chapter on the surface-water resources by R. F. Carter and A. C. Lendo: Georgia Geol. Survey Bull. 64, 174 p.

McCallie, S. W., 1898, A preliminary report on the artesian well system of Georgia: Georgia Geol. Survey Bull. 7, 214 p.

——— 1908, A preliminary report on the underground water of Georgia: Georgia Geol. Survey Bull. 15, 376 p.

——— 1913, A preliminary report on the mineral springs of Georgia: Georgia Geol. Survey Bull. 20, 190 p.

MacNeil, F. S., 1947, Geologic map of the Tertiary and Quaternary formations of Georgia: U.S. Geol. Survey Oil and Gas Inv. (Prelim.) Map 72.

Meinzer, O. E., 1923, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p., 31 pls.

Piper, A. M., 1944, A graphic procedure in the geochemical interpretation of water analyses: Am. Geophys. Union Trans., pt. 6, p. 914–923.

Piper, A. M., Garrett, A. A., and others, 1953, Native and contaminated ground waters in the Long Beach-Santa Ana area, California: U.S. Geol. Survey Water-Supply Paper 1136, 320 p.

Reeside, J. B., Jr., and others, 1957, Correlation of Triassic formations of North America exclusive of Canada: Geol. Soc. America Bull., v. 68, p. 1451–1513.

Sayre, A. N., and Livingston, Penn, 1945, Ground-water resources of the El Paso area, Texas: U.S. Geol. Survey Water-Supply Paper 919, 190 p.

Smith, E. A., 1886, Summary of the lithological and stratigraphical features and subdivisions of the Tertiary of Alabama: Alabama Geol. Survey Bull. 1, p. 7–14.

——— 1888, Report of progress for the years 1884–88: Alabama Geol. Survey, 24 p.

Smith, E. A., and Johnson, L. C., 1887, Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama Rivers: U.S. Geol. Survey Bull. 43, 189 p.

Spencer, J. W., 1891, First report of progress, 1890–91: Georgia Geol. Survey, Admin. Report, p. 5–10.

Stephenson, L. W., and Veatch, J. O., 1915, Underground waters of the Coastal Plain of Georgia, and a discussion of the quality of the waters, by R. B. Dole: U.S. Geol. Survey Water-Supply Paper 341, 539 p.

Thomson, M. T., and Carter, R. F., 1955, Surface water resources of Georgia during the drought of 1954: Georgia Geol. Survey Inf. Circ. 17, pt. 1, 79 p.

Thomson, M. T., Herrick, S. M., Brown, Eugene, and others: 1956, Availability and use of water in Georgia: Georgia Geol. Survey Bull. 65, 416 p.

U.S. Department of Agriculture, 1956, The 1954 census of agriculture: v. 1, pt. 17.

U.S. Public Health Service, 1946, Public Health Service drinking water standards: Public Health Repts., v. 61, no. 11, p. 371–384.

U.S. Salinity Laboratory Staff, 1954, Saline and alkali soils: U.S. Dept. Agriculture, Agr. Handbook 60, 160 p.

U.S. Weather Bureau, 1953, Local climatological data with comparative data, Albany, Georgia: U.S. Dept. Commerce, 4 p.

Vallely, J. L., and Peyton, Garland, 1954, Mineral industry of Georgia: U.S. Bur. Mines and Minerals Yearbook. Preprint, 17 p.

Vaughan, T. W., 1900, The Eocene and lower Oligocene coral faunas of the United States, with descriptions of a few doubtfully Cretaceous species: U.S. Geol. Survey Mon. 39, 263 p.

Veatch, J. O., and Stephenson, L. W., 1911, A preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, 466 p.

Wait, R. L., 1957, History of the Albany, Georgia, water supply: Georgia Min. Newsletter, p. 143–147.

Waring, F. H., 1949, Significance of nitrates in water supplies: Am. Water Works Assoc. Jour., v. 61, no. 11, p. 371–384.

Warren, M. A., 1944, Artesian water in southeastern Georgia with special reference to the coastal area: Georgia Geol. Survey Bull. 49, 140 p.

Warren, W. C., and Thompson, R. M., 1943, Bauxite and kaolin deposits of Wilkinson County, Ga.: U.S. Geol. Survey Strategic Minerals Inv. (Prelim.) Map.

Wilmarth, M. G., 1938, Lexicon of geologic names of the United States including Alaska: U.S. Geol. Survey Bull. 896, pts. 1 and 2, 2396 p.

INDEX

U.S. GOVERNMENT PRINTING OFFICE: 1963 O—654863