Geology and Ground-Water Resources of Montgomery County, Alabama

By D. B. KNOWLES, H. L. READE, JR., *and* J. C. SCOTT

With special reference to the MONTGOMERY AREA

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By Doyle B. Knowles, H. L. Reade, Jr., and John C. Scott

ABSTRACT

Montgomery County includes an area of 790 square miles in east-central Alabama. The economy of Montgomery County is related primarily to the growing and processing of agricultural products.

The county is in the northern part of the Coastal Plain. It consists of parts of four divisions of the Coastal Plain: the terraces, the Black Prairie, the Chunnennuggee Hills, and the flood plains. The county drains north and northwest into the Alabama and Tallapoosa Rivers, except for a small area in the southern part of the county that is drained by tributaries of the Conecuh River.

Sedimentary rocks of Late Cretaceous age underlie Montgomery County. They are divided, in ascending order, into the following: Coker and Gordo formations of the Tuscaloosa group; Eutaw formation; and Mooreville and Demopolis chalks, Ripley formation, Prairie Bluff chalk, and Providence sand of the Selma group. The Clayton formation of Tertiary age crops out in a small area in the southern part of the county. Pleistocene terrace deposits of the ancestral Alabama River overlie the older rocks in the northern part of the county. Recent alluvium underlies the flood plains of the larger streams. The Cretaceous and younger rocks consist chiefly of clay, chalk, sandstone, sand, and gravel, and a few thin beds of limestone. These deposits are underlain by a basement complex of pre-Cretaceous crystalline rocks.

Large-scale withdrawals of water began in the Montgomery area about 1885. Pumpage by the city of Montgomery in 1958 averaged about 15 million gallons per day. It is estimated that an additional 10 to 15 million gallons per day was pumped in the county for industrial, irrigation, domestic, and stock use.

The principal aquifer in the country is the Eutaw formation. It supplies water to the city of Montgomery municipal wells, to industrial wells in the Montgomery area, and to most domestic and stock wells in the northern two-thirds of the county. Irrigation wells also tap the Eutaw. Yields from wells range from 350 to 600 gallons per minute.

The Gordo formation, the upper part of the Coker formation, and the Pleistocene terrace deposits in the Montgomery area also yield moderate to large quantities of water to municipal and industrial wells. The lower part of the Coker formation is not developed as a source of water supply, but information obtained during the investigation that led to this report indicates that it may be a potential source of water to wells of large capacity. Sand beds in the Ripley formation, Providence sand, and Recent alluvium in the southern part of the county yield adequate amounts of water to domestic and stock wells.

Most of the ground water used in Montgomery County occurs under artesian conditions, although water-table conditions occur in the Pleistocene terrace deposits and Recent alluvium, and in the outcrop areas of the Eutaw and Ripley formations and the Providence sand.

Most of the water recharging the Coker, Gordo, and Eutaw formations in their areas of outcrop also is discharged in these areas; only a small quantity of water moves downdip beneath the overlying chalk beds. The natural discharge, and hence the natural recharge, is estimated to be 0.2 to 0.3 million gallons per day per square mile of outcrop.

All ground water in the county is of chemical quality that is satisfactory for most uses, although locally it is high in iron or chloride content and is hard. Water from the Eutaw formation a few miles southwest of Montgomery's West well field is very high in chloride content. This water moves toward the cone of depression in the piezometric surface produced by pumping in the West well field.

Much additional ground water could be pumped from the Eutaw formation, especially south of Montgomery's West well field. Additional water also is available from the upper part of the Coker formation. Before large ground-water developments are planned, however, the problems of well spacing and pumping rates should be studied in order to determine the maximum development permitted by the supply. Observation wells should be installed in the Eutaw formation southwest of Montgomery's West well field to detect encroachment of water of high chloride content from adjacent Lowndes County.

INTRODUCTION

LOCATION AND EXTENT OF AREA

Montgomery County, in east-central Alabama, includes an area of 790 square miles, and, according to the 1950 census, had a population of 138,965. It is bounded on the north by Autauga and Elmore Counties; on the east by Macon, Bullock, and Pike Counties; on the south by Pike and Crenshaw Counties; and on the west by Lowndes County.

Montgomery, the county seat, is on a sharp bend in the Alabama River in the northern part of Montgomery County (fig. 1). It is the capital of Alabama and the third largest city in the State. According to the 1950 census, the population of the city proper was 106,525, and the population of the surrounding urbanized area was 2,943.

PURPOSE AND SCOPE OF INVESTIGATION

The water supply for Montgomery is pumped from wells, and in 1957 the pumpage averaged 15.2 mgd (million gallons per day). It is estimated that an additional 10 to 15 mgd was pumped from wells in Montgomery County for industrial, irrigation, and private use. The purpose of this investigation was to determine the thickness, character, and areal extent of the water-bearing beds underlying Montgomery County, with special reference to the Montgomery mu-

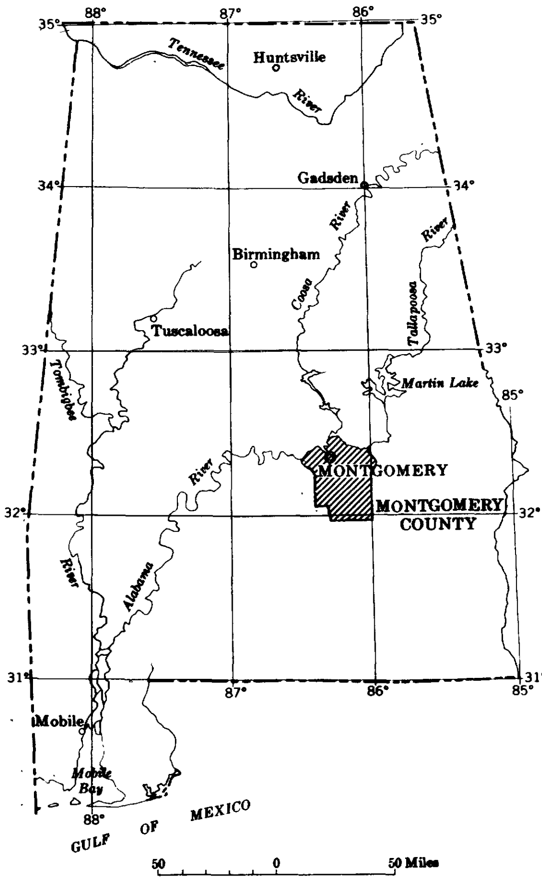

FIGURE 1.—Index map of Alabama showing Montgomery County.

nicipal area; to estimate the capacity of the beds to absorb, store, and transmit water; and to determine the chemical character of the ground water.

In 1941 the city of Montgomery had 12 test wells drilled northwest and west of the city to determine the thickness and areal extent of the water-bearing beds. Development of the city's West well field began as a result of this test-drilling program. As the demand for water increased and as the well fields were expanded from year to year, it became apparent that a comprehensive investigation of the quantity and quality of available ground water was essential for planning the orderly development of future water supplies. In April 1951, therefore, the U.S. Geological Survey in cooperation with the Water Works and Sanitary Sewer Board of the city of Montgomery began a detailed investigation of the geology and ground-water resources near the city and a less detailed investigation throughout the county. The studies were completed in October 1954. The investigation in Montgomery County supplemented the statewide program of ground-water studies by the U.S. Geological Survey in cooperation with the Geological Survey of Alabama.

The investigation was made under the direction of P. E. LaMoreaux, formerly district geologist in charge of cooperative ground-water investigations in Alabama and now chief of the Ground Water Branch of the U.S. Geological Survey. The latter stages of the preparation of this report were under the general supervision of William J. Powell, who succeeded Mr. LaMoreaux as district geologist.

AGRICULTURAL AND INDUSTRIAL DEVELOPMENT

Cattle raising is the principal occupation in rural Montgomery County. The uniform distribution of rainfall and the rich soil of the county makes year-round pastures possible. Production of cotton, corn, peanuts, oats, and lumber also contribute to the economy.

Montgomery is an important market for livestock, cotton, and lumber. It has the largest cattle market east of Fort Worth, Tex., and south of the Ohio River. Maxwell and Gunter Air Force Bases are at Montgomery and contribute substantially to the economy of the area. Major industries include the manufacture of commercial fertilizer, lumber and lumber products, textiles and clothing, insecticides, concrete products, building bricks, asphalt products, and machinery. The processing of livestock and poultry, cotton, and dairy and food products also contributes to the economy.

HISTORY OF MUNICIPAL GROUND-WATER SUPPLY

The first public water-supply system for Montgomery was organized in 1885 by a private corporation. Water was obtained from 6 wells drilled in what is now the city's Northeast well field in the northern part of Montgomery. All these wells flowed, according to reports, when they were drilled in 1885; well J–121 (Knowles and others, 1960, table 1), drilled to a depth of 633 feet, is reported to have flowed at a rate of 200 gpm (gallons per minute). Many private wells in the Montgomery area also had natural flows. As more and more wells were drilled, water levels declined, and, by 1899 (Smith, 1907, p. 209–210), most of the wells in the Montgomery municipal area had ceased to flow.

The city of Montgomery acquired the property of the private water system in 1895, and 12 additional wells with airlift pumps were drilled and equipped in 1899. The combined capacity of these wells, all in the Northeast well field, is reported to have been 5 mgd. As demands for water increased, additional wells were drilled in the Northeast well field, and the West well field in the western part of Montgomery was developed in 1941.

The municipal water system by 1949 included 31 wells having a capacity of 17 mgd. The Water Works and Sanitary Sewer Board, a public corporation, took over operation of the system in 1950. The water system in 1958 included 17 wells in the Northeast well field and 31 wells in the West well field. The West well field now extends about 7 miles west of Montgomery. The 48 wells are reported to have a combined capacity of about 31 mgd.

PREVIOUS INVESTIGATIONS

The geology and ground-water resources of Montgomery County had not been studied in detail prior to this investigation. Several reports, however, contain information on the geology or ground-water resources of all or part of the county.

Information on the geology of Montgomery County was published as early as 1858 in the second biennial report of the Geological Survey of Alabama by Michael Tuomey, first State Geologist. The report contains several measured geologic sections along the Alabama River. An outline of the geology of the county and a measured geologic section at Washington Ferry on the Alabama River is given in "Report on the Geology of the Coastal Plain of Alabama," by E. A. Smith and others (1894). Information on many water wells drilled prior to 1904 and a description of the geology of Montgomery County is included in "The Underground Water Resources of Alabama," by E. A. Smith (1907). Other reports that contain information on the geology of Montgomery County include: "The Cretaceous formations," by L. W. Stephenson (1926); "Stratigraphy of Upper Cretaceous series in Mississippi and Alabama," by L. W. Stephenson and W. H. Monroe (1938); "Notes on Deposits of Selma and Ripley age in Alabama," by Watson H. Monroe (1941); "Upper Cretaceous of West-Central Alabama," by Winnie McGlamery (1944); "Correlation of the Outcropping Upper Cretaceous Formations in Alabama and Texas," by W. H. Monroe (1946); "The Cretaceous of East-Central Alabama," by D. H. Eargle (1948); "Geologic Map of the Selma Group in Eastern Alabama," by D. H. Eargle (1950); and "Profile showing geology along U.S. Highway 331, Montgomery County, Alabama," by H. L. Reade, Jr., and John C. Scott (1959).

C. W. Carlston made a reconnaissance of the ground-water resources of the Cretaceous area of Alabama in 1940 and recorded data on 107 wells and chemical analyses of water from 24 wells in Montgomery County. The results of this investigation are given in "Fluoride in the Ground Water of the Cretaceous Area of Alabama," by Carlston (1942) and in "Ground-Water Resources of the Cretaceous Area of Alabama," by Carlston (1944). The geology and ground-water resources of the Montgomery municipal area are described briefly in "Interim Report on the Geology and Ground-Water Resources of Montgomery, Ala. and Vicinity," by W. J. Powell and others (1957). Most of the basic data collected during these investigations and during the study that led to this report are included in "Geology and Ground-Water Resources of Montgomery County, Ala. with special reference to the Montgomery Area," by D. B. Knowles and others (1960).

METHODS OF INVESTIGATION

WELL INVENTORY

All available data concerning water wells in Montgomery County were collected and studied during the investigation. The data included drillers' logs and information on the well location, diameter, depth, water level, casing and screens, yield and drawdown, use, water-bearing formations and other pertinent facts related to wells and to the occurrence and availability of ground water. The drillers' logs and other records of wells are given by Knowles and others (1960, tables 1 and 3). The locations of wells are shown on plate 1.

Wells of large capacity are concentrated in the Montgomery area, chiefly in the northwest corner of grid J and the northwest half of grid K (pl. 1). Most of these wells are used, or formerly were used, to supply water to the city. Wells in the remainder of the county are used chiefly for domestic or stock supplies. These wells generally were drilled only a short distance into the shallowest water-bearing bed; thus, they give little information on the thickness and character of the water-bearing beds.

GEOLOGIC MAPPING

The geology was mapped in the field on aerial photographs, having a scale of 1:20,000, and later transferred to a base map having a scale of 1:63,360. Geologic contacts were mapped by automobile traverses and by pacing along exposures. The contact lines drawn on the photographs later were modified stereoptically. Indefinite or inferred contacts are shown on the geologic map (pl. 1) by dashed lines. Geologic sections were measured by planetable, hand level, or steel tape.

TEST DRILLING

A substantial part of the investigation was the drilling of 44 test wells with a total footage of 24,770 feet, by a contractor for the

Geological Survey, and the analyzing of the resultant data. The test wells generally were drilled to the first lignitic bed in the Coker formation and ranged in depth from 200 to 1,219 feet. Samples of the materials penetrated were collected at frequent intervals; logs compiled from the microscopic examination of the samples are given by Knowles and others (1960, table 4). Mechanical analyses of selected samples were made in the laboratory (Knowles and others, 1960, tables 5–7). Five of the test wells were cased and screened for use as observation wells to determine the fluctuations in water level in the principal water-bearing formations. Four of the test wells were utilized in aquifer tests to determine the hydraulic characteristics of the water-bearing material.

In addition to the test wells drilled during this investigation, the city of Montgomery drilled 21 test wells during 1941–51 and 11 test wells or supply wells during 1954–57 with a total footage of 26,061 feet. Logs prepared from the microscopic examination of samples collected during the drilling of these wells also are given by Knowles and others (1960, table 4).

An electric log, consisting of a spontaneous-potential curve and a single-point-resistance curve, was made after each test well was completed and was used in conjunction with the sample logs to determine the thickness and lithologic character of the formations penetrated.

WATER SAMPLING

Water samples collected from many of the wells were analyzed in the field for chloride content and hardness. The results of these analyses are given by Knowles and others (1960, table 1). Water samples from selected wells tapping the principal water-bearing formations were analyzed in the laboratory. Samples of water for chemical analysis were also collected at various depths from most of the test wells. The results of chemical analyses, together with analyses made during earlier studies, are given by Knowles and others (1960, table 2).

WELL-NUMBERING SYSTEM

The numbering of wells in Montgomery County is based on the Federal system of subdivision of the public lands which divided the public land into townships approximately 36 square miles in area. In the well-numbering system used in this report, Montgomery County is divided into townships designated by letters, in alphabetical order, beginning with "A" in the northeast township. The wells within a township are numbered consecutively, each number prefixed by the letter identifying the township, for example, B–1, B–2, B–3 (pl. 1).

ACKNOWLEDGMENTS

The writers wish to thank the many persons who have contributed information and assistance during the field investigation and during the preparation of this report, particularly C. T. Perry, general manager, and G. W. Cowham, water superintendent, city of Montgomery Water Works and Sanitary Sewer Board, and Lowell Cady and H. F. Wiedeman of Wiedeman and Singleton, Engineers, Atlanta, Ga. Acknowledgment also is made to Layne-Central Co., Acme Drilling Co., Black Belt Drilling Co., and Stoudenmire Well Co. for supplying drill cuttings, logs, and records of wells, and to the citizens of Montgomery County for their cooperation in supplying other data on wells.

The field investigation was made by H. L. Reade, Jr., and John C. Scott, the tables of basic data were compiled by Scott and Doyle B. Knowles, and the report was prepared by Knowles. The discussion of the geology of Montgomery County was revised and modified from a manuscript report prepared by Reade.

PHYSICAL FEATURES

TOPOGRAPHY

The altitude of Montgomery County ranges from about 100 feet, along the Alabama River at the Lowndes County boundary, to about 550 feet above mean sea level, about 3½ miles west of Pine Level in southeastern Montgomery County.

Montgomery County is in the northern part of the Coastal Plain physiographic province. The county consists of parts of four physiographic divisions of the Coastal Plain: the terraces, the Black Prairie, the Chunnennuggee Hills, and the flood plains (pl. 2).

The terraces constitute a belt averaging about 6 to 8 miles wide adjacent to the Alabama and Tallapoosa Rivers in the northern part of the county. Three terraces, at altitudes of about 140 to 170 feet, 180 to 200 feet, and 295 to 310 feet form a plain sloping northward toward the Alabama and Tallapoosa Rivers. The terraces merge and were not differentiated in this investigation.

A cuesta (a ridge characterized by a steep slope in one direction and a long, gentle slope in the other) lies south of the terraces in the outcrop area of the Eutaw formation in the north-central part of the county. The cuesta is only about 10 miles long and 2 miles wide, and is not shown on plate 2. This area is rugged topographically except where modified by the terraces. Semmes (1929, p. 202, fig. 37) includes the outcrop area of the Eutaw formation in the Fall Line Hills physiographic division. Fenneman (1938) uses the same classification. Monroe (1941, p. 29), however, states: "* * * the term 'Fall Line hills' is scarcely appropriate inasmuch as the true Fall Line does not extend west or south of the region of outcrop of the metamorphic rocks of the Piedmont Plateau." The area of outcrop of the Eutaw formation in Montgomery County is small, and is not differentiated from the terraces.

The Black Prairie, generally known as the "Black Belt," which lies immediately south of the terrace area (pl. 2), is underlain by the Mooreville and Demopolis chalks. It ranges in altitude from about 200 to 350 feet above mean sea level. The northern part of the Black Prairie, developed on the Mooreville chalk, has a gently rolling terrain that is characterized by deep black soil that supports a natural grassland. The Arcola cuesta scarp, formed by the resistant beds of the Arcola limestone member at the top of the Mooreville chalk, occurs at the southern edge of this part of the Black Prairie. South of the Arcola cuesta scarp, in the outcrop area of the Demopolis chalk, the topography of the Black Prairie is relatively flat and is characterized by abundant bald spots of chalk. The black soils characteristic of the northern part are not as widespread south of the Arcola scarp. The southern edge of the Black Prairie is more rolling and forms the lower slopes of the High Ridge cuesta of the Chunnennuggee Hills physiographic division.

The Chunnennuggee Hills are a series of cuestas south of the Black Prairie, in the outcrop area of sand, clay, chalk, and limestone of the Ripley formation, Prairie Bluff chalk, Providence sand, and Clayton formation. The topography is characterized by steep-sided hills and deep, narrow ravines that range in altitude from about 425 to 525 feet above mean sea level.

A line of hills in the eastern part of this area is formed on the outcrop of the Cusseta sand member of the Ripley formation. These hills are a westward extension of the Enon cuesta of Bullock County (Monroe, 1941, p. 37). The topography is rugged and has been deeply dissected by tributaries of Catoma Creek, which drain northward from the scarp of the High Ridge cuesta.

The High Ridge cuesta (pl. 2) trends eastward across southern Montgomery County. The scarp of this cuesta forms the northern boundary of the Chunnennuggee Hills in the western part of the county and is immediately south of the line of hills formed on the outcrop of the Cusseta sand member of the Ripley formation in the eastern part of the county.

The Lapine cuesta occurs on the outcrop of the Providence sand in the southwestern part of the county. The scarp of the cuesta is a prominent topographic feature above the back slope of the High Ridge cuesta. The type area for this cuesta is a high northward-facing hill near Lapine on the Montgomery-Pike County boundary.

The valleys of Pintlalla Creek and its tributary, Pinchony Creek; Catoma Creek and its tributaries, Ramer, Little Catoma, Sandy, Little Sandy, Dry, Thompson, and Baskin Mill Creeks; and Line Creek contain flood plains (pl. 2). They trend northwestward across the Black Prairie and terraces to the Alabama and Tallapoosa Rivers. A large part of the flood-plain area is poorly drained, is inundated during flood stages of the streams, and is used mainly for timber and as pasture.

DRAINAGE

The divide between the Alabama and Conecuh Rivers is formed by the north-facing scarp of the High Ridge cuesta in southern Montgomery County. Streams north of this divide flow northward and northwestward to the Alabama and Tallapoosa Rivers, and those south of the divide flow southward and southwestward to the Conecuh River.

Most of the Black Prairie is drained by Catoma Creek and its tributaries, Ramer, Little Catoma, Sandy, Thompson, Baskin Mill, Little Sandy, and Dry Creeks and Baldwin Slough. Catoma Creek leaves the Black Prairie near the southwestern edge of Montgomery, and empties into the Alabama River about 5 miles west of Maxwell Air Force Base. A small area in the western part of the Black Prairie is drained by Pintlalla Creek and its tributary, Pinchony Creek. Pintlalla Creek flows northwestward and empties into the Alabama River about 3 miles downstream from Catoma Creek. Line Creek, which heads in Bullock County and forms the boundary between Montgomery and Macon Counties, drains a small area of the Black Prairie in the northeastern part of the county and flows into the Tallapoosa River about 2 miles northeast of Brassell.

Drainage that originates mainly on the terraces is poorly developed. The streams flow northward and northwestward to the Tallapoosa and Alabama Rivers. Miller and Wescott Creeks, which drain the eastern part of the terrace area northward to the Tallapoosa River, are the best developed drainageways.

Drainage from most of the Chunnennuggee Hills, which includes an area of about 200 square miles in the southern part of the county, is southward and southwestward into Crenshaw and Pike Counties, chiefly by Patsaliga Creek and its tributaries, Weaver Mill, Jackson, Greenbrier, and Olustee Creeks. Patsaliga Creek flows into the Conecuh River near Andalusia in Covington County. A small area of the Chunnennuggee Hills in the southeastern part of the county, coextensive with the outcrop area of the Cusseta sand member of the Ripley formation, drains northwestward to tributaries of the Alabama River.

CLIMATE

The climate of Montgomery County is humid and mild. The average annual precipitation at Montgomery during the period of record, 1873–1957, was 51.12 inches. The annual precipitation ranged from 26.82 inches in 1954 to 78.25 inches in 1929. March has the most precipitation, an average of 6.17 inches; October has the least, an average of 2.27 inches. The annual and average monthly precipitation for the period of record are summarized graphically in figure 2.

The average annual temperature at Montgomery during 1873–1957 was 65.8° F. The average monthly temperature ranged from 49.2° F in January to 81.7° F in July (fig. 2).

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

GENERAL GEOLOGY, STRATIGRAPHY, AND STRUCTURE

The geologic formations that crop out in Montgomery County are of sedimentary origin and are assigned to four series: the Upper Cretaceous, Paleocene, Pleistocene, and Recent. The Upper Cretaceous series includes the Eutaw formation, Mooreville and Demopolis chalks, Ripley formation, Prairie Bluff chalk, and Providence sand; the Paleocene series includes the Clayton formation; the Pleistocene series includes terrace deposits of the ancestral Alabama River; and the Recent series includes alluvium. These rocks consist chiefly of clay, chalk, sandstone, sand, gravel, and a few thin beds of limestone. The distribution of the outcropping formations is shown on plate 1.

The Coker and Gordo formations of the Upper Cretaceous series do not crop out in the county but are penetrated by wells. They consist chiefly of clay, sand, gravel, and a few thin beds of lignite. A basement complex of crystalline rocks of undetermined age underlies the Coker formation.

The chief sources of water supply in Montgomery County are beds of sand and gravel in the Coker, Gordo, and Eutaw formations, and the Pleistocene terrace deposits. Adequate water supplies for domestic and stock use also are pumped from the Ripley formation and Providence sand in the southern part of the county and from Recent alluvium along the streams.

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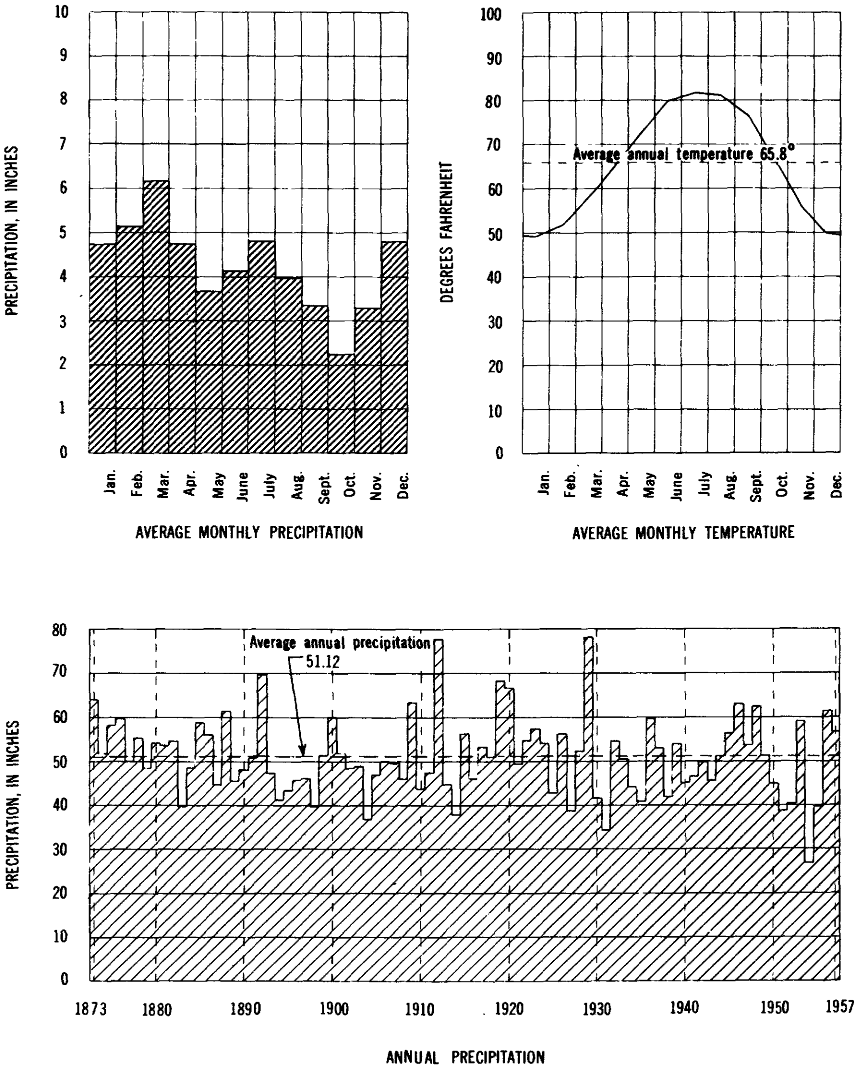


FIGURE 2.—Average monthly precipitation, average monthly temperature, and annual precipitation at Montgomery, 1873–1957.

A generalized section of the geologic formations in Montgomery County and their water-bearing properties is given in table 1.

Rocks of Cretaceous age crop out in roughly parallel eastward-trending belts across Montgomery County. They dip about 40 to 65 feet per mile, except where the dip is influenced by local structure, southwestward in the western part of the county to southeastward in the eastern part. Because the dip of the beds is greater than the slope of the land surface, the formations are found at progressively greater depths southward from their areas of outcrop. Terrace deposits of the ancestral Alabama River and flood-plain deposits of present streams, both of Quaternary age, overlie the rocks of Cretaceous age.

The lithology, thickness, and attitude of the rocks penetrated by wells are shown graphically in five stratigraphic sections. One of the sections (pl. 3) is oriented approximately down the dip of the Eutaw formation and extends from the northern part of Montgomery County near Boylston to Ramer in the southern part. The remaining sections (pls. 4–7) extend eastward across the northern part of the county approximately along the strike of the formations. The intervals screened in wells of Montgomery's West well field are shown on plate 6.

The geologic structure of the Cretaceous rocks in Montgomery County is relatively simple. The configuration of the top of the pre-Cretaceous crystalline rocks in the Montgomery area is shown in figure 3. The basement complex, upon which the rocks of Cretaceous age rest, slopes southwestward in the western part of the area and southeastward in the eastern part about 60 to 100 feet per mile. A shallow depression, whose origin is indeterminate, trends southwestward on the surface of the bedrock southwest of Maxwell Air Force Base.

The configurations of the surfaces of the Coker and Gordo formations in the Montgomery area are shown in figures 4 and 5, respectively. The two formations dip generally southwestward about 40 feet per mile. They also contain southwestward-trending depressions in their surfaces in the vicinity of Maxwell Air Force Base. The depression in the Gordo surface is deeper and of greater areal extent than that in the Coker surface. These depressions correlate in position with the shallow depression in the basement complex (fig. 3).

The surface of the Eutaw formation in Montgomery County is shown on plate 8. The Eutaw dips southwestward in the western part of the county, southward in the central part, and southeastward in the eastern part. The dip ranges from about 25 feet per mile in the Montgomery area to about 65 feet per mile in the southern part of the county near Ramer (pls. 3, 8).

TABLE 1.—*Generalized section of the geologic formations in Montgomery County and their water-bearing properties*

System	Series	Stratigraphic unit			Thickness (feet)	Lithology	Water-bearing properties
Quaternary	Recent	Alluvium			0–40±	Sand, white to light-gray, silty, poorly sorted, lensing; some yellowish-orange to bluish-gray sandy clay.	Yields small supplies of water of good quality to shallow wells in valleys of Pintlalla, Catoma, and Line Creeks and their tributaries.
	Pleistocene	Terrace deposits			10–100±	Sand, pale-yellowish-orange, crossbedded, medium to very coarse grained, poorly sorted, ferruginous, quartzitic; dark-reddish-brown sandy clay; and lenses of well rounded gravel ranging in diameter from 4 to 256 mm.	Yields moderate to large supplies of water of good quality to wells in northern part of county; highly permeable sand and gravel.
Tertiary	Paleocene	Midway group	Clayton formation		----------	Chalk, gray, sandy; grayish-white fossiliferous limestone; and gray sandy clay. Present only as outlier on high hill on Montgomery-Crenshaw County boundary.	Relatively impermeable; not a source of ground water.
		Selma group	Providence sand	Upper member	85	Sand, pale-yellowish-orange, crossbedded, fine- to coarse-grained, poorly sorted; interbedded with white, pale-red-purple, and moderate-reddish-brown massive clay. Present as outliers capping high hills is southern Montgomery County.	Not used as a source of water supply in Montgomery County but probably would yield small supplies of water to shallow wells in outcrop area. Seeps issue at base, in places.
				Perote member	60	Sand, dark-gray to yellowish-orange, very fine to fine-grained, micaceous, carbonaceous, ferruginous, calcareous-cemented, fossiliferous, thinly laminated with clayey silt; some thin beds of hard limonitic sandstone.	Yields small supplies of water of good quality to wells in outcrop area.
			Prairie Bluff chalk		50–90	Chalk, light-olive-gray to yellowish-gray, massive, silty to finely sandy, micaceous, glauconitic, fossiliferous; becomes increasingly sandy toward top. Thins eastward and merges with Providence sand in Bullock County.	Relatively impermeable; not a source of ground water.
			Ripley formation	Upper member	180–315	Sand, greenish-gray to yellowish-gray, cross-laminated, fine- to very coarse-grained, poorly to well sorted, micaceous, ferruginous, limonitic, glauconitic, calcareous, fossiliferous; greenish-gray to pale-olive silty to sandy fissile micaceous, calcareous fossiliferous clay; and thin beds of hard-gray to yellowish-gray fine- to medium-grained argillaceous micaceous ferruginous glauconitic calcareous-cemented fossiliferous sandstone.	Yields small supplies of soft to moderately hard water to dug wells from the upper weathered zone and to a few drilled wells from the basal sand. Sands have low permeabilities.
				Cusseta sand member	0–120	Sand, light-gray to pale-yellowish-orange, fine- to medium-grained, micaceous, glauconitic, fossiliferous; light-gray to white calcareous-cemented fossiliferous sandstone; and greenish-gray to white sandy chalk. Thins westward and merges into upper part of Demopolis chalk in central Montgomery County.	Yields small supplies of soft to hard water to wells in southern part of county. Sands have low permeabilities.

Cretaceous	Upper cretaceous		Demopolis chalk		250–420	Upper and lower parts are chalk, light-greenish-gray to yellowish-gray, silty to finely sandy, clayey, micaceous, fossiliferous; separated by a bed of relatively pure fossiliferous chalk; contains bentonitic clay in southwestern part of county.	Relatively impermeable; not a source of ground water.
			Mooreville chalk	Arcola limestone member	5–10	Limestone, impure, light-gray, thin-bedded, hard, dense, fossiliferous; two to four beds, 6 inches to 1 foot thick, separated by a bed of gray to pale-olive calcareous clay 3 to 6 feet thick.	Relatively impermeable; not a source of ground water.
				Lower member	600	Chalk, light-greenish-gray to yellowish-gray, silty to finely sandy, argillaceous, ferruginous, fossiliferous; in eastern part of county grades laterally into gray to yellowish-orange sandy calcareous clay.	Relatively impermeable; not a source of ground water.
		Eutaw formation			3–400	Sand, light-greenish-gray, cross-laminated, fine- to medium-grained, well-sorted, micaceous, glauconitic, fossiliferous; interbedded with greenish-gray micaceous glauconitic fossiliferous clay and sandy clay. Upper part contains several hard beds, 6 inches to 1 foot thick, of light-gray to white fossiliferous medium-grained quartzitic glauconitic calcareous-cemented sandstone.	Yields moderate to large supplies of water from massive sands in upper and lower parts of formation. Water from upper sands is locally high in iron content. Extensively developed as a source of municipal water supply by city of Montgomery. Tapped by a few flowing wells in valleys of Catoma and Line Creeks.
		Tuscaloosa group	Gordo formation		195–340	Sand, pale-yellowish-orange, medium- to coarse-grained, poorly sorted, quartzitic, ferruginous-cemented; interbedded with moderate-reddish-brown to pale-red-purple clay. Generally contains a thin bed of gravel at the base and elsewhere in the formation.	Yields small to moderate supplies of water of good quality from sands in middle part of formation. Sands are poorly sorted and cemented and have relatively low permeabilities. Extensively developed as source of municipal water supply by city of Montgomery. Tapped by a few flowing wells in valley of Alabama River in northwestern part of county.
			Coker formation		360–600±	Sand in upper 300 to 400 feet, light-greenish-gray, medium- to coarse-grained, well-sorted, micaceous, quartzitic, glauconitic, fossiliferous; thinly laminated with greenish-gray lignitic fossiliferous clay. Lower 150 to 200 feet is chiefly pale-yellowish-orange medium- to coarse-grained arkosic sand interbedded with reddish-brown, pale-red-purple, and pale-green sandy clay. Contains thin beds of hard calcareous sandstone throughout.	Yields moderate to large supplies of water of good quality from sands in upper part of formation. Extensively developed as source of municipal water supply by city of Montgomery. Sand beds in lower 150 feet not tapped by wells but are potential sources of supply to wells of large capacity.
Pre-Cretaceous crystalline rocks					Unknown	Biotite mica schist.	Relatively impermeable; not a source of ground water.

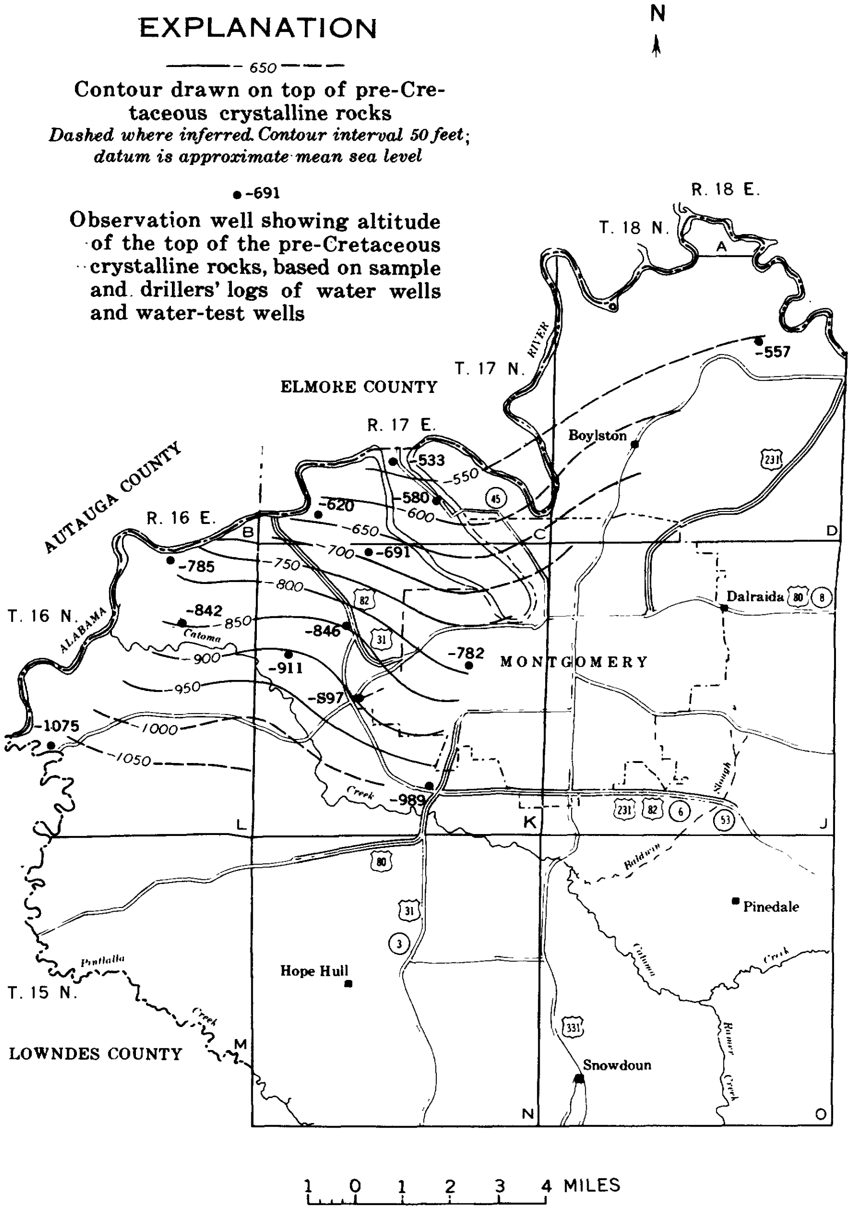


FIGURE 3.—Map showing the approximate altitude of the top of the pre-Cretaceous crystalline rocks in the Montgomery area.

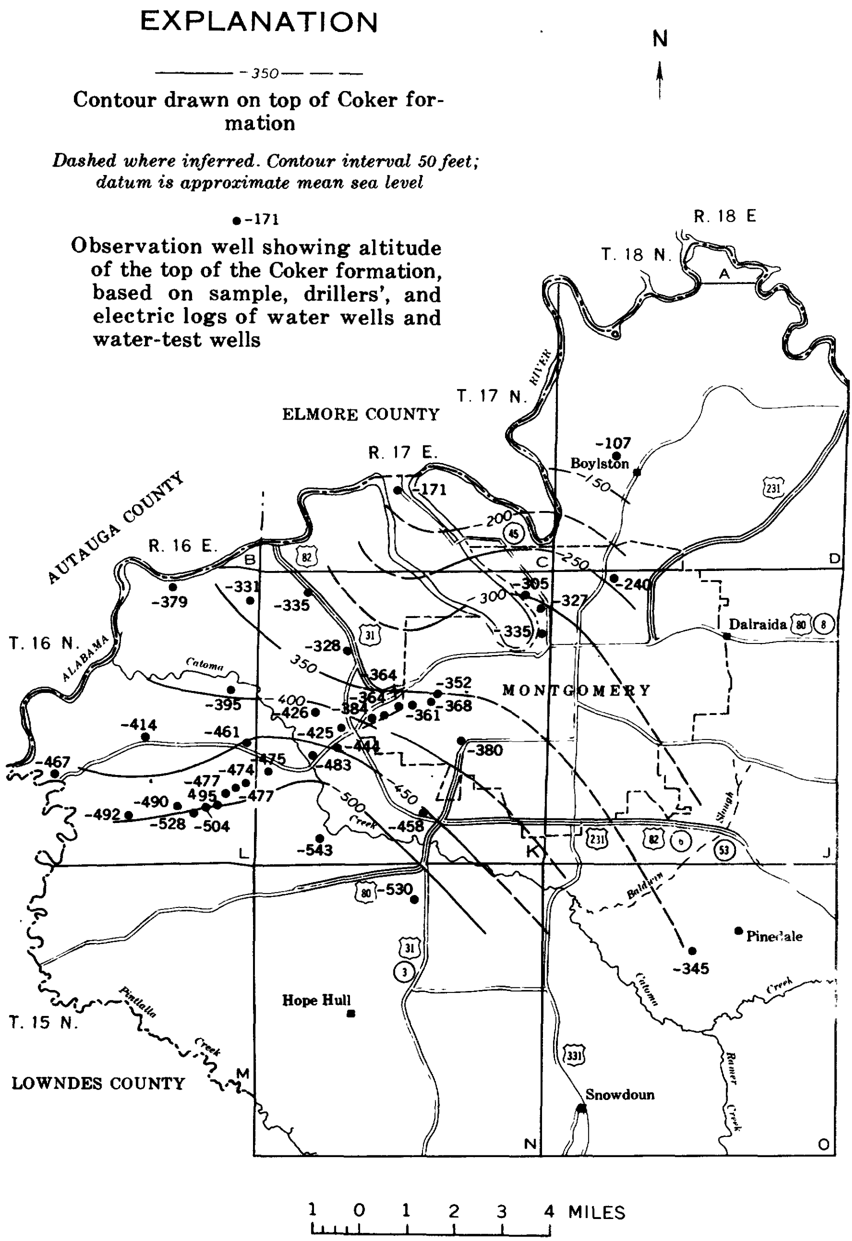


FIGURE 4.—Map showing the approximate altitude of the top of the Coker formation in the Montgomery area.

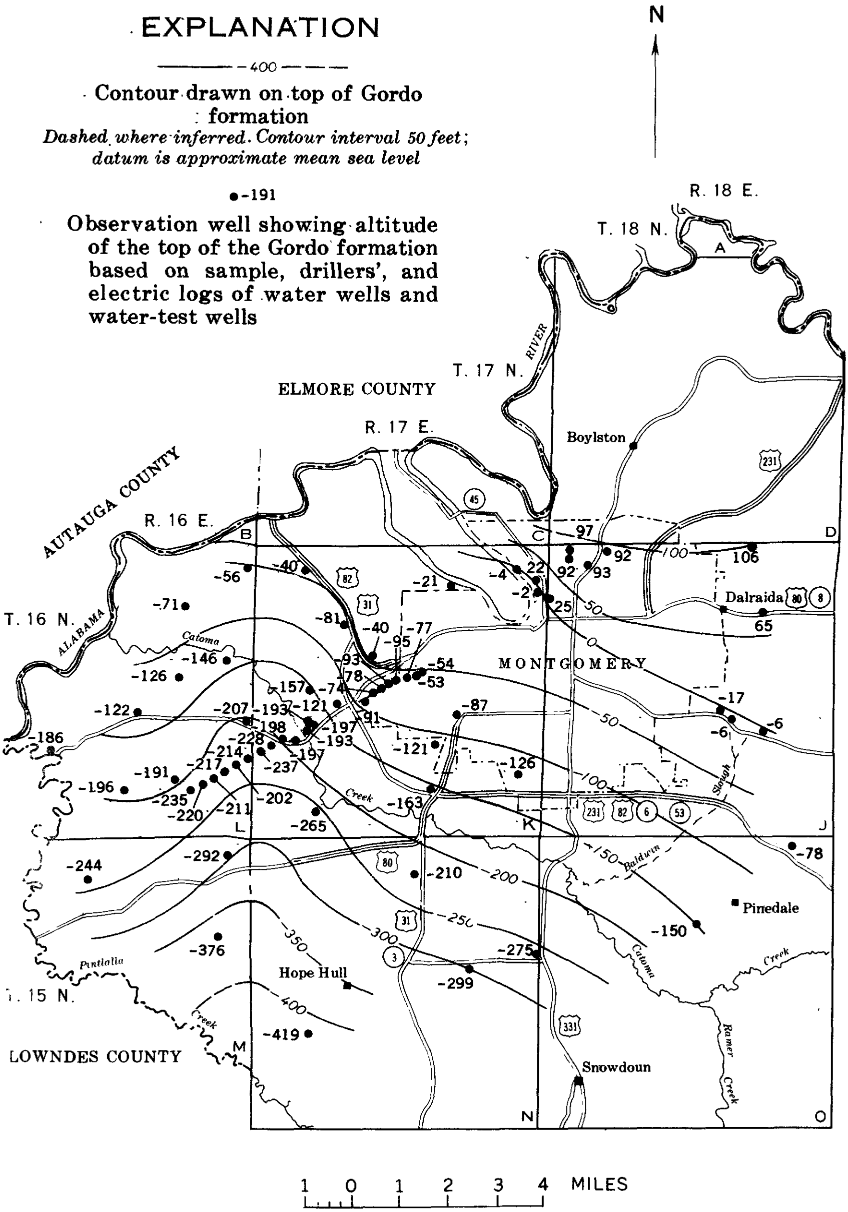


Figure 5.—Map showing the approximate altitude of the top of the Gordo formation in the Montgomery area.

PRE-CRETACEOUS CRYSTALLINE ROCKS

Crystalline rocks do not crop out in the county but have been penetrated by deep wells drilled in the Montgomery area. These rocks form the basement complex upon which the Cretaceous rocks were deposited. The crystalline rocks in their area of outcrop north of Montgomery County consist of schist, gneiss, granite, quartzite, and marble, and range in age from Precambrian to Triassic (Eargle, 1955, p. 7). The crystalline rocks were exposed for a long period and were deeply weathered and eroded before the overlying rocks of Late Cretaceous age were deposited. The eroded surface of the crystalline rocks in northwestern Montgomery County slopes southwestward in the western part and southeastward in the eastern part at about 60 to 100 feet per mile (fig. 3); the dip of the beds, however, is much greater.

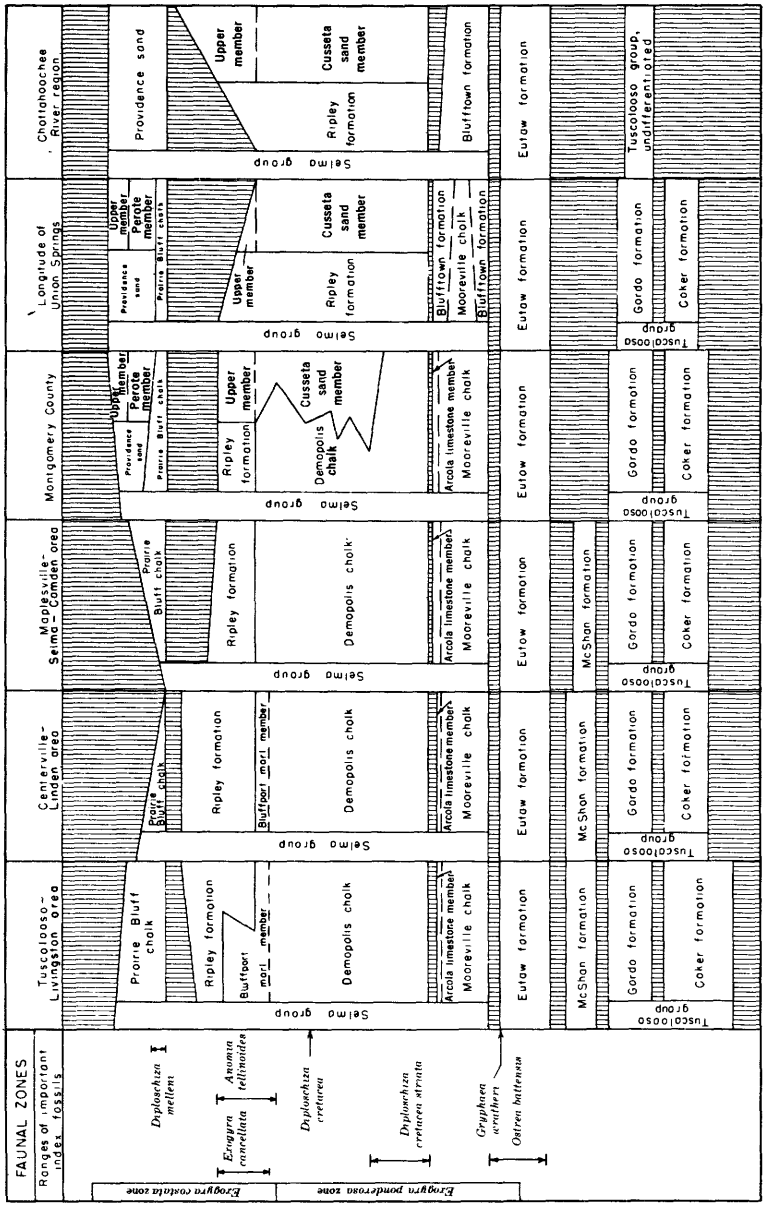
The depth to the pre-Cretaceous crystalline rocks in the Montgomery area ranges from 686 feet below the land surface (Knowles and others, 1960, well C–3, table 4), near the Alabama River and about 3 miles north of Maxwell Air Force Base, to 1,215 feet (Knowles and others, 1960, well L–36, table 4), in the valley of Pintlalla Creek about 7 miles southwest of the air base. The crystalline rocks have not been drilled in the central or southern parts of the county but are believed to lie 3,000 feet or more below the land surface at the southern boundary of the county.

The crystalline rocks are dense and relatively impermeable and are not an aquifer in Montgomery County.

CRETACEOUS SYSTEM

The Cretaceous system is represented by deposits of Late Cretaceous age that crop out in a crescentlike belt 40 to 50 miles wide that extends through the central part of the State. The beds dip southwestward in the western part of the State, southward in the central part, and southeastward in the eastern part. Montgomery County is in the central part of the State where the direction of dip changes.

The Upper Cretaceous deposits in western Alabama, in ascending order, include: the Coker and Gordo formations of the Tuscaloosa group; McShan formation; Eutaw formation; Mooreville and Demopolis chalks, Ripley formation, and Prairie Bluff chalk of the Selma group. Eastward, the chalk formations merge laterally into strata consisting mainly of sand and clay. The Upper Cretaceous deposits in eastern Alabama in the Chattahoochee River region, in ascending order, include: the Tuscaloosa group, undifferentiated; Eutaw formation; Blufftown and Ripley formations, and Providence sand of the Selma group. The Mooreville chalk intertongues with the



Modified from Monroe (1946)

FIGURE 6.—Correlation chart of the outcropping Upper Cretaceous formations in Alabama.

Blufftown formation east of Montgomery County, in Macon and Bullock Counties. The Demopolis chalk in southern Montgomery County intertongues with its partial stratigraphic equivalent, the Cusseta sand member of the Ripley formation, and the Prairie Bluff chalk intertongues with the Providence sand. The stratigraphic relations of the outcropping formations of Late Cretaceous age in Alabama are shown in figure 6.

TUSCALOOSA GROUP

The Tuscaloosa formation was first named and described by Smith and Johnson (1887, p. 95–116) to include the variegated clay, sand, and gravel between the Paleozoic rocks and the Eutaw formation as it was described by them. Hilgard (1860, p. 62–75) included these beds in the Eutaw group. Smith and Johnson restricted the name "Eutaw" to strata of post-Tuscaloosa age in separating the Tuscaloosa formation from the Eutaw group as defined by Hilgard. Monroe and others (1946, p. 187–212) divided the outcropping Tuscaloosa formation of Smith and Johnson in western Alabama, in ascending order, into the Cottondale, Eoline, Coker, and Gordo formations and raised the Tuscaloosa to the rank of group. Drennen (1953) redefined the Coker formation to include the Cottondale, Eoline, and Coker formations of Monroe. The classification of Drennen is followed in this report.

COKER FORMATION

The Coker formation crops out north of Montgomery County in Elmore and Autauga Counties. The top of the Coker formation is 280 feet below the land surface in well D–17, about 4 miles northeast of Montgomery, and 740 feet below the land surface in well N–2, about 6½ miles southwest of Montgomery. The Coker has not been tapped by wells in the southern two-thirds of Montgomery County; however, the top of the Coker was penetrated 1,635 feet below the land surface in an oil test in Lowndes County, about 18 miles west of Sprague, and it is estimated to be 2,100 to 2,200 feet below the land surface at the southern boundary of Montgomery County. The Coker is generally 500 to 700 feet below the land surface in the northwestern part of the county near Montgomery's West well field.

Thickness and lithology.—The Coker formation is composed of poorly consolidated beds of clay, sand, and gravel, and ranges in thickness from 362 feet in well C–3, near the Alabama River about 3 miles north of Maxwell Air Force Base, to 608 feet in well L–36, in the valley of Pintlalla Creek about 7 miles southwest of the air base.

The upper 300 to 400 feet of the Coker formation consists of light-greenish-gray medium- to coarse-grained glauconitic micaceous quartzose sand that is thinly laminated with greenish-gray micaceous clay. The formation generally contains lignite and thin-shelled fossils near the top, and beds of hard calcareous sandstone are common throughout the formation. The basal 150 feet of the Coker is chiefly pale-yellowish-orange medium- to coarse-grained arkosic sand that is interbedded with moderate-reddish-brown, pale-red-purple, and pale-green sandy clay. The Coker formation contains several thick beds of sand that can be correlated from well to well throughout the northern part of the county.

Stratigraphic relations.—The Coker formation was deposited in a shallow marine environment. It unconformably overlies the pre-Cretaceous crystalline rocks and is in turn unconformably overlain by the Gordo formation. An examination of drill cuttings from wells K–24 and L–36 (Knowles and others, 1960, table 4) attests that pale-yellowish-orange medium- to coarse-grained sand and greenish-gray clay of the Coker overlie biotite-mica schist of the bedrock. The contact of the Coker and Gordo formations is characterized by a change from the beds of thinly laminated glauconitic sand and greenish-gray clay of the Coker to the poorly sorted sand and varicolored clay of the Gordo. The contact in the Montgomery area generally is marked by a thin bed of quartz gravel at the base of the Gordo.

Water supply.—The Coker formation is one of the principal aquifers in Montgomery County. It has been developed as a source of water supply principally by the city of Montgomery. Most of the municipal wells tapping the Coker are multiple-screened wells that also tap the overlying Gordo or Eutaw formations, or both; therefore, the quantities of water that individual wells pump exclusively from the Coker formation is unknown. The yield of well J–119 in the Northeast well field, however, is believed to be mainly from the Coker. This well was reported to have had a drawdown in water level of 50 feet after pumping 620 gpm for 8 hours in 1957.

Wells in the Montgomery area that tap the Coker formation generally are screened only in the upper 100 to 150 feet of the formation, although three recently drilled wells, J–119, J–120, and K–136, (Knowles and others, 1960, tables 1 and 4) are screened in the upper 200 to 300 feet. The sand beds in the upper part of the Coker are coarser and more permeable than the sand beds in the overlying Gordo and Eutaw formations, and it is believed that the upper part of the Coker formation is the principal aquifer tapped by the municipal wells. Drill cuttings are available from only two wells, K–24 and L–36, (Knowles and others, 1960, table 4) that penetrate the entire thickness of the Coker formation in the Montgomery area. The beds of sand in the lower part of the formation in these wells are comparable in thickness and grain size to those in the upper part. It is probable that wells tapping the entire Coker formation would yield 1,000 gpm or more within practical limits of drawdown.

GORDO FORMATION

The Gordo formation in northern Montgomery County is covered by a thin mantle of terrace deposits of Pleistocene age but is exposed in bluffs along the Alabama River and north of Montgomery County in Autauga and Elmore Counties. The top of the Gordo formation is 30 feet below the land surface in well D–17, about 4 miles northeast of Montgomery, and 640 feet below the land surface in well N–21, about 10 miles southwest of Montgomery. The top of the Gordo is 200 to 400 feet below the land surface in the vicinity of Montgomery's West well field. The Gordo has not been drilled in the southern half of the county, but it is estimated to be about 1,800 to 1,900 feet below the land surface at the southern boundary of the county.

Thickness and lithology.—The Gordo formation ranges in thickness from 195 feet in well O–31, about 7 miles southeast of Montgomery, to 338 feet in well K–136, in Montgomery's Northeast well field in the northern part of the city. It averages about 250 to 300 feet in thickness in the Montgomery area.

The Gordo formation consists chiefly of pale-yellowish-orange medium- to coarse-grained ferruginous quartzose sand that is interbedded with moderate-reddish-brown to pale-red-purple sandy clay. A thin bed of quartz gravel, common throughout the formation, constitutes the base of the formation in the Montgomery area. Beds composed chiefly of clay occur near the top and bottom of the Gordo. These are separated by beds that are composed principally of sand. The sandy section ranges in thickness from about 40 to 100 feet. The beds of sand in the Gordo formation are generally clay- or ferruginous-cemented.

Stratigraphic relations.—The Gordo formation was deposited under nonmarine conditions, as indicated by the fluvial cross lamination and cut and fill structure in exposures in Autauga and Elmore Counties. It unconformably overlies the Coker formation and is in turn unconformably overlain by the Eutaw formation. The contact between the Gordo and Coker formations in northern Montgomery County is generally a thin bed of quartz gravel at the base of the Gordo; in the absence of the bed of gravel, beds of poorly sorted sand and varicolored clay of the Gordo overlie beds of thinly laminated glauconitic sand and greenish-gray clay of the Coker. The beds of varicolored nonglauconitic sand and clay at the top of the Gordo formation contrast sharply with the beds of greenish-gray glauconitic sand and clay of the Eutaw formation. The upper contact of the Gordo is generally chosen at the base of the lowermost glauconitic bed in the Eutaw.

Water supply.—The sand beds in the Gordo formation are poorly sorted and partly cemented and are less permeable than those in the Eutaw or Coker formations. Most Montgomery municipal wells are screened opposite sand beds in the Gordo, and many are also screened opposite sand beds in the Eutaw or Coker formations (pl. 6). Some of the first wells in Montgomery's Northeast well field tapped only the Gordo formation; all but three of these wells, however, are now abandoned. The wells still in use have yields ranging from 120 to 480 gpm (Knowles and others, 1960, J–19 and J–32, table 1). Most of the withdrawals from the Gordo are by the city of Montgomery; however, a few industrial and private wells, generally yielding less than 100 gpm, also tap the formation.

Three flowing wells, L–9, L–10, L–15 (Knowles and others, 1960, table 1) in the lowland areas near the Alabama River in the northwestern part of the county tap the Gordo formation. The flows from these wells ranged from ¾ to 8 gpm in 1952, and their water levels ranged from 5 to 12 feet above the land surface. Well L–36 flowed 20 gpm during a drill-stem test in 1952 from a bed of sand in the Gordo formation at a depth of 450 to 521 feet below land surface. Wells J–39 and J–40, tapping the Gordo in Montgomery's Northeast well field, were reported to have flowed 92 and 60 gpm, respectively, in 1885. These wells had ceased flowing by 1899, and the piezometric surface was about 100 feet below the land surface in 1953. As the piezometric surface declined, the natural flows also declined until most of the wells tapping the Gordo formation in the Montgomery area have ceased to flow.

The Gordo formation in most of the Montgomery area probablv is incapable of supplying more than 200 gpm of water to wells.

EUTAW FORMATION

Hilgard (1860, p. 62–75) first used the name Eutaw for the Cretaceous strata between the Paleozoic basement rocks and the Tombigbee sand group, as he defined it. Smith and Johnson (1887, p. 198) removed the name Eutaw from their Tuscaloosa formation but included the Tombigbee sand group in the upper part of the Eutaw formation as redefined by them. Stephenson (1914, p. 14) formally defined the Tombigbee sand group as the upper member of the Eutaw formation, the Tombigbee sand member. Hilgard did not designate a type locality other than Eutaw, Greene County, Ala., but the upper part of the Eutaw formation and its contact with the overlying Mooreville chalk is exposed 4½ miles south of Eutaw, at Choctaw Bluff on the Black Warrior River.

Monroe and others (1946, p. 207) further restricted the Eutaw formation in western Alabama by elevating a lower unit of the Eutaw, the McShan, to formational rank. The Eutaw formation overlaps the McShan in Autauga County and rests directly on the Gordo formation in Montgomery County. As used in this report, the Eutaw formation includes the strata between the Gordo formation and the Mooreville chalk.

Distribution.—The Eutaw formation crops out in a narrow belt that is as much as 2 miles wide and about 11 miles long, which trends westward through the city of Montgomery. It is exposed also in three small areas along the Alabama River in the northwestern corner of the county (pl. 1). The Eutaw is covered by terrace deposits of Pleistocene age east and west of the main body of outcrop shown on the geologic map. The Eutaw in the eastern part of the Montgomery area extends northward beneath the terraces to about the latitude of Gunter Air Force Base. Most of the area of outcrop of the Eutaw formation is in urban Montgomery.

Thickness and lithology.—Only the upper part of the Eutaw formation is exposed in Montgomery County, but interpretation of well logs in the Montgomery area indicates that in the subsurface it ranges in depth from 3 feet in well J–118, in Montgomery's Northeast well field, to 405 feet in well M–15, about 10 miles southwest of Montgomery. It averages about 250 to 300 feet in thickness south of where it dips beneath the Mooreville chalk. A depression is present in the surface of the Gordo formation southwest of Maxwell Air Force Base, and the average thickness of the Eutaw in this area is about 325 feet (pl. 5, fig. 7). The beds of sand in the Eutaw formation also are thickest in the area overlying the depression in the surface of the Gordo (fig. 8).

The Eutaw formation consists chiefly of light-greenish-gray cross-laminated fine- to medium-grained well-sorted micaceous fossiliferous glauconitic sand that is interbedded with greenish-gray micaceous glauconitic fossiliferous clay. Beds of greenish-gray sandy clay also are common. The upper part of the formation contains several thin beds, 6 to 12 inches thick, of hard light-gray to white medium-grained calcareous-cemented sandstone that is glauconitic, quartzose, and fossiliferous. The top of the formation, in most exposures in the county, is one of these hard fossiliferous beds (fig. 9).

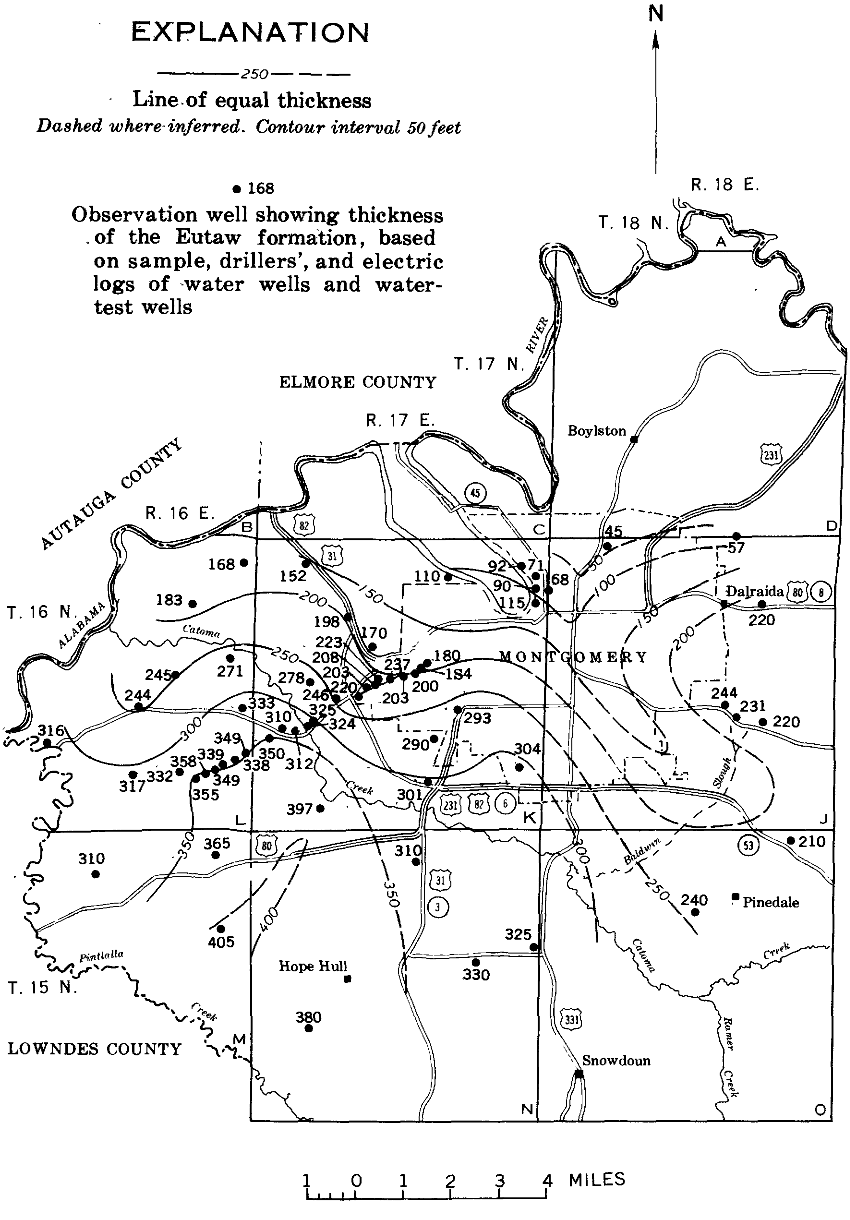


FIGURE 7.—Map showing the thickness of the Eutaw formation in the Montgomery area.

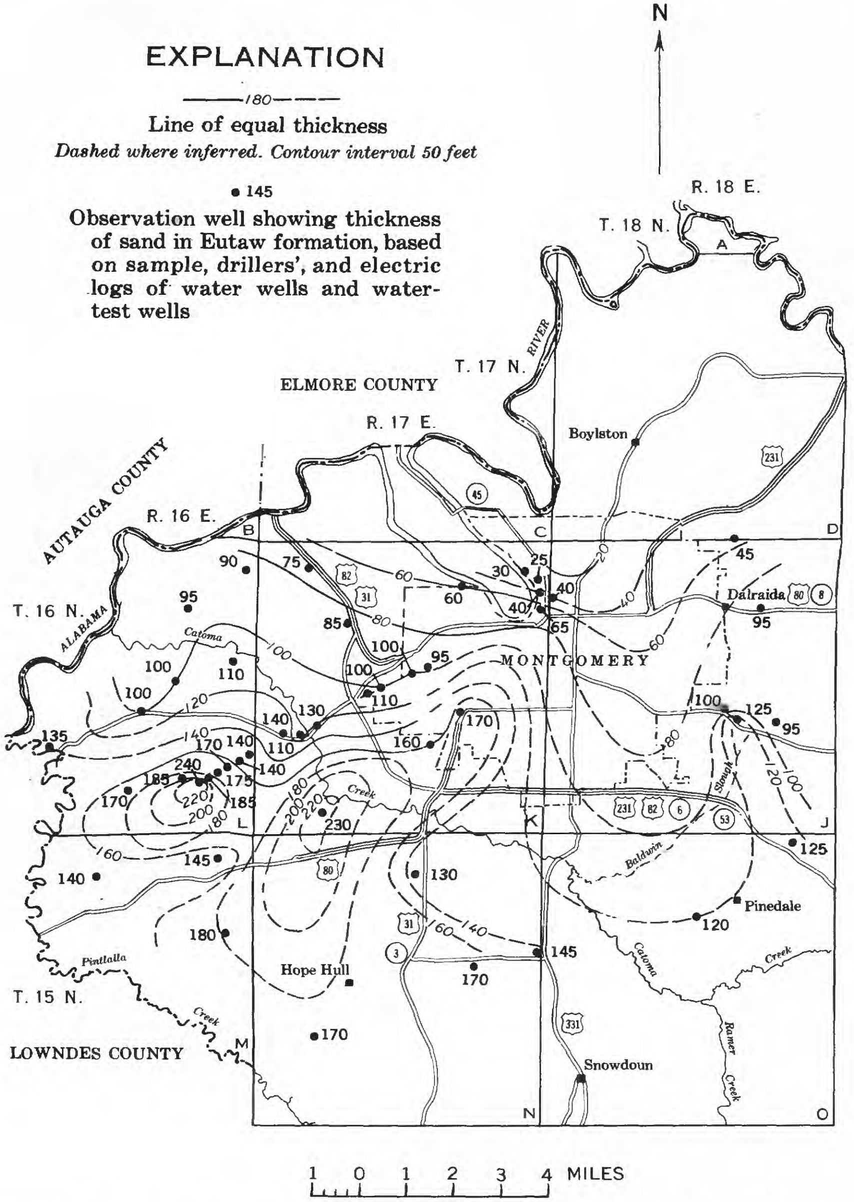


FIGURE 8.—Map showing the thickness of sand in the Eutaw formation in the Montgomery area.

FIGURE 9.—Contrast of Eutaw formation and Mooreville chalk showing hard sandstone bed in Eutaw formation in west bank of Atlantic Coast Line Railroad cut at Fairview Avenue in Montgomery. Photograph by H. L. Reade, Jr.

The sediments constituting the Eutaw formation are typical of a shallow marine environment, and, in exposures, the sand beds are finely cross laminated (fig. 10*A*). Borings of the near-shore organism *Halymenites major* (fig. 10*B*) are common throughout the formation (Brown, 1939, p. 253–254).

Representative section of the upper part of the Eutaw exposed south of the Holding and Reconsignment Point Depot in the NW¼ SE¼ sec. 22, T. 16 N., R. 16 E. (fig. 10).

	Thickness (Ft)
Mooreville chalk:	
Chalk, yellowish-gray, sandy, glauconitic; contains *Baculites* sp., *Trigonia* sp., *Inoceramus* sp., and phosphate nodules	1.0
Eutaw formation:	
Sand, yellowish-gray, medium-grained, subangular to subrounded, sparsely glauconitic, micaceous, quartzose; slightly cemented with calcium carbonate; contains *Gryphaea wratheri, Hardouinia bassleri,* and fish vertebrae. Phosphate nodules in upper 1 ft	5.5
Sandstone, white, medium-grained, subangular to subrounded, glauconitic, micaceous, quartzose, calcareous-cemented; weathers to pale brown; abundant echinoids, *Hardouinia bassleri,* and *Gryphaea* sp. Many specimens of *Gryphaea* contain *Drillia* borings. Borings of *Halymenites major* also are conspicuous. Forms resistant ledge	1.2
Sand, massive, yellowish-gray, medium-grained, subangular to subrounded, micaceous, quartzose; weathers to white; slightly cemented with calcium carbonate. Shark teeth and fish vertebrae abundant	2.5

A

B

FIGURE 10.—Exposures of upper part of the Eutaw formation west of the Holding and Reconsignment Point Depot in the NW¼SE¼ sec, 22, T. 16 N., R. 16 E., showing: *A*. Cross-laminated glauconitic sand and bed of hard calcareous sandstone; and *B*. *Halymenites major* Lesquerex borings in cross-laminated glauconitic sand. Photographs by H. L. Reade, Jr.

	Thickness (Ft)
Eutaw formation—Continued	
Sand, yellowish-gray; weathers to pale yellowish-orange, medium-grained, subangular to sub-rounded, glauconitic, micaceous, quartzose. Abundant borings of *Halymenites major* obscures bedding and forms resistant bed	3.5
Sand, yellowish-gray, cross-laminated, fine- to medium-grained, subangular to subrounded, glauconitic, micaceous, quartzose; some borings of *Halymenites major* filled with calcareous-cemented sand and ironstone concretions	11.4

Fossils in the Eutaw formation in Montgomery County include *Ostrea battensis* Stephenson, *Gryphaea wratheri* Stephenson, *Hardouinia bassleri* (Twitchell), *Veniella* sp., and *Cassidulus* sp.

Stratigraphic relations.—The Eutaw formation rests unconformably on the Gordo formation and dips southward at a rate of about 40 to 65 feet per mile. The contact is not exposed in Montgomery County, but it is characterized in the subsurface by a change from typical greenish-gray glauconitic beds of sand and clay of the Eutaw to varicolored nonglauconitic beds of sand and clay of the Gordo.

The Eutaw formation is overlain unconformably by the Mooreville chalk. The unconformity in the western part of Montgomery County is characterized by a thin bed of sandy glauconitic chalk at the base of the Mooreville that contains abundant shark teeth and phosphatized molds of fossils. The contact is more difficult to determine in the eastern part of the county because glauconitic sand of the Eutaw grades upward into sandy glauconitic chalk of the Mooreville.

Water supply.—The Eutaw formation is extensively developed as a source of water for municipal, industrial, domestic, and stock use, and for irrigation in Montgomery County.

The Eutaw formation in the southern part of Montgomery's Northeast well field is thin and yields little water to wells, but in the West well field most of the Eutaw section is present. Municipal wells in the West well field are screened only in the lower part of the formation because the water in the upper part of the Eutaw in this area is relatively high in iron content. Yields from municipal wells tapping the Eutaw formation range from 350 to 600 gpm.

Most of the water for industrial use in the Montgomery area is supplied by the city. A few industries, however, have wells that tap the Eutaw formation. Most of the industrial wells are of relatively small capacity, but wells K–138 and K–139 are reported to yield 500 gpm each.

Most of the wells tap the Eutaw formation in the middle two-thirds of the county, in the area of outcrop of the Mooreville and Demopolis chalks. Wells in this part of the county are used chiefly for domestic purposes and for watering stock; they generally penetrate only the upper sand beds of the Eutaw formation because only small quantities of water are required. The Eutaw lies at progressively greater depths southward across this area, and is 1,393 feet below the land surface at Ramer, about 1 mile south of the outcrop of the chalk; the Eutaw formation, however, is the shallowest source of ground water except the Recent alluvium in the valleys, where small quantities of ground water are available.

Rainfall in Montgomery County (fig. 2), although normally adequate for most crops, is almost annually deficient for short periods during the growing season, and supplemental irrigation from wells tapping the Eutaw formation is practiced on a small scale in the county. The irrigated lands are fairly well distributed in the northern part of the county and extend as far south as Tharin. Only 20 wells were used for irrigation in 1957; however, the development of ground water for supplemental irrigation is expected to expand rapidly. Irrigation wells in the Eutaw are reported to yield from about 100 to 400 gpm.

The Eutaw formation is tapped by flowing wells in a small area south of Montgomery in the valley of Catoma Creek and along the Montgomery–Macon County boundary in the valley of Line Creek. These wells flow from about ½ to 10 gpm. Even before large ground-water withdrawals began in the Montgomery area (Smith, 1907, p. 213), wells tapping the Eutaw flowed only in a few areas in the county.

Where the entire section of the Eutaw formation is present in the Montgomery area, wells capable of yielding 500 to 1,000 gpm each probably can be drilled. The potential for the development of wells of large capacity is greatest south of Montgomery's West well field where the sand in the Eutaw formation is thickest (fig. 8). It is believed that wells yielding as much as 1,500 gpm each can be drilled in this area.

SELMA GROUP

The name Selma chalk was first used by Smith and others (1894, p. 15, 22, 27, 255, 276–286) as a coname with the lithologic term "Rotten limestone", which had been introduced by Winchell (1857, p. 91–92) for the Cretaceous chalk of Alabama. The Selma was raised to rank of group in Mississippi in 1945 and included all Upper Cretaceous strata above the Eutaw formation (Mississippi Geol. Soc. Geol. Map of Mississippi). In 1946, Monroe extended this designation to include Alabama. As presently defined, the Selma group in Montgomery County consists of, from bottom to top: the Mooreville chalk, including an unnamed lower member and an upper Arcola limestone member; the Demopolis chalk; the Ripley formation, including a basal Cusseta sand member and an unnamed upper member; the

Prairie Bluff chalk; and the Providence sand, including a basal Perote member and an unnamed upper member.

A profile showing the geology along U.S. Highway 331 from about 1 mile north of Snowdown, in the central part of Montgomery County, to about 3 miles south of Strata, in the southern part, was prepared as a part of this investigation. It was published as Geological Survey of Alabama Map 10 (Reade and Scott, 1959) and, with some revision, is included as plate 9 in this report. All the rocks of the Selma group, except the Cusseta sand member of the Ripley formation and the unnamed upper member of the Providence sand, are exposed along the profile; thus, it includes most of the Cretaceous rocks exposed in the county.

MOOREVILLE CHALK

The name Mooreville tongue was first used by Stephenson (1917, p. 243–250) for strata exposed at Mooreville, Lee County, Miss. It is equivalent to the lower unnamed marly member and the Arcola limestone member of the Selma chalk of Monroe (1941, p. 56). The Mooreville, with the Arcola limestone member at the top, was raised to the rank of formation in Mississippi in 1945 (Mississippi Geol. Soc. Geol. Map of Mississippi). Monroe extended the usage to Alabama in 1946.

The strata now called the Arcola limestone member was observed and described by Withers (1833, p. 187–189), Tuomey (1850, p. 122–123), Thornton (1858, p. 241–242), Smith and Johnson (1887, p. 85), Smith and others (1894, p. 279–280), and others, but it was not until 1938 that the unit was formally named (Stephenson and Monroe, p. 1655–1657). The type locality of the Arcola limestone member is at old Arcola landing on the Warrior River, about 5 miles northeast of Demopolis, Hale County, Ala., in the NE¼ sec. 4, T. 18 N., R. 3 E. This locality is about a hundred miles west of Montgomery.

Distribution.—The Mooreville chalk crops out across the central part of Montgomery County in a westward-trending belt about 14 miles wide (pl. 1). It is overlain by Recent alluvium in the valleys of Pintlalla, Pinchony, Catoma, and Ramer Creeks and their tributaries. The area in which the Mooreville chalk crops out is characterized by gently rolling hills that are underlain by a deep black soil that supports a natural grassland. Resistant beds of the Arcola limestone member form the scarp of the Arcola cuesta at the southern edge of the Mooreville outcrop (pl. 2 and fig. 11).

Thickness and lithology.—The Mooreville chalk is about 600 feet thick in Montgomery County. The Arcola limestone member, at the top of the Mooreville, is about 10 feet thick in western Montgomery

FIGURE 11.—Exposure of Arcola limestone member of Mooreville chalk in the NW¼ SE¼ sec. 27, T. 14 N., R. 19 E., showing hard, resistant limestone beds. Photograph by H.L. Reade, Jr.

County, but it thins to about 5 feet in the eastern part. The Mooreville chalk is well exposed along U.S. Highway 331 in the western part of the county (pl. 9, beds 1–19, 22).

The Mooreville chalk was formed in warm shallow seas, and Foraminifera, Ostracoda, and other microfossils that suggest a warm shallow marine environment comprise a large percentage of the chalk. Thin-shelled mollusks are abundant.

The Arcola limestone member consists of 2 to 4 beds from 6 to 12 inches thick of light-gray impure limestone that is dense and thinly bedded (fig. 11). The limestone beds are separated by a bed of gray to pale-olive calcareous clay that is 3 to 6 feet thick. Fossils are abundant in the Arcola; it contains *Exogyra ponderosa* Roemer, *Anomia argentaria* Morton, *Paranomia scabra* (Morton), *Ostrea plumosa* Morton, and *Gryphaeostrea vomer* (Morton).

The unnamed lower member in the western part of the county is chiefly gray to pale-olive silty to finely sandy, argillaceous fossiliferous chalk. It grades laterally into a gray to yellowish-orange sandy calcareous clay in the eastern part. The basal 20 to 40 feet is very glauconitic and sandy in the western part of the county. Hard ledges near the base contain phosphatic molds of fossils, shells of *Ostrea* sp., *Pecten* (*Neithea*) sp., *Placenticeras* sp., *Veniella* sp., *Inoceramus* sp., *Mortoniceras* sp., *Gyrodes abyssina* (Morton), *Baculites asper* Morton, *Anomia argentaria* Morton, and several other species.

A very glauconitic bed of chalk overlies slightly glauconitic chalk about 30 feet above the base of the Mooreville in eastern Montgomery

County, a mile east of the Masonic home. These strata farther east are characterized by a dense impure limestone that contains many shells and phosphatic casts of fossils.

Stratigraphic relations.—The Mooreville chalk unconformably overlies the Eutaw formation and dips southward about 40 feet per mile. The unconformable contact in western Montgomery County is characterized by a bed of sandy glauconitic chalk, from 6 to 12 inches thick, at the base of the Mooreville that contains abundant shark teeth and phosphatized molds of fossils (fig. 9). The contact is less conspicuous in the eastern part of the county, and the glauconitic sand of the Eutaw formation grades upward into sandy glauconitic chalk of the Mooreville. East of Montgomery County, in Macon and Bullock Counties, the Mooreville chalk intertongues with the Blufftown formation, and in the Chattahoochee River region it grades into and is replaced by the Blufftown.

The Arcola limestone member at the top of the Mooreville is unconformably overlain by the Demopolis chalk. The contact is characterized by chalk that contains phosphatic molds of fossils and *Drillia* borings in reworked fossils. The chalk overlies hard fossiliferous limestone of the Arcola.

Water supply.—The Mooreville chalk is relatively impermeable in Montgomery County, and is not an aquifer but is the confining bed for water in the underlying Eutaw formation. Water supplies in the outcrop area of the Mooreville are obtained from deep wells that tap beds of sand in the Eutaw formation or, at a few places, from shallow wells that tap Recent alluvium in the flood plains of Pintlalla, Ramer, and Catoma Creeks. Water for domestic use at a few places in the rural areas of the county is stored in cisterns excavated into the chalk.

DEMOPOLIS CHALK

The name Demopolis was first used by Smith (1903, p. 12–14) for strata that now includes the Arcola limestone member of the Mooreville chalk and the lower part of the Demopolis chalk. Monroe (1941, p. 65) extended the usage to include all chalky and marly beds that lie between the Arcola limestone member of the Mooreville chalk below and the Ripley formation above and named these beds the Demopolis member of the Selma chalk. The Demopolis member was made a formation, the Demopolis chalk of the Selma group, in Mississippi in 1945 (Mississippi Geol. Soc. Geol. Map of Mississippi). This usage was extended to Alabama by Monroe in 1946.

The type locality of the Demopolis chalk is the bluff of chalk on the Tombigbee River at Webb and Sons cotton warehouse in Demopolis, Marengo County, Ala., about a hundred miles west of Montgomery.

Distribution.—The Demopolis chalk crops out in a westward-trending belt across southern Montgomery County. The area of outcrop ranges in width from 7 to 10 miles in the western part of the county. The Demopolis in the west-central part of the county, between Robinson Crossroads and Ramer, is split into two eastward-extending tongues by a westward-extending tongue of the Cusseta sand member of the Ripley formation (pl. 1). The upper tongue extends eastward in a belt about a mile wide from north of Ramer to about 2 miles southwest of Pine Level, where it merges into the Ripley formation. The lower tongue extends eastward in a belt 3 to 5 miles wide from about 2 miles south of Robinson Crossroads into western Bullock County.

Thickness and lithology.—The entire section of Demopolis chalk is exposed along U.S. Highway 331 in the west-central part of the county, where it is about 420 feet thick (pl. 9, beds 20–21, 23–46). The upper tongue is about 80 feet thick east of the longitude of Dublin, and the lower tongue is about 225 feet thick. The lower tongue underlies the Cusseta throughout the eastern part of the county, and, in the longitude of Downing, it is about 240 feet thick.

The lower part of the Demopolis, about 200 feet thick, consists of pale-olive to yellowish-gray silty to finely sandy micaceous fossiliferous chalk that weathers to a light brown (pl. 9). The top of this section is characterized by a zone of *Diploschiza cretacea* Conrad and *Terebratulina filosa* Conrad. The *Diploschiza cretacea* zone is about 70 feet thick in the vicinity of Ada and consists chiefly of pale-olive to grayish-yellow sandy chalk (fig. 12). Weathered surfaces of the chalk are littered with calcareous nodules.

The upper part of the Demopolis chalk is more argillaceous than the lower part and contains abundant mica and very fine grained sand. It is about 140 feet thick along U.S. Highway 331 in the western part of the county, where it consists of pale-olive very finely sandy micaceous chalk that weathers moderate reddish brown (pl. 9). The upper part of the Demopolis grades eastward into calcareous bentonitic clay that merges with the Ripley formation. It also contains a bed of bentonitic clay in the southwestern part of the county near Devenport.

The upper and lower parts of the Demopolis are separated by a thick bed of relatively pure chalk that contains abundant shells of *Gryphaea convexa* (Say). Other fossils include *Anomia argentaria* Morton, *Ostrea falcata* Morton, *Paranomia scabra* (Morton), *Ostrea plumosa* Morton, *Gryphaea mutabilis* Morton, *Pecten* (*Neithea*) sp., *Cardium* sp., *Exogyra* sp., and *Turritella* sp. The *Gryphaea convexa* zone is exposed in a road cut along U.S. Highway 331 about 2 miles south of

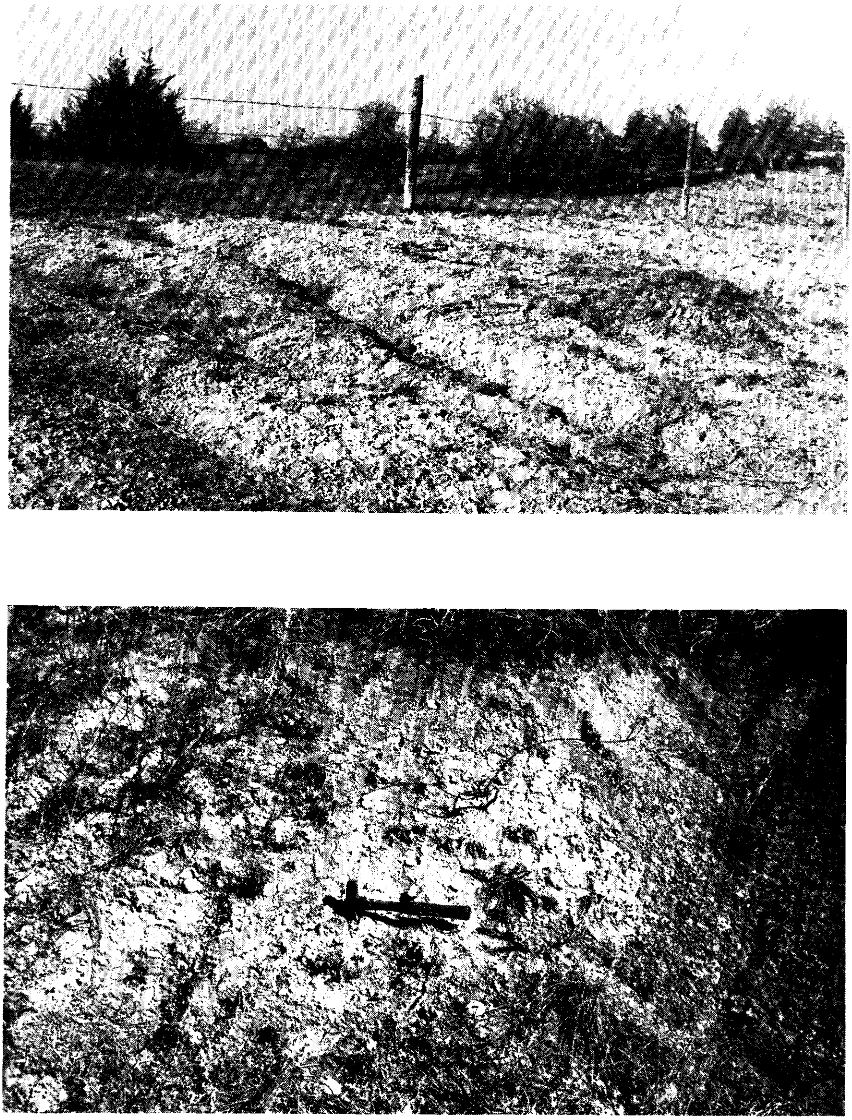


FIGURE 12.—Exposure of Demopolis chalk in road cut on U.S. Highway 331 about a mile south of Ada showing pale-olive sandy chalk that is weathered, jointed, and fractured.

Ada and can be traced to the area east of Ada where the upper part of the Demopolis merges with the Cusseta sand member of the Ripley.

Stratigraphic relations.—The Demopolis chalk rests unconformably on the Arcola limestone member of the Mooreville chalk and dips southward about 40 feet per mile. The contact is sharp in fresh exposures and is characterized in the Demopolis by a zone of phosphatic molds of fossils and reworked fossils containing *Drillia* borings that overlies hard fossiliferous limestone of the Arcola limestone member of the Mooreville.

The Demopolis chalk is conformably overlain by the upper member of the Ripley formation in western Montgomery County, as the Cusseta sand member of the Ripley is not present in that area. It is at a slightly lower stratigraphic position than it is farther west in eastern Sumter County, where the upper part of the Demopolis intertongues with the Ripley. The contact between the Demopolis chalk and Ripley formation is well exposed about half a mile north of Strata, where light-olive-gray finely sandy micaceous chalk of the Demopolis grades upward into pale-yellowish-orange fine- to medium-grained micaceous sand of the Ripley that contains borings of *Halymenites* sp. (pl. 9, beds 46–47).

The stratigraphic position of the top of the Demopolis becomes progressively lower eastward from Ada, and the upper tongue of the Demopolis interfingers with the Ripley formation in the vicinity of Pine Level. The lower tongue of the Demopolis chalk is conformably overlain by the Cusseta in the eastern part of the county.

Water supply.—The Demopolis chalk is relatively impermeable and is not an aquifer in Montgomery County. Water supplies in the outcrop area are obtained from deep wells that tap sand beds in the Eutaw formation, or at a few places, from shallow wells that tap Recent alluvium in the flood plains of Pintlalla, Ramer, and Catoma Creeks. Water for domestic use at a few places in the rural areas of the county is stored in cisterns excavated in the chalk.

RIPLEY FORMATION

The name Ripley group was first used by Hilgard (1860, p. 83–95) for strata in Mississippi between the top of the "Rotten limestone" (Mooreville chalk and Demopolis chalk) and what was then considered to be the base of the Tertiary deposits. Hilgard applied the name to deposits of equivalent age in Alabama in 1871. Smith and Johnson adopted the same usage in Alabama in 1887, but with Langdon in 1894 extended the usage in eastern Alabama to include deposits older than those included in the Ripley of Mississippi. Harris (1896, p. 31–32) and Stephenson (1914, p. 15) showed that the uppermost beds previously described as Ripley in Alabama were of Tertiary age. A bed of limestone (chalk), also included in the upper part and described previously as being Ripley in Alabama, is now termed the Prairie Bluff chalk (Stephenson, 1914, p. 15; Stephenson and Monroe, 1937).

The name Cusseta sand was first used by Veatch (1909, p. 86–99) for the middle unconsolidated sand of the Ripley of Smith and others

(1894, p. 423–426). Stephenson (Veatch and Stephenson, 1911, p. 72, 152) applied the name to the lower part of the Ripley formation and made it a member, the Cusseta sand member. The Cusseta was raised to formational rank in 1938 by Stephenson and Monroe (p. 1649–1650). Eargle redefined the Ripley formation in 1948 and designated the Cusseta sand as the lower member. The upper part of the Ripley is shown on Eargle's map as the Ripley formation undifferentiated and is stratigraphically equivalent to the Ripley formation of western Alabama. The Ripley formation undifferentiated of Eargle is here designated the unnamed upper member of the Ripley.

Typical sections of the Cusseta sand member are exposed in railroad cuts between Cusseta and Manta on the Seaboard Air Line Railway in Chattahoochee County, Ga. (Veatch and Stephenson, 1911). A type locality of the Ripley formation was not designated, but Monroe (1941, p. 103) considered the sand, clay, and limestone that underlies the Owl Creek formation in Tippah, Union, and Pontotoc Counties, Miss., to be typical of the formation.

Distribution.—The Cusseta sand member of the Ripley formation crops out in the southeastern part of the county in a belt about 1 to 3 miles wide. The area of outcrop extends westward between two eastward-extending tongues of the Demopolis chalk (pl. 1). This member crops out in steep, rugged hills that are a westward extension of the Enon cuesta (Monroe, 1941) in Bullock County.

The upper member of the Ripley formation crops out across the southern part of the county in a westward-trending belt, which widens from about 1 mile in the southwestern part of the county, in the vicinity of Strata, to about 8 miles in the southeastern part (pl. 1). The area of outcrop of the upper member forms the steep, rugged hills of the High Ridge cuesta, whose northward-facing scarp forms the drainage divide between the Alabama River to the north and the Conecuh River to the south (pl. 2).

Thickness and lithology.—The Cusseta sand member is about 120 feet thick in the eastern part of the county at the longitude of Downing. It thins westward to about 105 feet in the central part of the county at the longitude of Dublin. The Cusseta sand member intertongues with the Demopolis chalk about 3 miles east of Ada.

The upper member of the Ripley formation is about 180 feet thick in western Montgomery County along U.S. Highway 331 (pl. 9, beds 47–73, 75–77), but it thickens eastward as the Demopolis chalk thins. It is about 220 feet thick in the central part of the county at the longitude of Dublin and is about 315 feet thick in the eastern part, at the longitude of Downing.

The Cusseta sand member was deposited in a shallow marine environment and consists chiefly of beds of calcareous sandstone, sandy chalk, and sand that contain abundant shallow marine fossils. The Cusseta sand member along a county road about 2 miles west of Pine Level, consists from bottom to top of a 20-foot bed of light-greenish-gray fine- to medium-grained glauconitic sand; a 6-foot bed of light-gray to white calcareous-cemented fossiliferous sandstone containing *Gryphaea convexa* (Say) that grades upward into a 30-foot bed of greenish-gray to white sandy chalk; and a 36-foot bed of pale-yellowish-orange massive fine-grained micaceous sand that contains borings of *Halymenites major* Lesquerex near the top (fig. 13).

The upper member of the Ripley formation was desposited in a shallow-water marine environment. Alternating thick zones of sand and calcareous clay indicate climatic changes or uplift of the bordering land masses during deposition. The upper member consists chiefly of gray to reddish-brown fine- to coarse-grained sand that is cross-laminated, micaceous, glauconitic, abundantly fossiliferous, and, in places, is cemented with calcium carbonate; and pale-olive to dark-gray silty, micaceous, calcareous fossiliferous clay. The clay is about

FIGURE 13.—Exposure of Cusseta sand member of Ripley formation in roadcut along county road about 2 miles west of Pine Level showing massive sand. Photograph by H. L. Reade, Jr.

FIGURE 14.—Exposure of upper member of Ripley formation in roadcut along U.S. Highway 331 about 1.1 miles south of Sellers showing hard sandstone beds. Photograph by H. L. Reade, Jr.

as thick as the sand along U.S. Highway 231 in the eastern part of the county, and occupies most of the upper half of the formation. The clay becomes thinner eastward in Pike and Bullock Counties.

Several 1- to 2-foot beds of hard quartzose micaceous calcareous-cemented fossiliferous sandstone occur within the sand. These beds form ledges in roadcuts and other exposures that have the appearance of stairsteps (fig. 14). One of these sandstone beds occurs about 20 feet above the base of the member and can be traced from the southwest corner of the county to the vicinity of Ramer. This bed is abundantly fossiliferous (fig. 15), containing *Gryphaea mutabilis* Morton, *Gryphaeostrea vomer* (Morton), *Exogyra cancellata* Stephenson, *Anomia tellinoides* Morton, *A. argentaria* Morton, *Ostrea tecticosta* Gabb, *O. falcata* Morton, *O. panda* Morton, *O. plumosa* Morton, *Paranomia scabra* (Morton), *Crenella serica* Conrad, *Hamulus onyx* Morton, *H. squamosus* Gabb, *Pecten* (*Neithea*) sp., *Inoceramus* sp., and phosphatic casts of gastropods, chiefly *Turritella* sp. The formation contains *Ostrea tecticosta* Gabb, *O. falcata* Morton, and *O. subspatulata* Forbes about 110 feet above the base of the upper member in the SE¼ sec. 7, T. 12 N., R. 18 E.

Stratigraphic relations.—The Cusseta sand, the lower member of the Ripley formation, separates the Demopolis chalk into two east-

FIGURE 15.—Exposure of upper member of Ripley formation in roadcut along U.S. Highway 331 about 1.7 miles south of Sellers showing fossiliferous sandstone bed. Photograph by H. L. Reade, Jr.

ward-extending tongues in eastern Montgomery County and merges with the base of the upper tongue about 3 miles east of Ada. The top of the Cusseta becomes progressively higher stratigraphically eastward and thickens as the Demopolis thins. The Cusseta sand member of the Ripley formation is the exact time equivalent of the Demopolis chalk (Monroe, 1941, p. 100).

The Cusseta sand member conformably overlies the lower tongue of the Demopolis chalk. Its lower contact is characterized by pale-olive fine sandy chalk of the Demopolis that grades upward into light-greenish-gray fine- to medium-grained sand of the Cusseta. The Cusseta sand member is conformably overlain by the upper member, and, at the contact, massive fine-grained micaceous sand of the Cusseta grades upward into cross-laminated medium- to coarse-grained basal sand of the upper member that is typical of the Ripley formation in western Alabama.

The upper member of the Ripley formation conformably overlies the Demopolis chalk in the western part of the county, as the Cusseta

FIGURE 16.—Exposure in roadcut along U.S. Highway 331 about 2.6 miles south of Sellers showing contact of Prairie Bluff chalk and Ripley formation. Photograph by H. L. Reade, Jr.

was not deposited in that area. The contact is characterized by light-olive-gray fine sandy micaceous chalk of the Demopolis that grades upward into pale-yellowish-orange fine- to medium-grained micaceous sand of the Ripley.

The Ripley formation is overlain unconformably by the Prairie Bluff chalk. The unconformity is characterized by white glauconitic fossiliferous chalk at the base of the Prairie Bluff that contains phosphatic molds of fossils which overlies yellowish-gray fine-grained sand of the Ripley, that is micaceous, quartzose, calcareous-cemented, and fossiliferous (fig. 16).

Water supply.—The Ripley formation, including the basal Cusseta sand member, is a relatively unproductive aquifer in Montgomery County. It consists of about equal amounts of sand and clay, but most of the beds of sand are cemented with calcium carbonate and have relatively low permeabilities. Adequate supplies of water for domestic and stock use, however, are obtained from wells in the Ripley, as only small quantities are required.

Data are not available to determine the potential yield of wells from the Ripley formation in Montgomery County; however, west of Montgomery County in Lowndes County, the city of Fort Deposit obtains water from wells in the Ripley formation that are reported to yield 58 to 80 gpm (Scott, 1957).

PRAIRIE BLUFF CHALK

Strata that crop out at Prairie Bluff on the right bank of the Alabama River in the SW¼ sec. 32, T. 14 N., R. 7 E., Wilcox County, Ala., were named the Prairie Bluff limestone by Winchell (1857, p. 84–90). Smith and others (1894, p. 267–268) abandoned the name Prairie Bluff limestone and included the strata exposed at Prairie Bluff in the Ripley formation. Stephenson (1917, p. 250) revived Winchell's terminology but considered the chalk unit as a tongue of the Selma chalk (Mooreville and Demopolis chalks) that extended eastward from the main body of Selma chalk in Sumter County, Ala. Stephenson and Monroe (1937, p. 806–807) raised the Prairie Bluff to the rank of formation and defined it as unconformably overlying the Selma chalk in western Sumter County, Ala., and the Ripley formation in eastern Sumter County and to the east.

Distribution.—The Prairie Bluff chalk crops out in a narrow belt that trends eastward through southern Montgomery and northern Crenshaw and Pike Counties into Bullock County.

The area of outcrop of the Prairie Bluff chalk is characterized by hills of low relief on the backslope of the High Ridge cuesta.

Thickness and lithology.—The Prairie Bluff chalk thins eastward as the overlying Providence sand thickens. It is about 95 feet thick along U.S. Highway 331 in western Montgomery County, but thins to about 80 feet in the central part of the county south of Dublin, and to about 50 feet near the eastern edge of the county.

It is typically exposed along U.S. Highway 331 in southewestern Montgomery County (pl. 9, beds 74, 78, 79–85) where it consists chiefly of pale-olive to grayish- and greenish-yellow massive micaceous glauconitic fossiliferous silty to sandy chalk. In weathered exposures the Prairie Bluff is yellowish-gray to moderate-reddish-brown. Surface exposures in road cuts along U.S. Highway 331 commonly have slumped, and are littered with calcareous concretions in the lower part of the formation and limonitic concretions in the upper part.

In western Montgomery County the upper part of the Prairie Bluff chalk consists chiefly of light-greenish-gray massive very fine sandy micaceous chalk containing borings of *Halymenites major* Lesquerex in the upper few feet of the section. The lower 40 feet is purer chalk and contains a high percentage of calcium carbonate. It consists chiefly of white glauconitic fossiliferous chalk, containing abundant fossils and phosphatic molds of fossils.

In the eastern part of the county the Prairie Bluff chalk becomes clayey and sandy as it interfingers with the overlying Providence sand.

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The Prairie Bluff chalk lies entirely within the *Exogyra costata* zone (fig. 6). The basal part is abundantly fossiliferous, and contains phosphatic casts of pelecypods. *Liopistha protexta* (Conrad) are typical. Other fossils include *Exogyra costata* Say, *Gryphaea convexa* (Say), *G. mutabilis* Morton, *Anomia argentaria* Morton, *Ostrea plumosa* Morton, *O. tecticosta* Gabb, *Veniella conradi* (Morton), *Ostrea falcata* Morton, *Paranomia scabra* (Morton), *Plicatula urticosa* Morton, *Diploschiza melleni*, *Cardium* sp., *Turritella* sp., and *Pecten* (*Neithea*) sp., as well as echinoids and species of *Baculites* and *Belemnites*.

Stratigraphic relations.—The Prairie Bluff chalk unconformably overlies the Ripley formation, and dips southward at about 40 feet per mile. The unconformity is characterized by white glauconitic fossiliferous chalk at the top of the Prairie Bluff containing abundant fossils and phosphatic molds of fossils overlying yellowish-gray micaceous quartzose calcareous-cemented fossiliferous fine-grained sand of the Ripley formation (fig. 16). The unconformity separating the Prairie Bluff chalk and its eastern equivalent, the Providence sand, from the Ripley formation is second in magnitude in Alabama only to the unconformity at the base of the Eutaw formation (Monroe, 1946).

In western Lowndes County the upper part of the Prairie Bluff chalk intertongues laterally into fine-grained sand of the Providence sand. A long tongue of the Prairie Bluff extends eastward through Montgomery County into Bullock County beneath a westward extending tongue of the Providence. This tongue merges eastward into the Providence at a progressively lower stratigraphic position, and is replaced by the Providence in the longitude of Union Springs in Bullock County (Stephenson and Monroe, 1938, p. 1652). In Montgomery County, the Prairie Bluff chalk is overlain conformably by the Perote member of the Providence sand. At most surface exposures in the county light-greenish-gray finely sandy micaceous chalk of the Prairie Bluff, containing borings of *Halymenites major* Lesquerex, grade upward into gray very fine to fine grained laminated micaceous calcareous-cemented sand of the Perote member.

Water supply.—The Prairie Bluff chalk in Montgomery County is relatively impermeable, and is not an aquifer. In the outcrop area of the Prairie Bluff, water supplies for domestic and stock use are obtained from wells tapping beds of sand in the underlying Ripley formation.

PROVIDENCE SAND

The Providence sand was first named and described by Veatch (1909, p. 86) who defined it as including all Cretaceous strata above the Renfroes marl. Veatch assigned the Providence to the upper member of the Ripley formation as he used the term. The Providence sand was named for exposures in deep gullies at Providence, 8 miles west of Lumpkin in Stewart County, Ga. Stephenson (Veatch and Stephenson, 1911, p. 152, 192–200) described it more fully, and also considered it to be a member of the Ripley. Stephenson and Monroe (1938, p. 1652; see also Cooke, 1943, p. 34–39) raised the Providence sand to formational rank. In 1950, Eargle divided the Providence into the Perote member, for exposures along U.S. Highway 29 in the vincity of the town of Perote in southern Bullock County, Ala., and an unnamed upper member.

Distribution.—The Perote member of the Providence sand crops out in an area of about 6 square miles in the southwestern corner of the county and in 2 small areas in the southeastern corner (pl. 1). The area of outcrop is characterized by hills of moderate relief.

The unnamed upper member is present only as outliers in the southwestern part of the county, where it overlies the Perote member. The upper member forms a high, northward-trending ridge which is part of the High Ridge cuesta (pl. 2).

Thickness and lithology.—The Providence sand is about 145 feet thick along U.S. Highway 331 in the southwestern part of the county (Eargle, 1950). In this area, the Perote member is about 60 feet thick and the unnamed upper member is about 85 feet thick.

The Perote member consists chiefly of dark-gray fine-grained sand and clayey silt that is thinly laminated, carbonaceous, micaceous, calcareous-cemented, and fossiliferous. Fresh exposures contain thin fragile shells of pelecypods, principally *Exogyra costata* Say, *Anomia argentaria* Morton, and *Crenella serica* Conrad, and several species of gastropods, chiefly *Turritella* sp. Weathered outcrops are characterized by thin resistant limonitic beds of sandstone, that form prominent platy layers, and abundant ironstone concretions. The Perote member weathers to dark-reddish-brown silty clay. The presence of thinly laminated beds of fine-grained sand and thin beds of hard limonitic sandstone suggests that the Perote member was deposited in the lower limits of the neritic zone of a marine environment.

The unnamed upper member of the Providence sand consists chiefly of pale-yellowish-orange fine- to coarse-grained cross-laminated poorly sorted sand. The sand beds are interlaminated with thick beds of white, pale-red-purple, and moderate-reddish-brown clay. The cross lamination and poor sorting of the sands of the upper member are indicative of deposition in deltas.

Stratigraphic relations.—The lower part of the Providence sand intertongues with the upper part of the Prairie Bluff chalk in the vicinity of Fort Deposit in western Lowndes County. The Providence sand thickens and the Prairie Bluff chalk thins eastward, and the chalk pinches out in the vicinity of Perote in Bullock County. In Montgomery County, the Providence dips southward about 50 feet per mile.

The Perote member of the Providence sand rests conformably on the Prairie Bluff chalk in Montgomery County. The contact is well exposed in a road cut along U.S. Highway 331 about 2½ miles south of Strata where light-greenish-gray very fine sandy micaceous chalk containing many boring of *Halymenites* sp. of the Prairie Bluff grades upward into yellowish-gray very fine- to fine-grained well-sorted micaceous ferruginous sand of the Perote member (pl. 9, beds 85–86).

The Perote member is conformably overlain by the unnamed upper member. Thinly laminated fine-grained sand and clayey silt of the Perote member grades upward into cross-laminated fine- to coarse-grained sand of the upper member.

Along the southern border of Montgomery County, about 1½ miles east of Lapine, the Providence sand of Late Cretaceous age is overlain unconformably by the Clayton formation of Tertiary age. Here, the upper member of the Providence is overlain by gray sandy clay and chalk and grayish-white sandy fossiliferous limestone of the Clayton.

Water supply.—The Providence sand is not important as an aquifer in Montgomery County. In the outcrop area of the Perote member in the southwestern part of the county, a few dug wells obtain adequate water supplies for domestic and stock use from beds of fine-grained sand. No wells tap sand beds in the upper member in the county, but a few seeps issue at the contact of the fine- to coarse-grained sand of the upper member with the fine-grained sand and clayey silt of the Perote member.

TERTIARY SYSTEM

CLAYTON FORMATION

The Clayton formation was named by Smith (1892, p. 47) for exposures near Clayton in Barbour County, Ala. In eastern Alabama, along the Chattahoochee River, it is about 140 feet thick, and consists of light-gray massive sandy and argillaceous limestone that contains some sand at the base. The upper part of the Clayton is more sandy and glauconitic to the west, and intertongues with the Porters Creek formation in Wilcox County, Ala.

The Clayton formation is present only as an outlier in Montgomery County, covering an area of a few acres about 1½ miles east of Lapine on the southern Montgomery County boundary. It consists of gray sandy chalk and clay and grayish-white sandy fossiliferous limestone, which caps a high hill.

Because of its small extent, the Clayton formation is not an aquifer in Montgomery County. To the south at Luverne in Crenshaw County, however, two municipal wells in the outcrop area of the Clayton yield about 150 and 300 gpm of water each from the basal sand of the Clayton.

QUATERNARY SYSTEM

PLEISTOCENE TERRACE DEPOSITS

General features and distribution.—Pleistocene terrace deposits of the ancestral Alabama River lie unconformably on rocks of Late Cretaceous age in northern Montgomery County. These deposits crop out in a belt about 6 to 8 miles wide that approximately parallels the present river. Three terrace surfaces, at altitudes of about 140 to 170 feet, 180 to 200 feet, and 295 to 310 feet, can be recognized in the Montgomery area. The terrace surfaces indicate areas formerly occupied by channels of the Alabama River that were abandoned successively for lower channels. Each terrace forms a plain sloping towards the Alabama River, but the terraces merge into one another and the contacts separating them are difficult to distinguish. It was beyond the scope of this investigation to map the individual terraces, but they could be mapped with detailed study.

Thickness and lithology.—The terrace deposits range in thickness from about 10 to 100 feet. They consist chiefly of lenses of gravel and pale-yellowish-orange medium to very coarse grained crossbedded poorly sorted ferruginous quartzose sand (fig. 17). The gravel deposits are lenticular, and the gravel fragments range in size from pebbles (4 to 64 mm in diameter) to cobbles (64 to 256 mm in diameter); however, most are of pebble size. They are well rounded, and show the effects of long transportation. The beds of sand and gravel commonly are interbedded with dark-reddish-brown sandy clay.

The terrace deposits are of fluvial origin, and the predominance of quartz, quartzite, chert, and granite indicates that they were derived mainly from erosion of pre-Cretaceous crystalline rocks exposed north of Montgomery County.

FIGURE 17.—Exposure of Pleistocene terrace deposits in Montgomery-Roquemore Gravel Co. pit in NW¼NE¼ sec. 11, T. 16 N., R. 16 E. Photograph by H. L. Reade, Jr.

Water supply.—Beds of sand and gravel in the terrace deposits supply water to wells in northern Montgomery County for municipal, industrial, domestic, and stock use. The sand and gravel beds are very permeable, and wells of large capacity can be obtained where the terrace deposits are relatively thick.

Four wells in Montgomery's Northeast well field obtain all or most of their water supply from the terrace deposits (Knowles and others, 1960, wells J–115 to J–118, table 1). In 1957 these wells yielded 361 to 503 gpm each. In areas of northern Montgomery County where the saturated thickness of the terrace deposits is 50 feet or more, wells yielding 200 to 500 gpm probably can be obtained.

RECENT ALLUVIUM

Recent alluvial deposits unconformably overlie rocks of Late Cretaceous age in the valleys of Pintlalla, Catoma, and Line Creeks and their tributaries (pl. 1). These deposits consist chiefly of white to light-gray lenticular poorly sorted silty sand and yellowish-orange to bluish-gray sandy clay. The maximum thickness of the alluvium in Montgomery County is about 40 feet.

Water supply.—A few shallow dug and driven wells, ranging in depth from less than 10 to about 35 feet, obtain water from sand beds in the alluvium for domestic and stock use. The users of some of these wells experience water shortages during the summer and fall when the water table declines close to or below the bottoms of the wells. However, many of the wells in the topographically low areas near the streams yield year-round supplies that are adequate for domestic and stock use.

GROUND-WATER HYDROLOGY

The fundamental principles governing the occurrence and movement of ground water are given in reports by Meinzer (1923 *a*, *b*, 1931), Meinzer and others (1942), and others. The discussion that follows is a brief outline of these general principles that are essential to an understanding of ground-water conditions in Montgomery County.

SOURCE

Ground water is the water below the land surface that occurs in a zone where the enclosing material is fully saturated. The top of the saturated zone is called the water table, and its position is shown by the level at which water stands in nonartesian wells. Only that part of the subsurface water that lies in the zone of saturation can be pumped from wells or will flow from springs.

Ground water is derived from precipitation, and in Alabama the precipitation is principally rain. A part of the precipitation flows into streams and lakes as direct runoff, a part returns to the atmosphere through evaporation and transpiration, and a part seeps downward through the soil and rocks to become ground water. The ground water moves from higher to lower levels, generally, but not necessarily, down the dip of the rocks, later to be discharged into bodies of surface water by seepage or into the atmosphere by evaporation or through transpiration by plants.

Water seeping down through the soil first enters a zone of aeration (fig. 18), which lies between the land surface and the zone of saturation. A part of the water entering the zone of aeration is used to satisfy soil-moisture requirements, being held in this zone by molecular forces which counteract the force of gravity, and a part seeps to the water table and into the zone of saturation. All openings in the zone of saturation are filled with water, and it is the water in this zone that can be obtained by wells and that flows from springs.

OCCURRENCE AND STORAGE

Ground water occupies pores, fractures, and other openings in the rocks. The size, shape, and distribution of openings in rocks vary considerably from place to place and from rock type to rock type, and they control the storage and movement of ground water.

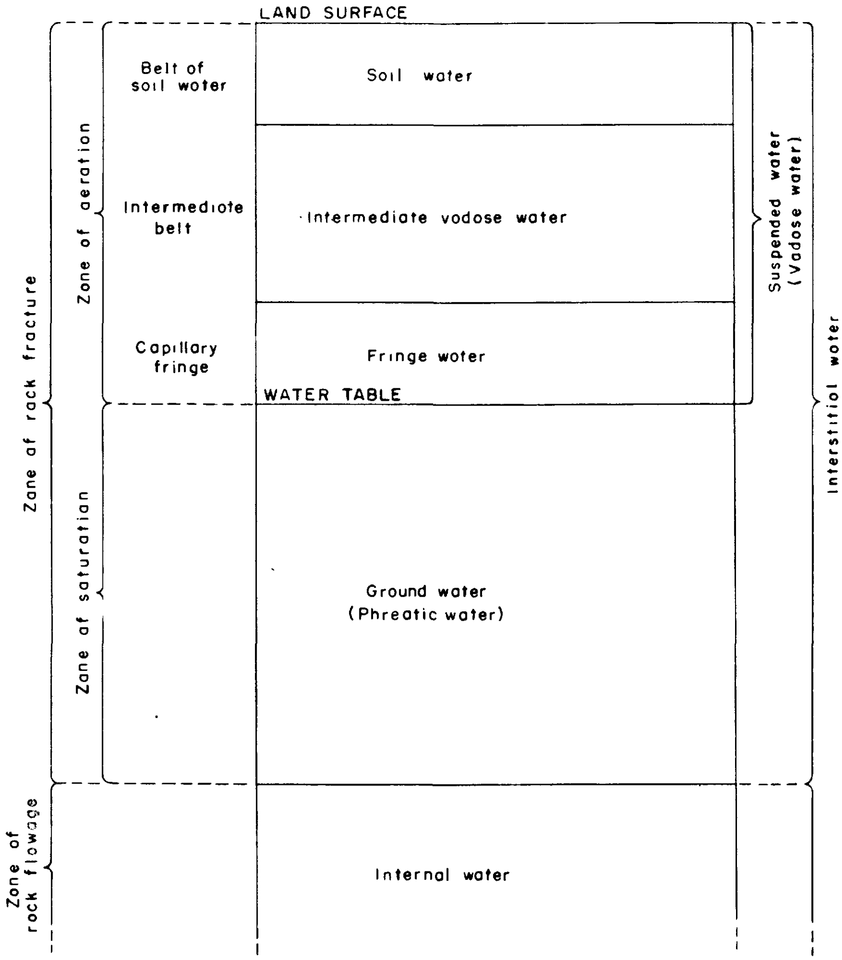

FIGURE 18.—Diagram showing divisions of subsurface water. (After O. E. Meinzer, 1923*b*.)

The porosity of a rock is its property of containing voids or open spaces. Porosity is the ratio, expressed as a percentage, of open space in a rock to its total volume. The porosity is influenced by the size, shape, and arrangement of particles, by the degree of sorting, compaction, and cementation of the particles, and by the amount of fracturing, solution, and recrystallization of the rock after its initial formation. The porosities of selected sand samples from wells penetrating the Eutaw, Gordo, and Coker formations in Montgomery County are given in Knowles and others (1960, tables 5, 6, and 7).

The permeability of a rock is a measure of its capacity to transmit water under a hydraulic gradient. Clay generally has a high porosity but a low permeability because its pore spaces, though numerous, are very small. A sand or gravel may have a lower porosity than clay but generally has a higher permeability because the interconnected open spaces are large through which water flows readily. Permeable zones through which ground water moves freely enough to supply wells are called aquifers.

WATER-TABLE AND ARTESIAN CONDITIONS

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by the bottom of a bed of clay or other relatively impermeable material which confines the water under hydrostatic pressure (fig. 19). Unconfined water in the zone of saturation moves slowly through the rocks down the slope of the water table. The water table is not a level or stationary surface; variations from place to place and from time to time in its shape and height occur as a result of many factors, such as the permeability and structure of the rocks, variations in the rate of withdrawal of water from wells and springs, and variations in rainfall which affects the rate of recharge.

Ground water that is under sufficient pressure to rise above the level at which it is encountered in a well, but which does not necessarily rise to or above land surface is termed artesian. Water in an aquifer under artesian pressure is restricted in direction of movement by the relatively impermeable overlying and underlying rocks (the confining beds, fig. 19). Rainfall and runoff seep into the aquifer where it crops out and percolates down gradient to become confined between relatively impermeable beds of clay, sandy clay, chalk, marl, or similar materials. Most artesian aquifers also receive some recharge water by leakage through the relatively impermeable overlying and underlying rocks. The pressure exerted on ground water in a confined aquifer is known as hydrostatic pressure. When a well penetrates a confined aquifer downdip from its intake area, the hydrostatic pressure causes the water to rise above the bottom of the confining layer. The imaginary surface to which water will rise in tightly cased artesian wells is called the piezometric surface (fig. 19). An artesian well will flow if the piezometric surface is above the land surface.

Although water-table conditions occur in Montgomery County in the outcrop areas of the Eutaw and Ripley formations and the Providence sand and in the Pleistocene terrace deposits and Recent alluvium, most of the ground water used in the county occurs under artesian conditions.

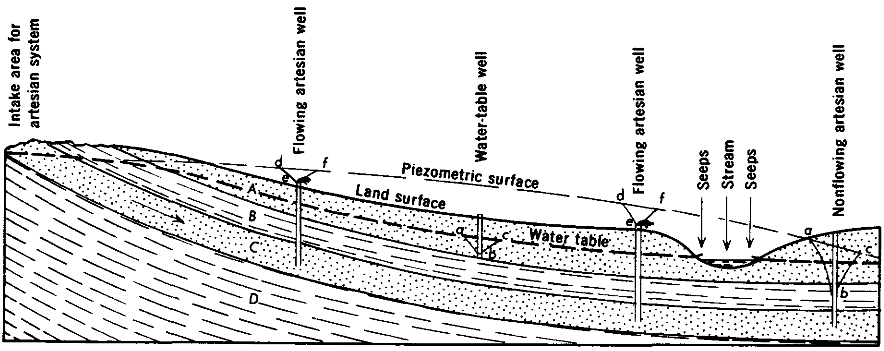

FIGURE 19.—Schematic diagram showing artesian and water-table conditions.

RECHARGE AND NATURAL DISCHARGE

The Eutaw, Gordo, and Coker formations, the principal aquifers in the Montgomery area, are recharged chiefly by infiltration of precipitation in their outcrop areas in northern Montgomery County and southern Autauga and Elmore Counties. The Eutaw and Gordo formations also receive recharge by downward leakage from the Pleistocene terrace deposits in northern Montgomery County, where the piezometric surface is at a lower level than the water table in the terrace deposits. However, data collected in this investigation are not adequate to estimate the magnitude of this downward leakage.

The Ripley formation, Providence sand, Pleistocene terrace deposits, and Recent alluvium are recharged chiefly by infiltration of precipitation in their outcrop areas. The Ripley formation and Providence sand also receive some recharge by seepage from surface streams crossing their outcrop areas.

The map of the piezometric surface in the Eutaw formation (pl. 12) indicates a gentle hydraulic gradient in the area where the Eutaw is confined by the relatively impermeable Mooreville chalk. Probably most of the water entering the Eutaw formation is discharged in the area north of the overlap of the Mooreville and only a small part of the water moves downdip beneath the Mooreville chalk.

Most of the natural ground-water discharge in the areas of outcrop of the Eutaw, Gordo, and Coker formations is by seepage into surface streams. Some water is also discharged by evapotranspiration, chiefly along surface streams where the water table is shallow, and by subsurface outflow into the Pleistocene terrace deposits. In most of the area of outcrop of the Pleistocene terrace deposits, however, the water in these deposits is recharging the underlying formations.

Autauga and Swift Creeks and Little Mulberry and Mulberry Rivers drain about 500 square miles of the area of outcrop of the Eutaw, Gordo, and Coker formations in Autauga and southwestern Elmore Counties. The sustained minimum dry weather flow of these streams in this area was estimated by M. A. Warren (written communication to H. L. Reade, Jr., 1953) from streamflow records to average about 0.3 to 0.4 cubic foot per second per square mile of drainage area. This sustained minimum dry-weather flow is equivalent to 4 to 5 inches of water per year over the area of outcrop. Thus, it is estimated that the natural ground-water recharge to the Eutaw, Gordo, and Coker formations is at least 4 to 5 inches of water per year.

The relatively high chloride content of water from the Eutaw formation in southwestern Montgomery County and in the central and southern parts of adjoining Lowndes County to the west is probably the result of lack of circulation of the ground water (pl. 15), and may indicate incomplete flushing of the formation. At least a part of the high chloride water in Lowndes County (Scott, 1957) is believed to have been trapped at the time these formations were deposited. The presence of high chloride water in the Eutaw formation further supports the premise that only a small part of the recharge water moves down the dip beneath the Mooreville chalk. There must be an outlet, however, for the water that does move beneath the chalk or there could be no movement. Ground water may escape through the overlying chalk. Although the chalk is relatively impermeable, water may move through it although slowly. Owing to the large area of the chalk that is in contact with the Eutaw formation substantial quantities of water may escape upward from the Eutaw.

PUMPAGE

The Coker, Gordo, and Eutaw formations are the most productive aquifers in Montgomery County and large quantities of water are pumped from these formations for municipal use by the city of Montgomery. Wells at industrial plants also withdraw substantial quantities of water from the Gordo and Eutaw formations and the Pleistocene terrace deposits, and a few wells of large capacity obtain water for irrigation from the Eutaw formation.

The largest withdrawals in Montgomery County are from well fields of the city of Montgomery. The first large-scale withdrawals apparently began about 1885 from the city's present Northeast well field. The wells in this well field obtain most of their water from the Gordo and Coker formations, although a few wells also obtain some water from the Eutaw formation and Pleistocene terrace deposits (Knowles and others, 1960, table 1). The amount of the early withdrawals is not known, because, until 1930, records were not maintained of the amount of water pumped. In 1899, however, the combined capacity of the wells in the Northeast well field is reported to have been about 5 mgd, although the average production was probably much less. The average daily pumpage from wells in the Northeast field gradually increased from about 3.8 mgd in 1930 to about 7.2 mgd in 1943, after which, owing to the development in 1941 of the West well field, it gradually was reduced to about 4.8 mgd in 1955. The withdrawals increased slightly during the period 1956–58, and averaged about 5.7 mgd during 1958. The increased pumpage was chiefly from newly drilled wells tapping the Coker formation and Pleistocene terrace deposits.

Development of the city of Montgomery's West well field began in 1941. The wells obtain water from the Coker, Gordo, and Eutaw formations. Many of the wells are constructed with multiple screens and draw from all three aquifers. Withdrawals averaged about 1 mgd during the last 6 months of 1941 and 1942. As pumpage from the Northeast well field was reduced and the demand for water increased, the average daily withdrawals from the West well field gradually were increased to about 9.6 mgd in 1958. The average daily pumpage by months from the Northeast and West well fields from 1930 to 1958 and maximum and minimum daily pumpage are shown on plate 10.

The combined average daily withdrawals from the city of Montgomery well fields averaged 15.3 mgd in 1958; the peak demands for water, however, are much greater.

In addition to the ground water pumped by the city of Montgomery, large quantities are also withdrawn for industrial, irrigation, domestic, and stock use in Montgomery County. The estimated average daily withdrawals in 1958 are as follows: industrial use, 5 mgd; irrigation use, 5 mgd; and domestic and stock use, 2 mgd. Most of this pumpage is from the Eutaw and Gordo formations and the Pleistocene terrace deposits; the pumpage from the Eutaw formation probably accounts for 75 to 80 percent of the total.

PUMPING TESTS

SPECIFIC CAPACITY OF WELLS

Pumping a well causes a drawdown in the water level. The relation between the yield and the drawdown in a pumped well is known as the specific capacity and is generally expressed in gallons per minute per foot of drawdown. For example, if a well is pumped at a rate of 1,000 gpm and the water level is lowered 100 feet, the specific capacity of the well is 10 gpm per foot of drawdown. In like manner, if the specific capacity of a well is 10 gpm per foot of drawdown, there is an implication that, within certain limits, the yield of the well will increase roughly 10 gpm for each foot of increased drawdown. This relationship is approximately correct for wells screened in granular aquifers, providing pumping at a constant rate has continued sufficiently long for the water level in the well to reach a condition of approximate equilibrium.

The specific capacity of a well is controlled by several factors. The most important of these factors are the transmissibility of the aquifer, and the "well entrance losses," which are related to the well construction and the degree of development of the well. The yield, drawdown, length of screen, and specific capacity of selected wells in the Montgomery area are given in table 2.

TABLE 2.—*Yield and specific capacities of selected wells in the Montgomery area, Montgomery County, Ala.*

[Water-bearing formation: Kck, Coker formation; Kg, Gordo formation; Ke, Eutaw formation; Qt, Pleistocene terrace deposits]

Well	Owner	Water-bearing formation	Length of screen (feet)	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per foot)
J-43	Capitol Trailways Inc.	Ke	20	68	13.6	5.0
46	City of Montgomery	Ke	67	245	115	2.1
		Kg				
115	do	Qt	20	407	55.5	7.3
116	do	Qt	20	361	41.1	8.8
117	do	Qt	20	473	45.5	10.4
118	do	Qt	20	503	48	10.5
119	do	Kg	20	620	50	12.4
		Kck	170			
120	do	Kg	110	416	126.7	3.3
		Kck				
K-35	do	Ke	----	350	45	7.8
51	do	Kg	55	444	77	5.8
		Kck	58			
52	do	Ke	140	650	100.4	6.5
		Kg				
		Kck				
56	do	Ke	22	759	90.0	8.4
		Kg	53			
		Kck	25			
59	do	Ke	100	350	88.7	4.0
		Kg				
		Kck				
60	do	Ke	17	450	76.5	5.9
		Kg	53			
		Kck	38			
70	do	Ke	100	805	79.6	10.1
		Kg				
		Kck				
71	do	Ke	35	361	47	7.7
72	do	Kg	46	383	86	4.4
		Kck	95			
74	do	Ke	40	737	81.9	9.0
		Kg	54			
		Kck				
75	do	Ke	80	720	99.1	7.3
		Kg				
		Kck				
76	do	Ke	----	542	72	7.5
		Kg	50			
		Kck	50			
80	do	Ke	89	372	138.0	2.7
		Kg	73			

TABLE 2.—*Yield and specific capacities of selected wells in the Montgomery area, Montgomery County, Ala.*—Continued

Well	Owner	Water-bearing formation	Length of screen (feet)	Yield (gallons per minute)	Drawdown (feet)	Specific capacity (gallons per minute per foot)
K-82	City of Montgomery	Ke	103	460	120.0	3.8
83	do	Ke Kg Kck	100	234	185	1.3
85	do	Ke Kg Kck	103	527	78	6.8
87	do	Ke Kg Kck	100	720	103	7.0
89	do	Ke Kg Kck	40 40 20	517	62	8.3
91	do	Ke Kg Kck	105	524	83.2	6.3
93	do	Ke Kg Kck	150	703	85	8.3
95	do	Ke	80	400	104.5	3.8
99	do	Ke Kg Kck	30 40 30	503	68	7.4
100	do	Kg Kck	90	317	79.4	4.0
105	do	Ke Kg Kck	100	510	69	7.4
123	do	Ke Kg Kck	68 13 38	566	130	4.4
124	do	Ke Kg Kck	125	439	180	2.4
136	do	Kg Kck	55 70	596	54	11.0
L-27	do	Ke Kg	85 32	700	72.5	9.7
M-11	Frank French	Ke		250	25	10.0
N-10	Tennala Dairy	Ke		120	23.5	5.1
O-8	Pat Harris	Ke		254	27.3	9.3

CAPACITY OF THE SANDS TO TRANSMIT AND STORE WATER

The withdrawal of water from a well causes a decline in the water level at the well, creating a hydraulic gradient towards the well. The piezometric surface has the form of an inverted cone centered at the well, known as the cone of depression. The cone becomes larger as the discharge continues until radial flow toward the cone equals the withdrawal. Other factors being equal, the quantity of water moving toward a well is proportional to the hydraulic gradient. Pumping two or more wells in the same area may result in mutual interference and excessive drawdown.

The amount of water that can be withdrawn perennially from a ground-water reservoir depends chiefly upon the capacity of the aquifer to transmit water from the areas of recharge to the points of withdrawal and upon the amount of recharge.

The rate at which water is transmitted depends on the coefficient of transmissibility of the aquifer and the hydraulic gradient. This coefficient may be expressed as the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical section of the aquifer 1 mile wide extending the full saturated height of the aquifer under a hydraulic gradient of 1 foot per mile. It may be expressed also as the number of gallons of water a day moving through a vertical strip of the aquifer 1 foot wide under a hydraulic gradient of 1 foot per foot or 100 percent.

The amount of water released from storage as the water level declines depends on the coefficient of storage of the aquifer. The coefficient of storage of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. In an artesian aquifer, the amount of water released from storage depends chiefly on the elasticity and compressibility of the sands and associated confining beds, and of the contained water.

Several aquifer tests were made in the Montgomery area to estimate the coefficients of transmissibility and storage of the Eutaw, Gordo, and Coker formations. These tests consisted of pumping a well at a uniform rate of discharge and observing the rate of drawdown in nearby observation wells, or of stopping the pump and observing the rate of recovery in the pumped well and in nearby observation wells. The results of the tests were analyzed using the nonequilibrium equation first developed by Theis (1935):

$$s=\frac{114.6Q}{T}\int_{u}^{\infty}\frac{e^{-u}}{u}du$$

$$\text{where } u=\frac{1.87r^2S}{Tt};$$

s is the drawdown, in feet, at any point of observation in the vicinity of a well discharging at a uniform rate; Q is the discharge of a well, in gallons per minute; T is the transmissibility of the aquifer in gallons per day; r is the distance, in feet, from the discharging well to the point of observation; S is the coefficient of storage, expressed as a decimal fraction; and t is the time, in days, since pumping started.

The nonequilibrium formula is based on the following assumptions: (1) The aquifer is homogeneous and isotropic; (2) the aquifer has infinite areal extent; (3) the discharge or recharge well penetrates and receives water from the entire thickness of the aquifer; (4) the coefficient of transmissibility is constant at all times and at all places; (5) the well has an infinitesimal diameter; and (6) water removed from storage is discharged instantaneously with decline in head. Despite the restrictive assumptions upon which it is based, the non-equilibrium formula has been applied successfully to many problems of ground-water flow.

The results of the pumping tests in the Montgomery area are summarized in tables 3, 4, and 5.

TABLE 3.—*Coefficients of transmissibility and storage computed from aquifer tests of wells screened in the Eutaw formation*

Well pumped	Well observed	Part of hydrograph analyzed	Coefficient of transmissibility (gallons per day per foot)	Coefficient of storage
K-95	K-94	Drawdown	14, 000	103 x 10^{-4}
	K-94	Recovery	14, 000	103 x 10^{-4}
Average			14, 000	100 x 10^{-4}
N-7	N-7	Recovery	27, 900	
	Observation well located 37 feet from Well N-7.	Drawdown	29, 800	1.3 x 10^{-4}
		Recovery	26, 800	.88 x 10^{-4}
Average			28, 000	1.1 x 10^{-4}

TABLE 4.—*Coefficients of transmissibility and storage computed from aquifer tests of wells screened in the Eutaw and Gordo formations and the upper part of the Coker formation*

Well pumped	Well observed	Part of hydrograph analyzed	Coefficient of transmissibility (gallons per day per foot)	Coefficient of storage
K-60	K-60	Recovery	20, 500	
	K-56	Drawdown	32, 400	6. 6 x 10^{-4}
	K-56	Recovery	29, 300	6. 3 x 10^{-4}
	K-74	do	35, 800	11 x 10^{-4}
Average			30, 000	7. 9 x 10^{-4}

TABLE 5.—*Coefficients of transmissibility and storage computed from aquifer tests of wells screened in the Gordo formation and the upper part of the Coker formation*

Well pumped	Well observed	Part of hydrograph analyzed	Coefficient of transmissibility (gallons per day per foot)	Coefficient of storage
K-100	K-100	Recovery	10, 500	
	K-101	Drawdown	8, 100	1. 8 x 10^{-4}
	K-101	Recovery	8, 700	4. 7 x 10^{-4}
Average			9, 000	3. 2 x 10^{-4}

The uses of the coefficients of transmissibility and storage include the prediction of water level declines, the design of well fields, and the determination of sustained well yields, if geologic and hydrologic conditions are favorable. Usually, the average of the coefficients, obtained from several tests, is used in such computations. Because of the variable thickness of the Eutaw formation (figs. 7–8), it is advisable to use the coefficients determined from the tests in Montgomery's West well field for that general area, and the values determined at the Montgomery municipal airport for that area. Figure 20 is presented to show in a general way the theoretical drawdowns that would be produced by pumping 1 mgd from an ideal aquifer having coefficients of transmissibility and storage as computed from the aquifer tests of the Eutaw formation in the vicinity of the city of Montgomery West well field and the Montgomery municipal airport.

The coefficient of storage of the Eutaw formation as computed from the pumping test in the West well field has a value that is indicative of a transition from artesian to water-table conditions (table 3). If pumping had been continued sufficiently long, a storage coefficient typical of water-table conditions (0.05 to 0.15) might have been obtained because water-level measurements in wells screened in the Eutaw formation in the West well field show that as of May and June 1957 the piezometric surface had declined to a level near the base of the confining beds.

Many of the wells in the city of Montgomery West well field are screened opposite water-bearing beds in the Eutaw and Gordo formations and the upper part of the Coker formation. This sequence of beds is the most productive in the Montgomery area, and supplies relatively large quantities of water to wells. Figure 21 shows in a general way the theoretical drawdown that would be produced by pumping water at 1 mgd from an ideal aquifer having a coefficient of transmissibility of 30,000 gpd per ft and a coefficient of storage of 4.3×10^{-4}, as computed from pumping tests on wells screened in the Eutaw and Gordo formations and the upper part of the Coker formation (table 4).

Some of the wells in the West well field are screened in the Gordo formation and the upper part of the Coker formation. An aquifer test of well K–100 indicated an average coefficient of transmissibility and storage of about 9,000 gpd per ft and coefficient of storage of 3.2×10^{-4} (table 5). Figure 22 is presented to show the theoretical

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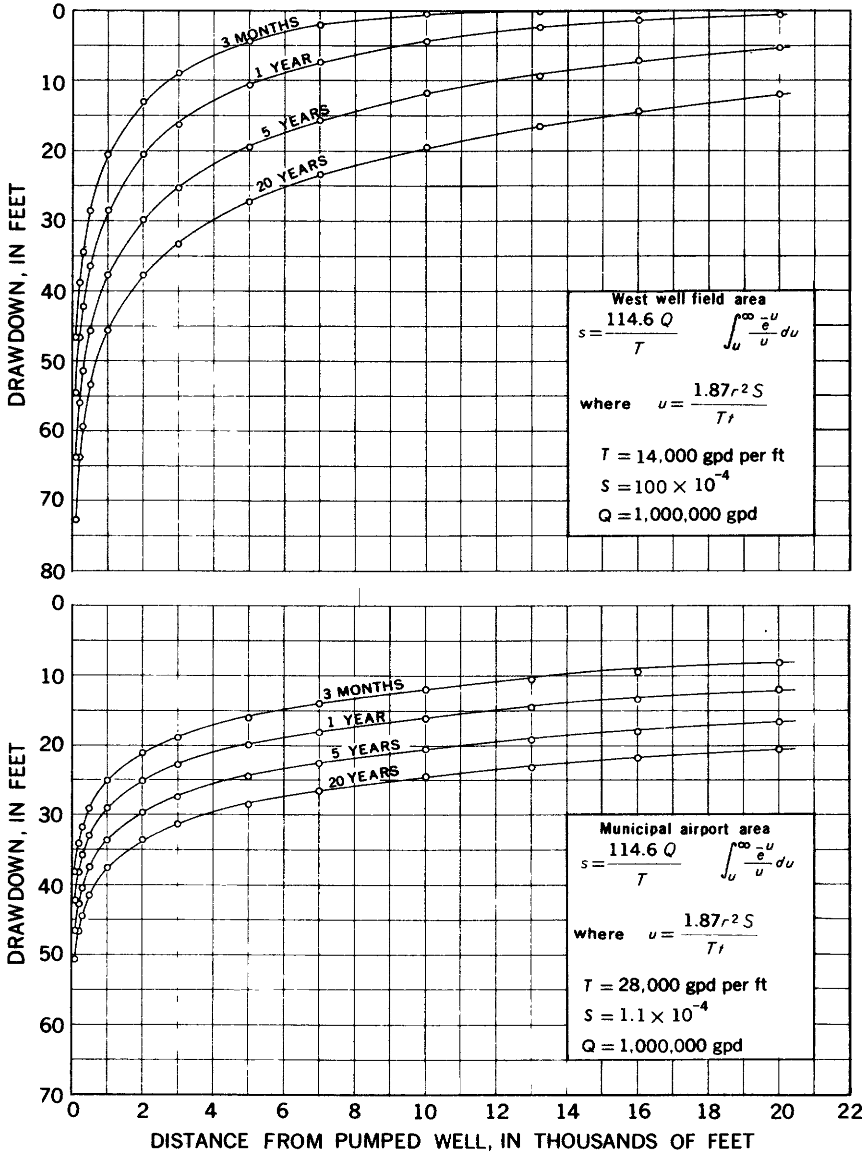

FIGURE 20.—Theoretical drawdown in an ideal aquifer, having coefficients of transmissibility and storage as computed from aquifer tests of the Eutaw formation.

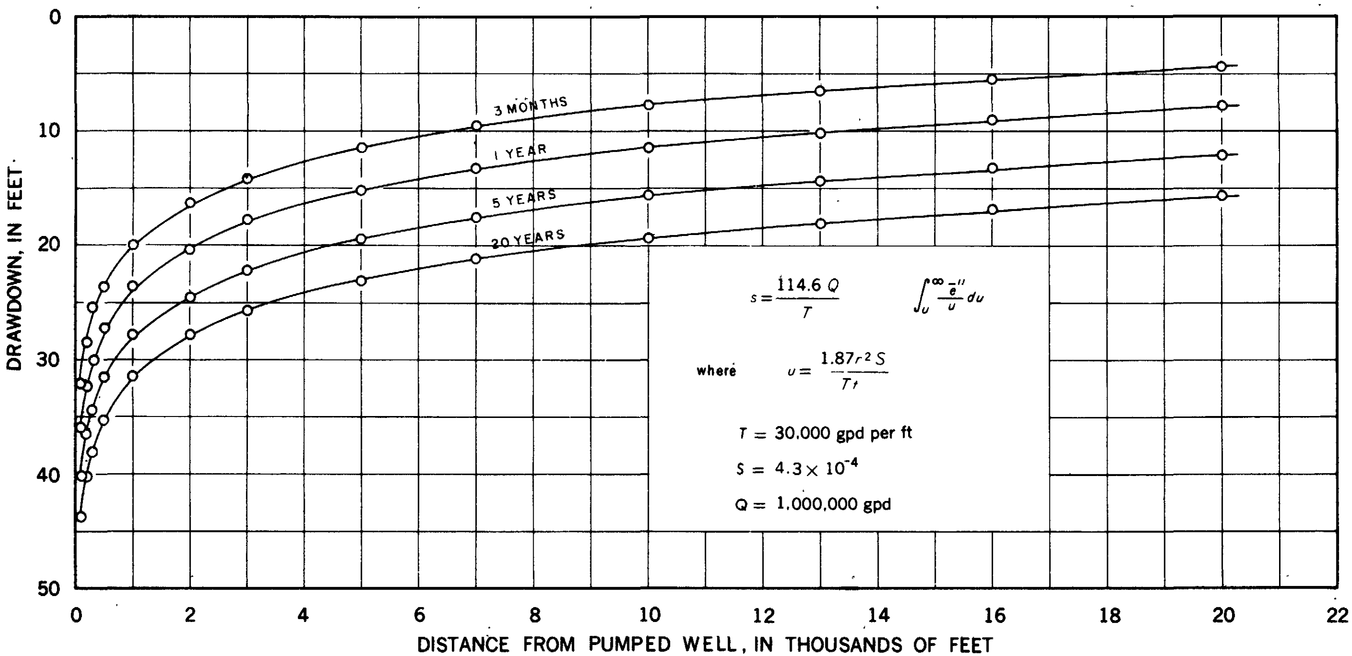

FIGURE 21.—Theoretical drawdown in an ideal aquifer, having coefficients of transmissibility and storage as computed from aquifer tests of the Eutaw and Gordo formations and the upper part of the Coker formation.

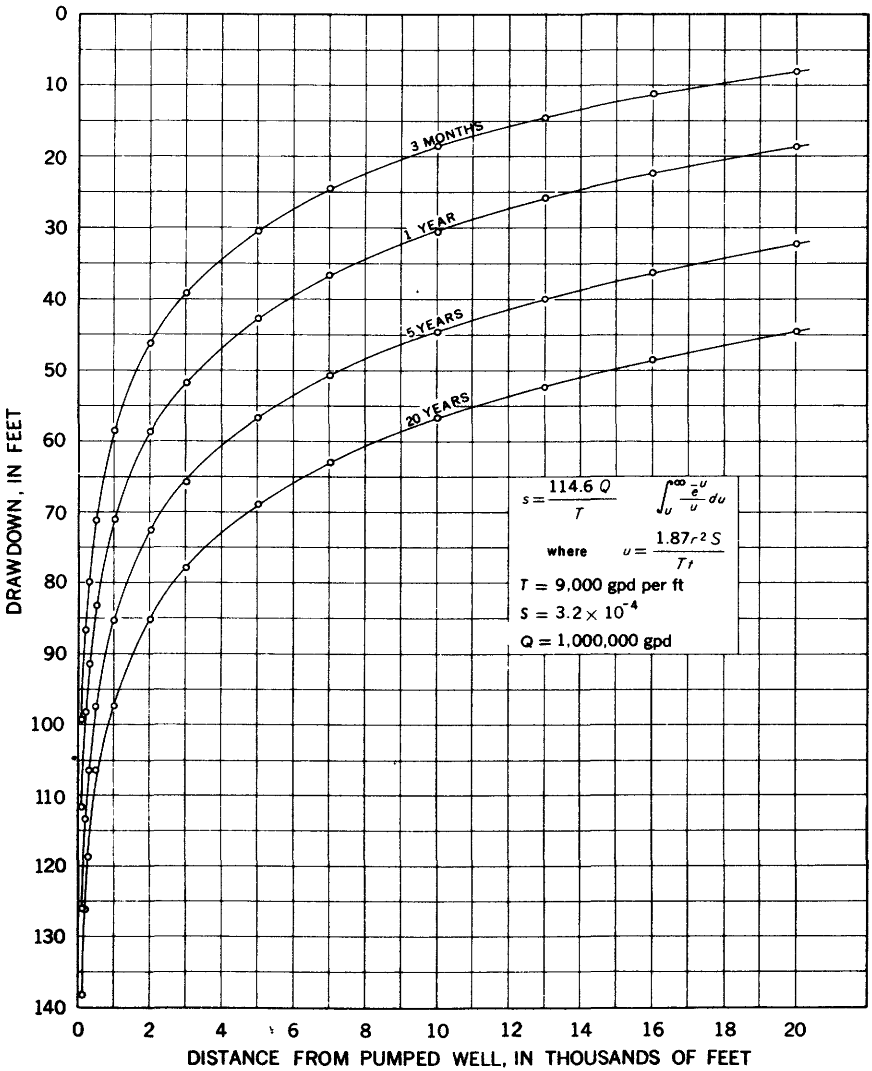

FIGURE 22.—Theoretical drawdown in an ideal aquifer, having coefficients of transmissibility and storage as computed from aquifer tests of the Gordo formation and the upper part of the Coker formation.

drawdown that would be produced by pumping water at 1 mgd from an ideal aquifer having these coefficients.

Only four aquifer tests were made in the Montgomery area. These tests indicate that the coefficients of transmissibility and storage of the water-bearing beds in the Montgomery area are variable, and therefore, should be applied with caution. Considerable additional data would be needed before the coefficients could be applied with confidence to predict the drawdown in wells.

Quantitative studies should also be undertaken to evaluate the performance of the multiple-screened wells in the city of Montgomery well fields. These studies should be directed toward determining the amount of water contributed to the multiple-screened wells by the Eutaw, Gordo, and Coker formations, respectively. More than half the length of screen in wells in the West well field are opposite sand beds in the Gordo formation; however, there are indications, although the quantitative supporting data are meager, that the transmissibility of the Gordo formation is small compared to that of either the Eutaw formation or the upper part of the Coker formation.

FLUCTUATIONS IN WATER LEVELS AND THEIR SIGNIFICANCE

Most of the early wells screened in sands in the upper part of the Coker formation flowed when drilled. Few measurements of the original head are available; however, according to Smith (1907) the heads in the city of Montgomery "Cook" and "Chapin" wells, J–42 and J–121 (Knowles and others, 1960, table 1), were 8 and 40 feet above land surface, respectively, in 1885; they are reported to have flowed at rates of 133 and 200 gpm, respectively.

The decline in the artesian head in the Coker formation began with the first large-scale withdrawals from the Northeast well field. The water levels have declined steadily since that time; for example, the level in the "Cook" well which is reported to have had a head of 8 feet above land surface in 1885 had declined to 63 feet below land surface by 1913 and to 121 by 1952, indicating a net decline of 129 feet in the 67 years from 1885 to 1952. Plate 11 shows hydrographs of four wells and precipitation at Montgomery.

Most of the early wells drilled in the Montgomery area that were screened in the Gordo formation also flowed. According to Smith (1907), most of these wells had ceased flowing by 1899. Flowing wells in the Gordo formation are now obtained only in the lowland areas near the Alabama River in the northwestern part of the county. Measurements of the original head in wells in the Gordo are not available; however, the depths to water in four wells J–24, J–26, J–27, and J–45 (Knowles and others, 1960, table 1) are reported to have ranged from 70 to 76 feet below land surface in 1913. Water levels in these same wells ranged from 107 to 131 feet below land surface in 1946.

The decline in artesian head of the Gordo formation apparently began with the first large-scale withdrawals from the Northeast well field in 1885. The water levels have declined steadily since that time as the pumpage from the Gordo throughout the Montgomery area has increased. The water-level decline in the Gordo since 1913 has been only slightly less than in the Coker formation; although the quantity of water withdrawn from the Coker is believed to have been much greater.

The fluctuations in water level produced by pumping from the Coker, Gordo, and Eutaw formations in the West well field are shown in the hydrograph for the period November 1951–58 of well K–83, a former production well screened in these formations and located near the center of the well field (pl. 11). This graph indicates a net lowering in water level of about 14 feet from April 1952 to March 1958.

Unlike wells tapping the Gordo and Coker formations, almost none of the early wells in the Montgomery area screened opposite the Eutaw formation flowed (Smith, 1907). Measurements of the original water level in these wells are not available; however, in 1923 the water level in well K–31, which is about midway between the Northeast and West well fields, is reported to have been about 50 feet below land surface. The level in this well had declined to a depth of 67 feet by 1957. Periodic measurements of water level in wells tapping the Eutaw during the period 1952–57 indicate that the only significant declines have been in the vicinity of the West well field (Knowles and others, 1960, table 8).

The declines in water levels in wells tapping the Eutaw formation have apparently been much less, in proportion to the quantity of water withdrawn, than those in wells drawing from the Gordo and Coker formations.

Plate 12 shows contours on the piezometric surface of the Eutaw formation based on water-level measurements made in May and June 1957. It shows a large depression in the southwestern half of the West well field as of 1957, which extended only about a mile south of the well field, but extended northward almost to the Alabama River—a distance of about 4 miles. The depression was separated by a ground-water divide from a shallower depression in the piezometric surface in the northeastern half of the well field. These two depressions were probably formerly a single large depression, but as new wells were drilled in the southwestern part of the field the pumpage from some of the older wells in the northeastern part was reduced resulting in local recovery in water levels in the northeastern part of the field.

A ridge of "high" appears in the piezometric surface southeast of Montgomery. It is not related to pumping, as there are only slight withdrawals from the Eutaw formation in eastern Montgomery County. The northwestern part of this high is in the area of outcrop of the Eutaw and may reflect recharge. The ridge in the piezometric surface also coincides with the thinning of beds in the Eutaw formation which may be related to geologic structure as evidence of faulting has been observed in the Eutaw a few miles north of this area in Elmore County.

In the central part of the county, where the piezometric surface of the Eutaw has not been influenced by pumping from the West well field, the contours indicate that water is moving in a general southwestward direction. In the vicinity of the West well field, water moves from all directions toward the centers of pumping.

QUALITY OF WATER

Water that falls as rain or snow contains only small quantities of dissolved mineral matter, but upon reaching the ground it begins to dissolve minerals from the soil and rocks. The amount and kind of minerals dissolved in ground water differs greatly from place to place depending upon such factors as the amount and type of organic material in the soil, the type of rocks through or over which the water moves, the length of time the water is in contact with the soil and rocks, and the temperature of the water. Some rocks contain highly soluble salts, and, as a result, water passing through or over them will become highly mineralized. Other rocks consist of relatively insoluble minerals, and the water passing through or over them will tend to dissolve relatively small amounts of mineral matter. Calcium is present in nearly all ground water because it is easily dissolved from deposits of limestone, gypsum, dolomite, and other rocks. Other constituents commonly found in ground water are sodium, potassium, magnesium, iron, manganese, bicarbonate, sulfate, chloride, fluoride, nitrate, and silica.

The chemical character of water may restrict its use for municipal, industrial, and domestic supply, or for irrigation. Requirements vary greatly from one industry to another, and the requirements for some industries are even more rigid than those for municipal supplies. The chemical character of water for municipal supplies is commonly judged by drinking water standards promulgated by the U.S. Public Health Service (1946) for water used by common carriers in interstate commerce. The average individual, however, can become adjusted to drinking water considerably higher in content of most of the constituents listed in these standards. The standards of the Public Health Service (1946) for certain common chemical constituents are:

1. Iron (Fe) and manganese (Mn) together should not exceed 0.3 ppm (parts per million).
2. Magnesium (Mg) should not exceed 125 ppm.
3. Chloride (Cl) should not exceed 250 ppm.
4. Sulfate should not exceed 250 ppm.
5. Fluoride should not exceed 1.5 ppm.
6. Dissolved solids preferably should not exceed 500 ppm, although, if such a water is not available, a dissolved-solids contents of 1,000 ppm may be permitted.

A water of excessive hardness is undesirable for many domestic and industrial uses because of its soap-consuming and scale-forming properties. Fluoride in drinking water in excess of 1.5 ppm may cause mottled enamel on children's teeth if the water is used during the period of calcification of the teeth—that is, roughly during the first 6 to 8 years of life (Dean and others, 1942).

The hardness and chloride content of water from many of the wells inventoried were determined in the field (Knowles and others, 1960, table 1). These determinations are accurate within limits of about 10 percent. Chemical analyses of water from selected wells used for municipal, industrial, domestic, and stock purposes and for irrigation were made in laboratories of the Geological Survey in Fayetteville, Ark., or Ocala, Fla. Other analyses were made by the city of Montgomery or by private laboratories (Knowles and others, 1960, table 2).

The more comprehensive analyses have been studied to determine the position and extent of the aquifers containing potable water. In Montgomery County the chemical character of the ground water depends on the geographic location and depth from which the water is withdrawn. In general the chemical character of the ground water is satisfactory for most uses; locally, however, the water from some of the aquifers is high in iron or chloride content, or is excessively hard.

COKER FORMATION

The upper part of the Coker formation is one of the principal acquifers in the Montgomery area. Water of good chemical quality is available in moderate to relatively large quantities throughout the area.

Specific information on the quality of water from the upper part of the Coker formation is available for only a few wells in the Montgomery area, as most of the wells that obtain water from the Coker also tap the Gordo or Eutaw formations or both. The water from wells screened only in the Coker has a hardness ranging from 5 to 109 ppm, and ranges in chloride content from 8 to 286 ppm; the hardness and chloride, however, are generally less than 25 ppm. The water is low in iron and fluoride content.

Water, part of which is obtained from the overlying Gordo and Eutaw formations, is also of good chemical quality. It usually has a hardness of less than 100 ppm, and generally contains less than 25 ppm of chloride, and less than 1 ppm of iron, fluoride, and nitrate.

There is very little information available on the quality of water from the Coker formation outside of the Montgomery area, as no water wells have been drilled deep enough to tap the Coker. The electric log of an oil test in southeastern Lowndes County, however, indicates that the upper part of the Coker formation probably contains fresh water in that area.

GORDO FORMATION

The Gordo formation supplies part of the water to many of the Montgomery municipal wells. It is generally of good chemical quality in the Montgomery area, except locally where it is high in iron content.

The water from the Gordo formation is soft. The hardness ranges from 2 to 95 ppm, but is generally less than 50 ppm. Bicarbonate in the water ranges from 18 to 214 ppm and averages about 100 ppm. The dissolved-solids content of the water ranges from 64 to 472 ppm and averages about 200 ppm. The water from most of the wells sampled contained less than 250 ppm of dissolved solids.

The chloride content of water from wells tapping the Gordo formation is generally low, ranging from 1.4 to 43 ppm, except for the water from wells D–36 and D–38 which had a chloride content of 123 and 365 ppm, respectively. Wells D–36 and D–38 are in the vicinity of Gunter Air Force Base and in this area the water from the Gordo formation is locally high in chloride content.

The iron content of water from the Gordo ranges from 0.02 to 4.5 ppm, but the water from most of the wells sampled contained less than 1.0 ppm of iron. The higher concentrations are in water from the upper 100 to 150 feet of the formation. The fluoride and nitrate contents of water from wells in the Gordo are generally less than 1 ppm.

No information is available outside the Montgomery area on the quality of water in the Gordo formation as no wells penetrate the Gordo elsewhere in the county; however, the electric log of an oil test well in southwestern Lowndes County indicates the water in the Gordo formation is probably fresh in that area.

EUTAW FORMATION

The Eutaw formation is the principal aquifer in Montgomery County. It is extensively developed as a source of water supply in the city of Montgomery West well field. Wells tapping the Eutaw also supply most of the water for domestic and stock use and for irrigation in the northern two-thirds of the county.

The water from the Eutaw formation contains from 3 to 591 ppm of bicarbonate. Only 5 of the 66 wells for which bicarbonate determinations are available, however, contain more than 300 ppm. The average bicarbonate content is about 200 ppm. The water from the Eutaw is relatively low in dissolved solids, averaging about 235 ppm. The nitrate content is generally below 2 ppm; however, the water from a few wells contains 5 to 10 ppm of nitrate, which may indicate surface contamination.

The iron content of water from the Eutaw formation is relatively high. The water from the lower part of the formation ranges from 0.09 to about 1 ppm in iron content. The water from the upper part of the formation, however, is excessively high in iron content, and contains from about 1 to 16 ppm of iron in most of the Montgomery area. The wells in the West well field are not screened in the upper part of the Eutaw because of this high iron content.

The fluoride content of water from wells tapping the Eutaw formation is generally less than about 1 ppm except in the southwestern part of the county. In this area the fluoride content of the water ranges from about 1 to 4.4 ppm (pl. 13).

The hardness and chloride content of water from the Eutaw formation in Montgomery County depend on the geographic and stratigraphic location. The water from wells tapping the Eutaw is generally soft and the hardness in most instances is less than 100 ppm, except in a small area near the center of the West well field and in an eastward-trending belt about 8 miles wide and 18 miles long in the north-central part of the county (pl. 14). The median hardness of 100 samples from wells in the Eutaw was 30 ppm. The water in the West well field has a hardness of as much as 135 ppm. The water in the Eutaw in the north-central part of the county is very hard, ranging in hardness from about 100 to 538 ppm.

The water from wells tapping the Eutaw formation in the Montgomery area contains less than 50 ppm of chloride except in an area of about 6 square miles at the southeastern corner of the city. Here the chloride content ranges from about 50 to 117 ppm (pl. 15). The chloride content of the water increases southwest of Montgomery, and southwest of a line trending approximately from where Pintlalla Creek empties into the Alabama River to Robinson Crossroads in the southern part of the county the water from the Eutaw contains more than 50 ppm. The chloride content increases sharply southwest of this line, and about 5 miles west of Sprague it is 351 ppm.

The chloride content of water from the Eutaw in the area about 2 miles southwest of the West well field is about 50 ppm. It increases sharply to the southwest, and in Lowndes County about 6 miles from the well field the chloride content of water from the Eutaw is 1,000 ppm. The lines of equal chloride content of water in wells in the Eutaw formation (pl. 15) suggest that high chloride water is moving from the southwest toward the West well field and the water-level contours (pl. 12) indicate movement in the same direction. Development of additional water from the Eutaw southwest of the present West well field may result in salt-water encroachment. A series of observation wells, approximately along the 50 ppm chloride line on plate 15, could be installed and sampled periodically to detect changes in the chloride content of water moving toward the West well field in the Eutaw formation.

RIPLEY FORMATION

Wells in the Ripley formation supply water for domestic and stock use in the southern part of the county. The water from the Ripley is soft to moderately hard, and otherwise is of good quality. The hardness of the water ranges from 6 to 275 ppm, but is generally less than 100 ppm. The water is relatively high in iron and nitrate, but low in chloride and fluoride.

PLEISTOCENE TERRACE DEPOSITS AND RECENT ALLUVIUM

The water from the terrace deposits contains only small amounts of chloride and fluoride. It is high in iron content in most parts of the Montgomery area, but is relatively soft, the hardness ranging from 5 to 101 ppm.

Water from the alluvial deposits in the county is soft to moderately hard, is low in chloride and fluoride, and is low to relatively high in iron content.

CONCLUSIONS

Much additional ground water of good quality can be developed in the Montgomery area. The lower part of the Coker formation, undeveloped at present, is a potential source of large ground-water supplies. Moderate to large quantities of water are available also from the upper part of the Coker formation and the Eutaw formation. Although the sand beds in the Gordo formation in downdip areas are partially cemented, small to moderate quantities of water can be obtained in most parts of the county. The Pleistocene terrace deposits in the Montgomery area are capable of yielding relatively large quantities of water to wells where their saturated thickness is 50 feet or more. In the southern part of the county, adequate water for domestic and stock use is available from the Ripley formation, the Providence sand, and the Recent alluvium.

The Eutaw formation is thicker south of Montgomery's West well field than elsewhere in the Montgomery area. Additional water for the city of Montgomery could be developed south and southeast of the present well field, and it is believed that wells yielding 1,000 gpm or more could be obtained. Wide spacing of wells to reduce pumping lifts and mutual interference should be considered in any new development. Exploration by test drilling and test pumping should be done before new well locations are selected.

The water from all the aquifers in the county is generally of good chemical quality. The water from wells in the Gordo formation is locally high in chloride content in the vicinity of Gunter Air Force Base. Some wells in the upper part of the formation contain water that is high in iron content. The water from the Eutaw formation is also high in iron content and, in the upper part, contains excessive amounts of iron in the Montgomery area. It is soft, except in an eastward-trending belt about 8 miles wide and 18 miles long in the north-central part of the county.

The chloride content of the water from wells in the Eutaw formation increases southwest of a line trending from near where Pintlalla Creek empties into the Alabama River to Robinson Crossroads in the southern part of the county. This area of high chloride water is only a short distance from Montgomery's West well field, and the high chloride water appears to be moving slowly toward the field. The West well field should not be extended farther southwest because of the danger of salt-water encroachment. Observation wells should be installed between the well field and the area of high chloride water and sampled periodically to forewarn of encroachment.

The water from some wells in the Ripley formation, Providence sand, and Recent alluvium is moderately hard, but otherwise is of good quality. The water in the Pleistocene terrace deposits is soft, but is high in iron content in the Montgomery area.

Water levels in the Coker and Gordo formations have declined more than 100 feet in north Montgomery since 1885. Since the development of the West well field in 1941, water levels in wells that tap the Eutaw formation have declined in southwest Montgomery. Significant declines in water level, however, have occurred only in the vicinity of the West well field.

Additional quantitative work is needed in the Montgomery area. Pumping tests should be made in the city's well fields to provide more accurate estimates of the coefficients of transmissibility and storage of the Coker, Gordo, and Eutaw formations. An evaluation of the performance of wells in the West field to determine the quantity of water yielded by each formation to wells tapping more than one formation should be made. It is suspected that the Gordo formation yields a relatively small proportion of the total water pumped in comparison to the thickness of the sand beds that are screened.

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