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GEOLOGY AND GROUND WATERS OF NORTHEASTERN ARKANSAS

BY

LLOYD WILLIAM STEPHENSON

AND

ALBERT FOSTER CRIDER

WITH A DISCUSSION OF

THE CHEMICAL CHARACTER OF THE WATERS

BY

RICHARD B. DOLE

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GEOLOGY AND GROUND WATERS OF NORTHEASTERN ARKANSAS.

By Lloyd William Stephenson and Albert Foster Crider.

INTRODUCTION.

PHYSIOGRAPHIC PROVINCES OF ARKANSAS.

Arkansas is divisible into two physiographic provinces. The area northwest of a line running from the northeastern corner of Randolph County southwestward through Powhatan, Searcy, and Little Rock, to near Arkadelphia, Clark County, and thence westward, is included in the division known as the Ozark province and embraces approximately 25,000 square miles. The rest of the State is included in the Gulf Coastal Plain, the area of which is approximately 27,500 square miles. More than half of the Gulf Coastal Plain falls within the physiographic division known as the Mississippi embayment, a broad arm which extends from the main plain up the valley of Mississippi River to the southern part of Illinois, a distance of approximately 250 miles. The Ozark province is separated from the Gulf Coastal Plain by an escarpment which in most places is well defined.

The Ozark province in this State is hilly to mountainous and lies 400 to 2,100 feet above sea level. North of Arkansas River the surface is a deeply dissected plateau, 500 to 1,500 feet above sea level, broken by one east-west ridge known as Boston Mountain, which rises to a maximum of about 2,000 feet above sea level. The part of the province south of Arkansas River is known as the Ouachita Mountains and consists of a series of ridges trending in a general east-west direction and rising 500 to 2,100 feet above sea level.

The Ozark province in Arkansas is drained chiefly by Spring, White, Arkansas, and Ouachita rivers, all of which flow in southeastward courses to or beyond its border.

The province is underlain by Paleozoic sedimentary rocks consisting of limestones, sandstones, and shales belonging to the Ordovician, Silurian, Devonian, and Carboniferous systems. In the plateau region north of Arkansas River these rocks lie nearly horizontal; in the region of Arkansas River valley, between Boston Mountain on the north and the Ouachita Mountains on the south, the strata are broadly folded; in the Ouachita Mountains south of Arkansas River the rocks are strongly folded into east-west synclines and anticlines.

In Arkansas the Gulf Coastal Plain ranges in elevation from 100 to 650 feet above sea level, and is divisible topographically into a series of interstream uplands in various stages of dissection, ranging in elevation from 200 to 650 feet above sea level, and a series of nearly level to gently rolling lowlands lying 100 to 300 feet above the same datum plane. A slight general slope southward characterizes both the uplands and the lowlands. The drainage of this part of the Gulf Coastal Plain reaches the Mississippi through numerous tributaries, the largest of which are St. Francis, White, Arkansas, Ouachita, and Red rivers.

The uplands are composed mainly of unconsolidated clays, loams, marls, sands, and gravels of Cretaceous and Tertiary age. The Cretaceous deposits outcrop in an east-west belt, 15 to 30 miles wide, lying south of the Ozark province and west of Ouachita River, both the Lower and Upper Cretaceous series being represented. Beds of Cretaceous age also lie buried beneath Tertiary strata in the vicinity of Little Rock and northeast of Little Rock in Lonoke and White counties, and Cretaceous strata come to the surface in the Grand-glaise terrace in the vicinity of Newark, Independence County.

Except in the areas mentioned, the soils in the Gulf Coastal Plain uplands are immediately underlain by strata of Tertiary age belonging to the Midway, Wilcox, Claiborne, and Jackson formations of the Eocene, and the Lafayette formation of the Pliocene (?). Locally the Tertiary strata in the uplands are overlain and concealed by deposits of late Pleistocene age, principally consisting of loess, sands, and gravels. The loess occurs on Crowleys Ridge in the northeastern part of the State. The soils in the lowlands are immediately underlain by alluvial deposits which consist of silts, loams, clays, sands, and gravels of Pleistocene and Recent age, which rest unconformably upon Cretaceous and Tertiary strata.

ACKNOWLEDGMENTS.

The field investigations on which the report is largely based were made by the authors jointly during May and June, 1905, under the direction of M. L. Fuller, supervising geologist in charge of Coastal Plain investigations, and by the senior author under the direction of T. Wayland Vaughan, geologist in charge of Coastal Plain investigations, during October, 1910, and half of September, 1912.

The field studies have been supplemented by much information relating to the ground-water resources of the area, obtained by correspondence with municipal authorities, postmasters, and well owners. The authors desire to acknowledge their indebtedness to the following persons for important contributions to the hitherto unpublished scientific results presented:

Mr. T. Wayland Vaughan, who collected and identified the invertebrate fossils from Little Crow Creek, east of Forrest City.

Mr. E. W. Berry, who, in company with the senior author, collected fossil plants from several localities in Crowleys Ridge, identified the fossil plant species listed in the report, and determined the Wilcox and Claiborne age of plant-bearing beds in Crowleys Ridge north of St. Francis County.

Dr. Paul Bartsch, who identified the loess fossils from several localities on Crowleys Ridge in St. Francis and Phillips counties.

Mr. E. Wesley Shaw, who made petrographic studies of specimens of loess from various localities in the area, and who offered valuable suggestions regarding the geologic history of the late Tertiary and Quaternary deposits.

Grateful acknowledgments are also extended to the many citizens who furnished valuable information regarding the ground-water resources of the area, especially to Mr. E. G. Norton, of Brinkley, who contributed data relating to wells in Monroe, St. Francis, and other counties, and to Mr. W. H. Fuller, of Lonoke, who furnished an account of the early history of the rice industry.

BIBLIOGRAPHY.

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MACLURE, WILLIAM, Observations on the geology of the United States of America, with some remarks on the effect produced on the nature and fertility of soils by the decomposition of the different classes of rock: Am. Philos. Soc. Trans., new ser., vol. 1, 127 pp. and map.

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NUTTALL, THOMAS, Observations on the geological structure of the valley of the Mississippi: Acad. Nat. Sci. Philadelphia Jour., vol. 2, pt. 1, pp. 14–52 (esp. pp. 33–48).

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MARCOU, JULES, A geological map of the United States and the British Provinces of North America, Boston.

1854.

WARDER, JOHN A., A geological reconnaissance of the Arkansas River, 27 pp., Cleveland.

1858.

MARCOU, JULES, Geology of North America, with two reports on the prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California: 144 pp., 9 pls., Zurich.

OWEN, DAVID DALE, First report of a geological reconnaissance of the northern counties of Arkansas, pp. 1–191, 10 pls. (esp. pp. 19–41), Little Rock.

Includes notes on the following counties: Greene (now in part Clay County), Poinsett (now in part Cross County), Jackson, Independence, and White (pp. 19–41). Owen correlates the unconsolidated deposits of Crowleys Ridge in northern Arkansas, including those of both Eocene and Pleistocene age, with the Quaternary; the hard Eocene quartzites he referred erroneously to the Potsdam sandstone (Cambrian).

COX, EDWARD T., First report of a geological reconnaissance of a part of the State of Arkansas: pp. 193–256, Little Rock.

1860.

OWEN, DAVID DALE, Second report of a geological reconnaissance of the middle and southern counties of Arkansas: pp. 1–153, 7 pls. (esp. pp. 146–153), Philadelphia.

Describes surface features, the soils, and certain geological features of portions of Arkansas, Jefferson, Crittenden, Mississippi, Craighead, and Phillips counties. Owen recognized the Eocene age of the fossiliferous marls exposed on Little Crow Creek east of Forrest City.

1861.

HUMPHREYS, A. A., and ABBOT, H. L., Report upon the physics and hydraulics of the Mississippi River: 456 pp., appendices pp. i–cxlvi, 20 pls., Philadelphia.

Contains much information pertaining to the physiography of the valley of Mississippi River and its main tributaries, and considerable data on the composition of the immediate river banks.

1872.

HILGARD, E. W., On the geological history of the Gulf of Mexico: Am. Assoc. Adv. Sci. Proc., vol. 20, pp. 222–236.

The first systematic account of the geology and geological history of the Gulf embayment region. The paper includes a black-and-white sketch map showing the distribution of the Cretaceous, Tertiary, and Quaternary formations.

SMITH, EUGENE A., Remarks on the geology of the Mississippi Bottom: Am. Assoc. Adv. Sci. Proc., vol. 20, pp. 252–261.

1880.

WHITE, C. A., Descriptions of new invertebrate fossils from the Mesozoic and Cenozoic rocks of Arkansas, Wyoming, Colorado, and Utah: U. S. Nat. Mus. Proc., vol. 3, pp. 157–162 (esp. p. 161).

1881.

WHITE, C. A., On certain Cretaceous fossils from Arkansas and Colorado: U. S. Nat. Mus. Proc., vol. 4, pp. 136–139 (esp. p. 137).

WILSON, E. H., Report on the results of borings at Memphis, Tenn., Helena, Ark., Arkansas City, Ark., Greenville, Miss., and Lake Providence, La., with data pertaining to similar work previously executed: U. S. Mississippi River Com. Progress Report, 47th Cong., 1st sess., S. Ex. Doc. No. 10, Appendix J and Ji, pp. 139–257.

Contains much information on the character of the alluvial deposits of Mississippi River (esp. pp. 139–239).

1884.

HILGARD, E. W., and HOPKINS, F. V., Report upon the examination of specimens from borings on the Mississippi River between Memphis and Vicksburg: U. S. Mississippi River Com. Progress Report, 48th Cong., 1st sess., H. Ex. Doc. No. 37, Appendix N, pp. 479–497.

Hilgard's conclusions are in accordance with the views of the present writers as regards the major structural features of the valley, but differ from them in respect to certain interpretations of age and geologic history; it is believed, for instance, that a large part of the erosion which excavated the valley to the level of the base of the Quaternary alluvial deposits and much of the subsequent filling of the valley to the present surface level have taken place since the deposition of the loess and not prior to that time, as stated by Hilgard.

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Hill described the general physiographic, geologic, and structural features of the State, and showed that the major divisions recognizable on the basis of natural phenomena form parts of great provinces which are more broadly developed outside of Arkansas.

1891.

CHAMBERLIN, T. C., and SALISBURY, R. D., On the relationship of the Pleistocene to the pre-Pleistocene formations of the Mississippi Basin south of the limit of glaciation: Am. Jour. Sci., 3d ser., vol. 41, pp. 359–377.

Contains references to the gravel and loess deposits capping Crowleys Ridge. The gravels they believe to be of pre-Pleistocene age and separated from the overlying loess by an erosion unconformity. In terms of the accepted classification of that time, the loess is correlated with the first glacial epoch. On the evidence of an apparent soil zone in the body of the loess, observed at Forrest City and elsewhere in the ridge, the loess is subdivided; the part below the soil zone is referred to the first episode of the first glacial epoch and the part above the soil zone to the second episode of the first glacial epoch. The alluvial filling of the Mississippi Valley is referred in time to the second glacial epoch.

McGEE, W J, The Lafayette formation: U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 347–521 (esp. pp. 470, 471).

CALL, R. ELLSWORTH, The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 1–223.

Includes a general description of the ridge and detailed descriptions of many geologic sections and other natural features. A map showing the geographic position of the ridge accompanies the report. St. Francis County is given special attention in a chapter entitled "Report on St. Francis County" (pp. 143–183), accompanied by a topographic and geologic map of a part of the county on a scale of 4 miles to the inch, with a contour interval of 10 feet. Supplementary to the report are descriptions of geologic sections on Arkansas River in White, Woodruff, Lonoke, and Prairie counties, and at Memphis, Tenn.

Call recognizes the Tertiary age of the strata composing the core of Crowleys Ridge, but he does not differentiate the Wilcox, Claiborne, and Jackson formations, which outcrop in succession from the northern to the southern end of the ridge. Although he recognizes the fact that the main body of the gravels is younger than the underlying sands and clays, he does not clearly distinguish between the Eocene strata and the overlying Lafayette formation. The loess capping the ridge he correlates correctly with the Pleistocene.

BRANNER, J. C. In the preface to vol. 2 of the Arkansas Geol. Survey Ann. Rept. for 1889, pp. xi–xvi.

Branner gives a brief account of the origin of Crowleys Ridge and describes the depression which brought into existence the conditions necessary to the deposition of the Tertiary (Eocene) deposits of the embayment. He recognizes that at a later time the Mississippi River followed a course west of Crowleys Ridge and that through its agency the great lowland between the ridge and the Ozark province was eroded out and partially refilled; he states that Ohio River, following a course southward east of the ridge, was accomplishing similar results in the area now known as the Mississippi lowland; the junction of the two streams was somewhere south of Helena. Crowleys Ridge is correctly interpreted to be an erosion remnant which separates these two great valleys.

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HARRIS, GILBERT D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, esp. pp. 10–15.

Shows the existence of strata of Midway Eocene age along the western border of the Gulf Coastal Plain in White, Lonoke, and Pulaski counties. The correlation is based on the evidence afforded by invertebrate fossils. The Midway is underlain in the same counties by strata of Upper Cretaceous age, correlated on the evidence of invertebrate fossils taken from wells and identified by T. W. Stanton, of the U. S. Geological Survey; the Cretaceous was not positively identified in surface outcrops in these counties.

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BOND, FRANK, and KEENEY, GEO. H., Irrigation of rice in the United States: U. S. Dept. Agriculture Bull. 113, pp. 1–77.

MARBUT, C. F., The evolution of the northern part of the lowlands of southeastern Missouri: Missouri Univ. Studies, vol. 1, No. 3, 63 pp., 3 pls.

Describes the main drainage events of the embayment area in southeastern Missouri and many of the lesser phenomena. Marbut states that Mississippi River in the early part of the second glacial epoch flowed from Cape Girardeau southwestward, west of Benton Ridge and Crowleys Ridge; Ohio River flowed southward, east of these ridges, and joined the Mississippi south of the southern extremity of Crowleys Ridge in Arkansas. The lowland produced by the erosion of Mississippi River he designated the Advance lowland, from the village of Advance, situated upon the lowland in Stoddard County, Mo.

After the main features of the Advance lowland had been fashioned by Mississippi River the stream was captured by Ohio River; first, at the point now marked by the gap separating the northern extremity of Crowleys Ridge from the southern extremity of Benton Ridge; and, second, at the point now occupied by the Mississippi between Grays Point and Commerce, Scott County, Mo. The lowland produced by the erosion of Ohio River and by the combined erosion of the Ohio and Mississippi, after the capture of the latter stream, was designated by Marbut the "Cairo lowland," which he subdivided into the Charleston lowland, Sikeston Ridge, and the Morehouse lowland.

The author discusses at considerable length the manner in which these great feats were accomplished, and also the details of many minor incidents connected with the major processes. The paper is accompanied by a topographic map on a scale of approximately 3 miles to the inch with a 20-foot contour interval (Plate VI) and a black and white geologic map on the same base (Plate VII).

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PURDUE, A. H., Northern Arkansas (water resources): U. S. Geol. Survey Water-Supply Paper 114, pp. 188–197.

——— Water resources of the contact region between the Paleozoic and Mississippi embayment deposits in northern Arkansas: U. S. Geol. Survey Water-Supply Paper 145, pp. 89–119.

Describes in a general way the topography, geology, and water resources of the area; but few detailed sections are given. A black and white geologic map on a small scale (Plates II and III) accompanies the report.

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CARTER, WILLIAM T., Jr.; MEEKER, F. N.; SMITH, HOWARD C.; and WORTHEN, E. L., Soil survey of Prairie County, Ark.: U. S. Dept. Agr. Bur. Soils Field Operations, 1906, pp. 1–36.

SHEPARD, EDW. M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, 224 pp., 6 pls., 6 figs.

1908.

BRANNER, J. C., The clays of Arkansas: U. S. Geol. Survey Bull. 351, 247 pp., 1 pl., 20 figs.

Includes a general account of the topography and geology of the State, a geologic map on a small scale (Plate I), an account of the general stratigraphic distribution of the clays, and a detailed account of the distribution of the clays by counties. The descriptions of the counties of the northeastern part of the State includes for each county a brief statement of the physiography and geology, and in many cases well logs and detailed descriptions of localities.

1911.

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1912.

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Includes a compilation of the known facts regarding the phenomena accompanying and resulting from the earthquake, gathered from many sources, and the results of several season's work by the author in the area. From the available data he makes deductions regarding the origin and cause of the earth movement, and concludes that the ultimate cause was a disturbance in the consolidated basement rocks underlying the deposits of the Gulf Coastal Plain. A map which shows the distribution of the various recognizable effects of the earthquake, such as sunk lands, areas of fissuring, areas of sand blows, and areas of landslides, accompanies the paper.

MUNN, M. J., Exploration for natural gas and oil at Memphis, Tenn.: The resources of Tennessee, vol. 2, No. 2, pp. 48–68, Tennessee Geol. Survey.

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[Miocene, Pliocene, and Pleistocene of] south Atlantic and eastern Gulf Coastal Plain and north end of Mississippi embayment: Idem, pp. 806–813.

[Eocene and Oligocene of] Texas, Louisiana, and Arkansas: Idem, pp. 723–728.

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1914.

MISER, H. D., New areas of diamond-bearing peridotite in Arkansas: U. S. Geol. Survey Bull. 540, pp. 534–546.

Discusses the age of the igneous rocks of southwest Arkansas, which he shows were intruded during the period represented by the unconformity separating the Trinity formation (Lower Cretaceous) and the Bingen sand (Upper Cretaceous).

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PHYSIOGRAPHY.

CLASSIFICATION OF FEATURES.

The area covered in this report is included within the broad northward-extending arm of the Gulf Coastal Plain known as the Mississippi embayment and embraces approximately 13,250 square miles, extending from Mississippi River westward to the border of the Ozark province and from the Missouri State boundary southward to Arkansas River. The embayment may be subdivided into uplands and lowlands.

Probably more than nine-tenths of the area treated in this report presents a lowland type of topography and is embraced within the two physiographic divisions of the Mississippi embayment designated the Advance lowland and the Mississippi lowland.

The Ozark province, a rugged, hilly area lying 400 to 1,500 feet above sea level, borders the Gulf Coastal Plain on the northwest. This higher land is separated from the Coastal Plain by an escarpment, which at most places is sharply defined.

COASTAL PLAIN UPLANDS.

Southwest of Arkansas River.—Between Arkansas and Ouachita rivers is an extensive, partly dissected upland, the elevation of which is 200 to 500 feet above sea level. This upland is terminated on the northeast by a more or less clearly defined escarpment, which overlooks the Advance lowland and marks its southwest boundary. The difference in elevation between the upland and the Advance lowland is 150 to 250 feet.

Crowleys Ridge.—Crowleys Ridge is a belt of upland which, with certain important interruptions, extends from Stoddard County, Mo., where the maximum width is 18 miles, southwestward through Clay County, Ark., to Craighead County, Ark., and thence southward to Helena, Phillips County. In Phillips County the crest of the ridge is about 400 feet above sea level; the elevation gradually increases northward to 500 feet above sea level in Clay County, and to a maximum of 600 feet in Stoddard County, Mo. The elevation of the crest above the lowlands to the east and west ranges from 100 to 260 feet, the greatest difference being in Stoddard County, Mo.

In Arkansas the ridge varies in width from one-half mile to 12 miles; the broadest part of the belt is in Craighead and Greene counties, where the width is 8 to 12 miles, and the narrowest part is near Dee, in Craighead County, where there is a low gap, through which the Helena branch of the St. Louis, Iron Mountain & Southern Railway passes. The ridge has been completely cut at three places; one gap, in Stoddard County, Mo., is occupied by Castor River; another, on the border between Clay County, Ark., and New Madrid County, Mo., serves as the passageway of St. Francis River from the Advance lowland to the Mississippi lowland; the third, in Lee County, Ark., is several miles wide and is occupied by L'Anguille River.

The surface of the ridge is dissected by numerous small perennial and intermittent streams, most of which flow either to the east or to the west at right angles to the trend of the ridge; at many places the topography is rugged, but elsewhere erosion has passed beyond the stage of maturity, and the hills present smoothly rounded, gentle slopes. Several of the larger streams flow through relatively broad, shallow valleys.

The ridge is sharply separated from the adjoining lowlands by escarpments of varying degrees of steepness. At many places in Cross, St. Francis, Lee, and Phillips counties the east-facing slope is an abrupt bluff; in Craighead, Greene, and Clay counties the west-facing slope is relatively steep. The broader valleys and the more gently rounded hills have been cleared for cultivation, but the greater part of the area is covered with timber.

Benton Ridge (in Missouri).—Benton Ridge, in Scott County, is a northeastward extension of Crowleys Ridge, but is separated from it by a gap 10 miles wide; Benton Ridge terminates near Commerce just west of Mississippi River.

Grandglaise terrace.—Bordering the Ozark province and extending with certain interruptions from the northeastern part of White County through Independence County to the southern part of Lawrence County, is a narrow, more or less clearly defined bench, here designated the Grandglaise terrace, which lies 250 to 325 or 350 feet above sea level, and from 40 to 100 or 125 feet above the Advance lowland on the east. This terrace has been dissected by numerous streams crossing it from the Ozark province to the Advance lowland, chief of which is White River, and in places, particularly in Jackson County, small streams running parallel with the terrace along its western margin partly separate it from the Ozark hills to the west, leaving the terrace represented only by a ridge.

The term "Grandglaise area" was first used by Purdue[1] for the portion of the terrace between "Coffeyville and Bradford," in Lonoke and White counties. Since the terrace north of White River in Independence and Lawrence counties is the northward continuation of the terrace at Grandglaise, it is appropriate to extend the application of the term to that area.

Chinquapin Ridge.—An elevated tract in Lonoke County extending from the border of the Ozark province in the vicinity of Austin and Cabot to the eastward and southward for several miles has been locally termed Chinquapin Ridge; Purdue[2] called it the "sandhill" area. The exact limits of this tract have not been determined, but its north-south extent is believed to be about 12 miles, and its east-west extent is approximately 6 miles. The area presents a series of rolling hills rising to a maximum of 375 or 400 feet above sea level, and 125 to 150 feet above the level of the adjoining Advance lowland. The soils consist mainly of reddish, ferruginous sands derived from sandy strata probably of Eocene age which compose the body of the hills. The southwestern end of the ridge is expressed on the Little Rock topographic map by the 300-foot contour, which appears on the map east and north of Bayou Two Prairie and south of Cabot. A small elevated tract west of Bayou Two Prairie, in the vicinity of Jacksonville, expressed on the Little Rock map by the 300-foot contour, may be considered an isolated remnant of this ridge, as may also a similar small elevated tract north of Cypress Bayou and southwest of Beebe, in the southern part of White County.

Jones Ridge.—In addition to the uplands already described, there is one minor elevation in Arkansas, known as Jones Ridge, which deserves brief mention. This ridge is in the northeastern part of Greene County, between Cache River and the St. Louis, Iron Mountain & Southern Railway, where the nearly level surface of the lowland is broken by a northeast-southwest swell, 3 or 4 miles long, one-quarter to one-half mile wide, and 30 to 40 feet high. The probable age and relations of the ridge are discussed on page 111.

Chickasaw Bluffs (in Kentucky, Tennessee, and Mississippi).—The Mississippi lowland is bordered on the east in Kentucky, Tennessee, and Mississippi by an area lying about 400 feet above sea level or 100 to 150 feet above the level of the lowland. This higher land is separated from the lowland to the west by a line of bluffs, known as Chickasaw Bluffs, which extends from northeast to southwest, approximately parallel to the general course of the Mississippi River; north of Memphis the bluffs are nowhere more than 15 miles

[1] Water resources of the contact region between the Paleozoic and Mississippi Embayment deposits in northern Arkansas: U. S. Geol. Survey Water-Supply Paper 145, p. 94, 1905.

[2] Idem, p. 93.

from the Mississippi River, but south of Memphis they form the eastern boundary of Yazoo bottom, which lies east of the river and has a maximum width of 65 miles.

COASTAL PLAIN LOWLANDS.

ADVANCE LOWLAND.

The name "Advance lowland" is derived from the village of Advance, in the northern part of Stoddard County, Mo., and was first used by Marbut[1] in 1902 for a belt of lowland extending from the Mississippi River at Cape Girardeau, Mo., southwestward to Mingo, in the western part of Stoddard County, and thence southward into Arkansas.

From Cape Girardeau to Mingo the Advance lowland is 2½ to 6 miles wide; southward from Mingo it broadens out, and from the Arkansas State line to the latitude of Jonesboro, in Craighead County, is 25 to 30 miles wide; from Craighead County southward it broadens, reaching a maximum of about 90 miles in the latitude of Little Rock, which width it maintains approximately to its junction with the Mississippi lowland.

The Advance lowland is limited on the east by Crowleys Ridge, on the northwest by the Ozark province, on the southwest by the upland south of the Arkansas River, and on the southeast by the Mississippi lowland. The Advance lowland merges into the Mississippi lowland along a line which runs from Helena in an approximate southwestward direction to the southern part of Arkansas County.

The surface of the Advance lowland is, in general, a nearly level or gently rolling plain, which stands about 342 feet above sea level at Cape Girardeau, Mo., whence it slopes gradually southwestward and southward at an average rate of about two-thirds of a foot a mile to about 150 feet above sea level at its southern extremity in Arkansas.

Although now crossed by numerous streams the main topographic features of the Advance lowland are obviously the product of one great agent; Marbut[2] has shown that the lowland in Missouri is an abandoned valley of Mississippi River, and the conclusion seems justified that this great stream once meandered in the area included in this division in Arkansas.

At the present time the Advance lowland in Arkansas is drained chiefly by Arkansas, White, and L'Anguille rivers and their tribu-

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[1] Marbut, C. F., The evolution of the northern part of the lowlands of southeastern Missouri: Missouri Univ. Studies, vol. 1, No. 3, 63 pp. (esp. p. 4), 7 pls., 1902.

[2] Idem, pp. 47–63.

taries. Arkansas River enters the lowland at Little Rock, flows southeastward, and joins Mississippi River in Desha County; its principal tributary is Bayou Meto, and there is a network of bayous in Arkansas, Jefferson, Lonoke, and Pulaski counties.

White River enters the lowland at Batesville, Independence County, flows in a general southward course, and enters Mississippi River by means of a network of distributaries through a part of which the waters of Arkansas River also flow. The principal western tributaries of White River, from north to south, are Little Red River, Bayou Des Arc, Wattensas Bayou, and Big Lagrue Bayou. Black River enters Arkansas in Clay County, flows southwestward near the western border of the lowland, and joins White River near Newport, Jackson County. Cache River rises in the northern part of Clay County, flows southwestward near the center of the lowland, and joins White River near Clarendon. Bayou De Vue, a tributary of Cache River, parallels the latter stream about 8 or 10 miles to the eastward, from Craighead County southwestward to Monroe County. Big Creek flows from the western part of St. Francis County southward to the western part of Phillips County, where it joins White River.

The only other important stream in the area is L'Anguille River, which rises in the northern part of Poinsett County, flows southward a short distance west of Crowleys Ridge, turns southeastward, and leaves the Advance lowland through a gap at Crowleys Ridge in Lee County.

The streams of the Advance lowland flow through broad, shallow valleys which are a few feet to a maximum of 35 or 40 feet below the level of the interstream areas. All the larger streams flow in courses approximately parallel to the linear direction of the main lowland, but in detail the channels are sinuous and the currents are sluggish.

The bottom lands are characterized by numerous swamps, bayous, lakes, and abandoned stream channels, which at many places are separated by low ridges rising only a few feet above the level of the depressions. The flood plain soils are fertile and support a vigorous growth of timber; where well situated as regards drainage they can be made to yield large crops of cotton, corn, and other products. Many of the low ridges are cultivated.

Between the flood plains of the streams are gently undulating plains, underlain except at certain places by silty loams and clays. The soils vary from dark, fertile, sandy or nonsandy loams, to light-gray, silty loams and clays which are not well suited to many of the common crops; in most places the soils rest on compact clay subsoils which are almost impervious to water. At many places the clay soils are ferruginous and are filled with numerous small concretions of iron oxide; soils of this character are locally termed "buckshot lands."

A. PRAIRIE PHASE OF THE ADVANCE LOWLAND, A QUARTER OF A MILE NORTHEAST OF OBEAR, CRAIGHEAD COUNTY.

B. LOW CIRCULAR MOUND AT BALD KNOB.

A typical example of the small mounds common in certain parts of the Coastal Plain of Arkansas, Louisiana, and eastern Texas.

A considerable part of the interstream areas consists of irregularly distributed small and large tracts of gently undulating grass-covered prairie lands. Grand Prairie is an irregular but nearly continuous tract of prairie, extending from northwest of Lonoke, in Lonoke County, southeastward through Prairie County nearly to the southern extremity of Arkansas County. The prairie is broken by numerous slightly depressed patches and strips of timbered land, and by the shallow valleys of numerous small creeks and bayous. Prairie Longue is a similar but smaller tract in Lonoke County south of Bayou Two Prairie. Numerous patches of prairie land lie between Bayou De Vue and L'Anguille River in Lee, Monroe, St. Francis, Woodruff, Cross, Poinsett, and Craighead counties. (See Pl. I, *A*.) The prairie soils are best suited to grazing, the raising of hay, and rice culture.

Surrounding and separating or partly separating the patches and tracts of prairie lands are slightly depressed lands supporting a growth of such trees as post and other small varieties of oak, sassafras, persimmon, and sumac.

In places gently undulating areas, with soils that appear to be essentially like the prairie soils, are timber covered except where artificially cleared. Tracts of this kind are found in many of the counties, but particularly in those lying directly east of the border of the Ozark province.

West of and bordering Crowleys Ridge is a belt of heavily timbered land, the soils of which are more fertile than most of the soils of the interstream areas elsewhere in the Advance lowland; this belt owes its fertility to wash materials from Crowleys Ridge.

At many places in the Advance lowland, but particularly in Clay, Randolph, and Lawrence counties in the north, and in the counties bordering the Ozark province, there are tracts of rolling timbered land composed of numerous low ridges of sand or sandy loam, which in general trend parallel to the stream courses. Some of these ridges appear to be a part of the alluvial deposits of the present streams, but many of them rise above extreme high-water level, are probably of Pleistocene age, and may properly be classed as interstream lands.

In Monroe and Phillips counties, west of the southern extremity of Crowleys Ridge, is a ridge 10 to 30 feet high and 2 to 3 miles wide, known as Hickory Ridge, which extends from near Blackston, in the former county, southeastward to several miles beyond Marvell in the latter county. There are several similar ridges between Hickory Ridge and the southern nose of Crowleys Ridge. Along the western side of Crowleys Ridge, in Phillips County, is a well-defined terrace, 1 to 3 miles wide and 30 or 40 feet higher than the bottom lands of Caney Creek, which lies immediately to the west; the terrace is separated from the ridge on the east and the bottom lands on the west by abrupt escarpments, and probably corresponds in elevation to the ridges just described. The series of ridges and the terrace have probably been produced by erosion where the streams of the Advance lowland pass down to the Mississippi lowland, which lies 30 or 40 feet lower.

MISSISSIPPI LOWLAND.

The Mississippi lowland in Arkansas includes all the area east of Crowleys Ridge and a belt 5 to 20 miles wide bordering Mississippi River on the west south of the southern extremity of Crowleys Ridge. In Missouri this lowland includes the area southeast and south of Crowleys Ridge and south of Benton Ridge. The eastern boundary of the lowland in Kentucky, Tennessee, and Mississippi is the Chickasaw Bluffs.

The Mississippi lowland is a gently undulating plain, sloping southward at a rate of about three-fourths of a foot per mile from an elevation of about 340 feet above sea level at the northern end of the Mississippi embayment region near Commerce, Scott County, Mo., to about 105 feet at the southern boundary of Arkansas.

Mississippi River, which forms the eastern boundary of the State, eventually receives all the drainage of the Mississippi lowland. In Arkansas and Missouri the surface immediately west of Mississippi River in any given cross section of the valley is the highest part of the lowland, and there is a slight gentle slope to the west. As a result of this condition the surface waters flow westward, eventually reaching the Mississippi through several tributaries that parallel the main stream for long distances.

St. Francis River enters the lowland at the northeastern corner of Clay County and flows in a general southerly course near the western border of the lowland to a point 8 or 10 miles north of the southern extremity of Crowleys Ridge, near Helena, where it joins Mississippi River. Little River, which enters the lowland between Benton Ridge and the northern extremity of Crowleys Ridge in Missouri, flows southward and joins St. Francis River in Poinsett County, Ark.

Much of the lowland in Missouri and Arkansas presents a network of lakes, bayous, and abandoned stream channels, separated by areas of swamp land and by low ridges of sand and sandy loam. Nearly all these bodies of water are connected with the drainage systems of Little and St. Francis rivers. Much of the area is subject to overflow from Mississippi and St. Francis rivers.

A large area in the western part of the lowland, embracing parts of New Madrid, Dunklin, and Pemiscot counties, Mo., and Clay, Greene, Craighead, Poinsett, and Mississippi counties, Ark., is known as the St. Francis Sunk Lands. However, recent investigations of the Land Office and the United States Geological Survey have shown either the much smaller size or the nonexistence of many of the large lakes shown on the maps. The bearing of these facts, which were received too late for incorporation in the maps accompanying this report, on the claim that large tracts in this area sank during the time of the New Madrid earthquake, in 1811 and 1812,[1] has not been determined.

The depressions of the lowland are everywhere separated by low, rolling ridges, most of which are of relatively small extent and rise only a few feet above the level of the depressed areas. Two such areas, however, are of sufficient extent to deserve mention. Sikeston Ridge, or Big Prairie, is an elevated tract rising about 20 feet above the surrounding lowland, 2 to 4 miles wide, and extending from south of Lake St. John, Scott County, Mo., southward to New Madrid, in New Madrid County.

Another low ridge, resembling Sikeston Ridge, extends, with several interruptions, from the southern part of Stoddard County, Mo., a little west of south in a slightly sinuous course through Dunklin County, Mo., into the northern part of Mississippi County, Ark.; from north to south the different parts of this ridge are known, respectively, as Rosebriar Prairie, West Prairie, Grand Prairie, and Big Lake Highlands.

A belt of land, nowhere more than 5 or 6 miles wide, which borders Crowleys Ridge on the east from Clay County southward to the southern part of Craighead County, is a few feet higher than the main lowland to the east, and is underlain by "buckshot" clay soil similar to some of the prairie soils west of Crowleys Ridge, and may be of the same age (Pleistocene). This area is partly covered with materials washed from Crowleys Ridge.

Throughout the greater part of the Mississippi lowland the surface is underlain by dark, fertile loams, sandy loams, and sands, which support a vigorous growth of timber.

In a large area, including parts of New Madrid, Dunklin, and Pemiscot counties, Mo., and Clay, Greene, Craighead, Poinsett, and Mississippi counties, Ark., the ridges of sandy loam separating the depressions are dotted with so-called sand blows, which are low circular or irregular patches of clean white sand believed to have been extruded from underground sources during the time of the New Madrid earthquake in 1811 and 1812.[2] The sand blows contain but little vegetable mold and are poorly productive.

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[1] Fuller, M. L., The New Madrid earthquake: U. S. Geol. Survey Bull. 494, pp. 64–75, 1912.

[2] Idem, pp. 79–83.

SMALL MOUNDS.

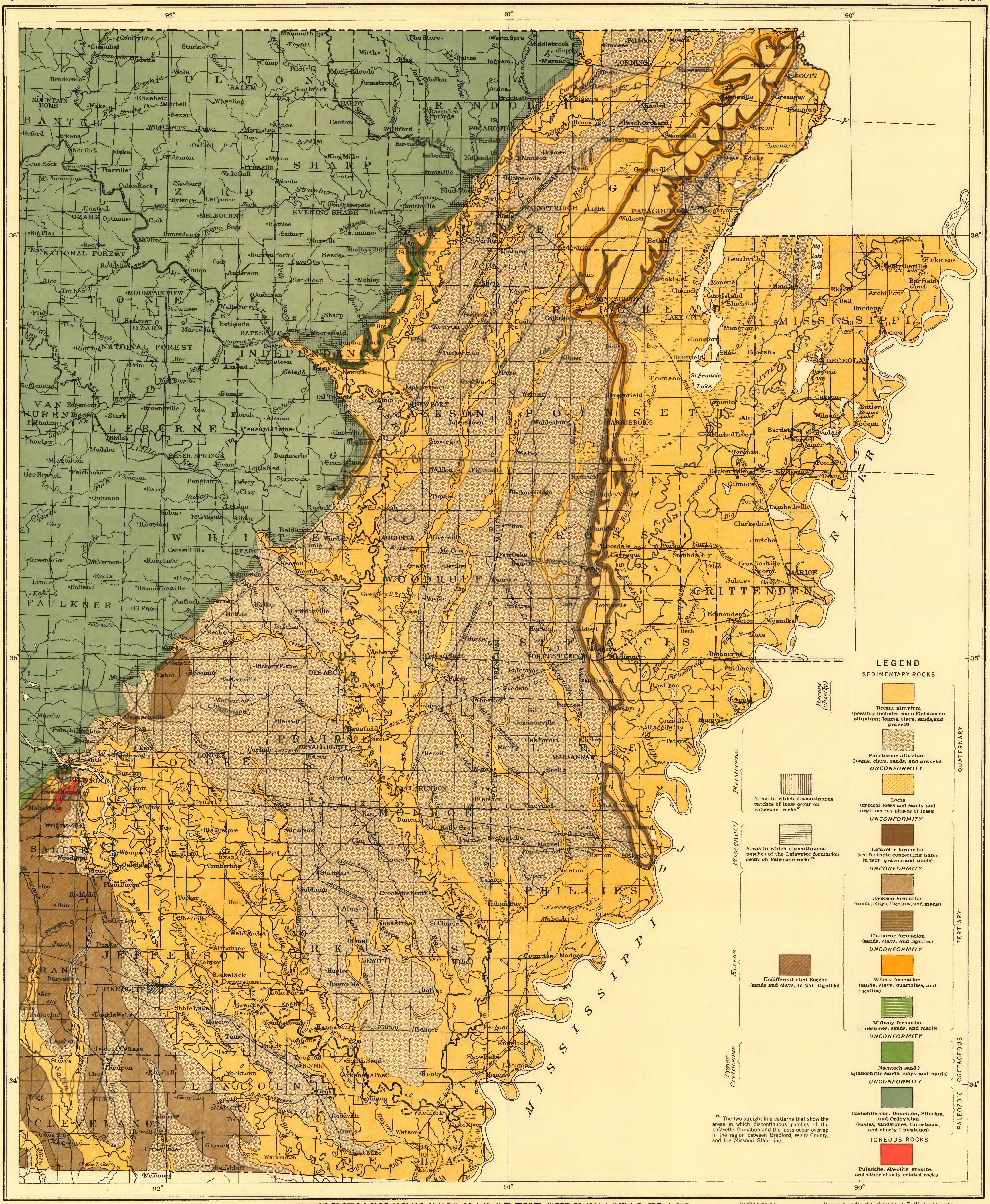
Low circular mounds, 20 to 100 feet in diameter and 1 to 4 feet high (see Pl. I, *B*), constitute a curious but minor topographic feature in certain parts of Arkansas and in places are numerous. Similar mounds of like origin in adjoining States have been described by Veatch.[1]

The writers have observed these mounds in Pulaski, Jefferson, Lonoke, White, Jackson, Independence, Lawrence, and Clay counties. The materials composing some of the mounds are slightly coarser and lighter in color than the surrounding soils, but others appear to be essentially like these soils in structure, composition, and color. The mounds are not restricted to any particular type of topography except that they were not observed on the flood plains of the present streams. They occur on the interstream areas of the Advance lowland, on the Coastal Plain uplands along the western border of the embayment, and on the slopes of the Paleozoic hills bordering the Coastal Plain.

No theory thus far proposed seems satisfactorily to explain the origin of the mounds. Veatch discussed the several hypotheses that have been advanced to account for them (pp. 56–59 of the report cited) and regarded the spring and gas-vent theories, the dune theory, and the ant-hill theory as most deserving consideration. The occurrence of the mounds in various topographic positions and on geologic formations of all ages from Cretaceous to Pleistocene would seem to render the spring and gas-vent theories untenable.

Their uniformly circular shape is believed to preclude the possibility of their having been formed by wind. The same objection seems to apply to the theory of their formation by ants or burrowing animals; besides, no such mounds are known to be in process of formation at the present time, and if formed by either of these agencies the species responsible for their construction, whether insect or rodent, has either migrated from the region or become extinct. The theory that they are of human origin is one that appeals strongly to the imagination, chiefly because of the remarkable symmetry of the mounds and their distribution. Their vast numbers in certain areas, however, would seem to preclude the possibility of their having been formed by man. For instance, along the line of the Texas & Pacific Railway between Texarkana and Annona, Tex., a distance of more than 50 miles, the mounds occur in astonishing numbers. Many fields are almost completely covered with them, the outer edges of many of

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 55–59, 1906.



R. B. Marshall, Chief Geographer
A. F. Hassan, Cartographer
Compiled in 1912 and 1913

PRELIMINARY GEOLOGIC MAP OF THE GULF COASTAL PLAIN OF NORTHEASTERN ARKANSAS

Scale $\frac{1}{500000}$

10 0 10 20 30 Miles

10 0 10 20 30 40 Kilometers

1916

Prepared under the direction of T. Wayland Vaughan by L. W. Stephenson and A. F. Crider.

The map of the area southwest of Arkansas River is essentially a copy of the map by A. C. Veatch, in Professional Paper 46, U. S. Geological Survey, 1906, Plate III. Other published geologic data have been drawn upon freely in the construction of the remainder of the map.

the mounds even being in contact with one another. In order to account for their construction by human beings it would seem necessary to postulate a prehistoric race numbering many millions.

GEOLOGY.

GENERAL COMPOSITION AND STRUCTURE OF THE AREA.

The Mississippi embayment is a broad arm of the Gulf Coastal Plain extending about 250 miles up the valley of Mississippi River to the southern extremity of Illinois. The area is surrounded on the west, north, and east by a territory in which are consolidated sedimentary rocks of Paleozoic age. Structurally the embayment is a down-warped trough of Paleozoic rocks filled to the level of the present surface with deposits, mostly unconsolidated, ranging in age from Cretaceous to Recent. The axis of the trough trends slightly west of south and the maximum depth, though not determined, probably exceeds 3,000 feet; the depth at Memphis has been shown by well borings to be more than 2,500 feet.

The areal distribution of the geologic formations which outcrop within the area treated in this report is indicated on the geologic map, Plate II. An idea of the structure of the Mississippi embayment may be had by referring to the geologic sections given in Plates III and IV. A–B–C–D (Pl. III) is a section along the linear direction of Crowleys Ridge from the northern extremity of the ridge in Stoddard County, Mo., to the southern extremity of the ridge in Phillips County, Ark.; E–F (Pl. III) is a section across the embayment from the vicinity of Supply, Randolph County, Ark., to a point 12 miles east of Paris, Henry County, Tenn.; G–H (Pl. IV) is a section across the embayment from Grandglaise, Jackson County, Ark., to a point 10 miles south of Decaturville, Decatur County, Tenn.; I–J (Pl. IV) is a section extending partly across the embayment from Little Rock, Pulaski County, Ark., to near Helena, Phillips County, Ark. In these sections the elevation of the upper surface of the Eocene is in most places represented too low, owing to the necessary exaggeration of the thickness of the Lafayette formation.

Deposits of Cretaceous age occupy the bottom of the trough and probably reach a maximum thickness of 2,000 feet or more. They outcrop in a relatively narrow belt along the eastern limb of the trough in Alabama, Mississippi, Tennessee, and southern Illinois, and along the western limit of the trough in the vicinity of Newark, Independence County, Ark.; they are also present at a relatively shallow depth along the border of the Ozark province from Little Rock, Pulaski County, northeastward to Beebe, White County.

The Cretaceous deposits are overlain by Eocene deposits, including in ascending order the Midway, Wilcox, Claiborne, and Jackson formations, 1,000 feet or more in aggregate thickness. These formations outcrop east of Mississippi River in Mississippi, Tennessee, Kentucky, and southern Illinois; they form the core of Crowleys Ridge in Arkansas; they outcrop in the Coastal Plain uplands of south-central Arkansas, and in small areas along the western margin of the embayment from Little Rock northeastward to the southern part of Independence County. In the broad belt of outcrop east of Mississippi River the Eocene deposits are partly overlain by gravels and sands of the Lafayette formation (Pliocene?) and the latter are in turn partly overlain by deposits of loess (Pleistocene). The same succession of surficial deposits occurs above the Eocene in Crowleys Ridge. On the crests of the Paleozoic hills bordering the embayment on the west and in places capping the Grandglaise terrace are scattered deposits of gravel, sand, and argillaceous loam, which probably represent, respectively, the Lafayette formation and the loess.

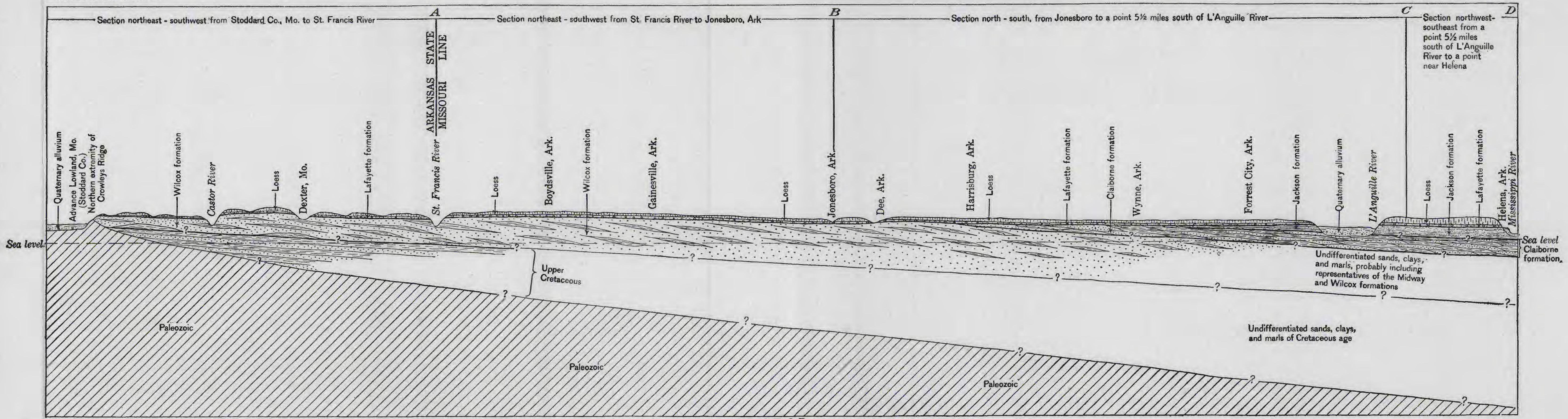
The Cretaceous and Eocene deposits, the overlying Lafayette formation, and the loess have been partly removed by the erosive action of Mississippi and Ohio rivers to depths of 100 to 225 feet below the present surface of the lowlands, and the valleys have been partly refilled by deposits brought in by the same streams. In this manner the Advance and Mississippi lowlands which cover the greater part of the area under consideration have been formed.

PALEOZOIC ROCKS.

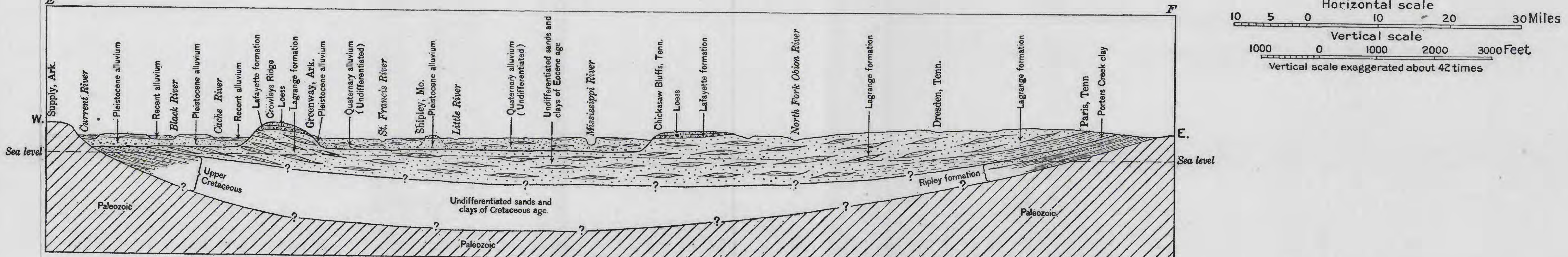
Outcropping Paleozoic rocks.—The area treated in this report is bordered on the northwest by the Ozark province. In the contact region between the Gulf Coastal Plain and the Ozark province the rocks composing the latter consist of Paleozoic limestones, sandstones, and shales, representing the Ordovician, Silurian, and Devonian systems, which outcrop from Independence County northward to the State line, and the Carboniferous system, which outcrop from Independence County southward to Pulaski County.

The pre-Carboniferous rocks of Independence, Lawrence, and Randolph counties, which are chiefly magnesian limestones of the Ordovician system and subordinately limestones of Silurian and sandstones and shales of Devonian age, lie nearly horizontal or are only gently folded. The Carboniferous rocks of Independence, Jackson, White, Lonoke, and Pulaski counties, which include representatives of both the Mississippian and Pennsylvanian series, consist mainly of cherts, shales, and sandstones, with, however, a subordinate amount of limetones; these rocks vary in position from nearly horizontal to strongly folded.

From Little Rock northeastward to Missouri the Paleózoic hills immediately west of the Gulf Coastal Plain rise 400 to 500 feet or



A-B-C-D



E-F

A-B-C-D, GEOLOGIC CROSS SECTION ALONG A LINE FOLLOWING THE TOP OF CROWLEYS RIDGE FROM THE NORTHERN EXTREMITY IN STODDARD COUNTY, MO., TO THE SOUTHERN EXTREMITY IN PHILLIPS COUNTY, ARK.
E-F, GEOLOGIC CROSS SECTION FROM A POINT NEAR SUPPLY, RANDOLPH COUNTY, ARK., TO A POINT 12 MILES EAST OF PARIS, HENRY COUNTY, TENN.

more above sea level, or 100 to 200 feet or more above the level of the Advance lowland to the east. The boundary is marked by a relatively abrupt escarpment which is believed to be a sea cliff formed along an early Eocene shore line.

Buried Paleozoic rocks.—The Paleozoic rocks are separated from the deposits of the Coastal Plain by a steep eastward-sloping nonconformable contact, which is the continuation beneath the surface of the ancient erosion escarpment that separates the Coastal Plain from the Ozark province. The contact maintains its relatively steep position to only a small depth, probably 20 to 50 feet, beyond which it flattens out and extends eastward beneath the deposits of the Coastal Plain at a slight dip, probably nowhere exceeding 75 feet to the mile. The buried Paleozoic rocks have been reached in numerous wells near the western margin of the Gulf Coastal Plain at depths ranging from 20 to 60 feet.

Little is known concerning the depth to the Paleozoic basement rocks in the Mississippi embayment except in close proximity to its outside rim. A few deep wells, however, have thrown some light on the subject.

A well at Newport, Jackson County, is believed to have entered the Paleozoic rocks at a depth of 655 feet.

A well at Stuttgart, Arkansas County, 40 miles southeast of the Paleozoic border, stopped on solid rock at a depth of 1,200 feet; the available data are insufficient to determine whether the rock was an indurated layer in the deposits of the Coastal Plain or the Paleozoic basement rocks.

A 1,265-foot well at Jonesboro, Craighead County, 30 miles from the Paleozoic border, did not reach the basement rocks.

A 960-foot well at Campbell,[1] Dunklin County, Mo., 24 miles from the Paleozoic border, also failed to reach the basement rocks.

A 960-foot well at Paducah, Ky., encountered Paleozoic limestone at a depth of 300 feet.

Two wells at Morehouse,[2] New Madrid County, Mo., 16 miles from the nearest outcrop of Paleozoic rocks, struck Cambrian limestone at depths of 690 and 696 feet, respectively.

A 2,007-foot well at Marked Tree, Poinsett County, Ark., 44 miles southeast of the Paleozoic border, did not reach the basement rocks.

A well near Memphis, Tenn., near the center of the Mississippi Embayment and about 145 miles south of the head of the embayment, was drilled to a depth of 2,500+ feet and did not reach the basement rocks.

[1] Shepard, E. M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, pp. 175, 176, 1907.

[2] Idem, p. 175.

MESOZOIC AND CENOZOIC FORMATIONS.

Generalized section.

A generalized section of the Mesozoic and Cenozoic formations of the Coastal Plain of eastern and northeastern Arkansas is given in the following table:

Generalized section of the Mesozoic and Cenozoic rocks of northeastern Arkansas.

System.	Series.	Formation.	Characteristics.	Thickness.
Quaternary.	Recent.		Alluvium; water-bearing.	*Feet.* 0-75
	Pleistocene.		Alluvium; yields large quantities of water.	100-200
			Loess; not an important water-bearer.	0-140
		Unconformity		
Tertiary.	Pliocene (?).	Lafayette formation.	Gravels and sands; water-bearing in part.	0-80
		Unconformity		
	Eocene.	Jackson formation.	Sands, clays, and marls; water-bearing in part.	0-200
		Claiborne formation.	Sands, clays, lignites, and marls; water-bearing.	100-200
		Unconformity (?)		
		Wilcox formation.	Sands, clays, and lignites; water-bearing.	500-1,000
		Midway formation.	Limestones, sands, and marls; probably water-bearing in buried extension.	a 22
		Unconformity		
Cretaceous.	Upper Cretaceous.	Nacatoch sand (?).	Glauconitic sands, clays, and marls; probably water-bearing in buried extension.	a 80
		Unconformity		
(Paleozoic rocks undifferentiated.)				

a Maximum observed thickness.

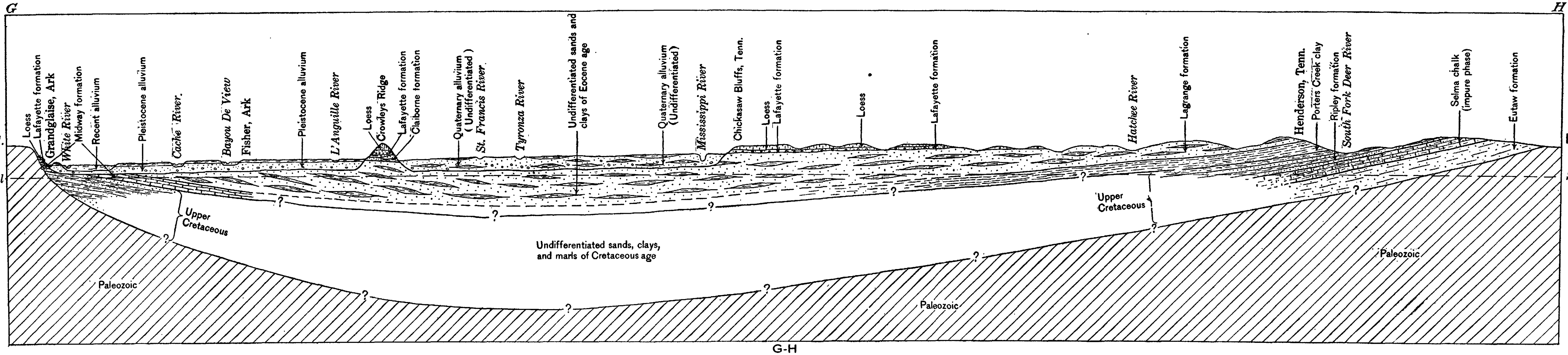
Cretaceous system.

IGNEOUS INTRUSIONS OF LATE LOWER CRETACEOUS OR EARLY UPPER CRETACEOUS AGE.

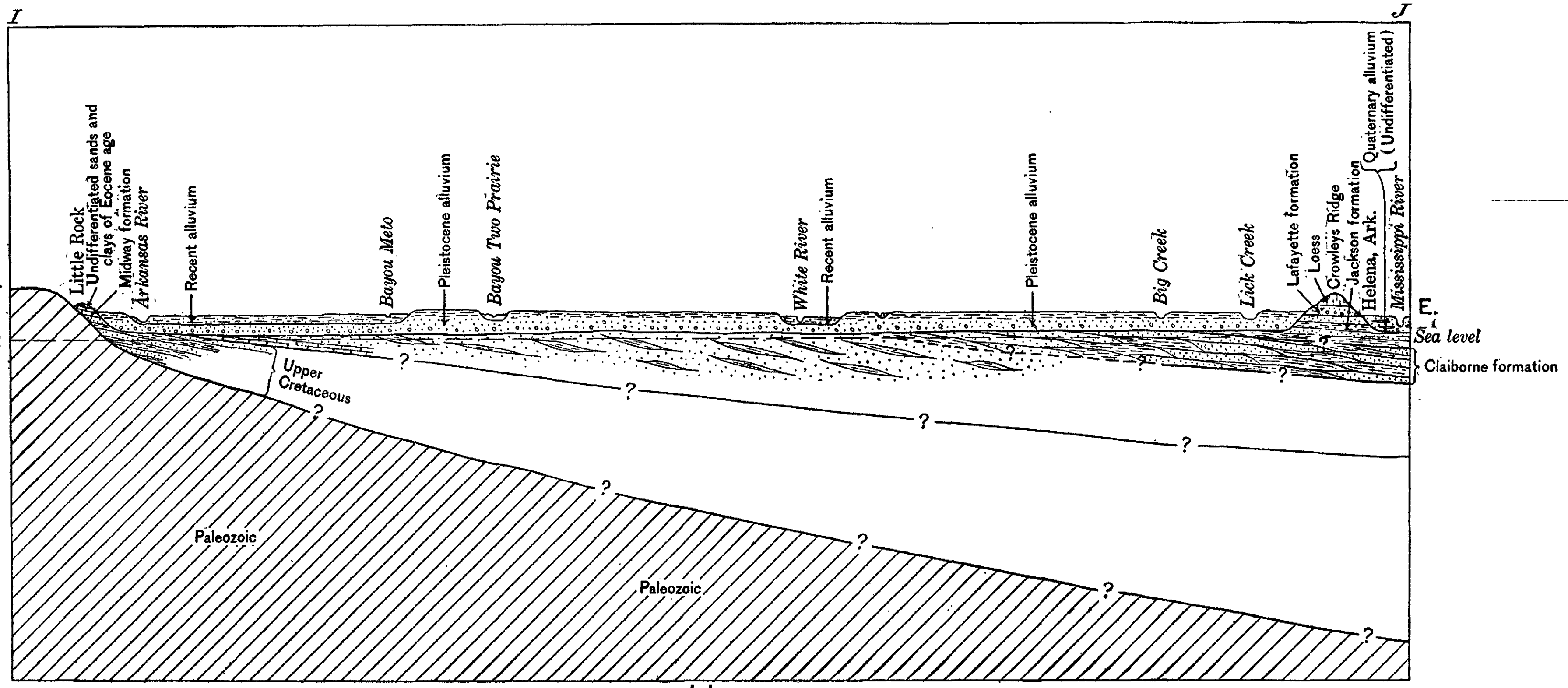
Igneous intrusive rocks occur in one small tract in the area covered by the geologic map (Pl. II) accompanying this report. This tract is in Pulaski County, a few miles south of Little Rock, and is known as the Fourche Mountain region. The igneous rocks consist of Pulaskite (blue granite), elæolite syenite (gray granite), and several other related varieties of rock. Associated with the igneous rocks and with the adjacent Tertiary sediments are important deposits of bauxite, the chief ore of aluminum.

Williams[1] regarded the age of these rocks as late Cretaceous or early Tertiary.

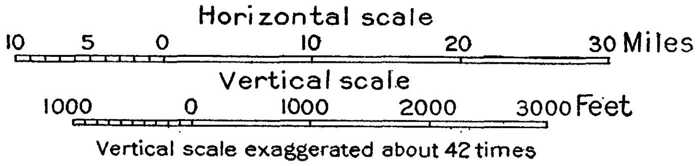
[1] Williams, J. F., The igneous rocks of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 2, pp. 5, 123, 1891.



G-H



I-J



G-H GEOLOGIC CROSS SECTION FROM A POINT NEAR GRANDGLAISE, JACKSON COUNTY, ARK., TO A POINT 10 MILES SOUTH OF DECATURVILLE, DECATUR COUNTY, TENN.
I-J, GEOLOGIC CROSS SECTION FROM A POINT NEAR LITTLE ROCK, ARK., TO A POINT NEAR HELENA, ARK.

Miser[1] has recently shown that the peridotites of southwest Arkansas, which are believed to be of approximately the same age as the igneous rocks near Little Rock, cut the Trinity formation (Lower Cretaceous), and that pebbles of several kinds of the igneous rocks of the region are included in the basal gravels of the Bingen sand (basal Upper Cretaceous). The Trinity and Bingen formations are separated by an unconformity and the intrusions must have occurred during the interval which it represents. In a more recent unpublished statement Miser expresses the opinion that the time of the intrusions was late Lower Cretaceous or early Upper Cretaceous, and they may have accompanied the downwarping that produced the transgression of the Upper Cretaceous sea in the Mississippi embayment.

UPPER CRETACEOUS SERIES.

CHARACTER AND DISTRIBUTION.

Strata of Upper Cretaceous age outcrop in a narrow area along the western border of the Mississippi embayment in Independence County; however, Cretaceous deposits are believed to be present beneath younger formations throughout practically all the area treated in this report. The buried deposits are believed to be referable to the Upper Cretaceous, although in the center of the Mississippi embayment Lower Cretaceous deposits may intervene between the base of the Upper Cretaceous and the Paleozoic basement rocks.

The data available indicate that the Cretaceous deposits consist chiefly of argillaceous and sandy marls, sands, and clays of marine origin and attain their maximum thickness in the south-central part of the Mississippi embayment; according to the interpretation of logs of wells at Memphis, Tenn., the deposits have been penetrated from a depth of 1,135 feet to a depth of over 2,500 feet, showing here a thickness of over 1,300 feet.

. The buried Cretaceous strata of this area are the northwestward and westward continuation of deposits that outcrop in Mississippi, Tennessee, Kentucky, and southern Illinois and the northeastward continuation of deposits that outcrop in southwestern Arkansas.

In southwestern Arkansas the Cretaceous deposits have been divided in ascending order into the Trinity sand of the Lower Cretaceous, and the Bingen sand, the Brownstown marl, the Annona chalk, the Marlbrook marl, the Nacatoch sand, and the Arkadelphia clay of the Upper Cretaceous. East of Mississippi River in the States enumerated the deposits have been divided in ascending order into the Tuscaloosa formation, the Eutaw formation, the Selma chalk, and the Ripley formation, all of Upper Cretaceous age.

[1] Miser, H. D., New areas of diamond-bearing peridotite in Arkansas: U. S. Geol. Survey Bull. 540, pp. 541–545, 1914.

Only meager data have been obtained for differentiating into formations the buried Cretaceous strata of the Mississippi embayment. The marls encountered in wells along the western border of the area at Little Rock, Cabot, and Beebe contain a fauna corresponding in age to the fauna of the Nacatoch sand in southwestern Arkansas, of the Navarro formation in Texas, and of the typical Ripley strata exposed in Tippah County, Miss. The meager fauna found in surface outcrops in the vicinity of Newark, Independence County, is certainly of Upper Cretaceous age, and, although too imperfect to admit of an exact correlation, the containing beds probably represent the northward extension of the Nacatoch sand.

Deep wells, which are believed to have penetrated strata of Cretaceous age, have been drilled in Jackson, Arkansas, Craighead, Mississippi, and Poinsett counties, Ark.; at Memphis, Tenn.; and at Campbell, Dunklin County, Mo. (see pp. 42–44); a Cretaceous fossil has been obtained from an excavation at Cairo, Ill.

NACATOCH SAND (?).

GENERAL FEATURES.

The name Nacatoch is derived from Nacatoch Bluff on Little Missouri River, Clark County, Ark., and was first used by Veatch[1] for a series of Upper Cretaceous sands in southwest Arkansas, which intervenes between the Marlbrook marl and the Arkadelphia clay. According to Veatch, the formation corresponds approximately to the Washington greensand of Hill,[2] but the latter name was found to be preoccupied by the Washington County group described by Stevenson[3] in 1876.

In northeastern Arkansas the deposits regarded as representing this formation outcrop in the Grandglaise terrace in gullies and along valley slopes from near Magness and Newark in Independence County northeastward to the southern part of Lawrence County.

In southwestern Arkansas the formation outcrops in a belt 2 to 8 miles wide, extending from near Arkadelphia, Clark County, southwestward to the western part of Hempstead County.

In Independence and Lawrence counties the formation rests unconformably upon Paleozoic rocks of Carboniferous and pre-Carboniferous age, and is overlain unconformably by gravels of the Lafayette formation. The buried representatives of the formation in White, Lonoke, and Pulaski counties rest unconformably upon Carboniferous rocks and are overlain, probably unconformably, by Eocene strata and chiefly by the Midway formation.

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 26, 27, 1906.

[2] Hill, R. T., The Neozoic geology of southwestern Arkansas: Arkansas Geol. Survey Ann. Rept., vol. 2, pp. 72–75, 1888.

[3] Pennsylvania Second Geol. Survey Rept. K, pp. 44–46, 1876.

Where observed in outcrops in Independence County the formation consists mainly of glauconitic sands interbedded with drab or gray laminated clays. The glauconite is present in all stages of oxidation, rendering the sands reddish or brownish in color, and locally the beds are indurated to brownish, ferruginous sandstones. Iron carbonate concretions in various stages of oxidation were observed at one locality, and calcareous and fossiliferous layers occur locally in the formation.

The materials of the formation recognized in wells in White, Lonoke, and Pulaski counties (pp. 40, 41) consist of bluish-gray calcareous fossiliferous sandstones and clays.

Owing to the small extent and paucity of the exposures, little is known concerning the structure of the formation in central and northeastern Arkansas. However, considerations based on the general structure of the Mississippi embayment lead to the opinion that the strata strike approximately northeast and southwest parallel to the trend of the eastern border of the Ozark province, and dip slightly to the east or southeast away from that border.

In the vicinity of Newark, Independence County, the formation contains a few poorly preserved fossil mollusks and shark teeth, and a few species of mollusks have been obtained from the beds of the formation penetrated in wells in White, Lonoke, and Pulaski counties. The names of some of the more important fossils are given in the discussion of the correlation of the formation on page 42.

LOCAL DETAILS.

Independence County.—In valleys and gullies cutting the Grandglaise terrace, in the vicinity of Newark, Independence County, are exposures of greenish to reddish or brownish, more or less completely oxidized greensand, interbedded with subordinate layers and lenses of laminated drab clay, the age of which as shown by poorly preserved fossils is Upper Cretaceous. Several localities were examined in detail and are described in subsequent paragraphs.

Two miles north of Newark, on the upper road leading to Sulphur Rock, the following section is exposed in the road ditches on the west-facing slope of Thomas Creek valley along a distance of about one-quarter mile.

Section 2 miles north of Newark on upper road leading to Sulphur Rock; west-facing slope of Thomas Creek valley.

[Top of section 100± feet above level of Advance lowland, aneroid reading.]

	Feet.
Pliocene (?) (Lafayette formation):	
3. Heavy bed of gravel capping the hill east of the creek valley; consists mainly of angular to partially rounded brown, gray, and red pebbles and cobbles of chert and flint up to 6 inches or more in length; materials from this bed have drifted down over the valley slope to the base of the hill	25±

Upper Cretaceous (Nacatoch sand?):	Feet.
2. Greenish-drab weathered clay, poorly exposed	25±
1. Dark-green to reddish or brownish, more or less oxidized, highly glauconitic sand, and drab laminated clay, the clay predominating in the upper 15 or 20 feet and the sand predominating in the lower 40 or 45 feet; the glauconite in the sand is present in all stages of oxidation from dark-green, slightly oxidized grains to completely oxidized grains; locally the sand is indurated to dark-brown ferruginous sandstone, and one such layer, 20 or 25 feet above the base, contains poorly preserved fossils, among which were recognized an unidentified coral, Exogyra (print of a small valve), *Turritella trilira* Conrad (?), and a shark tooth (field No. 270)	60
	110±

Two and one-half miles north of Newark, 20 or 25 feet of materials corresponding to layer No. 1 of the preceding section are exposed in a gully in a field just east of the road leading to Cord. The materials here consist of glauconitic greensand interbedded with layers of drab laminated clay, yellow ocher-like ironstone, and more or less completely oxidized concretions of iron carbonate, many of which have an unoxidized core. Ten or fifteen feet above the base of the section is a discontinuous concretionary layer of coarse, calcareous, glauconitic sandstone containing small black phosphatic pebbles and a few poorly preserved waterworn fossils; the individual lenses are several feet in length and 3 to 4 inches in thickness. The following Cretaceous fossils were recognized: *Ostrea tecticosta* Gabb, Ostrea sp. (young individual), and Anomia sp. (a ribbed form) (field No. 271).

In a gully on a public road leading west from the Magness-Sulphur Rock road, about 1 mile north of Magness and 3 miles west of Newark, the following section is exposed:

Section in public road leading west from the Magness-Sulphur Rock road, 1 mile north of Magness.

[Top of section 100± feet above level of Advance lowland, aneroid reading.]

Pleistocene (?) (loess?):	Feet.
Yellowish and brownish pebbly loam capping the hill	2–3
Pliocene (?) (Lafayette formation):	
Gravel composed of pebbles and cobbles of flint and chert up to 8 or 10 inches in length	3–4
Unconformity.	

	Feet.
Upper Cretaceous (Nacatoch sand?):	
Red oxidized glauconitic sand, locally indurated to ferruginous sandstone, with interbedded subordinate layers of laminated clay	20
Gravel composed chiefly of pebbles of flint and chert, with some fragments of sandstone; the pebbles are angular to smoothly rounded, are gray, black, and brown, and reach 3 or 4 inches in length	½–1
Unconformity.	
Paleozoic (Carboniferous):	
Dark compact shale	15
	43±

Soft fossiliferous limestone or marl, which probably belongs to the Nacatoch sand, is encountered in wells at and near Newark. However, none of the fossiliferous material has been saved for examination. Specific localities, where the material has been reported, are a well in Newark, where 3 feet of gray limestone or marl containing mollusks and shark teeth was penetrated between the depths 18 and 21 feet (see log, p. 194), and 2 miles north of Newark, where, in a phosphate prospecting pit, dug to an undetermined depth, a similar bed of marl was encountered.

The exposures described show that the body of the Grandglaise terrace in the vicinity of Newark is composed of strata of Upper Cretaceous age, probably representing the northward extension of the Nacatoch sand of southwest Arkansas. The Cretaceous is overlain by gravels of the Lafayette formation, reaching a maximum thickness of 25 or 30 feet, and above the latter is a thin layer, not everywhere present, of sandy and pebbly loam, believed to represent the loess of Crowleys Ridge.

Between Newark, Independence County, and Strawberry, Lawrence County, stratified sands and clays, probably of the same age as the Cretaceous strata in the vicinity of Newark, are exposed in places in the Grandglaise terrace, and have been examined at the following-described localities:

Three miles north of Newark, on the Newark-Powhatan road, alternating beds of sand and pinkish-gray clay rest upon Paleozoic sandstone.

In sec. 2, T. 13 N., R. 4 W., alternating beds of red sand and gray clay are exposed near the top of the terrace, which is here well developed and rises about 90 feet above Black River bottom.

Between Dota and Cord the terrace is 2 to 3 miles wide. Highly stratified sands and clays were observed to maximum heights of 70 to 90 feet above the level of Black River bottom; gravels of the Lafayette formation and yellow loams, probably representing the loess of Crowleys Ridge, overlie the sands and clays at many places.

Stratified sands and clays were observed in the vicinity of Saffel post office (now discontinued). Three-quarters of a mile north of

Saffel a few feet of gray to blue clay, interstratified with red sand and overlain by 2 to 10 feet of yellow loam, is exposed; the loam resembles certain facies of loess in Crowleys Ridge and is believed to be of the same age as the loess (Pleistocene). The loam forms the surface material of the terrace from about 3 miles south of Saffel to Strawberry, in Lawrence County.

South of Independence County.—Most of the known data regarding the existence of buried deposits of Cretaceous age along the western border of the Mississippi embayment, south of Independence County, have been published by Harris.[1] With reference to specimens of marl encountered in wells at Beebe, White County, at depths not exceeding 64 feet, Harris says:

A fragment of this marl from Beebe was obtained by the present writer from the State Survey collection, and when examined its Cretaceous characters were definitely ascertained. The matter was accordingly submitted to the Mesozoic Division of the United States Geological Survey, and Dr. T. W. Stanton reports finding in it the following species of Cretaceous (Ripley) fossils:

Nucula percrassa Conrad.
Gari? elliptica Gabb.
Veleda lintea Conrad?
Scaphites conradi (Morton).
Baculites anceps Lamarck.
Placenticeras sp.

Harris gives other data as follows:

Lonoke County.—Among some material sent to the United States Geological Survey in 1890 by Dr. Branner are three or four fragments of *Exogyra costata* labeled "Well at Cabot Station, Iron Mt. R. R., Lonoke Co., Arkansas, sec. 18, 4 N., 9 W.; E. C. Buchanan, collector, April, 1873." Another package, marked "Well at Cabot, Hendricks," contains numerous specimens of an Anomia and *Cardium eufaulense?* and other more indistinct forms, all imbedded in a bluish gray calcareous sandstone resembling closely the concretionary rocks of the upper Ripley group.

From a well at Cabot, known as the Nusury well, owned by Mr. George P. Murrell, the junior author of the present report obtained fossiliferous material, taken between the depths of 20 and 46 feet, which on lithologic grounds are separable into dark-gray calcareous clay, with numerous fragments of shells, in part arranged in seams and pockets, and gray calcareous stndstone.

Among the poorly preserved fossils in the clay the senior author has identified the following forms: *Leda pinnaforma* Gabb, *Anomia argentaria* Morton?, Crassatellites sp., Cardium sp., *Cyprimeria depressa* Conrad, Scaphites sp. In the sandstone he recognized Nucula sp., Glycymeris sp. (young individual), Anomia sp. (ribbed form), and *Cardium eufaulense* Conrad.

In regard to the Cretaceous strata in Pulaski County, Harris says:

Pulaski County.—It is at present impossible to say to what extent the Eocene deposits of Pulaski County are underlaid by Cretaceous. In the vicinity of

[1] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 10–15, 1894.

Little Rock, however, there is good, though not absolutely positive evidence, that beneath the limestone layer of the Midway Eocene there are Cretaceous deposits from 10 to 30 feet in thickness. A package was sent to the United States Geological Survey by Dr. Branner, marked "J. S. Taylor's well, West 7th Street, near Bishop Street, Little Rock; E. C. Buchanan, collector, July, 1875," containing the following Cretaceous forms:

Anomia (as at Cabot).
Cardium eufaulense?
Leptosolen biplicata (Stanton's identification).
Turritella trilira.

The striking similarity between the matrix and fossils from this locality to those found at Cabot has led to the suspicion, though perhaps ungrounded, that all may have come from the latter place and at some time had been improperly labeled. Yet, even though this be true, there are other evidences which go far to show that there are Cretaceous deposits within the limits of the city of Little Rock.

Harris[1] also describes several exposures of bog iron ore, ferruginous sand and clay, and sand, which he believes to be of Cretaceous age, at several localities within the city of Little Rock. These beds underlie strata of undoubted Midway (Eocene) age and the ferruginous bed in places contains obscure casts of fossils, among which are questionably identified impressions of Baculites and *Exogyra costata.* These localities are as follows:

Intersection of Nineteenth Street or "Hot Springs road" and the St. Louis, Iron Mountain & Southern Railway; 10 feet of bog iron ore overlain by 20 feet of white and yellow sand.

The flanks of the depression in western Little Rock through which the St. Louis, Iron Mountain & Southern Railway passes.

The corner of Sixth and Wolfe streets; ferruginous concretions with obscure casts.

On Twelfth and Thirteenth streets, west of the St. Louis, Iron Mountain & Southern Railway, about 100 yards south of the Hot Springs road; ferruginous bed with indistinct impressions of fossils.

The data indicate the presence of Upper Cretaceous strata, probably representing the Nacatoch sand, at a relatively shallow depth along the western margin of the Mississippi embayment from Little Rock at least as far north as Beebe, White County.

CORRELATION.

Surface deposits in the vicinity of Newark, Independence County, have yielded the following species:

Species from Cretaceous deposits exposed near Newark, Independence County.

Unidentified coral.	Anomia sp. (ribbed form).
Ostrea tecticosta Gabb.	Turritella trilira Conrad (?)
Ostrea sp. (young individual).	Unidentified shark tooth.
Exogyra (print of small valve).	

[1] Harris, G. D., op. cit., pp. 13, 14.

The fossils enumerated are characteristic Upper Cretaceous forms, but those identified specifically, with the possible exception of the ribbed Anomia, have rather wide vertical ranges within the Upper Cretaceous and are therefore not of much value in establishing an exact correlation with known sections elsewhere. In terms of the Upper Cretaceous section of southwestern Arkansas, both *Ostrea tecticosta* Gabb and *Turritella trilira* Conrad might be taken as indications of any one of the Upper Cretaceous formations, from the Brownstown marl to the Arkadelphia clay, inclusive. So far as known, the type of Anomia found at this place is restricted in range to the upper part of the Upper Cretaceous, and this form probably limits the possible correlation of the beds to either the Nacatoch sand or the Arkadelphia clay. The highly glauconitic character of the deposits, however, is strong though not conclusive evidence that they represent the northward extension of the Nacatoch sand.

This correlation is strengthened by the evidence afforded by certain of the Cretaceous fossils found in wells in Lonoke and White counties, such as *Exogyra costata* Say, *Gari? elliptica* Gabb, *Scaphites conradi* (Morton), and *Baculites anceps* Lamarck. (See p. 40.) In known sections these fossils are restricted in range and indicate that the containing beds are approximately synchronous with the Nacatoch sand. The deposits in the vicinity of Newark, Independence County, are believed to be the northward continuation of these buried strata.

CRETACEOUS STRATA PENETRATED IN WELLS AND EXCAVATIONS.

Well at Newport, Jackson County.—A 1,000-foot well at Newport, Jackson County, a log of which is given on page 197, passed through 500 feet of quicksand between depths of 155 and 655 feet; the quicksand is probably referable in part or in whole to the Cretaceous.

Well at Stuttgart, Arkansas County.—In 1906 and 1907 a 1,200-foot oil-prospecting well was drilled near Stuttgart, Arkansas County. (See incomplete log on p. 152.) Glauconitic sand, which may be referable to the Cretaceous, was penetrated between the depths of 950 and 1,078 feet.

Wells at Jonesboro, Craighead County.—At the city waterworks plant at Jonesboro, in Craighead County, two wells have been drilled to depths of 1,214 and 1,265 feet, respectively. An approximate log of the deeper well is given on page 169. It is believed that several hundred feet of Cretaceous strata were penetrated in the lower part of the boring.

Wells in Mississippi County.—Wells in Mississippi County at Blytheville (depth 1,448 feet), at Burdette (depth 1,495.5 feet), and at Wilson (depth 1,567 feet) entered the Cretaceous and probably penetrated several hundred feet of strata of that age in the lower parts of the borings. Incomplete logs of the Blytheville and Burdette wells are given on pages 225 and 226.

Well at Marked Tree, Poinsett County.—A 2,007-foot well at Marked Tree, in Poinsett County, probably penetrated not less than 1,000 feet of Cretaceous strata in its lower part. (See p. 245.)

Wells at Memphis, Tenn.—Several deep wells have been drilled at Memphis, Tenn. The logs of two of them, the depths of which are, respectively, 1,583 and 1,794 feet, are quoted on pages 176 and 177. In 1911–12 an oil-prospecting well was drilled on Old Hen and Chicken Island, near Memphis, to a depth of 2,500+ feet. No fossils have been obtained from these wells and the attempted correlations were based on the lithologic character of the materials penetrated. According to Ashley's interpretation of the log of oil-prospecting well No. 1 on Hen and Chicken Island, quoted on page —, 155 feet of blue clay, penetrated between the depths 980 and 1,135 feet, represents the Porters Creek clay (Eocene); 454 feet of sand and clay, sand predominating, between the depths 1,135 and 1,589 feet, represent the Ripley formation (Upper Cretaceous); clay and sand, clay predominating, between the depths 1,589 feet and the bottom of the well at 1,794 feet, represent the Selma chalk (Upper Cretaceous).

According to information obtained by correspondence with Mr. H. L. Armstrong, of Memphis, the oil-prospecting well on Old Hen and Chicken Island is believed to have completely penetrated the clay representing the Selma chalk at a depth of 2,375 feet, making a total thickness of 786 feet for this formation. If this interpretation is correct, the well penetrated at least 125 feet of the Eutaw formation which underlies the Selma.

Well at Campbell, Dunklin County, Mo.—A 960-foot well at Campbell, Dunklin County, Mo., a log of which is quoted on page 163, is believed to have penetrated Cretaceous strata. According to Shepard, who published the log, the lower 20 feet of the section is of Ripley (Upper Cretaceous) age, but possibly a part of the overlying clay is also of Cretaceous age.

Excavation at Cairo, Ill.—Definite evidence of the presence of Upper Cretaceous strata as far north as southern Illinois is afforded by a fossil shell found near Cairo, Ill. The following data are quoted from a paper by the senior author:[1]

> This specimen was discovered in an excavation for a bridge pier and later came into the possession of the State Museum at Springfield, Ill. Thence it was sent to Dr. C. A. White, at the National Museum, Washington, D. C., and was identified by him as *Exogyra costata* Say. Recently the specimen was again sent to Washington by request and was determined by the writer to be

[1] Stephenson, L. W., The Cretaceous deposits of the eastern Gulf region: U. S. Geol. Survey Prof. Paper 81, p. 18, 1914.

a typical specimen of *Exogyra costata* var. *cancellata* Stephenson. The information given on the label accompanying the specimen is as follows: " Specimen No. 8358 of the State Natural History Museum, Springfield, Ill. Locality: Bottom of Ohio River; found in sinking a caisson for Illinois Central Railroad bridge near Cairo, Ill." The shell was not waterworn. Portions of the matrix in which the shell was originally embedded, adhering to the surface, consisted of fine, gray, calcareous, argillaceous, micaceous, marine sand. Although from the account of its discovery it can not be positively asserted that this specimen of Exogyra was in its original position in marine sand where found, the assumption that it was in place seems reasonable. Whether this marine sand exists as a lens in the predominantly shallow-water beds of the McNairy sand member [of the Ripley formation] or constitutes a northward extension of the stratigraphically lower, purely marine strata of the Ripley formation of Tennessee, which in Kentucky and Illinois have become overlapped and buried by the beds of the McNairy sand member, is not definitely known. However, on the assumption that the specimen belonged in place where found, the Cretaceous sea is shown to have extended, probably as a broad, open embayment, as far north as Cairo.

Tertiary system.

DISTRIBUTION.

Within the area here treated deposits of Tertiary age (Eocene) outcrop in Crowleys Ridge, in the upland southwest of Arkansas River, and, interruptedly, in a narrow belt along the western border of the Mississippi embayment from Little Rock, Pulaski County, at least as far northeast as the southern part of Independence County; if the scattered deposits of gravel which occur along the border of the Ozark province belong to the Pliocene, the Tertiary is represented all the way to the Arkansas line. Detailed descriptions of nearly all the more conspicuous exposures and of many of the less prominent ones have appeared in previous publications. It is not the purpose of this report to give a comprehensive account of all known localities of Tertiary rocks in the area, but those furnishing the most complete sequence of strata, those furnishing paleontologic data, and those which for other reasons are of especial interest will be described.

The Tertiary is represented by the Eocene series and, questionably, by the Pliocene series.

EOCENE SERIES.

FORMATIONS DIFFERENTIATED.

The Eocene deposits of the area have been differentiated only imperfectly, chiefly owing to lack of sufficient paleontologic data; however, evidence has been obtained to show the presence of strata representing the Midway, Wilcox, Claiborne, and Jackson formations.

The Midway formation outcrops along the western border of the Coastal Plain in the vicinity of Little Rock, Pulaski County, and in Lonoke, White, Jackson, and Independence counties. Undifferentiated strata of Eocene age outcrop in an elevated area in the northwestern part of Lonoke County.

Strata of Eocene age outcrop in places along the border of the Coastal Plain upland southwest of Arkansas River. These strata include the Midway formation in Pulaski County; undifferentiated Eocene strata in Pulaski, Sabine, Grant, and Jefferson counties; and the Jackson formation in Jefferson, Cleveland, and Lincoln counties.

The core of Crowleys Ridge, from a few feet to 100 feet or more above the level of the lowlands both east and west, is composed of irregularly and regularly bedded sands and clays, interbedded with subordinate layers and lenses of lignite. These deposits are of Eocene age and on the evidence of fossil plants and invertebrates may be roughly differentiated, in the ascending order of their age, into the Wilcox formation, the Claiborne formation, and the Jackson formation.

By combining paleontologic and physical criteria an attempt has been made to determine the areal distribution of each of the formations named, but the mapping is confessedly only an approximation to the true distribution.

MIDWAY FORMATION.

GENERAL FEATURES.

Name.—The name Midway[1] was first used by Smith and Johnson in 1887 for light-colored argillaceous limestone with projecting ledges and yellowish sands, exposed at Midway Landing and on Pine Barren Creek in Wilcox County, Ala., and traceable westward through Wil-

[1] The principal contributions to the subject of the Midway formation are listed below.

Smith, E. A., and Johnson, L. C., Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, pp. 62–67, 70, 1887.

Langdon, D. W., Geological section along the Chattahoochee River from Columbus to Alum Bluff: Georgia Geol. Survey First Report Progress, p. 95, 1891.

——— Variations in the Cretaceous and Tertiary strata of Alabama: Geol. Soc. America Bull., vol. 2, pp. 594, 595, 1891.

Spencer, J. W., Geological report on southwest Georgia: Georgia Geol. Survey First Report Progress, pp. 44–46, 1891.

Harris, G. D., The Tertiary geology of southwestern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 8, 9, 22–54, 1894.

——— The Midway stage: Bull. Am. Paleontology, vol. 1, No. 4, pp. 115–270 (1–156), 1896.

Dall, W. H., A table of the North American Tertiary horizons, correlated with one another and with those of western Europe, with annotations: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, p. 346, 1898.

Harris, G. D., and Veatch, A. C., A preliminary report on the geology of Louisiana: Louisiana Geol. Survey, pt. 5, pp. 63–73, 1899.

Vaughan, T. W., The Eocene and lower Oligocene coral faunas of the United States: U. S. Geol. Survey Mon. 39, p. 25, 1900.

Veatch, Otto, and Stephenson, L. W., Tertiary and Quaternary [Georgia]: Georgia Geol. Survey Bull. 26, pp. 216–226, 1911.

Vaughan, T. W., Texas, Louisiana, and Arkansas [Eocene of]: U. S. Geol. Survey Prof. Paper 71, pp. 723–725, 1912.

cox and Marengo counties to Tombigbee River. The terrane as thus defined formed the basal member of the so-called "Lignitic" and rested on the Cretaceous. In 1894 Harris redefined the application of the name, making it include all the beds between the top of the Cretaceous and the base of the "Lignitic," the latter name being restricted to the lignite and leaf-bearing clays and sands. He says:

The term "Midway series" was used by Smith and Johnson in 1887 to designate a calcareous formation lying at the base of the Eocene of Alabama, and was classified by them as a subdivision of the "Lignitic" (Eolignitic of Heilprin). Owing, however, to its persistent nature, occurring, interruptedly to be sure, from Georgia to western Texas, and to its generally marked lithological and paleontological differences from the remainder of "Lignitic" deposits, it seems advisable to make the terms of coordinate rank.

In a footnote he adds:

It is quite probable that the Black Bluff and Matthews Landing beds in Alabama should be classed in the Midway stage.

The Flatwoods clays of Hilgard[1] in Mississippi, the Porters Creek group of Safford[2] in Tennessee, and the Middleton formation of Safford[3] in Tennessee, Mississippi, and Alabama, represent parts or all of the Midway formation.

Areal distribution.—In Arkansas the Midway formation has been traced in surface outcrops in a belt a few miles wide, extending from a point near Rockport, on Ouachita River (west of Malvern), in Hot Springs County, northeastward along the western border of the Gulf Coastal Plain to Little Rock, Pulaski County. Northeast of Little Rock the formation has been recognized in wells and in outcrops at the following places: Questionably in a well at Jacksonville, Pulaski County; in wells and in outcrops at and near Cabot, Lonoke County; questionably in a well at Beebe, White County; in outcrops in an area not exceeding one-half mile in width, extending from the vicinity of Bradford, White County, to Depart Creek, in the southern part of Independence County.

East of Mississippi River the Midway formation outcrops in a belt a few miles wide extending from central Georgia along the southern border of the area of outcrop of the Upper Cretaceous westward through Alabama and northward through Mississippi to Hardeman County, Tenn. From Hardeman County northward through Tennessee and Kentucky to southern Illinois the Midway is represented at least in part by the Porters Creek clay.

[1] Hilgard, E. W., Agriculture and geology of Mississippi, 1860, pp. 110, 111: Am. Assoc. Adv. Sci. Proc., vol. 20, p. 222, 1871; Am. Jour. Sci., 3d ser., vol. 2, p. 391, 1871.

[2] Safford, J. M., The Cretaceous and Superior formations of west Tennessee: Am. Jour. Sci., 2d ser., vol. 37, pp. 368, 369, 1864.

[3] Safford, J. M., Notes on the Middleton formation of Tennessee, Mississippi, and Alabama: Geol. Soc. America Bull., vol. 3, pp. 511, 512, 1891.

Stratigraphic relations.—The formation in Arkansas rests upon strata of Upper Cretaceous age, except immediately along the western border of the Mississippi embayment, where the beds overlap slightly on the Paleozoic rocks. This relation is determined on the evidence of Cretaceous fossils found in wells at Beebe, White County; at Cabot, Lonoke County; and at Little Rock, Pulaski County; and on the occurrence of strata of probable Cretaceous age immediately beneath beds of undoubted Midway age in outcrops at Little Rock. The nature of the contact between the Cretaceous and the Midway formation has not been determined by observation, but from paleontologic evidence the relation may be inferred to be that of nonconformity. The same marked faunal contrast exists here between the Upper Cretaceous and the Midway formation as exists in Alabama between the Ripley formation and the Midway formation, which are known to be separated by an unconformity of regional extent.

Southwest of Arkansas River the Midway formation is overlain by undifferentiated strata of Eocene age. Northeast of Arkansas River, along the western border of the Mississippi embayment, the formation is overlain in part by undifferentiated strata of Eocene age, in part by deposits of questionable Pliocene age (Lafayette formation), and in part by Quaternary alluvial deposits.

Lithologic characters.—The formation in Arkansas consists of gray, more or less sandy and argillaceous limestones, some layers of which are crystalline, interbedded with calcareous sand or friable sandstone and marl. Fossil mollusks and shark teeth characterize the terrane, and in places the molluscan remains are present in great numbers, either intact, in fragments, or as casts and impressions.

Strike, dip, and thickness.—The strike of the strata composing the Midway formation in Arkansas is approximately northeast-southwest, parallel to the western border of the Mississippi embayment. In single outcrops, all of which are small, the beds appear to be nearly horizontal; probably, however, they dip slightly to the southeast at right angles to the border of the Ozark province, this being the general attitude of the Eocene strata of the embayment with respect to the bordering Paleozoic rim. The formation doubtless extends southeastward beneath the younger Eocene and the Quaternary deposits and reaches greater depths in that direction.

The maximum observed thickness of the formation in the area is in a cut of the St. Louis, Iron Mountain & Southern Railway, one-fourth mile south of Grandglaise, Lonoke County, where 22 feet of strata is exposed.

Physiographic expression.—Where exposed in White, Lonoke, and Independence counties the formation forms the base of a more or less clearly defined terrace or ridge, designated the Grandglaise terrace, the crest of which is 250 to 290 feet above sea level, or 40 to 80 feet above the level of the lowland to the east. The preservation of this erosion remnant is due, at least in part, to the relatively resistant character of the limestones of the formation.

Paleontologic character.—The formation is fossiliferous, yielding chiefly mollusks, although shark teeth are fairly abundant locally, and occasional fragments of crustaceans and echinoids have been found. The mollusks vary in their state of preservation from nearly perfect specimens to traces and fragments or molds and casts.

A list of the species identified from the formation is given in the discussion of correlation on page 53.

LOCAL DETAILS.

Pulaski County.—The Midway formation is exposed at numerous places in Little Rock and from Little Rock southwestward through Pulaski and Saline counties nearly to Rockport (west of Malvern) in Hot Springs County; in the same belt the formation is frequently reached in wells. Harris[1] has compiled the available data on this area, including the results of his own observations. The most complete section given by him is on Fourche Creek near the mouth of Crooked Creek, 8 or 9 miles southwest of Little Rock, in the NW. ¼ SW. ¼ sec. 8, T. 1 S., R. 13 W. He describes the locality in substance as follows:

Section on Fourche Creek, near the mouth of Crooked Creek, Pulaski County.

	Feet.
Soil	2
Yellowish and gray, more or less friable limestone; replete with *Enclimatoceras ulrichi* varying in size; the exterior of many of the fossils stained brownish by iron oxide	1½
Light-gray limestone containing innumerable specimens of *Ostrea pulaskensis* Harris	3
Light-yellowish and gray, somewhat sandy limestone, honeycombed and cavernous on weathered surface; at base replete with specimens of *Turritella mortoni* Conrad	8¼
Light-yellowish calcareous sandstone forming a ledge	2¾
White and black sand, tinged with yellow on the exterior, containing scattered blue nodules	2
Black shale exposed only at times of very low water	?
	19½+

[1] Harris, G. D., The Midway stage: Bull. Am. Paleontology, vol. 1, No. 4, pp. 130–132 (16–18), 1896.

Fossils specifically identified from this locality are:

Fossils from Fourche Creek, near the mouth of Crooked Creek, Pulaski County.

Cucullæa macrodonta Whitfield.
Ostrea crenulimarginata Gabb.
Ostrea pulaskensis Harris.
Venericardia planicosta Lamarck.
Calyptraphorus velatus Conrad.
Natica alabamiensis Whitfield.
Turritella mortoni Conrad.
Turritella multilira Whitfield.
Turritella alabamiensis Whitfield.
Potamides alabamiensis Whitfield.
Tubulostium dickhauti White.
Enclimatoceras ulrichi White.
Callianassa ulrichi White.

Northeast of Little Rock the formation is thought to have been encountered in a well at Jacksonville located on the property of A. J. McBride and drilled in 1904; a log of this well has been furnished by the owner and is given on page 259. The limestone penetrated between the depths 70 and 82 feet probably belongs to the Midway formation.

Lonoke County.—In the vicinity of Cabot, Lonoke County, a limestone belonging to the Midway formation is known to occur at the surface, and limestones and marl, probably belonging in part to this formation, are encountered in numerous wells and cisterns. However, some of the marls penetrated in wells have been shown to belong to the Upper Cretaceous, which underlies the Midway. (See p. 40.) Logs of two wells at Cabot are given on page 217.

Harris[1] gives the following data:

Farther to the southwest, in Lonoke County, the Midway stage appears in the vicinity of Cabot. A specimen of more or less friable limestone collected by the survey is filled with fragments of oyster shells.

On the line between sec. 18, T. 4 N., R. 9 W., and sec. 13, T. 4 N., R. 10 W., midway of the line (station 2230), Mr. J. A. Taff obtained specimens of:

Ostrea (young shells).
Turritella mortoni (cast).
Shark teeth and vertebræ.
Fragment of light-gray firm limestone.

Mr. E. C. Buchanan collected at T. 3 N., R. 11 W., sec. 12, NW. ¼ of SW. ¼, about 600 feet northwest of Henry's store (station 2444), a specimen of limestone closely resembling those obtained at station 2436 [near Bradford, White County], though no fossils besides Ostrea are determinable in it.

White County.—At Beebe, White County, and for a mile or so west of that place, marl which may be referable in part to the Midway formation is struck in wells at depths of 25 to 40 feet. Upper Cretaceous fossils have been recognized, however, in specimens of marl from this place, and it is certain that the Midway, if present, is underlain by the Cretaceous. (See p. 40.)

[1] Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 25, 26, 1894.

Call[1] has published a section constructed by combining a section exposed in a prospecting shaft, near Beebe, and the log of a near-by well. He says:

About 60 miles north of the Arkansas River localities just mentioned, near the village of Beebe, in White County, in T. 5 N., R. 8 W., SW. ¼ of SW. ¼ of sec. 5, there is exhibited a very instructive section in a shaft sunk to reach Eocene shell marls for commercial purposes. The locality is on the farm of Mr. Cyrus Heller. To the section as shown in the shaft there is added the record of a well driven a few hundred feet southwest of it. The position of the section near the western limit of the Tertiary area, which is less than 2 miles away, renders it of exceptional interest.

The section given by Call is in substance as follows:

Combined section of an exposure in a prospecting shaft near Beebe and the log of a near-by well.

	Thickness.	Depth.
	Feet.	*Feet.*
Humus	1	1
Whitish sandy clay, grading downward into red clay; in lower half, scattered pebbles of chert having a maximum diameter of 2 or 3 inches	10	11
Hard red, finely arenaceous clay	4	15
Light-colored stratified sandy clay containing an abundance of white chert pebbles and a few white sandstone pebbles	13	28
Argillaceous material with comminuted shell fragments; contains fragments of Dentalium, specifically undeterminable	1	29
Blue argillaceous material, with scattered pockets of greensand, containing an abundance of broken marine shells and a few perfect ones; recognized *Venericardia planicosta* Lamarck, *Turritella carinata* Lea [?]	35	64
(Unconformity).		
Soft blue shale of Carboniferous age; stopped drilling on hard white sandstone	47	111

The marl between the depths 29 and 64 feet is probably separable into two parts, the upper representing the Midway formation, from which the Tertiary fossils recognized by Call were taken, and the lower representing the Upper Cretaceous, from which the specimen of marl mentioned by Harris (p. 40) was taken.

In the northern part of the county, near the town of Bradford, on the St. Louis, Iron Mountain & Southern Railway, limestone of the Midway formation appears at the base of the narrow terrace or ridge known as the Grandglaise terrace. Northward from Bradford the first outcrops of the limestones are on the south and north side of a small creek which cuts the terrace, and from this place northward through Jackson County to the southern part of Independence County there are numerous outcrops of the rocks. The formation consists of ledges of limestone interbedded with gray calcareous unconsolidated sand.

The town of Bradford is underlain by the limestone which is encountered in wells; in a well on the property of W. D. Plant the rock

[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 14–17, 1891.

was reached at a depth of 20 feet and extended to a depth of 40 feet, where shale of Paleozoic age was encountered.

The following is a generalized section of the terrace at Bradford:

Generalized section at Bradford.

	Feet.
Top of terrace capped with gravel (Lafayette formation?).	
Red calcareous clay (Eocene)	5–10
Gray calcareous clay (Eocene)	5–20
Layers of limestone interbedded with unconsolidated sand (Midway formation)	20±
Thin layer of gravel consisting of pebbles and cobbles of soft brown sandstone which range in size up to 6 or 8 inches in diameter, with an average diameter of one-half to 1 inch; these are derived from rocks of Paleozoic age	½–1
Unconformity.	
Sandstone and shale of Paleozoic age	1+

West of Bradford the Midway formation rests against the Paleozoic rocks along a steep eastward-sloping contact which probably represents an ancient sea cliff.

Along the east side of the Grandglaise terrace at Bradford the alluvial deposits of the Advance lowland rest unconformably against the Midway strata; here also the contact slopes steeply eastward and represents an erosion cliff produced by the meandering of Pleistocene and Recent streams which traversed the lowland.

Harris[1] gives the following data in regard to exposures near Bradford:

At an old limestone quarry by the side of the railway, 1¾ miles north of Bradford, specimens of *Turritella mortoni* composed of crystalline calcite are of frequent occurrence; an indistinct cast of a cardium was also noted at the last-named locality.

One-eighth of a mile nearer Bradford, perhaps 200 yards west of the railway track, many bowlders of highly crystalline limestone are strewn about in a field. Besides innumerable fragments of molluscan forms, this limestone incloses rounded pebbles of greenish sandy shale with major diameters in some instances of no less than 2 inches. The recognizable fossils are:

Ostrea præ-compressirostra Harris [=O. crenulimarginata Gabb].
Venericardia planicosta Lamarck (small).
Psammobia (large and ill defined).

Jackson County.—The Grandglaise terrace is well developed in the vicinity of Grandglaise, Jackson County, although at most places small branch valleys partly separate the terrace from the Paleozoic rocks to the west. The following section of the Midway formation

[1] Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, p. 25, 1894.

is exposed in a cut of the St. Louis, Iron Mountain & Southern Railway one-fourth mile southwest of the station (see Pl. V, *A*):

Section in a cut of the St. Louis, Iron Mountain & Southern Railway one-quarter mile south of Grandglaise.

	Feet.
Top of hill and slope covered with brownish sandy loam and overgrown with vegetation	25
Midway formation:	
2. Limestone in layers 1 to 1½ feet thick, interbedded with thinner layers of soft gray calcareous sand; the limestone contains small greenish pebbles of sandstone which are particularly abundant in layers 5 to 8 feet above the base; the upper and lower surfaces of the limestone layers present numerous rounded and irregular concretionary projections which extend upward and downward into the intervening layers of sand; the limestones contain an abundance of imperfectly preserved fossil remains, among which T. W. Vaughan has identified the following: Belanophyllia sp., *Tornatellæa bella* Conrad, *Turritella mortoni* Conrad, and *Mesalia pumila* (Gabb) (field No. 272)	22
1. Concealed to the level of the Advance lowland	10
	57

The following is another section exposed about one-half mile southwest of Grandglaise; the part of the section above the limestone is obscured by weathering and is difficult to interpret:

Section exposed in a south-facing slope and railroad cutting just west of the St. Louis, Iron Mountain & Southern Railway, about one-half mile south of Grandglaise.

	Feet.
Pleistocene (loess?):	
6. Slope concealed by vegetation	10
5. Reddish massive, finely arenaceous and argillaceous loam resembling loess in texture; appears to grade downward into the next layer	12
Pliocene (?) (Lafayette formation):	
4. Red ferruginous argillaceous pebbly sand becoming very pebbly in the basal 1 to 2 feet; the pebbles consist of greenish sandstone and chert not exceeding 2 or 3 inches in diameter and not averaging over one-half inch in diameter	5
Eocene (?) (Midway formation?):	
3. Massive greenish-gray fine sand, oxidized to red in upper portion	8
Eocene (Midway formation):	
2. Limestone interbedded with sand, corresponding to the limestone described in the preceding section	5
1. Concealed to the level of the Advance lowland	10
	50

A. PEBBLY LIMESTONE WITH INTERBEDDED LAYERS OF CALCAREOUS SAND BELONGING TO THE MIDWAY FORMATION, ON THE ST. LOUIS, IRON MOUNTAIN & SOUTHERN RAILWAY A QUARTER OF A MILE SOUTH OF GRANDGLAISE, JACKSON COUNTY.

B. SANDS, CLAYS, AND LIGNITES OF THE WILCOX FORMATION ON BOLIVAR CREEK NEAR ITS POINT OF EMERGENCE FROM CROWLEYS RIDGE, 3½ MILES NORTH OF HARRISBURG, POINSETT COUNTY.

Exposures of limestone of the Midway formation, ranging from poor to fair, were observed along the eastward-facing slope of the Grandglaise terrace for a distance of about 2½ miles southwest of Grandglaise.

About one-half mile west of Grandglaise there is a poor exposure of limestone belonging to the Midway formation at the foot of the northwest-facing slope of a small branch valley which partially separates the ridge from the Paleozoic hills to the west.

Harris[1] gives the following data regarding two localities south of Grandglaise in Jackson County:

> Going southward toward Bradford the limestone ledges become more and more fossiliferous. Dr. J. C. Branner, in 1887, collected specimens from two points in this vicinity, giving as localities "Between 2 and 3 miles north of Bradford on the Iron Mountain Railway," and "Two miles north of Bradford on the Iron Mountain Railway." The former (station 2223, U. S. National Museum register) consist of light-gray limestone fragments holding on their ferruginated exterior numerous specimens of *Turritella mortoni* (composed of calcite) and coral.
>
> At the latter locality (station 2229) the following forms were recognized:
>
> Ostrea sp. (young).
> Cytherea sp. (a cast).
> Turritella mortoni Conrad.

Independence County.—The Midway formation extends from Jackson County northward into the southern part of Independence County. Harris[2] says:

> In Arkansas the Midway stage forms a low, terrace-like elevation on the northeast flank of the Paleozoic upland just to the south and southwest of Bayou Departe, Independence County.

CORRELATION.

The fossils of the terrane have been studied chiefly by Harris[1] and also by T. Wayland Vaughan. They have identified the following species:

Fossils from the Midway formation of Arkansas.

Belanophyllia sp. (identified by Vaughan).
Cucullæa macrodonta Whitfield.
Ostrea crenulimarginata Gabb.
Ostrea pulaskensis Harris.
Pecten alabamiensis Aldrich.
Venericardia planicosta Lamarck.
Calyptraphorus velatus (Conrad).
Tornatella bella Conrad (identified by Vaughan).
Natica alabamiensis Whitfield.
Turritella alabamiensis Whitfield.
Turritella mortoni Conrad.
Turritella multilira Whitfield.
Mesalia pumila (Gabb) (identified by Vaughan).
Potamides alabamiensis Whitfield.
Tubulostium dickhauti White.
Volutilithes limopsis Conrad?
Volutilithes petrosa (Conrad)?
Enclimatoceras ulrichi White.
Calianassa ulrichi White.

[1] Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 24, 25, 1894.
[2] Idem, p. 24.

Harris, on the evidence of the species identified by him, has correlated the formation in Arkansas with the Midway formation of Alabama.

Of the fossils from the section one-quarter mile southwest of Grandglaise (p. 52) Vaughan states:

The species are all known to occur in both the Midway and the overlying Wilcox, but *Mesalia pumila* Gabb does not range above the basal Wilcox; the collection offers no evidence opposed to the correlation of Harris.

WILCOX FORMATION.

GENERAL FEATURES.

Name.—The name Wilcox is derived from Wilcox County, Ala., and was proposed by A. F. Crider[1] in 1906 for 850 feet of "highly stratified, siliceous sands, laminated clays of various colors interstratified in places with beds of lignite, and lignitic clays," interposed between the Midway group below and the Claiborne group above.

Other terms which have been applied to the formation defined by Crider are "Northern Lignitic group,"[2] which is objectionable

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[1] Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. 283, pp. 25–28, 1906.

[2] Literature on the "Lignitic group":

Safford, James M., Geological reconnaissance of the State of Tennessee: First report, pp. 162–163, 1856.

Hilgard, E. W., A report on the geology and agriculture of the State of Mississippi, pp. 110–123, 1860.

Hilgard, E. W., On the Tertiary formations of Mississippi and Alabama: Am. Jour. Sci., 2d ser., vol. 43, pp. 34–39, 1867.

Hilgard, E. W., Geological history of the Gulf of Mexico: Am. Jour. Sci., 3d ser., vol. 2, pp. 394–396, 1871.

Smith, E. A., Summary of the lithological and stratigraphical features and subdivisions of the Tertiary of Alabama: Introduction to Alabama Geol. Survey Bull. 1, pp. 10–14, 1886.

Smith, E. A., and Johnson, L. C., On the Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, pp. 18, 38–67, 1887.

Loughridge, R. H., Report on the geological and economic features of the Jackson Purchase region: Kentucky Geol. Survey, pp. 41–52, 1888.

Spencer, J. W., Geological report on southwest Georgia: Georgia Geol. Survey First Rept. progress, p. 43, 1891.

McGee, W J, The Lafayette formation: U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 415–418, 1891.

Clark, W. B., Correlation papers—Eocene: U. S. Geol. Survey Bull. 83, 173 pp., 1891.

Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept., 1892, vol. 2, pp. 55–86, 1894.

Smith, E. A., Phosphates and marls of Alabama: Alabama Geol. Survey Bull. 2, pp. 47–50, 1892.

Smith, E. A., Langdon, D. W., and Johnson, L. C., On the geology of the Coastal Plain of Alabama: Alabama Geol. Survey Bull., pt. 1, pp. 147–192, 198–202, 488–491, 1894.

Vaughan, T. Wayland, The stratigraphy of northwestern Louisiana: Am. Geologist, vol. 15, p. 209, 1895.

Harris, G. D., The lignitic stage: Bull. Am. Paleontology, vol. 2, No. 9, pp. 1–36, 1897.

Harris, G. D., and Veatch, A. C., A preliminary report on the geology of Louisiana: Louisiana Geol. Survey, pt. 5, pp. 64–73, 1899.

because it is a lithologic and not a geographic term; Lagrange,[1] a term of broader significance than Wilcox, as it is known to include strata of Wilcox, Claiborne, and probably Jackson age; and "Chickasawan formation,"[2] also a term of broader significance than Wilcox.

The extension of the Wilcox formation into Georgia has been described by Veatch and Stephenson.[3]

A summary statement regarding the occurrence of the Wilcox formation in southwest Arkansas, Louisiana, and Texas has been given by Vaughan.[4]

Areal distribution.—The Wilcox formation outcrops in the basal portion of the east and west slopes of Crowleys Ridge and in the valley slopes of the larger streams cutting the ridge, from the vicinity of Harrisburg, Poinsett County, northward through Arkansas and Missouri to the northern extremity of the ridge in Stoddard County, Mo. East of Mississippi River the formation outcrops in a belt extending from west-central Georgia westward through Alabama and northward through Mississippi, Tennessee, and Kentucky to southern Illinois. From northern Mississippi northward the formation has not been accurately differentiated from the overlying deposits of Claiborne and Jackson age, all of which are included in the Lagrange formation.

Stratigraphic relations.—The basal portion of the formation in Arkansas does not appear at the surface, and for this reason its relations to underlying older formations have not been observed. However, from general considerations it is believed that the formation rests upon either older Eocene strata corresponding in age to the Midway formation or, if these are absent, upon strata of Upper Cretaceous age. At the northern extremity of Crowleys Ridge the terrane laps over upon rocks of Paleozoic age. Toward the southern limit of its areal extent in Crowleys Ridge the formation is overlain, probably unconformably, by the Claiborne formation.

Throughout its extent in Crowleys Ridge the formation is overlain unconformably by irregularly bedded sands and gravels belonging to the Lafayette formation (Pliocene?), or by disturbed materials derived from the Lafayette formation and the loess, which have found their way down over the slopes of the ridge by either redeposition, creep, or landslide.

Lithologic characters.—The formation in Crowleys Ridge is composed of irregularly bedded sands, locally indurated to sandstones

[1] Safford, J. M., Geology of Tennessee, pp. 424–426, Nashville, 1869.

[2] Dall, W. H., A table of the North American Tertiary horizons, correlated with one another and with those of western Europe: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 344–345, 1898.

[3] Veatch, Otto, and Stephenson, L. W., Tertiary and Quaternary [Georgia]: Georgia Geol. Survey Bull. 26, pp. 226–235.

[4] Vaughan, T. W., U. S. Geol. Survey Prof Paper 71, pp. 725, 726, 1912.

and quartzites, and irregularly bedded clays, with interbedded layers of lignite. From Jonesboro northward there are no exposures showing the complete sequence of strata composing the ridge, but from numerous small exposures examined in the area it seems apparent that the heavier beds of clay all occur at the base of the ridge and that beds of sand predominate above the clays. The clays vary in color from almost white to very dark, are lignitic in places, and in places are interbedded with layers of fairly pure lignite. Silicified stumps and logs have been observed in clay at one locality in the northern part of Greene County (p. 58).

The sands where unweathered are light in color, but on weathered surfaces are varicolored, presenting many shades between white and dark red or brown. Locally the sands have been indurated to sandstones, ranging in hardness from very soft rock to extremely hard quartzites. These rocks are exposed principally along the west slope of the ridge from Craighead County northeastward to the southern part of Clay County. The distribution of the quartzites in Arkansas is discussed in detail by Call.[1] (See also p. 61 of this report.) Marbut[2] has described similar quartzites near the northern extremity of the ridge in Stoddard County, Mo.

As shown by the Bolivar Creek exposure, 3½ miles north of Harrisburg (p. 62), the sands in the upper part of the formation become finer and more argillaceous than those at lower levels.

Strike, dip, and thickness.—Owing to the irregular bedding of the deposits composing the formation and also to the paucity of exposures, the strike of the strata can not be determined by observation; it is inferred, however, from the general structure of the embayment that the beds strike about northeast-southwest and dip to the southeast at the rate of a few feet per mile.

No data are available for determining the thickness of the terrane. In Mississippi the thickness was estimated by Crider to be 850 feet. Wells at Jonesboro, Craighead County, Ark. (1,265 feet deep), and at Campbell, Dunklin County, Mo. (960 feet deep), probably passed entirely through the formation and entered underlying older formations, but the information furnished by the wells is not sufficient to determine the position of the contact. Probably the thickness is not less than 500 feet nor greater than 1,000 feet.

Physiographic expression.—From Poinsett County northward the formation makes up the basal portion of Crowleys Ridge, and the steep and rugged character of the western side of the ridge is due, at

[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 90–102, 1891.

[2] Marbut, C. F., The evolution of the northern part of the lowlands of southeastern Missouri: Missouri Univ. Studies, vol. 1, No. 3, p. 26, 1902.

least in part, to the interbedded masses of quartzite and the heavy beds of clay which outcrop in places along the lower slopes. The existence of this part of the ridge is doubtless due to the resistance offered by the Wilcox strata to the meandering and actively eroding rivers of Pleistocene and Recent times. The present detailed surface features of the ridge, however, are determined mainly by the younger Lafayette formation and the loess which cap and blanket the greater part of the crest and slopes.

Paleontologic character.—The formation has yielded fossil leaves at three localities (see pp. 58, 59, 62); at the two more northerly localities the fossils exist as poor to well-preserved impressions in soft sandstone. At the Bolivar Creek locality (p. 62) leaf impressions and lignitized leaves are contained in chocolate-colored clays. Lignite is common in the formation, and a few beds of lignite a few inches to 5 feet in thickness have been observed or have been penetrated in wells in the area. In places the quartzites and sandstones of the formation are perforated with small cavities believed to be the impressions of rootlets. Silicified stumps of trees and logs have been observed in clay at one place (p. 58). A list of the species of fossil plants found in the formation is given on page 63 of this report.

LOCAL DETAILS.

Missouri.—Marbut[1] has described clays (or shales) and sands, probably belonging to the Wilcox formation, which constitute the basal portion of Crowleys Ridge in its northern extension in Missouri. The clays where observed outcrop in the base of the ridge and range in color from gray to black. They are overlain by irregularly bedded sands, which are locally indurated to sandstones and quartzites.

Clay County.—The most northerly exposure of the formation in Arkansas, and probably the lowest one stratigraphically, is at Chalk Bluff, on St. Francis River, in the northeastern part of Clay County. Call[2] describes this bluff as follows:

> The summit is crowned with fine gravel and coarse sands. The sands are all variegated, more or less indurated, false bedded where seen in good section, and are separated by thin strata of white and drab pipe clays into two or three beds of variable thickness. In places on the steeper and barren hillsides this clay is washed over the face of the hills and gives to them a white appearance, which doubtless gave the place the name of Chalk Bluff. Along the river front and in the deeper ravines of the east face of the bluff are the regularly stratified bluish and drab-colored clays of Tertiary age, containing a few fragments

[1] Marbut, C. F., The evolution of the northern part of the lowlands of southeastern Missouri: Missouri Univ. Studies, vol. 1, No. 3, pp. 21–27, 1902.

[2] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, p. 115, 1891.

of lignite. No fossils of any sort were to be found. Erosion has been great enough to expose these clays along the river banks and to a height of 35 to 40 feet in the deep ravines.

A small exposure of fossiliferous sandstone on the west-facing slope of Crowleys Ridge, 3 or 4 miles southwest of Boydsville, Clay County, is of much geologic interest. The outcrop is in the woods at the head of a small ravine about 100 yards west of the old Boydsville-Gainesville road and about one-fourth mile southwest of the point where the road crosses a small branch, the valley of which is cut down almost to the level of the lowland to the west. The exposure is inconspicuous, and anyone seeking the place should search along the slope from the branch just mentioned southward, following up each small ravine until he finds the outcrop.

The material consists of about 6 feet of soft, friable, stratified sandstone, splitting fairly well along the bedding planes and containing an abundance of well-preserved leaf impressions. The base of the exposure is 20 or 25 feet above the level of the lowland west of Crowleys Ridge and about 80 feet lower than the highest point of the road immediately to the east.

The locality was visited by E. W. Berry and the senior author, and the following species, identified by Mr. Berry, were collected:

Fossil plants from Crowleys Ridge, 3 or 4 miles southwest of Boydsville, Clay County.

Anemia eocenica Berry.[1]
Banksia tenuifolia Berry.[1]
Dryophyllum tennesseensis Berry.[1]
Nectranda lowei Berry.[1]

Mr. Berry states that these species are all common in the Wilcox formation of the eastern Gulf region.

Greene County.—Silicified stumps and logs of trees in clay of the Wilcox formation in the SW. ¼ SW. ¼ sec. 35, T. 19 N., R. 5 E., have been described by Call.[2] This locality is on the west slope of the ridge near the valley of Cache River, 6 or 7 miles north of Gainesville. Call says:

A hill of Tertiary blue clay rises about 40 feet above the bottomlands at this place. In cross section these clays are regularly and horizontally stratified, with little or no sand. Imbedded in this clay near the summit of the hill is a large stump of silicified wood, in place as it grew, with all its roots still imbedded and ramifying in every direction. Some 50 feet away, and at a point a little lower, occurs another stump, similarly disposed, and near at hand are two or three silicified logs. In the banks of a small stream about 300 feet south are many fragments of silicified woods, some of which are very large. The largest of these stumps has a diameter of 4 feet, and some of the logs are

[1] For description of this new species see Berry, E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91 (in press).
[2] Call, R. E., op. cit., p. 102.

scarcely smaller. The complete erosion of the overlying Pleistocene and the upper members of the Tertiary sands leaves this hill a singular feature of the ridge. Nothing like it has been seen elsewhere. A thin soil covers the clays, and this supports a stunted growth of oaks. Samples of this wood were examined by Prof. Knowlton and were found to represent a new species, to which he has given the name *Cupressinoxylon calli*.

An exposure of lignite in the Wilcox formation not far from the preceding is described by Call[1] as follows:

In sec. 36, T. 19 N., R. 6 E. [R. 5 E. (?)], in a small stream which is but a few feet above the general level of the Cache bottoms, is an outcrop of lignite about 3 feet in thickness. The outcrop is in the base of the hill and the bed disappears beneath the surface of the water. It is quite black when wet, but dries to a brownish black. It crumbles into small fragments on exposure to the air. Above it are about 15 feet of Tertiary clays, and above these the usual Orange sands [Wilcox]. A short distance down the stream it is underlain by a bed of light-drab fire clay.

Another exposure of fossiliferous rock similar to the Boydsville locality is near Hardys Mill, 3 or 4 miles west of Gainesville, Greene County, in sec. 30, T. 18 N., R. 5 E. Call[2] describes this locality as follows:

It is about one-half mile from Hardys Mill and on the face of a steep hill fronting west. The outcrop is a coarse sandstone, capped by a compact, fine-grained, very hard sandstone containing numerous casts and impressions of vegetable origin. While there is a rude resemblance to certain forms of water plants in the character and arrangement of these remains, there is not left sufficient structure on which to base an opinion as to their real affinities. But below this siliceous layer there is a heavy layer of sandstone of coarser texture, and not so much metamorphosed, in which occur numerous remains of fossil plants. Those remains are mainly in the form of impressions of leaves of dicotyledonous plants.

Call collected specimens of fossil plants from this locality and sent them to the U. S. National Museum. The collection was recently examined by E. W. Berry, who identified the following species:

Fossil plants from near Hardys Mill, Greene County.

Aralia notata Lesquereux.
Cinnamomum postnewberryi Berry.[3]
Ficus eolignitica Berry.[3]
Ficus vaughani Berry.[3]
Pteris eolignitica Berry.[3]

Berry states that one of the forms enumerated occurs in the Fort Union formation of the western interior and that the remainder are common in the Wilcox formation of the eastern Gulf region.

[1] Call, R. E., op. cit., p. 103.
[2] Idem, pp. 95, 96.
[3] For description of this new species see Berry, E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91 (in press).

Another section described by Call[1] in sec. 30, T. 18 N., R. 5 E., is about one-half mile distant from the Hardys Mill locality and is known as the Lovelady Place. The section, which reveals both clays and sands of the Wilcox formation, is as follows:

Section at the Lovelady Place, Greene County.

	Feet.
4. Light-colored thin soil, with much chert, supporting a heavy growth of pines	2
3. Hard coarse sandstone, identical with that at Hardys Mill; weathering greenish, softer below, regularly stratified	10
2. Soft cross-bedded particolored sands, red predominating, with numerous irregular patches of pure-white sand; becomes argillaceous toward base	20
1. Clay, sandy at top, less sandy below, light drab in color, becoming darker below and ending in a bed of lignite; the whole is regularly and horizontally stratified	25
	57

Layers 1, 2, and 3 of the section belong to the Wilcox formation.

On Poplar Creek, in Greene County, is an exposure described by Call,[2] which shows a ferruginous phase of the Wilcox and also the relation of this formation to the overlying Lafayette. The section is as follows:

Section on Poplar Creek, Greene County.

[NW. ¼ sec. 10, T. 16 N., R. 4 E.]

	Feet.
Pliocene (?) (Lafayette formation):	
4. Light-colored sandy humus with a few pebbles	3
3. Gravel with subordinate lenses of clay; much coarse sand is distributed throughout the gravel	10
2. Gravel and sand indurated to a conglomerate	1
Eocene (Wilcox formation):	
1. Cross-bedded, variegated, slightly indurated sands, white and yellow predominating, with scattered small masses of slate-colored pipe clay; locally cemented by iron oxide into hard, compact masses	12
	26

Craighead County.—From Craighead County northeastward to the southern part of Clay County exposures of quartzite, most of which are on the west-facing slope of the ridge, are numerous. These exist as masses of indurated sand in the Wilcox formation.

One of the best examples of the rock is in sec. 9, T. 15 N., R. 3 E., on the old William Lane place, about 4 miles northeast of Bono post office, Craighead County, where several large masses of extremely

[1] Call, R. E., op cit., pp. 97, 98. [2] Idem, p. 111.

hard, cross-bedded quartzite, 5 or 6 feet thick, outcrop on the western slope of the ridge just north of the public road. The base of the lowest mass is 20 or 25 feet above the level of the lowland to the west and the top of the highest one is about 40 feet above the same datum. The lowest mass is apparently not in its original position, but has slipped down the slope for an unknown distance; it is underlain by yellow stratified sand.

Just south of the road and a few rods south of the quartzite masses the following section is exposed in a gully, the bottom of which is only a few feet above the level of the lowland to the west:

Section in a gully on the William Lane place, 4 miles northeast of Bono, Craighead County.

	Feet.
Pleistocene:	
Yellow and brown loam, a facies of the loess	4
Pliocene (?) (Lafayette formation):	
Heavy bed of coarse gravel, consisting chiefly of pebbles, cobbles, and bowlders of chert, with a considerable admixture of quartzite fragments derived from the Wilcox formation; a few smoothly rounded quartz pebbles occur mixed through the gravel	15
Unconformity.	
Eocene (Wilcox formation):	
Laminated gray and yellow fine argillaceous sand with subordinate lenses of laminated clay; a thin layer of brown ferruginous sand, locally indurated, occurs along the top of this bed	15
	34

Exposures of quartzite.—Exposures of the quartzites of the Wilcox formation have been noted by Call[1] and others at the following places:

Craighead County, secs. 6, 7, T. 14 N., R. 3 E.
secs. 9, 16, 17, 20, 29, 31, 32, T. 15 N., R. 3 E.
Greene County, secs. 4, 5, 16, 17, 19, T. 16 N., R. 5 E.
secs. 1, 3, 25, 36, T. 17 N., R. 4 E.
secs. 13, 23 ?, 34, 35, 36, T. 18 N., R. 4 E.
secs. 2, 4, 7, 8, 9, 18, 30, T. 18 N., R. 5 E.
Greene and Clay counties, secs. 15?, 19, 20, 29, T. 19 N., R. 6 E.

Poinsett County.—Call describes a section on Bolivar Creek in Poinsett County, 3½ miles north of Harrisburg (NW. ¼ SW. ¼ sec. 8, T. 11 N., R. 4 E.), concerning which he says:[2]

By far the best section exhibited in Poinsett County is on Bolivar Creek, 3½ miles north of Harrisburg, on the west side of the ridge. Bolivar Creek is the largest stream in this part of the county and constitutes the main tributary to, or is, rather, the chief source of the L'Anguille River. The exposure faces north

[1] Call, R. E., op. cit., pp. 93, 94. [2] Idem, pp. 80, 81.

and is continuous for about 400 feet. The relations given in the section, however, are made out from observations extending over a mile, and represent a vertical distance of more than 100 feet. The point at which the lignite bed is exposed is only about 30 feet in height, but it underlies a vertical cliff at that place.

This locality was visited by the senior author, and the following section, which pertains only to the main exposure near the mouth of the creek, is based upon his observations (see Pl. V, *B*, p. 52):

Section on Bolivar Creek, 3½ miles north of Harrisburg, in north-facing bluff near the exit of the creek from Crowleys Ridge.

	Feet.
Pleistocene (loess):	
11. Brown loam, probably creep from a higher level	1
Pliocene (?) (Lafayette formation):	
10. Gravel, probably creep from a higher level	4
Eocene (Wilcox formation):	
9. Weathered brown fine argillaceous sand	3
8. Fine light-gray, faintly laminated argillaceous sand	11
7. Fine light-gray massive sand	4.5
6. Fine chocolate-colored argillaceous, faintly laminated sand	4.5
5. Dark chocolate-colored, very fine, very argillaceous sand	4
4. Dark-brown to black lignite	5
3. Brown argillaceous lignitic sand	1
2. Dark chocolate-colored tough clay, lignitic in upper portion; in places in the upper 2 feet contains numerous poorly preserved lignitized leaves and leaf impressions	3
1. Very tough light-greenish clay	2
	43

The layer of lignite (No. 4) and the clay layers (Nos. 1 and 2) are somewhat irregularly bedded and vary in thickness along the face of the bluff. In places the upper lignitic portion of layer No. 2 becomes a bed of true lignite 1 to 2 feet thick; a few lignitized logs and fragmental remains of lignitized stumps were seen in this layer.

Among the fossil leaves collected from layer No. 2, E. W. Berry has identified the following species:

Fossil plants from layer No. 2, Bolivar Creek section.

Ficus pseudomediafolia Berry.[1]
Juglans schimperi (Lesquereux)?
Palæodendron americanum Berry.[1]
Sapindus mississippiensis Berry.[1]
Sophora wilcoxiana Berry?

South of Bolivar Creek Crowleys Ridge rises about 115 feet (aneroid reading) above the bed of the creek; the ridge is here capped by brownish loam (loess), which rests upon a bed of gravel of the Lafayette formation.

[1] For description of this new species see Berry, E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91 (in press).

At several places between Harrisburg and Bolivar Creek sands and argillaceous sands, probably corresponding to layers Nos. 6, 7, 8, and 9, were observed in gullies near the base of the west-facing slope of the ridge.

CORRELATION.

Berry has identified species of fossil plants from three localities referable to the Wilcox formation; from two of the localities (one in Greene County, p. 58, and the other in Clay County, p. 58) he recognized the following nine species:

Fossil plants from the Wilcox formation in Clay and Greene counties.

Anemia eocenica Berry.[1]	Cinnamomum postnewberryi Berry.[1]
Banksia tenuifolia Berry.[1]	Ficus eolignitica Berry.[1]
Dryophyllum tennesseensis Berry.[1]	Ficus vaughani Berry.[1]
Nectandra lowei Berry.[1]	Pteris eolignitica Berry.[1]
Aralia notata Lesquereux.	

Berry states that all but one of the species enumerated occur in the Wilcox formation of the eastern Gulf region, and that the excepted species is common to the Fort Union formation of the western interior. On the evidence of these plants he correlates the containing beds with the Wilcox formation.

From the third locality, on Bolivar Creek, 3½ miles north of Harrisburg, Poinsett County (p. 62), Berry recognized five species, which he states indicate that the containing bed belongs near the top of the Wilcox. He says:

> I have no comparative data to prove that these forms do not extend into the Claiborne; however, none of the species have ever been found in the Claiborne, and in fact only one or two of the 250 species elsewhere found in the Wilcox have ever been found in the Claiborne. From this I conclude that the Bolivar Creek locality belongs to the Wilcox; I do not believe there is any lower Claiborne in Crowleys Ridge.

Although the contact between the Wilcox formation and the overlying Claiborne formation was not discovered, it is assumed, on the evidence afforded by the fossil plants, that the former does not appear in surface outcrops farther south in Crowleys Ridge than Harrisburg, Poinsett County.

CLAIBORNE FORMATION.

GENERAL FEATURES.

Name.—In 1834[2] and again in 1835[3] Conrad described a stratum of sand containing a rich molluscan fauna, exposed in a bluff on

[1] For description of this new species see Berry, E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91 (in press).

[2] Conrad, T. A., Observations on the Tertiary and more recent formations of a portion of the Southern States: Acad. Nat. Sci. Philadelphia Jour., vol. 7, pp. 116–129, 1834.

[3] Eocene fossils of the Claiborne, with observations on this formation in the United States: Fossil shells of the Tertiary formations of North America, vol. 1, No. 3, pp. 29–36, 1835. (See Harris's republication of Conrad's "Fossil shells," 1893, pp. 75–84.)

Alabama River, at the village of Claiborne, Monroe County, Ala. He referred to this bed as the "Claiborne deposits," and in a later publication as the "Claiborne sandstone"; the Eocene age of the fauna was recognized. Since the introduction of the name it has been applied by different investigators to deposits distributed geographically from North Carolina to the Rio Grande. By some the name has been given a broader and by others a more restricted application than the present accepted limits of the division.[1]

[1] The literature on the subject is voluminous and can only be enumerated, not reviewed, in this report.

Conrad, T. A., Observations on the Eocene formation and descriptions of 105 new species of that period from the vicinity of Vicksburg, Miss., with an appendix: Acad. Nat. Sci. Philadelphia Proc., vol. 3, pp. 280–281, 1846.

Conrad, T. A., Observations on the Eocene deposit of Jackson, Miss., with descriptions of 34 new species of shells and corals. Acad. Nat. Sci. Philadelphia Proc., vol. 7, 1854, 1855, pp. 257–263 (issued in 1856).

Hilgard, E. W., A report on the geology and agriculture of the State of Mississippi, pp. 123–128, 1860.

Hilgard, E. W., On the Tertiary formations of Mississippi and Alabama: Am. Jour. Sci., 2d ser., vol. 43, pp. 33–34, 1867.

Mell, P. H., jr., The Claiborne group and its remarkable fossils: Am. Inst. Min. Eng. Trans., vol. 8, pp. 304–313, 1880.

Heilprin, Angelo, On the relative ages and classification of the post-Eocene Tertiary deposits of the Atlantic slope: Acad. Nat. Sci. Philadelphia Proc., p. 184, 1882.

Heilprin, Angelo, The Tertiary geology of the eastern and southern United States: Acad. Nat. Sci. Philadelphia Jour., vol. 9, pp. 116, 120, 145–147, 1884.

Heilprin, Angelo, The Tertiary geology of the eastern and southern United States: Published by the author; p. 37, Philadelphia, 1884.

Meyer, Otto, The genealogy and the age of the species in the southern old Tertiary: Am. Jour. Sci., 3d ser., vol. 30, pp. 421–435, 1885.

Aldrich, T. H., Observations upon the Tertiary of Alabama: Am. Jour. Sci., 3d ser., vol. 30, pp. 300–308, 1885.

Smith, E. A., Remarks on a paper of Dr. Otto Meyer on Species in the southern old Tertiary: Am. Jour. Sci., 3d ser., vol. 30, pp. 270–275, 1885.

Langdon, D. W., Tertiary of Mississippi and Alabama: Am. Jour. Sci., 3d ser., vol. 31, pp. 202–209, 1886.

Aldrich, T. H., Notes on the distribution of Tertiary fossils in Alabama and Mississippi: Cincinnati Soc. Nat. Hist. Jour., vol. 8, pp. 256–257, 1886.

Aldrich, T. H., a preliminary report upon the Tertiary fossils of Alabama and Mississippi: Alabama Geol. Survey Bull. 1, pp. 44–49, 1886.

Smith, E. A., Summary of the lithological and stratigraphical features and subdivisions of the Tertiary of Alabama: Alabama Geol. Survey Bull. 1, Introduction, pp. 8–10, 1886.

Smith, E. A., and Johnson, L. C., On the Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, pp. 15–18, 25–34, 1887.

Langdon, D. W., Geological section along the Chattahoochee River from Columbus to Alum Bluff: Georgia Geol. Survey First Rept. Progress, 1891, pp. 96, 97.

Langdon, D. W., Variations in the Cretaceous and Tertiary strata of Alabama: Geol. Soc. America Bull., vol. 2, p. 588, 1891.

Clark, W. B., Correlation papers—Eocene: U. S. Geol. Survey Bull. 83, 173 pp., 1891.

Spencer, J. W., Geological report on southwest Georgia: Georgia Geol. Survey First Rept. Progress, pp. 51–53, 1891.

McGee, W J, The Lafayette formation: U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 413–418, 1891.

Smith, E. A., Phosphates and marls of Alabama: Alabama Geol. Survey Bull. 2, pp. 53, 62, 1892.

Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 87–187, 1894.

Smith, E. A., Langdon, D. W., and Johnson, L. C., On the geology of the Coastal Plain of Alabama: Alabama Geol. Survey Bull., pt. 1, pp. 17, 122–138, 232–235, 492, 494, 1894.

Vaughan, T. W., The stratigraphy of northwestern Louisiana: Am. Geologist, vol. 15, pp. 210–220, 1895.

As at present understood the term Claiborne is applied to the strata included between the Wilcox formation below and the Jackson formation above. In the other States in which the deposits have been recognized they have been subdivided on lithologic grounds into formations, and the term Claiborne group has been used. In Crowleys Ridge, where the deposits have not been subdivided, the term Claiborne formation is applied to the entire division.

In Louisiana the Claiborne has been subdivided in ascending order into the St. Maurice formation, which is composed of calcareous and glauconitic deposits of marine origin, and the Yegua or "Cockfield" formation, which consists of lignite-bearing sands and clays. The leaf-bearing clay in Crowleys Ridge near Cherry Valley, Cross County, described on page 69, is correlated by Berry with the Yegua ("Cockfield") formation of the Claiborne group. No deposits corresponding in lithologic character to the St. Maurice formation have been observed in Crowleys Ridge stratigraphically below the leaf-bearing clay at Cherry Valley, and there is reason to believe that only the upper part of the Claiborne is represented in northeastern Arkansas.

Areal distribution.—In northeastern Arkansas the Claiborne formation outcrops in the base of Crowleys Ridge to a probable maximum height of 100 feet above the adjoining lowlands, from the vicinity of Harrisburg, Poinsett County, to the southern part of Cross County.

East of Mississippi River deposits of the Claiborne group outcrop in North Carolina and from South Carolina southwestward through Georgia, westward through Alabama, and northward through Mississippi. The group is represented in Tennessee and Kentucky by a part of the Lagrange formation, but it has not been accurately differentiated from the strata of Jackson and Wilcox age, which are extensively developed in the same area and are also included in the Lagrange formation.

Vaughan, T. W., A brief contribution to the geology and paleontology of northwestern Louisiana: U. S. Geol. Survey Bull. 142, p. 15, 1896.

Dall, W. H., A table of the North American Tertiary horizons, correlated with one another and with those of western Europe, with annotations: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 342–343, 1898.

Harris, G. D., and Veatch, A. C., A preliminary report on the geology of Louisiana: Louisiana Geol. Survey, pt. 5, pp. 73–89, 1899.

Vaughan, T. W., The Eocene and lower Oligocene coral faunas of the United States: U. S. Geol. Survey Mon. 39, pp. 27–30, 1900.

Veatch, Otto, and Stephenson, L. W., Tertiary and Quaternary [Georgia]: Geol. Survey Georgia Bull. 26, pp. 235–296, 1911.

Vaughan, T. W., [Tertiary of] Texas, Louisiana, and Arkansas: U. S. Geol. Survey Prof. Paper 71, pp. 723–731, 1912.

Vaughan, T. W., [Eocene and Oligocene of] south Atlantic and eastern Gulf Coastal Plain and north end of Mississippi embayment: U. S. Geol. Survey Prof. Paper 71, pp. 731–739, 1912.

In southern Arkansas the Claiborne is probably represented by a part of the undifferentiated Eocene mapped by Veatch,[1] and deposits of this age have been recognized from northern Louisiana southwestward to the Rio Grande.

Stratigraphic relations.—In Crowleys Ridge the Claiborne formation rests upon the Wilcox formation, and the relation, though not determined with certainty, is probably that of nonconformity. Fossil leaves of upper Wilcox age have been found at the base of Crowleys Ridge, on Bolivar Creek, 3½ miles north of Harrisburg (p. 62), and fossil leaves of upper Claiborne age (Yegua) occur at the base of the ridge near Cherry Valley, Cross County (p. 69). From considerations based upon the general structure of the Mississippi Embayment and the slight inclination of the strata composing the Eocene, it is believed highly improbable that the full thickness of the Claiborne group of Alabama and Mississippi can be represented in outcrops in Crowleys Ridge, between the two localities mentioned. It seems necessary to assume, therefore, that the lower part of the Claiborne is represented by an unconformity. In a letter to the senior author, Berry discusses this hypothetical unconformity as follows:

> With regard to the Claiborne unconformity, I am convinced that the later Claiborne transgresses far to the north of the earlier. I have St. Maurice [lower Claiborne] plants from southern Arkansas and Yegua ("Cockfield") [upper Claiborne] plants from northwestern Mississippi, and the general relations of the deposits demand an unconformity. In materials away from the open sea—that is in littoral sands and lenses of estuarine clay, unconformities would scarcely even be detectable unless the unconformable deposits were laid down at very different depths, and consequently were of different lithologic character.

The Claiborne formation is overlain toward the southern limit of its occurrence in Crowleys Ridge by the Jackson formation; the relation is believed to be that of conformity.

Throughout the greater part of its extent in Crowleys Ridge the formation is overlain unconformably by gravels and sands of the Lafayette formation. Disturbed materials of the Lafayette formation and of the overlying loess have found their way down the slopes by redeposition, creep, and landslide, and have blanketed the Claiborne strata which would otherwise appear at the surface continuously along the base of the ridge.

Lithologic character.—The formation in Crowleys Ridge consists of regularly and irregularly bedded, more or less lignitiferous sands and clays, with subordinate, thin, interstratified layers of lignite. The sands are for the most part fine in texture, are commonly mica-

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 40, 1906.

ceous, and are light to dark in color. The clays are light drab to black and range in bedding from massive to thinly laminated, with fine micaceous sand partings; locally, as at Copperas Bluff, Cross County, they are strongly gypsiferous, the gypsum being present as crystals and presenting numerous clusters of acicular crystals.

Concretions of iron carbonate are common in the clays of the formation, and appear in many of the exposures in Cross County. Lignite is characteristic and occurs as comminuted particles or as larger fragments.

Strike, dip, and thickness.—The strike of the strata composing the Claiborne formation is inferred, from the general structure of the Gulf embayment, to be approximately northeast-southwest. The beds dip to the southeast at the rate of a few feet per mile. No accurate data are available for determining the thickness of the formation, but rough calculations based on the width of outcrop and an assumed dip of between 5 and 10 feet per mile, give a thickness of between 100 and 200 feet for the formation.

Physiographic expression.—The present surface features of Crowleys Ridge are determined mainly by the Lafayette formation and by the loess, which form the capping materials of the ridge. However, the existence of that part of the ridge underlain by the Claiborne formation is due to the resistance to erosion offered by the strata of this terrane, and particularly by the thicker beds of clay. In this respect the ridge may be said to be a topographic expression of the formation.

Paleontologic character.—Fossil leaves, poorly to fairly well preserved, have been collected from the formation at an exposure three-fourths of a mile southeast of Cherry Valley, Cross County; a list of the identified species is given on page 69. Comminuted particles and larger fragments of lignite are common in the formation throughout practically its whole thickness. At a few places thin layers and lenses of lignite have been observed. No remains of animals have been found in place in the formation; however, at an exposure 4 miles east of Wynne shark teeth and mouth plates were found loose in the bed of a gully.

LOCAL DETAILS.

The Claiborne formation is well exposed at many places in Crowleys Ridge in Poinsett and Cross counties. Call[1] has described numerous sections in detail. A few sections are given to show the general lithologic character of the formation.

[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 57–80, 1891.

Spencer Creek, Cross County.—Call[1] described a section on Spencer Creek, in Crowleys Ridge, 1 mile north of Harrisburg, Cross County, which is here repeated in substance, as follows:

Section on Spencer Creek 1 mile north of Harrisburg, Cross County.

	Feet.
Pleistocene (loess):	
Humus, with considerable sand and a few scattered pebbles	1
Yellowish loesslike marl, indurated below, weathering into vertical cliffs. This layer becomes much redder below and has occasional seams of pebbles with a matrix of red sand. At the very bottom the clay is almost entirely replaced by coarse, brick-red sand	20
Eocene (Claiborne formation?):	
Horizontally stratified white sands, alternating with light slate-colored layers of plastic clay, the thickness of the clay varying from half an inch to 5 inches. The thicker layers of clay are laminated, the laminæ being separated by thin layers of a very fine white sand, though these finer sand partings are sometimes stained yellow by iron oxide. Below the first 5 feet these clay bands almost entirely disappear and the whole becomes a very fine white horizontally stratified sand. This member is remarkable for the regularity and horizontality of its stratification	13
Stratified bluish to drab clays, with abundant small fragments of lignite scattered throughout, though in places these particles are arranged in zones 2 to 3 inches thick. Near the bottom is a heavy deposit of siliceous iron ore, in places forming the floor of the creek and elsewhere jutting out as a ledge from the bank. The thickness of this iron clay-stone varies from 1 foot to 15 or 20 inches	23
	57

Call says also:

Farther down the creek and west of the road is a continuation of the above section which extends its general features nearly half a mile to the west. In this exposure the iron clay-stone is nodulous and is represented by very large segregations instead of by a bed. Lignite is much more abundant and the fragments are larger than at the first-mentioned locality, but they are arranged in an undulating zone throughout the whole section. At the top of the section, for 7 feet of the total thickness, which is 25 feet, the character of the soil clearly resembles the loess clays and, though it is somewhat more deeply colored and more clayey than usual, it probably represents that deposit.

Although no fossils were found in this section, the presence of iron ore in the lowest layer and the regularity of the bedding exhibited by the two lower layers are regarded as evidence of their Claiborne age.

Cherry Valley section, Cross County.—The following is a section exposed on a small creek, where it leaves Crowleys Ridge about three-

[1] Call, R. E., op. cit., pp. 78, 79.

A. SANDS AND CLAYS OF THE CLAIBORNE FORMATION THREE-FOURTHS OF A MILE SOUTHEAST OF CHERRY VALLEY, CROSS COUNTY.

B. LEAF-BEARING CONCRETIONS OF IRON CARBONATE IN CLAY OF THE CLAIBORNE FORMATION AT THE LOWER END OF THE BLUFF SHOWN IN PLATE VI, *A.*

quarters of a mile southeast of Cherry Valley, Cross County (see Plate VI, *A* and *B*):

Section near Cherry Valley, Cross County.

	Feet.
Pleistocene (loess):	
Brown pebbly loam, which has probably crept down the slope from a higher level	3
Pliocene(?) (Lafayette formation):	
Gravel composed of pebbles of angular to partially rounded gray and brown chert; a few scattered, smoothly rounded quartz pebbles, and a few scattered angular chunks of ferruginous conglomerate. The gravel mantles down over the slope and the whole bed has probably crept down the slope from a higher level	5
Unconformity.	
Eocene (Claiborne formation):	
Faintly laminated fine, rather compact argillaceous sand, red in the upper 5 or 6 feet and grading downward into light greenish-gray sand streaked with yellow; this is a weathered phase of the material described in the next layer below	
Brown, faintly laminated, finely micaceous argillaceous sand with crystals of selenite and scattered small particles of vegetable matter	14
Massive fine light greenish-gray sand streaked with yellow	12
Laminated dark-gray and dark-brown, very sandy micaceous clay, with laminæ and thin layers of gray, brown, and yellow fine sand having a maximum thickness of 2 or 3 inches; the bed contains comminuted vegetable particles and a few scattered fragments of lignite	8
Massive, finely arenaceous dark greenish gray clay, with numerous black fossil leaves preserved as lignite; scattered through the clay are numerous concretions of iron carbonate with a maximum diameter of 2 or 3 feet, which contain numerous fairly well preserved leaf impressions (Pl. VI, *A*, *B*); maximum exposed thickness	5
	47

From the leaf-bearing bed at the base of the section the following species, identified by E. W. Berry, were collected by Berry and the senior author:

Fossil plants near Cherry Valley, Cross County.

Arthrotaxis (?) sp.
Citrophyllum eocenicum Berry (occurs also at Claiborne, Ala.).[1]
Inga arkansensis Berry.[1]
Mimusops claibornensis Berry.[1]
Persea gratissimifolia Berry.[1]
Ternstrœmites crowleyensis Berry.[1]
Ternstrœmites claibornensis Berry.[1]

[1] For description of this new species see Berry, E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91 (in press).

On the evidence of the species enumerated, Berry correlates the containing stratum with the upper Claiborne, and states that the bed probably corresponds in age to the lignitiferous division of the Claiborne group of Louisiana and Texas known as the Yegua ("Cockfield") formation.

Sections east of Wynne, Cross County.—The following section is exposed in a ravine about 4 miles east of Wynne, Cross County, and one-fourth mile south of the St. Louis, Iron Mountain & Southern Railway:

Section in a ravine 4 miles east of Wynne, Cross County.

	Feet.
Pleistocene:	
Loess	18
Pliocene (?) (Lafayette formation):	
Gravel with a matrix of sand	18
Eocene (Claiborne formation):	
Light-gray argillaceous sand, irregularly streaked with yellow, pink, and red	6
Interbedded light-drab arenaceous clay and light-gray sand	15
Pink and yellowish mottled argillaceous sand	1
Very dark lignitic clay, with two thin seams of pure lignite	1.5
Gray and yellowish argillaceous sand	8
Concealed by a landslide	30
Dark-drab arenaceous lignitic clay, more sandy in its upper portion; contains crystals of selenite an inch or more in length; this layer is exposed along the bottom of the ravine below the landslide; a few shark teeth and mouth plates were found loose in the bed of the ravine	30
	127.5

In a bluff at the foot of the ridge near the mouth of the ravine 15 feet of dark clay, containing crystals of selenite and concretions of iron carbonate, some of which are a foot or more in diameter, is exposed.

Another clear-cut section in which strata of the Claiborne formation are exposed is a south-facing bluff on a small creek 3 miles east of Wynne and one-eighth mile north of the St. Louis, Iron Mountain & Southern Railway:

Section in a bluff on a small creek 3 miles east of Wynne and one-eighth mile north of the St. Louis, Iron Mountain & Southern Railway.

	Feet.
Pleistocene (loess):	
Massive grayish and brownish loess, with a reddish band (*a*, fig. 1) 5 or 6 feet thick extending horizontally through the middle portion of the layer	40
Light-gray compact argillaceous sand, with scattered small pebbles probably derived from layer 3 (fig. 1)	2–6

	Feet.
Unconformity (?); a fairly sharp though not an absolutely sharp contact.	
Pliocene (?) (Lafayette formation):	
Gravel composed chiefly of subangular to partly rounded flint and chert pebbles and cobbles up to 5 or 6 inches in length, with a small percentage of smoothly rounded quartz pebbles up to 1 inch in length	0–5
Unconformity.	
Eocene (Claiborne formation):	
Dark-gray laminated compact shaly clay	5
Massive dark-gray to chocolate-tinted, very argillaceous sand, with numerous small particles of lignite; contains oval to spherical concretions of iron carbonate, which reach a maximum of 1 foot in diameter; small pieces of lignite form the nucleus of some of these concretions	7
	58

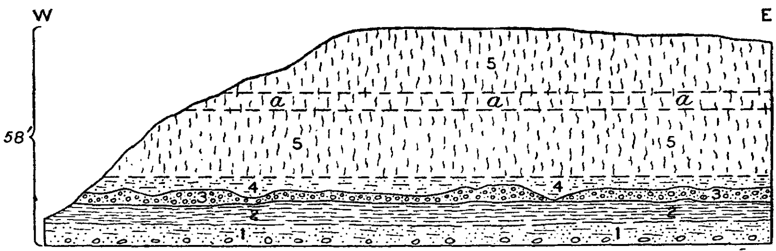


FIGURE 1.—Sketch to show the relations of formations exposed in a bluff on a small creek 3 miles east of Wynne, Cross County, and one-eighth mile north of the St. Louis, Iron Mountain & Southern Railway. 1 and 2, Claiborne formation; 3, Lafayette formation; 4, sandy layer at base of loess; 5, loess containing reddish band (*a*) near the middle.

The relations indicated in the section just described are graphically represented in figure 1.

Copperas Creek section, Cross County.—The site of Old Wittsburg is on St. Francis River, at the foot of the east-facing slope of Crowleys Ridge, about 5 miles east of Wynne, Cross County. Call[1] has described an exposure of the Claiborne formation on Copperas Creek north of Wittsburg. He says:

Two and a half miles north of Wittsburg Copperas Creek flows eastward from the ridge, and after a sinuous course through the alluvium of the St. Francis bottoms joins St. Francis River some distance to the south. Where it leaves the hills this stream has cut away the greater part of a north and south spur and exposed its stratigraphy.

[1] Call, R. E., op. cit., pp. 69–71.

The section given by Call is in substance as follows:

Section at Copperas Bluff, Cross County.

	Feet.
Pleistocene (loess):	
Light-yellow siliceous humus	2
Loess with abundant concretions of calcium carbonate in the middle portion; the lower portion contains pebbles, which are particularly abundant near the base; weathers into vertical cliffs	5
Pliocene (?) (Lafayette formation):	
Gravel composed mainly of yellowish chert with an intermixture of varicolored sand; contains also pebbles of sandstone 3 to 4 inches in diameter; this bed is 1 foot thick at the extreme end of the section and thickens to a maximum of 8 feet at the west end of the section	5
Eocene (Claiborne formation):	
Reddish, partly indurated, cross-bedded, rather coarse sand, with numerous small pieces of light-yellow ocher disseminated in patches	5
Stratified drab to purplish sandy clay, with numerous fragments of lignite	15
Ironstone nodules, distributed somewhat regularly in a narrow zone; some of the nodules are hollow or are filled with sand	1
Bluish stratified clay, with an abundance of comminuted vegetable matter and some fragments of lignite; contains also many crystals of gypsum	10
Layer of ironstone concretions which forms a ledge along the face of the bluff	1
White and yellowish fine stratified sand; the layer thins out and disappears toward the west	10
Dark-bluish sandy stratified clay, with organic matter and numerous large fragments of lignite; contains much selenite, partly in the form of acicular crystals radiating from a common center	12
	66

CORRELATION.

The leaf-bearing clay exposed in the section near Cherry Valley, Cross County (p. 69), is the key to the correlation of this formation. According to Berry the fossil plants identified from this stratum indicate its upper Claiborne age and its probable synchronism with the Yegua ("Cockfield") formation of Louisiana and Texas. The Yegua formation is the upper lignitiferous division of the Claiborne group of those States. Fossil leaves of upper Wilcox age have been identified by Berry from a locality on Bolivar Creek, 3½ miles north of Harrisburg, Poinsett County (p. 62). He believes the paleontologic evidence strong that only the upper or Yegua ("Cockfield") formation of the Claiborne, as developed in southern Arkansas and in Louisiana, is represented in Crowleys Ridge (see p. 63), and that the Claiborne of this area must therefore be separated from the underlying Wilcox formation by an unconformity, corresponding in time to the lower Claiborne of other areas.

Fossil invertebrates of lower Jackson age have been identified by T. Wayland Vaughan from a marl bed exposed on Little Crow Creek about 3 miles east of Forrest City, St. Francis County (pp. 76–78).

With these paleontologic criteria as a check the areal distribution of the Claiborne formation in Crowleys Ridge, as indicated on the map, is determined on the evidence afforded by certain lithologic data, which, though not so satisfactory as paleontologic evidence, may nevertheless be considered valid.

Many of the sections in Cross County here referred to the Claiborne formation include beds of clay containing concretions of iron carbonate, and at the Cherry Valley locality, to which reference has just been made, these concretions are leaf-bearing. The fact that the concretions have not been found in the Eocene of Crowleys Ridge, either north or south of Cross County, seems to justify the opinion that they are characteristic of the Claiborne formation of this area.

The invertebrate-bearing beds on Crow Creek east of Forrest City in St. Francis County, which have been correlated with the lower Jackson, do not contain iron carbonate concretions, and this seems to be a further confirmation of the belief that the concretions are characteristic of the Claiborne formation.

JACKSON FORMATION.

GENERAL FEATURES.

Name.—Conrad[1] in 1856 described a series of calcareous, fossil-bearing clays typically exposed at Jackson, Miss., and applied to them the name Jackson. Subsequently, the deposits have been traced with certain interruptions from North Carolina to eastern Texas.[2]

Areal distribution.—In Arkansas the Jackson formation outcrops in the base of Crowleys Ridge to a probable maximum height of 100 feet above the level of the lowlands, from the northern part of

[1] Conrad, T. A., Acad. Nat. Sci. Philadelphia Proc., vol. 7, 1854–55, p. 257, 1856.

[2] The more important papers relating to the Jackson formation are listed below.

Hilgard, E. W., A report on the geology and agriculture of the State of Mississippi, pp. 128–135, 1860.

Hilgard, E. W., On the Tertiary formation of Mississippi and Alabama: Am. Jour. Sci., 2d ser., vol. 43, pp. 29–33, 1867.

Heilprin, Angelo, On the relative ages and classification of the post-Eocene Tertiary deposits of the Atlantic slope: Acad. Nat. Sci. Philadelphia Proc., p. 184, 1882.

Heilprin, Angelo, The Tertiary geology of the eastern and southern United States: Acad. Nat. Sci. Philadelphia Jour., vol. 9, pp. 116, 120, 145, 147–148, 1884.

Heilprin Angelo. The Tertiary geology of the eastern and southern United States, p. 37. Published by the author, Philadelphia, 1884.

Meyer, Otto, The genealogy and the age of the species in the southern old Tertiary: Am. Jour. Sci., 3d ser., vol. 30, pp. 421–435, 1885.

Aldrich, T. H., Observations upon the Tertiary of Alabama: Am. Jour. Sci., 3d ser., vol. 30, pp. 300–308, 1885.

St. Francis County southward nearly to the southern extremity of the ridge in Phillips County. South of Arkansas River the terrane appears in Jefferson, Lincoln, Cleveland, Drew, and Bradley counties, Ark.

Stratigraphic relations.—In Crowleys Ridge the Jackson formation rests upon the Claiborne formation and is overlain unconformably by the Lafayette formation. The contact between the Jackson and Lafayette formations is very irregular, and varies in vertical position from near the level of the base of the ridge to at least 100 feet above that datum plane. The gravels and sands of the Lafayette formation and the loess that caps the ridge have found their way down the slopes by redeposition, creep, and landslides, and, except in ravines and stream bluffs, have almost completely blanketed the Jackson formation.

Lithologic character.—The Jackson formation in Crowleys Ridge consists of regularly and irregularly bedded, interstratified sands, clays, and fossiliferous marls of shallow-marine origin. Where the materials are unoxidized the colors range from light gray to dark greenish or bluish gray; where oxidation has taken place the materials are variegated with red, pink, yellow, and brown. The sands are massive to cross-bedded, vary in texture from fine to coarse, and

Aldrich, T. H., Notes on the distribution of Tertiary fossils in Alabama and Mississippi: Cincinnati Soc. Nat. Hist. Jour., vol. 8, pp. 256–257, 1886.

Smith, E. A., and Johnson, L. C., Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, pp. 19–25, 1887.

Langdon, D. W., Variations in the Cretaceous and Tertiary strata of Alabama: Geol. Soc. America Bull., vol. 2, p. 588, 1891.

Clark, W. B., Correlation papers; Eocene: U. S. Geol. Survey Bull. 83, pp. 68, 76, 1891.

Spencer, J. W., Geological report on southwest Georgia: Georgia Geol. Survey, First Rept. Progress, pp. 51–53, 1891.

McGee, W J, The Lafayette formation: U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 412–413, 1891.

Smith, E. A., Phosphate and marls of Alabama: Alabama Geol. Survey Bull. 2, pp. 53–55, 1892.

Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 87–176, 1894.

Smith, E. A., Langdon, D. W., and Johnson, L. C., On the geology of the Coastal Plain of Alabama, pp. 107–122, 376–385, Alabama Geol. Survey, 1894.

Vaughan, T. W., The stratigraphy of northwestern Louisiana: Am. Geologist, vol. 15, pp. 221–223, 1895.

Vaughan, T. W., A brief contribution to the geology and paleontology of northwestern Louisiana: U. S. Geol. Survey Bull. 142, p. 22, 1896.

Dall, W. H., A table of the North American Tertiary horizons, correlated with one another and with those of western Europe, with annotations: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, p. 342, 1898.

Harris, G. D., and Veatch, A. C., A preliminary report on the geology of Louisiana: Louisiana Geol. Survey, pt. 5, pp. 89–93, 1899.

Vaughan, T. W., The Eocene and lower Oligocene coral faunas of the United States: U. S. Geol. Survey Mon. 39, p. 30, 1900.

Veatch, Otto, and Stephenson, L. W., Tertiary and Quaternary [Georgia]: Georgia Geol. Survey Bull. 26, pp. 296–306, 1911.

Vaughan, T. W., [Eocene and Oligocene of] Texas, Louisiana, and Arkansas: U. S. Geol. Survey Prof. Paper 71, pp. 727, 728, 1912.

Vaughan, T. W., [Eocene and Oligocene of] south Atlantic and eastern Gulf Coastal Plain and north end of Mississippi embayment: U. S. Geol. Survey Prof. Paper 71, pp. 731–745, 1912.

in places contain small pebbles. The clays are massive to thinly stratified or laminated. The marls consist of calcareous and glauconitic sands or clays which in places, as on Little Crow Creek east of Forrest City, contain many fossil shells.

Particles and fragments of lignite are common in the formation and thin layers of lignite have been observed at a few places.

Strike, dip, and thickness.—From the general structure of the Coastal Plain in the Mississippi embayment it is believed that the strata composing the Jackson formation in Crowleys Ridge strike approximately northeast and southwest. From the data afforded by well records it is estimated that the beds dip to the southeastward at a rate which probably does not exceed 5 feet a mile.

The thickness of the formation has not been determined, but it probably does not exceed 200 feet in northeastern Arkansas.

Physiographic expression.—From Cross County southward to its southern extremity Crowleys Ridge, in so far as its existence is due to the resistance to erosion offered by the strata composing the Jackson formation, is a topographic expression of that formation. However, the present details of the surface have been determined largely by the Lafayette formation and the loess which form the capping materials of the ridge.

Paleontologic character.—The basal portion of the Jackson formation in Crowleys Ridge contains fossil mollusks ranging from poorly to well preserved. The most abundant species, *Ostrea alabamiensis* Lea, and the species *Modiola hamatoides* Call, together with some of the less common species, indicate that the containing materials were deposited in shallow marine waters. An abundant molluscan fauna is contained in the basal 22 feet of the section at White Bluff on Arkansas River, Jefferson County.

Lignite, in places segregated into thin beds, is common in the formation, and this also points to the shallow-water origin of the deposits.

Fossil mollusks and Foraminifera have been obtained from the Jackson formation in a well boring near Helena, Phillips County (see pp. 82, 83), and from well borings at Choctaw Bar, Desha County. Lists of fossils from the several localities mentioned are given on pages 78, 80, and 83.

LOCAL DETAILS.

From Cross County southward the east-facing slope of Crowleys Ridge is much steeper than the west-facing slope, a condition produced by the erosive action of St. Francis River, which at numerous places has cut against the foot of the ridge; the natural exposures which show the most complete sequence of strata are all in this steep, east-facing slope or in the deep ravines which cut the slope. A few of the more interesting sections and well logs are given in detail.

Call[1] has given a large amount of detailed information concerning this part of Crowleys Ridge.

St. Francis County.—The most northerly observed exposure that is believed referable to the Jackson formation is in the east-facing slope of the ridge 8 or 9 miles northeast of Forrest City, St. Francis County, and has been described by Call,[2] who says:

A section studied in the SE. ¼ of the NW. ¼ sec. 29, T. 6 N., R. 4 E., at a point where St. Francis River flows directly against the ridge and makes a sharp turn to the south, shows the sequence of strata from a height of 155 feet above it down to the river level. * * * For the greater part the section is nearly or quite vertical, and is mainly continuous from the loess top of the ridge to the Eocene clays at the water's level.

Call's section is in substance as follows:

Section on St. Francis River 8 or 9 miles northeast of Forrest City.

	Feet.
Pleistocene:	
Loess	60
Pliocene (?) (Lafayette formation in whole or in part):	
Sands and gravels with large masses of chert and some red pipe clay	40
Eocene (Jackson formation):	
Bluish or black stratified clays without fossils other than abundant small pieces of lignite	65
	165

The only natural exposure of the formation in Crowleys Ridge that has furnished important paleontologic data is a nearly vertical north-facing bluff on Little Crow Creek in St. Francis County, about a mile south of west of Madison, about one-eighth mile south of the Chicago, Rock Island & Pacific Railway, and about 3 miles east of Forest City. (See Pl. VII, *A* and *B*.) The section is as follows:

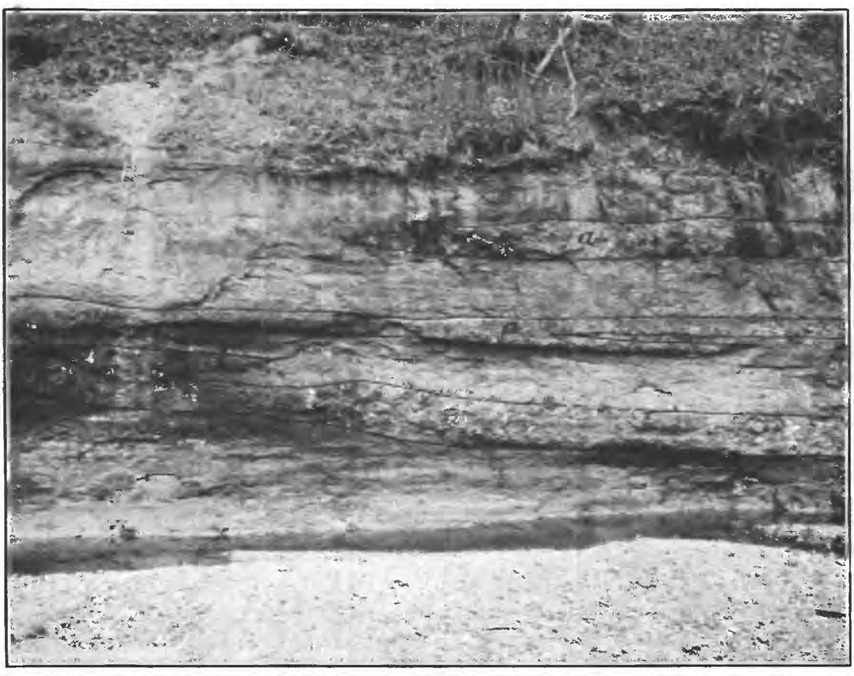
Section on Little Crow Creek near Madison, St. Francis County.

	Feet.
Pleistocene (loess):	
9. Gray massive loess which stands in a vertical cliff; grades downward into next layer	40
8. Dark-brown facies of loess, the so-called old soil zone; grades downward into next layer	3
7. Yellowish facies of loess; grades downward into next layer	7
6. Gray facies of loess, containing concretions of calcium carbonate; becomes light gray and sandy in lower portion and appears to grade downward into next layer; contains fossil shells, chiefly of land mollusks, in lower 10 feet (see list, p. 78)	15
5. Light-gray fine to medium grained argillaceous sand with subordinate lenses of gravel and scattered pebbles; locally ferruginous with numerous small limonite concretions	5

[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 36–57, 143–183, 1891.

[2] Idem, p. 56.

A. FOSSILIFEROUS CLAY OF THE JACKSON FORMATION OVERLAIN IN ASCENDING ORDER BY UNFOSSILIFEROUS SANDS AND CLAYS OF THE SAME FORMATION, THE LAFAYETTE FORMATION, AND THE LOESS, ON LITTLE CROW CREEK 3 MILES EAST OF FORREST CITY, ST. FRANCIS COUNTY.



B. NEAR VIEW OF THE BASE OF THE BLUFF ON LITTLE CROW CREEK SHOWN IN PLATE VII, *A.*

The successive positions of oyster beds as deposition continued are indicated by the black lines (*a*).

	Feet.
The contact as exposed at several places is sharp and probably is an unconformity.	
Pliocene (?) (Lafayette formation):	
4. Heavy bed of gravel composed chiefly of brown and gray, angular to partially rounded pebbles of flint and chert up to 12 inches in length, with a small percentage of white, clear, or pink, smoothly rounded pebbles of quartz up to 1 inch in length; the pebbles and cobbles are in a matrix of coarse, gray, yellow, and brown sand	6
Unconformity.	
Eocene (Jackson formation):	
3. Fine gray sand with a few small lenses of light-drab clay	7
2. Light-drab laminated clay with seams and thin lenses of light-gray fine sand	7
1. Dark-gray compact laminated sandy clay with interbedded layers, lenses, and pockets of compact dark greenish gray argillaceous, slightly glauconitic sand; contains comminuted particles of lignite and scattered larger pieces of lignite; interbedded with the clay in the lower 15 feet are lenses and layers of large oysters (see Pl. VII, *B*, and fig. 2) with an admixture of other smaller forms; an oxidized zone extends along the upper 2 feet of the bed	20
	110

The accumulations of oysters in layer No. 1 (see Pl. VII, *B* (*a*), and fig. 2) mark the successive positions of the beds of living oysters which, as deposition continued, advanced and retreated in response to fluctuating favorable and unfavorable conditions.

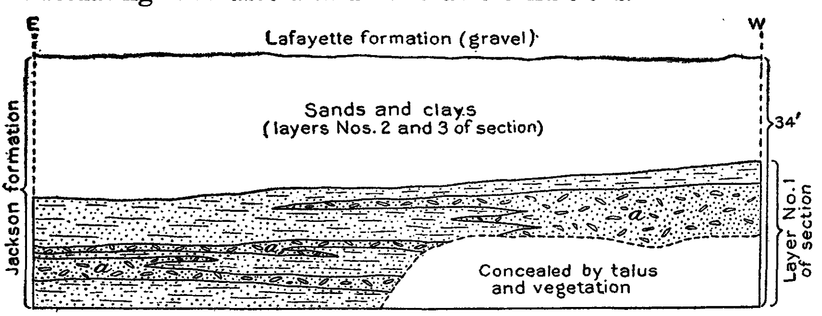


FIGURE 2.—Sketch to show the successive positions of oyster beds (*a*) as deposition continued, as revealed in the base of the bluff on Little Crow Creek, St. Francis County.

The marl bed, layer No. 1 of the section, was examined by Owen[1] as early as 1860 and was correlated by him with the Eocene.

In 1902 Harris[2] discussed the age of the marl and referred it provisionally to the Jackson formation.

[1] Owen, D. D., Second report of a geological reconnaissance of the middle and southern counties of Arkansas, pp. 412–420, 1860.

[2] See quotation on pp. 80–81 of this report.

In 1895 T. Wayland Vaughan collected and identified the following species from layer No. 1:

Fossils from Little Crow Creek, St. Francis County.

Mazzalina inaurata Conrad.
Pseudoliva vetusta (Conrad).
Buccinanops subglobosum (Conrad).
Odostomia sp.
Syrnola sp. 1.
Syrnola sp. 2.
Lunatia eminula (Conrad).
Turritella arenicola var. branneri Harris.
Trinacria sp. (also at Claiborne).
Arca sp.
Ostrea alabamiensis Lea (abundant).
Mytilus hamatoides Call.
Venericardia planicosta Lamarck.
Venericardia parva Lea.
Cytherea discoidalis Conrad.
Lucina papyracea Lea.

Nearly all the species listed are common to the Claiborne and the Jackson. Both Harris and Vaughan are of the opinion that this marl corresponds in stratigraphic position to the marl exposed at the base of White Bluff, Arkansas River, which Harris has shown to be of Jackson age.

From the deep cut east of Forrest City eastward along Little Crow Creek toward Madison, in descending order, 2 or 3 feet of greenish sand, several feet of very lignitic clay, and several feet of gray stratified compact sand, which belong to the Jackson formation, are exposed in the bed of Little Crow Creek near the railroad track. A partially lignitized and partially silicified log, 2½ feet in diameter, was observed in the lignitic layer.

Phillips County.—Some of the numerous well borings in the vicinity of Helena throw light on the geology of the northeastern part of Phillips County. Logs of four such borings are given on pages 237–238. Especial attention is called to the log of the boring on Crowleys Ridge near Helena, made under the auspices of the Mississippi River Commission, and known as "boring No. 2, Helena."[1] Fossil mollusks taken from this well between the depths 171.3 and 231.3 feet were reported upon by Hilgard as follows:

The fossiliferous clay and marl bed, 171.3 to 231.3 [feet], with its intercalated layer of bluish, impure limestone, is very distinctly characterized as Tertiary of the (marine) Claiborne group by the well-preserved specimens of the following shells: *Monoceros vetustas* Lea, *Actaeon lineatus* Lea, *Nucula magna* Lea, *Dentalium turritum* Lea, or *microstriatum* Heiler, *Natica minima* Lea, *N. magnoumbilicata* Lea, *Pleurotoma lonsdalii* Lea; there is besides an undescribed Pleurotoma, Flabellum, and Retepora.

Concerning the correlation of these beds Hilgard further says:[2]

Such as they are, however, these fossils overwhelmingly demonstrate the close correspondence of the beds penetrated at Helena and Choctaw Bar (whose

[1] Hilgard, E. W., U. S. Mississippi River Commission Ann. Rept. for 1883, Appendix T T of the Ann. Rept. of the Chief of Engineers for 1884, pp. 2892–2894. (Published also as House Ex. Doc. 37, 48th Cong., pp. 486–488, 1884.)

[2] Idem, p. 2886. (House Ex. Doc. 37, 48th Cong., p. 488, 1884.)

facies is altogether identical) with the lower portion of the Claiborne beds of Alabama; perhaps most nearly with those older ones which Dr. Eugene A. Smith, State geologist of Alabama, has lately examined at and near Woods Bluff, Ala., and which rest directly upon the oldest lignitic and flatwoods clays.

Although Hilgard correlated the shell-bearing beds penetrated in the Helena boring with the lower Claiborne, Harris,[1] has shown that the strata are younger and belong to the Jackson formation.

This correlation accords with Vaughan's reference of the Crow Creek marl to the lower Jackson (p. 78), for from considerations based on the general structure of the Mississippi embayment it seems improbable that the marl penetrated in the Helena well should be stratigraphically lower than the marl on Little Crow Creek.

Arkansas River localities.—Outside of Crowleys Ridge the only surface occurrences of the Jackson formation in the area under immediate consideration are on Arkansas River in Jefferson County. The most noted locality is White Bluff, which has been described by Call[2] and by Harris.[3]

Harris says (p. 88):

In Volume II of the annual report of the Geological Survey of Arkansas for 1889, Prof. Call defines this locality as on the south side of Arkansas River, 3 S., 10 W., sec. 19, W. ½ of SW. ¼ and NW. ¼ of NW. ¼ of sec. 30. He gives a section consisting of 10 distinct beds aggregating 125 feet in thickness, which "was observed 400 feet west of a deep gulch which cuts through the entire section at right angles to the face of the bluff, directly opposite the house of J. Wallace at White Bluff Landing." The lower 40 feet of this section he found to be fossiliferous. * * *

This classic locality was visited by the writer on the 19th and 20th of November, 1891, when the waters of Arkansas River had been unusually low. Figure 16 * * * represents the bluff at the gulch referred to by Prof. Call.

Harris's description of the highest portion of the section figured by him is essentially as follows:

Section of White Bluff, Arkansas River, Jefferson County.

	Feet.
a. Light-colored sand	5–10
b. Line of chert pebbles	?
c. Soil and sand	8
d. Light-grayish sandy clay	9
e. Very light pink colored clay, containing numerous well-preserved dicotyledonous leaves	8
f. Similar to layer "*i*"	9
g. Dark lignitic clays, containing two bands of lignite, separated from the overlying bed by a seam of pure lignite from 3 to 6 inches thick	5–9
Unconformity.	

[1] See quotation on p. 83 of this report.
[2] Call, R. E., Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 7–9, 1891.
[3] Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 87–94, 1894.

		Feet.
h.	White sand, stained yellowish in places	4–8
i.	Evenly laminated dark lignitic and more or less sulphurous shaly clay; between this bed and the former are occasional ferruginous concretions	11
j.	Dark-bluish sandy marl, containing an abundant molluscan fauna in its lower portion	22

Harris says further (p. 91):

In tracing these various beds down the river from White Bluff, they were observed to be fairly persistent and to decline sufficiently in this direction to carry the lower bed *j* beneath the water within a distance of 1½ miles. Near the lower end of the bluff one feature is especially prominent, namely, the line of chert pebbles. Prof. Call, as remarked above, laid special stress on the singular absence of such pebbles in situ along this bluff; he probably did not visit this portion of the escarpment. A few hundred yards below the place represented in figure 16, huge angular blocks of bed *e*, or the leaf-bearing pinkish clay, have broken off and fallen to the base of the bluff. Vast quantities of leaf impressions were observed in them.

From the lowermost layer of the section, Harris identified the following species:

Ostrea sp.
Nucula magnifica Conrad (small).
Leda albirupina Harris.
Venericardia planicosta Lamarck.
Cytherea discoidalis Conrad.
Tellina sp.
Corbula nasuta Conrad var.
Mactra albirupina Harris.
Dentalium minutistratum Gabb.
Actæon pomilius Conrad.
Bullinella jacksonensis Harris var. exta.
Terebra sp.
Pleurotoma near P. lonsdalii Lea.
Pleurotoma near P. childreni Lea.
Cancellaria impressa Conrad.
Volutilithes petrosus Conrad.
Mitra millingtoni Conrad.
Pseudoliva vetusta Conrad.
Mazzalina inaurata Conrad.
Levifusus branneri Harris.
Fusus sp.
Phos albirupina Harris.
Turritella arenicola var. branneri Harris.
Turritella clevelandia Harris.
Solarium bellastriatum Conrad.
Natica eminula Conrad.

Discussing these fossils, Harris says:

The general aspect of this fauna is indeed Claibornian, as was suggested by Heilprin and maintained more confidently by Call.

Yet the presence of such forms as *Solarium bellastriatum*, *Mitra millingtoni*, and *Bullinella jacksonensis* var., show that the fauna is uppermost Claibornian or perhaps transitional between that and the Jackson. The most common fossils obtained at this locality are: *Venericardia planicosta*, *Turritella arenicola* var. *branneri*, *Mazzalina inaurata*, *Pseudoliva vetusta*, *Cytherea discoidalis*, and *Volutilithes petrosus*, all of which are found in Arkansas associated with typical Jackson fossils, as will be shown further on.

In 1892 Harris,[1] in discussing the Arkansas River localities, said:

At the time of writing my report on the Tertiary of Arkansas (1892), I felt strongly inclined to refer the fossiliferous beds at White Bluff, on Arkansas River, to the Jackson; yet they had always been referred to the Claiborne,

[1] Harris, G. D., The geology of the Mississippi embayment, with especial reference to the State of Louisiana: Louisiana Geol. Survey, pt. 6, p. 22, 1902.

and there seemed not enough positive evidence in favor of the Jackson affinities to entirely warrant the change. Since then some of the new or supposedly new species from White Bluff have been found in abundance at Jackson, Miss., and at well-developed Jackson beds throughout Louisiana and east Texas. The Red Bluff beds, upstream a few miles from White Bluff, seem to be of the same horizon; and although I have not visited Crowleys Ridge personally, I feel quite confident, from Call's description of the beds and associated fossils, together with his correlations, that all should be placed in one and the same group. Accordingly the map of the Embayment area, as herewith published, shows the Jackson for the first time with its most probable northern distribution.

Call[1] describes a locality at Red Bluff, on Arkansas River, as follows:

There is an instructive section at Red Bluff, Jefferson County, in 3 S., 11 W., NE. ¼ of SE. ¼ sec. 12. At this locality there is exposed a section about five-eighths of a mile in length; the highest point, where the section was observed, is 276 feet above mean tide level. It is at the ferry, which is half a mile east of the western limit of the exposure. The section is best exhibited in a gully which enters the river at right angles to the face of the cliff. All the strata seen are horizontal.

Call's section is in substance as follows:

Section at Red Bluff, Arkansas River, Jefferson County.

	Feet.
Eocene (Jackson formation):	
Light-colored fine, very sandy humus, with scattered chert pebbles up to one-half inch in diameter	0.5
Soft light-yellow argillaceous sand, becoming darker below; contains numerous nodules of limonite	2.5
Dark carbonaceous earthy clay of varying thickness, less sandy than the overlying layer; resembles an old soil	.5
Irregularly stratified mottled sands and clays, light-yellow and brick-red predominating, with an occasional small pocket of white sand	4
Irregularly bedded sandstone forming a vertical and jutting face, thickest and hardest 100 feet west of the ferry; weathering on the upper surface, which occurred previous to the deposition of the overlying layer, is evidenced by potholes, ridges, etc.; the lower part of the sand is more regularly stratified than the upper part, and is of a brick-red color. Detached masses at the foot of the bluff contain pockets of pure white vitreous sand and very bright yellow and red potter's clay. Some of the layers of sandstone, especially the upper part, contain very hard tubes cemented with oxidized, manganiferous iron containing white sand	10.5
Soft yellow to reddish sand, with masses of bluish and yellowish potter's clay, becoming hard and intensely red at base	8

[1] Call, R. E., Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 10–13, 1891.

Eocene (Jackson formation)—Continued.	Feet.
Fine dark to black, irregularly stratified, slightly sandy clay, with much selenite, chiefly in the form of star-shaped clusters, up to several inches in length	20
Dark-brown fossiliferous sandstone, with unidentifiable fossils; the cement of the sandstone is iron oxide; the layer forms a jutting ledge along the bluff	.5
Light-bluish, slightly sandy clay, containing numerous needle-like and stellate crystals of selenite, especially abundant toward the basal portion	23

Call says, further:

The Eocene Ostrea bed, or shell marl, which usually underlies this member of the Tertiary in all Arkansas outcrops, is to be seen at low water near the west end of this bluff. Close by the point of the above section a nodulous sandy marl similar to that at White Bluff and having the same fossils was observed, but its stratigraphic relations could not be determined because cf the very heavy talus. It is thought that this marl bed is not quite horizontal in any portion of the region examined from the fact that it is seen at times rather high up in sections, and again it occurs only as lenticular masses in the bottom of streams and gullies. It is not a constant member of either this section or of that at White Bluff, appearing only at points in them.

Quotations from a paper by Gilbert D. Harris on the "Geology of the Mississippi embayment," which contains a discussion of the correlation of the White Bluff and Red Bluff sections, are given on pages 79–81.

CORRELATION.

The Eocene strata which outcrop in Crowleys Ridge from the northern part of St. Francis County southward nearly to the southern extremity of the ridge in Phillips County are correlated with the Jackson formation on the evidence of fossils obtained from an exposure of marl on Little Crow Creek, about 3 miles east of Forrest City, and from a boring at Helena. The Eocene age of the marl was recognized by Owen [1] as early as 1860.

The Jackson age of the bed was first suggested by Harris, whose discussion of the subject is given in a quotation on pages 80–81 of this report.

The first positive determination of the age of the marl on Little Crow Creek was that of T. Wayland Vaughan, who collected and identified the species listed on page 78; he correlates the bed with the marl at the base of White Bluff, which Harris has determined to be of Jackson age.

The fossils from the boring at Helena were first referred by Hilgard to the lower part of the Claiborne formation but were later shown by Harris to include characteristic Jackson species. Harris [2] says:

[1] Second report of a geological reconnaissance of the middle and southern counties of Arkansas, pp. 412–420, 1860.

[2] Geology of the Mississippi embayment: Louisiana Geol. Survey, pt. 6, pp. 22, 23, 1902.

It should be mentioned in this place that we have had access to Hilgard's type specimens from Helena [from the boring just mentioned] and Choctaw Bar [from four borings], and have found that his specific determinations of molluscan fossils is not of the most satisfactory kind. The species are the same in general as at White Bluff, Ark., hence, as shown above, of Jackson age.

In a footnote Harris lists the following species from the borings at Helena and Choctaw Bar:

Helena, boring No. 2.

Dentalium (very nearly smooth but with traces of longitudinal striation).
Volutilithes petrosus Conrad (fragments).
Corbula wailesiana Harris.
Corbula sp.
Phos hilli Harris (var.).
Pseudoliva vetusta (Conrad).
Pleurotoma denticula Basterot.
Actæon sp.
Natica sp.

Choctaw Bar, boring No. 1.

Venericardia planicosta Lamarck.
Dentalium (as at Helena).
Cadulus sp.
Pleurotoma sp.
Actæon sp.
Turritella (very small, unicarinate at base).
Phos hilli Harris.

Choctaw Bar, boring No. 2.

Phos hilli Harris.
Natica (small).
Pleurotoma infans Meyer.
Levifusus trabeatus Harris.
Cancellaria sp.
Corbula (small), probably C. wailesiana Harris.
Turritella clevelandia Harris.
Venericardia rotunda Lea.
Volutilithes petrosus Conrad.
Actæon sp.
Calyptraphorus velatus Conrad (tip).

Choctaw Bar, boring No. 4.

Turritella (small, sharply bi-carinate).
Phos hilli Harris.
Oliva cf. O. gracilis Lea.
Natica (small).
Venericardia parva Lea.
Corbula wailesiana Harris.

Choctaw Bar, boring No. 5.

Pseudoliva vetusta (Conrad).
Natica (small).
Pleurotoma denticula Basterot.
Venericardia planicosta Lamarck.
Turritella (tip, bicarinate).
Volutilithes petrosus Conrad.
Corbula wailesiana Harris.
Actæon sp.

The borings at Helena and Choctaw Bar were described by Hilgard[1] in 1884. The log of boring No. 2 at Helena is given on page 238 of this report. Choctaw Bar is a few miles above Arkansas City in Desha County, Ark. The fossils from the borings at this place were taken at depths between 151 and 185.2 feet.

The total thickness of Eocene strata overlying the marl exposed on Little Crow Creek and penetrated in the boring at Helena probably does not exceed 200 feet. The thickness of the Jackson formation in Mississippi has been estimated to be between 350 and 450 feet, and if this is a correct estimate it seems reasonable to assume

[1] U. S. Mississippi River Commission Ann. Rept. for 1883; Appendix T T of the Ann. Rept. of the Chief of Engineers for 1884, pp. 2891–2896 (published 1884). (Published also as House Ex. Doc. 37, 48th Cong., pp. 486–490, 1884.)

that the 100 feet or less of strata which overlie the marl bed of lower Jackson age in Crowleys Ridge in St. Francis, Lee, and Phillips counties is referable to the Jackson formation. Strata of Jackson age probably underlie the alluvium of Mississippi River valley from Helena, Phillips County, to Arkansas City, Desha County.

UNDIFFERENTIATED EOCENE.

Undifferentiated strata of Eocene age outcrop in the upland southwest of Arkansas River, in Pulaski, Sabine, Grant, and Jefferson counties. These are described by Veatch[1] as consisting of "lignitiferous clays and sands, containing no distinctive marine fossils."

In the northwestern part of Lonoke County, east of Cabot and south of Austin, is a hilly tract of country rising 100 to 125 feet above the level of the Advance lowland, or 350 to 375 feet above sea level; the exact limits of the area have not been determined, but the north-south extent is believed to be 10 or 12 miles and the east-west extent 5 or 6 miles. These hills appear to be composed mainly of coarse reddish ferruginous sand, with subordinate lenses and layers of drab clay, reaching a thickness of 100 feet or more. The weathered sands form the main constituent of the soils, and the clays are exposed at numerous places along the roads and in fields. These strata overlie deposits of undoubted Midway age and are believed to belong to the Eocene, though they are as yet undifferentiated. (See geologic map, Pl. II, p. 30.)

The following section is poorly exposed in the ditches of the public road one-half mile south of the station at Austin:

Section in public road one-half mile south of the station at Austin, Lonoke County.

	Feet.
Eocene:	
3. Reddish, ferruginous, coarse sand with occasional lenses of drab clay, and toward the base containing mechanically included clay balls; the materials are poorly exposed and much weathered	40
2. Drab weathered clay	5
1. Massive, weathered, glauconitic sand; the glauconite grains are partially weathered to brown	4
	49

In the Advance lowland west of Crowleys Ridge and the Mississippi lowland east of Crowleys Ridge stratified sands, clays, and marls of Eocene age, underlie 100 to 225 feet of alluvial material, and dip away from the rim of the Mississippi embayment at the rate of a few feet a mile. The Eocene deposits probably reach a maximum thickness of 1,000 to 1,200 feet or more within the area under consideration, and they rest upon deposits of Cretaceous age.

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 40, 1906.

The buried Eocene deposits probably represent, in ascending order, the Midway, Wilcox, Claiborne, and Jackson formations. Although a number of well borings have penetrated the deposits, data sufficient for differentiating the several formations named have not been obtained. However, considerations of structure make it possible in some places to determine with a fair degree of certainty the formation to which the water-bearing beds belong.

PLIOCENE SERIES.

LAFAYETTE FORMATION.

GENERAL FEATURES.

Name.—The name Lafayette is derived from Lafayette County, Miss., where materials once regarded as typical of the formation to which the name was intended to apply are exposed in railroad cuts and natural sections, particularly in the vicinity of Oxford. The history of the events leading up to the adoption of the name has been given by McGee.[1] As recent investigations have shown that the so-called Lafayette formation includes geologic deposits ranging in age from Cretaceous to Pleistocene, and as the deposits at the type locality are of Wilcox Eocene age, the name is unsatisfactory. It is tentatively used in this paper, pending consideration now being given to the complex of constituents included in the formation.

In certain parts of the Mississippi embayment, including parts of Mississippi, Tennessee, Kentucky, and Illinois east of Mississippi River, and Missouri and Arkansas west of that stream, are upland deposits of gravel and sand, to which the term "Orange sands" was applied previous to the adoption of the name Lafayette and which the name Lafayette was intended to cover. In this connection it should be stated that Safford,[2] who in 1856 introduced the term "Orange sand," did not clearly distinguish between the gravels and sands of later geologic age and the underlying Eocene sands and clays, although he seems never to have fully concurred with Hilgard, McGee, and others in regarding his Orange sand as a distinct surficial formation. Other subsequent investigators in Tennessee and Mississippi failed to make the same distinction. At a conference[3] held in San Francisco in 1891, and participated in by McGee, Hilgard, Loughridge, and LeConte, it was decided that the name Lafayette should supplant the name "Orange sands," and the beds exposed at Oxford, Lafayette County, were chosen as the type locality of the formation.

[1] McGee, W J, The Lafayette formation: U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 498–502, 1891.

[2] Safford, J. M., A geological reconnaissance of the State of Tennessee, p. 162, 1856.

[3] U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 500–501, 1891.

On the evidence of fossil plants Berry[1] has recently shown that the so-called type exposures of the Lafayette formation at Oxford are of Eocene age and referable to the Wilcox formation; the name, therefore, was unfortunately chosen. It is now demonstrated that gravel deposits similar to those referred to the Lafayette formation occur as terraces and valley fillings along the principal streams of the Coastal Plain and represent geologic formations of several different ages. The differentiation, characterization, and correlation of the terraces and associated fluvial phenomena are in progress, but the studies are not sufficiently advanced to correlate with confidence the phenomena of one area with those of another. Therefore the designation of certain gravel deposits in Tennessee, Kentucky, southern Illinois, and northeastern Arkansas as Lafayette is only provisional, for the gravels designated Lafayette in this report may subsequently be shown to be in part of Pleistocene age.

The distribution and character of the Lafayette formation in the Mississippi embayment east of Mississippi River have been treated by Crider[2] and Glenn,[3] the former with reference to Mississippi and the latter with reference to Tennessee, Kentucky, and southern Illinois.

Areal distribution.—The Lafayette formation is present in Crowleys Ridge throughout its entire extent from Stoddard County, Mo., to Phillips County, Ark. East of Mississippi River it is broadly developed over the northwestern part of Mississippi, the western parts of Tennessee and Kentucky, and the southern part of Illinois, where it rests upon Eocene and Cretaceous strata and laps over upon the Paleozoic rocks. Its detailed distribution in these States has, however, not been determined, and the formation is known to be absent in certain areas where it has heretofore been supposed to exist.

The formation is represented along the western margin of the Mississippi embayment in Arkansas by scattered deposits of gravel and sand which overlie the Eocene deposits in the Grandglaise terrace and occupy the east-facing slopes of the hills of the Ozark province; their distribution has not been determined in detail.

Stratigraphic relations.—In Crowleys Ridge the formation rests with a marked unconformity upon the beveled edges of the Wilcox, Claiborne, and Jackson formations; the contact varies in vertical position from near or a few feet above the level of the Mississippi lowland to 100 feet or more above that datum. Owing to disturbances in the nature of creep, landslides, and redeposition to which the ma-

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[1] Berry, E. W., The age of the type exposures of the Lafayette formation: Jour. Geology, vol. 19, pp. 249–256, 1911.

[2] Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. 283, pp. 44–46, 1906.

[3] Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in southern Illinois: U. S. Geol. Survey Water-Supply Paper 164, pp. 40–43, 1906.

terials have been subjected, it is difficult at many places to determine whether or not they are in their original place of deposition, and this fact has led to some confusion as to the stratigraphic relations of the deposits. However, there is abundant evidence to show that the deposits were laid down upon a strongly eroded surface.

In Crowleys Ridge the formation is overlain by deposits of loess of Pleistocene age and the relation between the two formations is believed to be that of nonconformity; this determination is based on sections examined east of Wynne, in Cross County (pp. 71, 92, 109); east of Forrest City, in St. Francis County (pp. 76, 93); and north of Helena, in Phillips County (pp. 94, 95), where unconformities more or less clearly defined have been noted. At some of the exposures in Crowleys Ridge, however, the contact between the two classes of deposits is not clearly defined. This interpretation is in substantial agreement with the conclusions of other investigators in adjacent areas. With reference to the attitude of the two formations in southern Illinois, Chamberlin and Salisbury[1] say:

The erosion slopes of the hills, cut out of the horizontally though irregularly stratified sands and gravels, are thus seen to be strewn with gravel, sandstone débris, and ferruginous concretions, originating from the same series higher on the slope. Overspreading the whole, covering the crests of the hills and the eroded edges of the sand and gravel layers, together with their thin covering of local débris, as above indicated, is the mantle of loess. It is absent only where recent erosion has been sufficient to effect its removal. How far the uniformity of distribution of loess over regions of strongly accentuated relief may be due to the creep of the plastic material down the slopes, is not here discussed; but this is not believed to be an adequate explanation of its uniform slope distribution. The loess and its clayey equivalents are confidently believed to have been deposited like a mantle over a previously eroded surface. If the body of the hills be Paleozoic rock with only a capping of gravel and sand the relation of the loess to the latter is not altered.

In a discussion of the relation of the Pleistocene deposits to the underlying Lafayette formation in the Mississippi embayment east of Mississippi River Glenn[2] says:

At some places along the Mississippi bluffs and in a belt 10 to 20 miles wide east of the bluffs the loess seems to rest unconformably directly on the Lafayette sands or gravels. At other places, however, there is a distinctly differentiated bed of soft, loose, light-colored sand between the two. This sand often contains rounded pebbles similar to those of the Lafayette beneath, from which they have evidently been derived. Like the sand, which may also have originated from the Lafayette, the pebbles are usually bleached to a light gray. This difference in color and the softness of the sand serve to differentiate the deposit at once from the red, case-hardened Lafayette beneath. This sand

[1] Chamberlin, T. C., and Salisbury, R. D., On the relationship of the Pleistocene to the pre-Pleistocene formations of the Mississippi basin south of the limit of glaciation: Am. Jour. Sci., 3d ser., vol. 41, pp. 367, 368, 1891.

[2] Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U. S. Geol. Survey Water-Supply Paper 164, p. 44, 1906.

may range in thickness up usually to 4 or 5, and exceptionally to 10 or 12 feet, and may attain its maximum and disappear again in 100 or 200 yards.

It [the sand] commonly though not everywhere shows distinct unconformity on the Lafayette beneath and as a rule seems to grade upward into the lower, darker part of the loess without any perceptible break. Where the sand seems to be absent the lowest part of the loess is usually somewhat sandy, and may contain a small pebble here and there for several feet upward from its base. It is likely that in such cases the sandy basal part of the loess is the representative of the sand found elsewhere.

From the last quotation given it would appear that in Tennessee and Kentucky the loess, or the thin bed of soft sand which in places occurs at the base of the loess, rests unconformably upon the Lafayette formation.

Locally, on the higher parts of Crowleys Ridge north of Craighead County the loess has been eroded away leaving the gravels capping the tops of the hills.

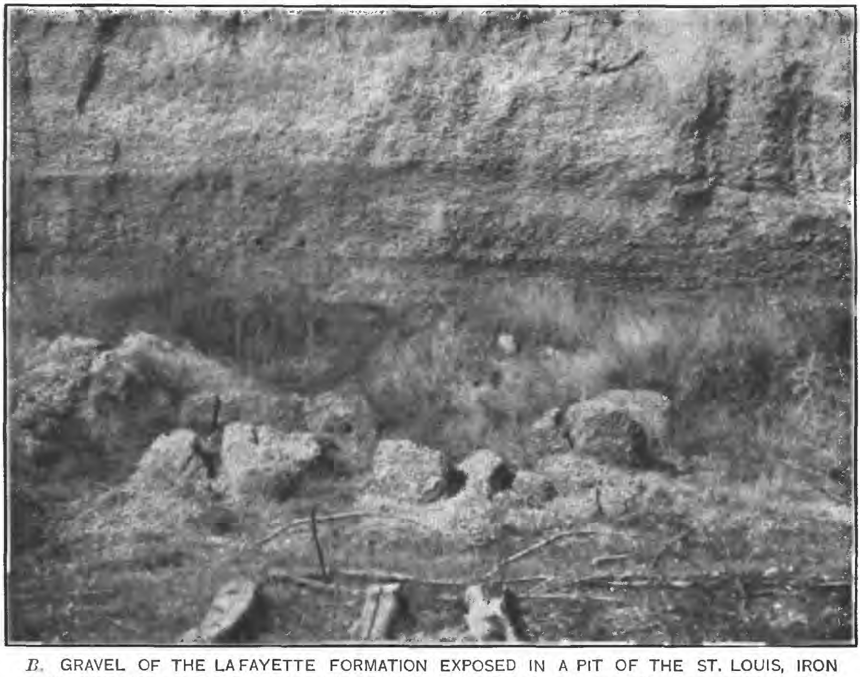
Lithologic character.—The Lafayette formation in Crowleys Ridge is composed of irregularly bedded gravels and coarse sands. In general heavy beds of gravel occupy the base of the formation and consist mainly of subangular to partly waterworn pebbles and cobbles of chert, the latter rarely exceeding a foot in longest dimension. (See Pl. VIII, *A*.) The pebbles and cobbles were derived from the cherty limestones of the Ozark province, as indicated by the contained fossils of Paleozoic age. In places fragments of sandstone and quartzite, more or less waterworn, are mixed through the gravels; these fragments were derived in part from the quartzites of the Wilcox formation exposed in the northern part of Crowleys Ridge, and in part from the Paleozoic rocks of the Ozark province. At most of the exposures of gravel occasional small, smooth, waterworn pebbles of quartz may be found. (See p. 99.)

At some of the exposures revealing the thicker parts of the formation the basal gravels are overlain by coarse cross-bedded sands with numerous lenses and layers of gravel of greater or less extent; locally thin layers of laminated clay have been noted in the sands. At some places the gravels and sands are intermixed with lumps of mechanically derived clay.

Both the sands and gravels are varicolored and have been strongly oxidized. At many places the basal gravels have been cemented by iron oxide into a hard, ferruginous conglomerate, and at a few places the sands have been observed partially indurated to red sandstones. These indurated masses have formed where percolating waters carrying iron oxide in solution have had their downward circulation checked by compact layers of clay or other impervious materials.

Thickness.—The Lafayette formation in Crowleys Ridge ranges in thickness from a few feet to a maximum observed thickness of 80 feet. The difference in thickness at different places is due in part

A. GRAVEL OF THE LAFAYETTE FORMATION EXPOSED IN THE WEST SLOPE OF CROWLEYS RIDGE NEAR COLT, ST. FRANCIS COUNTY.



B. GRAVEL OF THE LAFAYETTE FORMATION EXPOSED IN A PIT OF THE ST. LOUIS, IRON MOUNTAIN & SOUTHERN RAILWAY 2 MILES WEST OF NEWARK, INDEPENDENCE COUNTY.

to the unconformable relations of the formation to the underlying Eocene deposits, in part to the variable amounts of materials deposited at different places and in part to the erosion which followed the deposition of the materials. The maximum observed thickness of the formation (80 feet) in Crowleys Ridge is in the section at the Big Spring, 2½ miles north of Helena, Phillips County.

Physiographic expression.—In so far as Crowleys Ridge is composed of the materials of the Lafayette formation the ridge is a topographic expression of the formation. The outcropping beds of gravel have determined in part the detailed topographic features of the slopes of the ridge. From Craighead County northward the loess has been removed from the top of the ridge at numerous places by erosion, leaving the gravels as the capping materials; at such places the resistance to erosion offered by the gravels is checking what would otherwise be a rapid reduction in the height of the ridge.

LOCAL DETAILS.

Gravels and sands of the Lafayette formation are exposed at many places in Crowleys Ridge throughout its length, from Stoddard County, Mo., to Phillips County, Ark. Detailed descriptions of many localities have been given by Call,[1] who, however, did not clearly differentiate this formation from the underlying Eocene sands, which, with the sands and gravels of the Lafayette formation, he included in the so-called "Orange sands."

At most places in Crowleys Ridge the basal part of the Lafayette formation consists of a heavy bed of gravel which rests with a marked unconformity upon the underlying Eocene sands or clays, and, with local exceptions, no difficulty is found in determining the contact between the deposits of the two ages.

Deposits of sand and gravel in the form of erosion remnants occur at many places along the western border of the Mississippi embayment, some forming a part of the Grandglaise terrace and others resting upon the Paleozoic rocks of the Ozark province.

A few typical sections will be described in this report.

Clay County.—According to Call[2] (p. 57 of this report) the summit of the ridge at Chalk Bluff, on St. Francis River, in the northern part of Clay County, is capped with fine gravels and coarse sands.

Southwest of Chalk Bluff, in Clay County, the gravels have been observed at numerous places on the crest and on the slopes of Crowleys Ridge. Where they occur on the divide they are covered with a few feet of loess, except locally, where the latter has been removed by erosion.

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[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 30–142, 1891.

[2] Idem, pp. 114, 115.

On the Boydsville-Gainesville road, 2 or 2½ miles southwest of Boydsville, a bed of indurated gravel cemented with iron oxide forms a hard, ferruginous conglomerate capping the divide of the ridge.

The loess of Clay County is nearly everywhere underlain by coarse dark red sands, in places pebbly, which appear to grade upward into the more typical loess. Whether this sand belongs to the Lafayette formation or should be considered a sandy phase of the loess was not determined.

Greene County.—Exposures of the formation are numerous in Greene County. A section exposed in a public road one-eighth of a mile west of Gainesville is as follows:

Section in public road one-eighth of a mile west of Gainesville.

	Feet.
Pleistocene (loess):	
Light-colored loam	4
Red loamy clay	2
Pliocene(?) (Lafayette formation):	
Gravel consisting of pebbles of chert of different colors, brown predominating, up to 5 inches in longest diameter, with an intermixture of small, smoothly water-worn pink and white quartz pebbles; locally indurated to a ferruginous conglomerate	.5
Coarse red, somewhat argillaceous sand	6
	12.5

Three and one-half miles west of Gainesville the road leading to Beech Grove crosses a ridge 200 feet higher than the lowland to the west (aneroid reading); 30 feet below the top of the ridge a bed of gravel is poorly exposed in the slope and is overlain by a red phase of loess.

From 4 to 7 miles west of Paragould where a public road crosses the highest part of the ridge (475 to 500 feet above sea level) are beds of gravel not exceeding an observed thickness of 5 feet, overlain, except locally, by 1 to 5 feet of brownish or reddish loam (loess). The gravels consist chiefly of gray, brown, and pink subangular to fairly well rounded pebbles of flint and chert up to 6 inches in length, with a considerable percentage of white, partially rounded to smoothly rounded pebbles of quartz up to 1 inch in length.

An exposure on Poplar Creek, NW. ¼ sec. 10, T. 16 N., R. 4 E., which reveals 30 feet of materials referable to this formation, has been described by Call.[1] This section is given on page 60 of this report.

[1] Call, R. E., op. cit., p. 111.

Craighead County.—An exposure in a gully on the old William Lane place, 4 miles northeast of Bono, Craighead County, sec. 9, T. 15 N., R. 3 E., which shows the relation of the Lafayette formation to the underlying Wilcox formation and to the overlying loess, is described on page 61.

One of the best exposures of the formation in Crowleys Ridge is on the farm of Mrs. Mahala Shelton, 6 miles southwest of Jonesboro, on the south side of one of the small headwater streams of L'Anguille River. The section is about 200 feet long and 45 to 50 feet high; the base of the section in the bed of the stream is a few feet lower than the level of the lowland to the west.

Section on the Shelton farm, 6 miles southwest of Jonesboro.

	Feet.
Pleistocene:	
Loess mixed with pebbles, with a thin layer of pebbles along the base (varies in thickness along the bluff from 2 to 6 feet); this material has probably all crept down the slope from a higher level, which explains the unconformable relation of the loess to the underlying Lafayette formation at this locality	4
Unconformity.	
Pliocene ? (Lafayette formation):	
Coarse, red sand grading downward into coarse gray sand, the whole crossbedded (varies in thickness along the bluff from 6 to 10 feet)	10
Pebbles and sand intermixed, containing lumps of white plastic clay	4
Coarse, strongly crossbedded, pink-tinted sand, forming as a whole a nearly horizontal bed	13
Sand and gravel interstratified	4
Massive to cross-bedded gravel consisting mainly of subangular to partly waterworn brown chert pebbles and cobbles, reaching a maximum dimension of 1 foot; red, pink, gray, and black chert pebbles were also observed; a few small, smoothly waterworn pink and white quartz pebbles occur mixed with the chert. The thickness varies along the bluff from 4 to 11 feet	11
Unconformity.	
Eocene (Wilcox formation):	
Coarse white to yellow cross-bedded sand (varies in thickness along the bluff from 4 to 11 feet)	4
	50

Poinsett County.—Gravels of the Lafayette formation are poorly exposed on the west-facing slope of Crowleys Ridge at Harrisburg, Poinsett County. The main bed crops out on the crest of the steep part of the slope about 75 feet above the level of the Advance lowland, and talus gravels occur at numerous places below the crest.

Although no clear-cut exposure was observed, the gravel bed probably exceeds 10 feet in thickness in the vicinity of the town. The gravels consist predominantly of brown, partially rounded to smoothly rounded pebbles of flint and chert, up to 1 foot in length, and some of them contain impressions of Paleozoic crinoids; a few of the chert pebbles are gray, pink, and red tinted. A noticeable proportion of the gravels consists of white, pink, and clear, partly rounded to smoothly rounded pebbles of quartz up to 1½ inches in length. The gravels in the vicinity of Harrisburg are overlain by loess which, on the higher parts of the ridge east of the town, probably reaches a maximum thickness of 25 feet or more.

Beds of gravel similar to those at Harrisburg occur on Crowleys Ridge practically throughout its length in Poinsett County. Call[1] has described several localities and has recorded a maximum observed thickness of 40 feet of deposits referable to the formation.

Cross County.—Five feet of gravel of the Lafayette formation is exposed above the Claiborne formation in the section near Cherry Valley, Cross County, described on page 69.

Near the west end of a cut of the St. Louis, Iron Mountain & Southern Railway, 1 mile east of Wynne, the formation is seen in relation to the underlying Claiborne formation and to the overlying loess.

Section in an excavation for road metal 1 mile east of Wynne, near the west edge of Crowleys Ridge and just south of the St. Louis, Iron Mountain & Southern Railway.

	Feet.
Pleistocene (loess):	
3. Gray loess grading downward into brown coarse sandy loess at base; scattered pebbles present in the lower 2 or 3 feet	10
Contact fairly sharp and undulates 2 or 3 feet in a distance of a few rods.	
Pliocene(?) (Lafayette formation):	
2. Coarse gravel, consisting chiefly of subangular to fairly well rounded pebbles and cobbles of brown and gray flint and chert up to 6 inches in length, with a small percentage of smoothly rounded, white, pink-tinted, and clear quartz pebbles up to 1 inch in length; the pebbles and cobbles are in a matrix of coarse, reddish sand; a few inches to 1 foot of the basal portion of the bed is indurated to a hard ferruginous conglomerate	16
Unconformity.	

[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 77–83, 1891.

Eocene (Claiborne formation):	Feet.
1. Dark chocolate-tinted fine argillaceous massive sand, weathering to gray; contains numerous brown comminuted fragments of vegetable matter	8
	34

The gravel as it occurs under the loess beneath the crest of Crowleys Ridge, 1½ miles east of Wynne, is described in a section given on page 109 of this report.

Another instructive exposure on a small creek, 3 miles east of Wynne and one-eighth mile north of the St. Louis, Iron Mountain & Southern Railway, is described on page 70 of this report, and is illustrated by a graphic section showing the unconformable relation of the Lafayette formation to the underlying Claiborne formation, and the probably unconformable relation to the overlying Pleistocene deposits.

Gravels belonging to the formation are described in two sections given on pages 70 and 71, one located 2½ miles north of the site of old Wittsburg[1] and the other 4 miles east of Wynne. In each place the gravels rest upon the Claiborne formation.

St. Francis County.—A section which reveals the formation resting upon the Jackson formation and overlain by loess is exposed on Little Crow Creek about 3 miles east of Forrest City and about one-eighth of a mile south of the Chicago, Rock Island & Pacific Railway. This section is described on pages 76–78.

The formation is exposed at the base of a north-facing bluff of Little Crow Creek about 1 mile east of Forrest City and just south of the Chicago, Rock Island & Pacific Railway. The section is as follows:

Section on Little Crow Creek, 1 mile east of Forrest City.

Pleistocene (loess):	Feet.
3. Loess, faintly banded; becomes sandy and grades into next layer below	50
2. Light-gray fine compact sand with scattered pebbles	4
Unconformity (?); contact is irregular but not very sharp.	
Pliocene(?) (Lafayette formation):	
1. Gravel composed chiefly of subangular to partly rounded pebbles of flint and chert up to 4 or 5 inches in length, with a small percentage of smoothly rounded white, clear, and pink quartz pebbles up to 1 inch in length; the matrix consists chiefly of coarse gray, red, and yellow sand; fine light-gray sand resembling that of layer No. 2 is mixed with the gravels to a depth of a few inches to a foot below the top	6
	60

[1] Call, R. E., op. cit., pp. 69–71.

Lee County.—Phillips post office (now discontinued) was located at the foot of the east-facing slope of Crowleys Ridge near the southern boundary of Lee County. In a gully just west of the site of the post office the following section is exposed:

Section in a gully just west of the site of Phillips post office.

	Feet.
Pleistocene:	
4. Loess, sandy at base; one fragment of a land shell observed	10
Unconformity, probably due to the creep of the loess down the slope from a higher level.	
Pliocene (?) (Lafayette formation):	
3. Red cross-bedded pebbly calcareous sand, drying with a hard, harsh surface; contains spherical concretions of sand and calcium carbonate up to 3 or 4 inches in diameter, which in places are segregated into botryoidal clusters	15
2. Light-gray cross-bedded sand containing a few small pebbles and scattered spherical concretions of sand and calcium carbonate	7
1. Gravel composed chiefly of iron-stained chert pebbles, reaching a maximum diameter of 3 or 4 inches	10
	42

Phillips County.—The following section is exposed in a ravine just north of the "Big Spring" on the east side of the ridge, 2½ miles north of Helena, Phillips County:

Section in ravine just north of "Big Spring" on the east side of Crowleys Ridge, 2½ miles north of Helena, Phillips County.

	Feet.
Pleistocene (loess):	
Poorly exposed, except 30 or 40 feet of massive gray loess in the basal portion	130
Unconformity somewhat obscured by weathering.	
Pliocene (?) (Lafayette formation):	
Coarse gray, reddish, and yellowish, irregularly bedded sand, with numerous scattered pebbles and small to large lenses and layers of gravel, interbedded with subordinate thin layers of laminated pink and drab clay; thick lenses of coarse cross-bedded sand were observed; in places the sands contain mechanically included balls of pink clay; gravel predominates in the basal 10 feet of the section, but is interbedded with lenses of coarse sand; the pebbles consist chiefly of subangular to partly rounded flint and chert up to 3 or 4 inches in diameter, with a few small, smoothly rounded quartz pebbles	80
	210

The Lafayette materials of this section differ from those of most parts of the ridge north of Lee County in the predominance of sand and in the presence of thin beds of drab and pink-tinted, laminated clay. The gravels, however, appear to differ in no essential respect from the typical gravels observed at many localities in the ridge to the north.

The water of Big Spring emerges from the coarse gravel at the base of the Lafayette.

Near a small spring which emerges from the foot of the east slope of the ridge, one-quarter mile south of the Big Spring, are several gullies that reveal the contact between the Lafayette formation and the overlying loess. The section here is as follows:

Section in gullies near a small spring about 2¼ miles north of Helena and one-quarter of a mile south of the Big Spring, Phillips County.

	Feet.
Pleistocene (loess):	
Poorly exposed, except 25 feet of gray calcareous massive loess in the basal portion	80
Unconformity; the contact as seen in several exposures is absolutely sharp and undulates through a vertical distance of a foot or more in small exposures (Pl. IX, *B*).	
Pliocene (?) (Lafayette formation):	
Coarse gray cross-bedded sand, variegated with pink, red, yellow, and black, with interbedded thin layers of laminated drab to pink clay; in places the sand contains pebbles and water-rolled lumps of pink and drab clay	25
Concealed to the level of the Mississippi lowland	15
	120

Exposures in the northern outskirts of Helena at the foot of the east-facing slope of Crowleys Ridge reveal in places coarse, pebbly sands and gravels corresponding to the deposits referred to the Lafayette formation in the two preceding sections; at one place a layer of gravel 4 or 5 feet thick was observed immediately beneath the loess but the contact with the loess was not clearly exposed.

Western border of the Mississippi embayment.—Scattered remnants of gravel were observed on the hills of the Ozark province west of McAlmont, Pulaski County.

Two miles west of Beebe, White County, the Ozark hills rise 40 or 50 feet above the level of the Advance lowland. A few chert pebbles were observed scattered about on the Carboniferous sandstones and weathered shales which appear to compose the body of the hills.

Two miles south of Searcy the following section was examined in a cut of the Searcy branch of the Chicago, Rock Island & Pacific

Railway on the east-facing scarp which separates the Ozark province from the Advance lowland:

Section in cut of Chicago, Rock Island & Pacific Railway 2 miles south of Searcy.

	Feet.
Pliocene (?) (Lafayette formation):	
Sandy loam	1–3
Gravel	¼–1
Unconformity.	
Paleozoic (Carboniferous):	
Thin-bedded greenish-gray argillaceous sandstone	8
	12

The loam and gravel of this section blanket down over the slopes of the hill.

One and one-half miles south of Searcy, on the road leading to Higginson, a bed of gravel 5 or 6 feet thick was observed resting on Paleozoic rocks and overlain by 1 to 2 feet of sand and sandy loam.

A short distance northwest of the town of Judsonia, which is at the northwestern border of the Advance lowland, the Ozark hills rise 50 to 75 feet above the lowland level. In places on these hills a thin covering of gravel of the Lafayette formation was observed resting on sandstone of Carboniferous age. The gravels consist chiefly of chert, but several small, smoothly rounded pebbles of quartz were seen.

In Jackson County the Grandglaise terrace is partly separated from the Paleozoic rocks to the west by small valleys. At some places on the northwest slope of the ridge thus formed are numerous rounded pebbles, cobbles, and bowlders, probably derived from a bed of gravel of the Lafayette formation.

Five feet of reddish ferruginous sand, with pebbles in the basal portion, considered referable to the Lafayette formation, appears in a section one-half mile south of Grandglaise and just west of the St. Louis, Iron Mountain & Southern Railway. The sand rests on Eocene strata and is overlain by reddish loam of probable Pleistocene age. A description of this section is given on page 52 of this report.

About one-half mile north of Grandglaise very coarse gravel outcrops in the road; although poorly exposed, this bed probably rests upon Paleozoic rocks and is overlain by a loamy, claylike material, resembling a facies of the loess of Crowleys Ridge.

At Newark and vicinity, in Independence County, Upper Cretaceous deposits form the body of the Grandglaise terrace and are overlain by deposits of gravel of the Lafayette formation which range in thickness from a few inches to 25 feet or more. The gravels are overlain by a few inches to an observed thickness of 5 or 6 feet of yellowish, brownish, and reddish, more or less sandy and pebbly loam, which is believed to be of Pleistocene age.

The best exposure of the gravels observed in the vicinity of Newark is in a ballast pit of the St. Louis, Iron Mountain & Southern Railway on the edge of the Grandglaise terrace 2 miles west of the town. (See Pl. VIII, *B*, p. 88.)

Section exposed in a ballast pit of the St. Louis, Iron Mountain & Southern Railway 2 miles west of Newark, Independence County.

	Feet.
Pleistocene? (loess?):	
Yellow and brownish pebbly and sandy loam	3
Contact obscured by weathering.	
Pliocene (?) (Lafayette formation):	
Gravel composed of subangular to smoothly rounded pebbles of brown, gray, and reddish chert up to 3 inches in length, with a few small lenses of coarse reddish sand and sandy clay; some of the pebbles bear the prints of Paleozoic fossils; a talus covering partly obscures the basal 5 or 6 feet	20

The base of this section is about 10 feet above the level of the Advance lowland, along the border of which the railroad extends east and west. In a section exposed in a gully 1 mile north of Magness, Independence County, gravel of the Lafayette formation was observed resting on glauconitic sands of Upper Cretaceous age and overlain by a few feet of pebbly loam. (See section, p. 38.)

A bed of gravel capping a hill 2 miles north of Newark is described in a section given on page 38. Gravels cap the Grandglaise terrace at numerous places between Dota and Cord.

Remnants of gravel deposits, believed to represent the Lafayette formation, are scattered about the east-facing slopes of the hills of the Ozark province between Black Rock and Powhatan, in Lawrence County.

A few pebbles, probably representing remnants of the Lafayette formation, occur on the slopes of the Ozark hills just west of the ferry at Tabor, Clay County.

CORRELATION.

The deposits of gravel and sand in Mississippi, Tennessee, Kentucky, and southern Illinois to which the name Lafayette is applied, rest unconformably on Paleozoic, Cretaceous, and Tertiary strata and are overlain, in part, by loess of Pleistocene age. Exactly similar deposits of gravel and sand in Crowleys Ridge occupy an analogous position with reference to underlying Eocene strata of Wilcox, Claiborne, and Jackson age and overlying deposits of loess of Pleistocene age. On lithologic and structural grounds the deposits in Crowleys Ridge may therefore be correlated with the gravels having the same relations east of Mississippi River.

The geologic series to which the Lafayette formation belongs has not been determined with certainty, chiefly because of the lack of paleontologic data. According to Chamberlin and Salisbury,[1] the formation is separated from the overlying loess by an unconformity which is indicated by a well-marked structural break and by the oxidation to which the pre-loessial materials have been subjected.

At some localities in Crowleys Ridge the Lafayette formation appears to be separated from the loess by a well-marked unconformity, but at many places the contact is more or less obscure; the materials composing the former have undoubtedly been subjected to strong oxidation.

The best and most convincing argument for the pre-Pleistocene age of the Lafayette formation is that based on the composition of the gravels. On this subject Salisbury[2] says:

> The gravels of Crowleys Ridge are, in all characteristics which are essential to the present discussion, like those of western Kentucky and Tennessee, like those of southern Illinois and southeastern Missouri. There are minor differences in their constitution, dependent on the differences of the rocks from which they are derived, but these are not especially significant, so far as the question of the age of the gravels is concerned. It is to be noted that the gravels of southern Illinois, of southeastern Missouri, of western Tennessee and Kentucky, as well as those of Crowleys Ridge, occupy a geographic position which makes it necessary to suppose that the drainage of the ice of the first episode passed through the region which they occupy. If these gravels date from this time they should contain pebbles of northern drift. It would not be necessary to suppose that all the gravel deposited by a stream springing from the glacier would necessarily be northern, since extra-glacial tributaries might bring in material from extra-glacial sources in the ordinary process of river degradation. But emphasize the importance of this latter consideration as we may, it yet remains an indisputable fact that were the conditions of drainage such that tributaries could bring gravel to their main in great quantities, the main itself, if springing from the ice, would inevitably bring something of glacial débris, which would be found mixed with the material of more local origin, which the tributaries might have brought in. And this would be true even if the accumulation of the gravels took place at an early stage of the glaciation of the first episode, long before the ice approached the latitudes under consideration; for the drainage basin of the Mississippi reaches several hundreds of miles to the northward and probably extended still farther in that direction at an early stage of the ice invasion, when the ice had so far spread itself over the British possessions as to prevent drainage into Hudson's Bay.

[1] On the relationship of the Pleistocene to the pre-Pleistocene formations of the Mississippi Basin south of the limit of glaciation: Am. Jour. Sci., 3d ser., vol. 41, pp. 359–377, 1891.

[2] On the relationship of the Pleistocene to the pre-Pleistocene formations of Crowleys Ridge and adjacent areas south of the limit of glaciation: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 240–242, 244, 1891.

If, then, the Orange sands and gravels were accumulated during the first glaciation of the first glacial epoch, as valley or estuary deposits, we should of necessity have northern material a constituent of these sands and gravels. Such, however, is not the fact. In the hundreds of exposures of gravel which the writer has seen, large numbers of which in various localities in Arkansas and in the other States already named have been examined in detail for this especial purpose, not a single pebble of demonstrably northern origin has ever been found. Northern pebbles have been found associated with pebbles derived from the gravels under consideration, but only in such situations that the secondary character of the deposits containing such pebbles was certain, or altogether probable, from considerations entirely independent of those here noted. And the freedom from northern gravel and sand does not characterize the Orange sands simply in their more southern distribution, where the local material might naturally be more abundant than to the north, but even up to the northern limit of the Orange sand regions scarcely more than a score of miles from the southern border of the glacial drift, the northern pebbles are likewise altogether absent. And it is not simply glacial pebbles that are wanting. The absence of glacial sand and silt from the Orange sand formation is equally conspicuous and significant.

* * * * * * *

And even if an occasional northern Archean pebble should hereafter be found in the Orange sand, we should not, on the strength of this evidence alone, regard our conclusion as invalidated, for the drainage basin of the Mississippi reaches well back into the area of Archean rocks, and it would not be at all surprising if Archean pebbles from this source should have found their way into the lower Mississippi Valley before the glacial period.

At nearly all the localities of the Lafayette formation examined in Crowleys Ridge the gravels, which are composed predominantly of flint and chert, contain scattered, smoothly rounded quartz pebbles, few more than 1½ inches in diameter. The small size of the pebbles and the evident long-continued wear to which they have been subjected suggest that they have been transported great distances. E. W. Shaw is actively engaged in a study of this subject and suggests the following as possible sources of the quartz: The veins of quartz cutting the crystalline rocks in the northern part of the Mississippi basin, probably not an adequate source; conglomerates in the Paleozoic rocks of the upper Mississippi basin; postulated gravel deposits of Cretaceous and Tertiary age in the same basin, now largely though probably not entirely, removed; and the crystalline rocks of the Piedmont area east of the Appalachian Mountains. The ultimate source of the quartz in the Paleozoic and later conglomerates of the upper Mississippi River basin would be either the crystalline rocks of Canada or those of the Piedmont; it seems improbable that any of the quartz has been derived from the Rocky Mountain region. The question of the possible transportation of quartz pebbles from the Piedmont region along the ancient drainage courses or shore lines has not been sufficiently studied.

The evidence seems to be convincing that the materials composing the Lafayette formation in Crowleys Ridge were deposited before the continental glaciers of Pleistocene time had brought their load of materials down the Mississippi Valley from the far north to within a relatively short distance of the head of the Mississippi embayment; in other words, they were deposited in pre-Pleistocene time. How long the deposition of the gravels and sands of the Lafayette formation antedated the beginning of the Pleistocene is a matter of conjecture. Probably, however, the time was relatively short, geologically speaking. The thinness of the formation, its nearly horizontal attitude, and the unconsolidated condition of the materials would seem to preclude the lapse of any great length of time between its deposition and the deposition of the overlying loess, for the oscillations to which the Mississippi embayment was subjected prior to Pleistocene time and the accompanying erosion would probably have resulted in the complete destruction of the formation. The formation is believed, therefore, to be of late Pliocene age.

Quaternary system.

PLEISTOCENE SERIES.

LOESS.

AREAL DISTRIBUTION.

In Arkansas the materials classed as loess cap Crowleys Ridge or mantle its slopes from the Missouri State boundary on the northern border of Clay County southward to the southern extremity of the ridge, near Helena, Phillips County. Fragmentary erosion remnants of yellowish, reddish, and brownish argillaceous loam, which probably represent the loess, occur along the western margin of the Mississippi embayment, in places capping the Grandglaise terrace and elsewhere resting upon the east-facing slopes of the hills of the Ozark province.

North of Arkansas the loess forms the capping material of Crowleys Ridge to its northern extremity in Stoddard County, Mo., and is also present on Benton Ridge in Scott County, Mo.

East of the Mississippi lowland the loess occurs on the upland in a belt 5 to 25 miles or more in width, paralleling the Chickasaw Bluffs, and extending from southern Illinois southward through Kentucky, Tennessee, and Mississippi to Louisiana.

The general distribution of loess in North America has been summarized by Chamberlin and Salisbury[1] as follows:

In North America the loess does not occur east of the Mississippi basin and has no great development east of the Wabash River. It is widespread in Illi-

[1] Chamberlin, T. C., and Salisbury, R. D., A college textbook of geology, pp. 887, 888, 1909.

nois and the States along the Missouri and in the States along the Mississippi farther south. Within this area the distribution is peculiar in that it follows the main streams that led away from the Iowan drift sheet, and is found especially on the bluffs overlooking the valleys. On this account it was formerly known as the Bluff formation. In this bluff position it has more than its average thickness and coarseness of grain, and grows thinner and finer in grain back from the river bluffs until it is lost in a vanishing edge. At the same time its material loses its distinctive characteristics.

Just south of the borders of the Iowan and Wisconsin drift sheets it mantles many of the divides between the main streams, but farther south it is more confined to the valley borders. It has little regard for topography and can hardly be said to have an upper limit. Within the drift-covered part of the Mississipi basin it occurs (1) as a surface mantle overlying drift and (2) between sheets of drift. South of the drift there are in places distinct sheets of loess, sometimes separated by a well-developed soil zone. The surface of the lower sheet shows the effects of prolonged weathering and oxidation in some places. Loess occurs in isolated spots even as far west as Washington and Oregon.

STRATIGRAPHIC POSITION.

The loess forms the capping material of Crowleys Ridge, and where undisturbed from its original position rests on the Lafayette formation. The nature of the contact between the loess and the Lafayette formation in Crowleys Ridge is believed to be that of unconformity, for at several localities, notably in Cross, St. Francis, and Phillips counties, there is a structural break, more or less clearly marked, separating the two classes of deposits. (See Pl. IX, *B*, and fig. 1, p. 71.) However, at many places the contact is obscured by weathering and its true character is difficult to detect. In the eastern and northern parts of the Mississippi embayment other investigators have observed an unconformity between the two formations. The time hiatus represented by this unconformity is believed to include an undetermined portion of early Pleistocene time, and perhaps a relatively brief portion of late Pliocene time.

Throughout the extent of Crowleys Ridge deposits of loess are found mantling the slopes of the ridge, at many places entirely to the base; in places it is obvious that disturbances in the nature of landslides, creep, or redeposition have taken place, but at many places it is not so apparent that shifting of this character has occurred. However, more of the mantling is probably to be explained in this way than has been supposed by previous students of the ridge.

At numerous places north of Craighead County the loess has been entirely removed from the crest of the ridge by erosion, leaving the Lafayette formation as the capping material.

LITHOLOGIC CHARACTER.

The loess of Crowleys Ridge presents several facies of gray, brown, or reddish silt, varying in composition from typical loess, of very fine texture, to both argillaceous and sandy facies of loess.

The composition of loess has been described by Chamberlin and Salisbury[1] as follows:

The term loess is used both as a textural and a formational name. Lithologically, it is a silt intermediate between sand and clay. It is generally free from stones of all sorts, except the concretions developed in it since its deposition. In the exceptional cases where stones occur in it, they are confined to its very bottom, or are found in loess which has slumped or been washed down from its original position. It is sometimes interstratified with sand, especially at its base, where it is thick. On slopes and at their bases loess is often mingled with slope wash, talus, etc.

The loess contains angular, undecomposed particles of the commoner carbonates (calcite and dolomite) and silicates (feldspars, amphiboles, pyroxenes, micas, etc.), and several of the rarer silicates have been identified. Magnetite also is a common, though never an abundant, constituent. All these are subordinate to quartz. These constituents strongly suggest that the material of the loess was derived from the flour of the glacial mill. In color it is predominantly buffish brown, but in not a few places it has a grayish (bluish) cast a few feet below the surface.

The loess often stands with vertical faces for long periods, where sand or clay would be degraded into slopes. Roads on the loess tend to assume the form of little canyons, because the silt of the roadbed is washed or blown away, while that on either side stands up with steep or even vertical slopes. Weathered faces of the loess often show a rude columnar structure, the columns being 1 to several feet in diameter. The loess, as a rule, shows no stratification, but in its coarser phases there is often some suggestion of such structure, and where interbedded with sand stratification is sometimes distinct.

In the more complete exposures of loess in Crowleys Ridge, as in the deep cut of the St. Louis, Iron Mountain & Southern Railway at Wynne (p. 109), a distinct banding of the materials, due to slight differences in color, texture, and composition, is discernible. In the Wynne section and at a few other places in the ridge a nearly horizontal dark band, resembling an old soil, has been observed traversing the body of the loess 10 to 20 feet below the surface. This may be the same as the old soil which has been traced by E. W. Shaw, of the United States Geological Survey, throughout a considerable part of the Gulf embayment. Apparently it means that the deposition of the loess was interrupted by an erosion interval, and this interval may have been between Iowan and Wisconsin time.

Although the loess of Crowleys Ridge is in the main massive, evidences of stratification have been observed at some places, particularly toward the base of the deposits; at many places the loess grades downward into basal sands or clays. Pebbles are not uncommon in the basal materials.

In bluff and gully exposures and in artificial cuttings the loess tends to stand in vertical walls. (See Pls. VII, *A*, IX, *A*, and X, *B*.)

Ten samples of loess and residual clay from selected localities in Crowleys Ridge and one sample of doubtful loess from the Grand-

[1] Op. cit., pp. 885–887, 888.

A. LOESS EXPOSED IN A GULLY ON THE EASTWARD-FACING SLOPE OF CROWLEYS RIDGE NEAR HELENA, PHILLIPS COUNTY.

B. UNCONFORMABLE CONTACT BETWEEN THE LAFAYETTE FORMATION AND THE LOESS IN A GULLY NEAR A SMALL SPRING AT THE FOOT OF CROWLEYS RIDGE, A QUARTER OF A MILE SOUTH OF THE BIG SPRING AND 2¼ MILES NORTH OF HELENA.

glaise terrace in Jackson County were submitted to E. W. Shaw, who has furnished the following report on their petrographic and mechanical characters:

The method used in studying the mineralogical composition of the specimens of loess consisted in examining first the material in its natural condition, the sample being taken from the interior of a specimen where there was no possibility of including extraneous dust; then a sample gotten by carefully washing a considerable amount of loess to get rid of the finest claylike particles; and, finally, particles obtained by treating this washed material with a heavy liquid, generally bromoform, to sort out the heaviest particles. The bromoform was usually diluted with benzene until it had a specific gravity of 2.75, sufficient to float the most abundant minerals, quartz, orthoclase, and microcline, and also the calcite which is present in some specimens, and allow the heavier particles, particularly the ferromagnesian minerals to settle to the bottom.

Specimen 26206: From 8 to 10 feet below surface in cut of St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne, Ark. Full thickness of loess exposed at this place about 78 feet, apparently all in place. In general aspect this specimen is grayish-yellow with a slight brownish tinge, rather compact and claylike, and yet including numerous small, irregular tubes, probably root impressions running through it in various directions. Compared with average loess this specimen seems to be rather unusually fine grained and homogenous. Only a very small proportion of the grains are so fine that it is impossible or even difficult to determine their mineralogical identity. On the other hand, grains large enough to be ordinarily termed sand grains are rare. Besides quartz and orthoclase (which is more or less altered) other feldspars are present, and also biotite, hornblende, zircon, fluorite, rutile, tourmaline, and apatite. Epidote, muscovite, and sillimanite are present in particles barely large enough to identify.

Specimen 26207: From 12 or 15 feet below surface in cut of St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne, Ark. This specimen is compact and has a decided carbonaceous appearance, its color being a rather dark brownish gray. It is much like No. 26206 except that it is not quite so uniform in grain and it seems to lack biotite, fluorite, and albite.

Specimen 26208: From 15 or 20 feet below surface in cut of St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne, Ark. This specimen has a dirty yellowish color, is rather hard and coherent, and is made up of quartz, chert, muscovite, several feldspars, zircon, sillimanite, staurolite, and possibly other minerals.

Specimen 26209: From 30 or 40 feet below surface in cut of St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne, Ark. This specimen is a light brownish yellow in color and is of a texture which might be stated as that of typical loess. Quartz constitutes about 90 per cent of this specimen; chert is abundant, and other minerals, particularly the feldspars, but also muscovite, biotite, epidote, zircon, and hornblende, are present in scattered particles.

Specimen 26210: From 51 to 56 feet below surface in cut of St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne, Ark. This specimen is of a reddish-brown color and unusually clayey; probably an old residual soil. It differs from most of the other samples in that a much larger portion is impossible of mineralogical determination, chert particles are unusually numerous, the feldspars are much weathered, and it seems to contain little, if any apatite, hornblende, or orthoclase.

Specimen 26211: From about 60 feet below the surface in cut of St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne, Ark. This specimen is of a light buff color, with a decided pinkish tinge and mottled with yellow. The minerals are quartz, chert, several feldspars, biotite, muscovite, tourmaline, zircon, rutile, kyanite, and garnet.

Specimen 26212: From 30 or 35 feet below the surface at the west end of Elm Street, Helena, Ark. This specimen is of a dark gray, differing markedly in containing much calcite, as well as the more abundant minerals, quartz, and some flint, orthoclase, microcline, epidote, biotite, and zircon.

Specimen 26213. From about 80 feet below the surface at the west end of Elm Street, Helena, Ark. This specimen is of a dark gray, differing markedly in color from most loess, and resembling the old loess underlying the Illinoisan till in southern Illinois. It has a typical loess texture, being quite porous and absorbent. It is made up principally of quartz and chert, but contains much more or less altered orthoclase, microcline, and probably other feldspars, muscovite, sillimanite, hornblende, epidote, and zircon.

Specimen 26214: From 8 or 10 feet below surface one-half mile southwest of Grandglaise, Ark. This specimen is reddish-buff in color and is not a very typical sample of loess, being much less pervious and more like residual clay. The minerals observed are quartz and flint, in particles having a considerable range in size, muscovite, biotite, magnetite, zircon, tourmaline, epidote, sillimanite, and apatite.

Specimen 26215: From near bottom of gully 15 feet deep 3½ miles west of Paragould, Ark. This specimen is of a brownish-buff color and not very porous. Probably the loess here has crept a little. It contains in addition to quartz many rather large grains of biotite, chert, and hornblende, and smaller particles of magnetite, zircon, rutile, brookite, garnet, and sillimanite.

Specimen 26216: From 20 to 23 feet below surface in cut of Chicago, Rock Island & Pacific Railway one-quarter mile east of Forrest City, Ark. This specimen is of a dark grayish-brown color, and carbonaceous in appearance, but fine grained and homogeneous. The minerals observed are quartz, flint, muscovite, feldspar of several varieties, augite, magnetite, rutile, tourmaline, and kyanite.

A part of each specimen was sent to the United States Bureau of Soils, which very generously made the mechanical analyses given in the following table, according to its standardized method:

Mechanical analyses of 10 samples of loess and loesslike material from Crowleys Ridge, Ark., and of one sample from the Grandglaise terrace.

	26206	26207	26208	26209	26210	26211	26212	26213	[a]26214	26215	26216
Fine gravel (2 to 1 mm.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse sand (1 to 0.5 mm.)	.0	.2	.4	.0	.0	.0	.0	.0	.2	.2	.2
Medium sand (0.5 to 0.25 mm.)	.1	.1	.3	.0	.6	.1	.1	.1	.1	.1	.1
Fine sand (0.25 to 0.1 mm.)	.2	.3	.6	.1	.6	1.1	.2	.1	6.0	.5	.2
Very fine sand (0.1 to 0.05 mm.)	3.8	2.6	7.0	9.5	7.7	9.4	7.8	5.6	10.6	4.4	4.8
Silt (0.05 to 0.005 mm.)	84.2	82.3	78.2	83.2	59.3	82.3	86.9	85.5	70.3	78.2	84.7
Clay (0.005 to 0 mm.)	11.4	14.3	12.9	7.0	31.8	6.9	4.7	8.6	12.5	16.4	10.0

[a] Sample from one-half mile southwest of Grandglaise, Jackson County, Ark.

The following analyses of samples of loess from Wisconsin, made for W. C. Alden by the Bureau of Soils in 1910, are inserted for purposes of comparison:

Mechanical analyses of samples of loess from Wisconsin.

	23189	23190	23191
Fine gravel (2 to 1 mm.)	0.0	0.0	0.1
Coarse sand (1 to 0.5 mm.)	.0	.0	.1
Medium sand (0.5 to 0.25 mm.)	.0	.2	.1
Fine sand (0.25 to 0.1 mm.)	.7	1.0	1.7
Very fine sand (0.1 to 0.05 mm.)	19.6	5.1	18.2
Silt (0.05 to 0.005 mm.)	64.8	81.5	63.1
Clay (0.005 to 0 mm.)	14.7	12.2	16.4

23189. Loess, Bridgeport, Crawford County, Wis., near Mississippi River.
23190. Loess on late Wisconsin drift, Columbia County, Wis.
23191. Composite of loess loams; Driftless Area near Baraboo, Wis.

THICKNESS.

On Crowleys Ridge the loess varies from a thin veneer to a layer with a measured thickness of 139 feet. In general, the deposits are thinner north of Craighead County than south of that county; the maximum thickness of 139 feet is shown by the record of a well boring on the ridge near Helena, Phillips County (see log, p. 238), and a thickness of 130 feet was measured by the aneroid in the section at the Big Spring, 2½ miles north of Helena (see p. 94).

PHYSIOGRAPHIC EXPRESSION.

Although the existence of Crowleys Ridge is due to the resistance to erosion offered by the Eocene strata which compose the core of the ridge, the detailed surface features are determined chiefly by the loess which almost completely covers its crest and slopes. Where erosion has advanced to a mature stage the topography produced by the loess is characterized by smoothly rounded slopes and broad, shallow valleys; where the conditions have favored the rapid cutting of small valleys and deep ravines the loess stands up about their sides in nearly vertical walls. These extremes and intermediate stages are represented in the topography of the ridge.

PALEONTOLOGIC CHARACTER.

The only fossils found in the loess of Arkansas are the shells of various species of land mollusks and one bivalve fresh-water mollusk; these have been observed only in the southern part of Crowleys Ridge in Phillips, Lee, and St. Francis counties, where at certain places numerous well-preserved specimens are scattered through the materials. Call[1] has published lists of species from several localities. Lists of species from three localities identified by Paul Bartsch and a list from one of these localities identified by William H. Dall are given on pages 107 and 108 of this report.

[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 39, 49, 166–168, 1891.

LOCAL DETAILS.

The loess is exposed at hundreds of places in Crowleys Ridge. Along the western margin of the Mississippi embayment there are scattered remnantal deposits of reddish and yellowish loamy clays which rest upon either the Paleozoic rocks of the east-facing slopes of the hills of the Ozark province or form the capping materials of the Grandglaise terrace.

A few of the more complete exposures of loess in Arkansas will be described in following paragraphs.

Helena, Phillips County.—At the southern extremity of Crowleys Ridge, west of Helena, the loess attains its greatest thickness in Arkansas—139.7 feet—determined by a boring on the ridge west of the town. (See log, p. 238.) Good exposures occur in road cuttings, other artificial excavations, and ravines. The materials are gray to yellowish and brownish in color and contain numerous small irregular concretions of calcium carbonate, apparently distributed indiscriminately through the mass. For the most part the materials appear to be massive, but at one or two fresh cuttings faint banding has been observed. The well-preserved remains of land mollusks are numerous in places. The following is a section prominently exposed in an excavation near the west end of Elm Street, Helena:

Section in an excavation near the west end of Elm Street, Helena.

	Feet.
Pleistocene (loess):	
Gray massive calcareous loess exhibiting faint banding; contains scattered remains of land shells throughout nearly the whole thickness, and at scattered intervals the shells are bunched together in large numbers. (See statement of petrographic character, sample No. 26212, and mechanical analysis of same sample in the table, p. 104)	75
Very dark greenish gray (wet) compact, massive, tough, finely arenaceous loess, with an oxidized zone a few inches to 1 foot thick in the upper portion; resembles the loess in texture, but differs in color and plasticity from common loess. (See statement of petrographic character, sample No. 26213, and mechanical analysis of same sample in the table, p. 104)	10
	85

The following fossils collected from the upper 75 feet of loess at this locality and from materials corresponding to this layer at near-by localities (field No. 269) were identified by Dr. Paul Bartsch:

Fossils from loess at Helena, Ark.

Polygyra appressa Say.
Polygyra zoleta Binney.
Polygyra monodon Rackett.
Polygyra elevata Say.
Polygyra albolabris Say
Polygyra multilineata Say.
Polygyra stenotrema Ferussac.
Pyramidula alternata Say.
Pyramidula perspectiva Say.
Helicodiscus parallelus Say.
Conulus fulvus Draparnaud.
Zonitoides arboreus Say.
Zonitoides minusculus Binney.
Gastrodonta ligera Say.
Gastrodonta sp.
Vitrea sp.?
Vitrea indentata Say.
Succinea luteola Gould.
Circinaria concava Say.

A thickness of 130 feet of loess was measured by the aneroid in a section exposed in a gully near the Big Spring, 2½ miles north of Helena, a description of which is given on page 94 of this report. Another section one-quarter mile south of the Big Spring, which shows the unconformable relations of the loess to the underlying Lafayette formation, is described on page 95. (See Pl. IX, *B*, p. 102.)

Forrest City, St. Francis County.—On the north-facing side of a deep cut of the Chicago, Rock Island & Pacific Railway one-quarter mile east of Forrest City, St. Francis County, the following section is exposed:

Section in cut of Chicago, Rock Island & Pacific Railway one-quarter mile east of Forrest City.

	Feet.
Pleistocene (loess):	
Gray massive calcareous loess with concretions of calcium carbonate; grades downward into next layer below	20
Dark-brown loess resembling an old soil, with concretions of calcium carbonate; grades downward into next layer below. (See statement of petrographic character, sample No. 26216, and mechanical analysis of same sample in the table on p. 104)	3
Yellowish loess with concretions of calcium carbonate; grades downward into next layer below	8
Gray massive loess with concretions of calcium carbonate	11
Gray massive loess with faint horizontal lines of yellow iron oxide simulating bedding planes; contains calcium carbonate concretions and becomes sandy and ferruginous in the basal 4 or 5 feet; contains numerous land shells and one fresh-water species (see list below)	14
	56

When examined in 1905, 4 feet of pebbly cross-bedded sand streaked with yellow, probably belonging to the Lafayette formation, was observed beneath the loess in the center of the cut. In 1912 this had become concealed by talus.

The following fossils collected from the lowermost layer of the section just described were identified by Dr. Paul Bartsch:

Fossils from loess in cut of Chicago, Rock Island & Pacific Railway one-quarter mile east of Forrest City (Field No. 267).

Polygyra stenotrema Ferussac?
Polygyra appressa Say.
Polygyra monodon Rackett.
Polygyra sp.?
Polygyra sp.?
Circinaria concava Say.
Circinaria concava Say (young).
Sphærium sp.? (fresh-water bivalve).
Helicodiscus parallelus Say.
Strobilops labyrinthica texasiana Pilsbry.
Helicina orbiculata Say.
Pomatiopsis lapidaria Say.
Succinea avara Say.
Lymnæa parva Lea.
Vitrea indentata umbilicata Singley.
Zonitoides minusculus Binney.
Bifidaria contracta Say.
Bifidaria corticaria Say.
Bifidaria sp.?

In a collection made from the same locality in 1905 (U. S. Nat. Mus. catalogue No. 6405) William H. Dall has identified the following species:

Planorbis trivolvis Say.
Pomatiopsis lapidaria Say.
Polygyra hirsuta Say.
Polygyra monodon Rackett.
Succinea avara Say.
Circinaria concava Say.
Heliocodiscus lineatus Say.
Zonitoides arboreus Say.
Bifidaria contracta Say.
Strobilops labyrinthicus Say.
Helicina occulta Say.

Seventy feet of loess is exposed in the section on Little Crow Creek described on page 76. (See Pl. VII, *A*.) From a layer 50 to 65 feet below the surface in this section Dr. Bartsch identified the forms Polygyra sp.? and Sphærium sp.? (a fresh-water bivalve).

Sixty feet of loess appears in a bluff on St. Francis River, where the river strikes against the foot of the eastern slope of the ridge 8 or 9 miles northeast of Forrest City. (See section, p. 76.)

Wynne, Cross County.—The cut of the St. Louis, Iron Mountain & Southern Railway through the crest of Crowleys Ridge 1½ miles east of Wynne, Cross County, reveals the full thickness of the loess at that place. The cut is over 80 feet deep and has been widened several hundred feet by the removal of material used for ballast on the railroad embankments. In the north-facing side of the excavation, including a deeper trench extending in a linear direction through the cutting, the following section is exposed:

A. "OLD SOIL" ZONE IN LOESS ON SOUTHWARD-FACING SIDE OF CUT OF ST. LOUIS, IRON MOUNTAIN & SOUTHERN RAILWAY 1½ MILES EAST OF WYNNE, CROSS COUNTY.

B. LOESS EXPOSED IN A CUT OF THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY THROUGH CROWLEYS RIDGE A QUARTER OF A MILE EAST OF FORREST CITY, ST. FRANCIS COUNTY.

Section in cut of St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne.

	Feet.
Pleistocene (loess):[1]	
7. Light-gray facies of loess	15
6. Dark-brown facies of loess, resembling an old soil; contains a few small brown chert pebbles	6
5. Light-gray facies of loess	30
4. Harsh red ferruginous facies of loess mottled in places with gray	5
3. Light-gray facies of loess tinted with pink	12
2. Light pinkish-gray, finely arenaceous clay grading downward into light greenish-gray argillaceous sand, containing numerous small concretions of impure limonite and a few small pebbles of chert and quartz; resembles loess in texture	8–10
Unconformity; contact is sharp and varies in vertical position as much as 2 feet in a horizontal distance of 2 yards.	
Pliocene (?) (Lafayette formation):	
1. Gravel composed chiefly of brown and gray subangular to partly rounded pebbles of flint and chert up to 6 inches in length, with a small percentage of smoothly rounded to partly rounded white or clear quartz pebbles up to 1 inch in length	3

The different facies of loess described in this section produce distinct bands in the deposits; the layers are not sharply defined but grade into each other. At one place on the south-facing side of the same cut the so-called old soil zone, corresponding to layer No. 6 of the section, is well exposed in a less complete section, as follows:

Section on south-facing side of a cut of the St. Louis, Iron Mountain & Southern Railway 1½ miles east of Wynne.

	Feet.
Recent:	
4. Artificial fill of loess	6
Pleistocene (loess):[2]	
3. Light-gray facies of loess; grades downward into next layer below	12
2. Dark-brown facies of loess, resembling an old soil zone; grades downward into next layer below	3
1. Light-gray facies of loess, similar to layer No. 3	5
	26

The dark band, layer No. 2, of the section is well shown in the photograph reproduced in Plate X, *A*.

Forty or 45 feet of loess is well exposed in a south-facing slope on a small creek 3 miles east of Wynne and one-eighth mile north

[1] See statements of petrographic character and mechanical analyses as follows: Layer No. 3, sample No. 26211, text and table, p. 104; layer No. 4, sample No. 26210, p. 103, and table, p. 104; layer No. 5, sample No. 26209, p. 103, and table, p. 104.

[2] See statements of petrographic character and mechanical analyses as follows: Layer No. 1, sample 26208, p. 103, and table, p. 104; layer No. 2, sample 26207, p. 103, and table, p. 104; layer No. 3, sample 26206, p. 103, and table, p. 104.

of the St. Louis, Iron Mountain & Southern Railway; this section is described in detail on page 71 of this report.

Eighteen feet of loess appears in the upper part of the section exposed in a gully about 4 miles east of Wynne and one-quarter mile south of the St. Louis, Iron Mountain & Southern Railway, described on page 70.

In the section 2½ miles north of the site of Old Wittsburg, described on page 70, the thickness of the loess is 49 feet; concretions of calcium carbonate are abundant in the middle portion of this exposure.

Jonesboro, Craighead County.—In the vicinity of Jonesboro, Craighead County, are numerous exposures of loess, which commonly appear in the form of a dark loam, lacking calcareous concretions and fossils; light-colored and reddish facies of the loess are also to be seen. In places the argillaceous content increases and the materials become dark loamy clays. The thickness is as a rule 30 feet or less. One of the best exposures has been described by Call[1] as follows:

Three or four miles west of Jonesboro, on the line of the Kansas City, Fort Scott & Memphis Railway, are several cuts across low spurs of the ridge. These cuts disclose only the loess clays, but show them better than any other section in the county. They may be here divided into three layers on the usual color basis, as follows:

	Feet.
1. Siliceous or sandy humus, with much clay	2
2. Tough red clayey loess, much fissured, the faces of the fissures black with dendritic segregations of manganese. This member is removed for railway ballast and is so hard as to require blasting	7
3. Looser, yet tough, more yellow soil, weathering into vertical faces	15

This cutting is duplicated at several places. This one shows the characteristic mode of occurrence and coloration of the loess.

Greene County.—The loess in Crowleys Ridge in Greene County commonly appears either as reddish, argillaceous loam or as lighter-colored facies of loam. Along the public road leading west from Paragould loess, for the most part poorly exposed, is the only material to be seen in the road ditches and cuttings. In a gully at the roadside, 3½ miles from town, a thickness of 15 feet of the loess was observed; a statement of the petrographic character of a sample of this material (sample 26215) and a mechanical analysis of the same sample are given on page 104. From 4 miles west of town westward across the ridge to the margin of the Advance lowland, a thin blanket of loess not exceeding 5 or 6 feet forms the surface material and rests upon gravels of the Lafayette formation, which appear at frequent intervals.

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[1] Call, R. E., op. cit., p. 89.

At Gainesville red, mottled, and light-colored facies of the loess are exposed in the road ditches, and in places the materials contain numerous small, irregular concretions of calcium carbonate. In places in Greene County the loess has been entirely eroded away from the crest of the ridge, leaving the underlying gravels of the Lafayette formation as the capping materials.

In the Advance lowland, in the northwestern part of Greene County, is an isolated ridge known as Jones Ridge, which is composed mainly of materials believed to represent the loess. The ridge trends in a northeast-southwest direction between Cache River and the St. Louis, Iron Mountain & Southern Railway, is 3 or 4 miles long, one-quarter to one-half mile wide, and 30 or 40 feet high. The surface, though considerably dissected, presents smoothly rounded gentle slopes, offering no complete exposures of the materials. A few poor exposures on the slopes of the ridge reveal a dark, somewhat sandy clay loam, grading downward into reddish argillaceous sand. As these materials resemble closely facies of loess observed in Crowleys Ridge to the east in Greene County, they have been correlated with that formation.

Clay County.—In Clay County the loess of Crowleys Ridge appears in the form of light-yellow, brown, and dark-red, noncalcareous, more or less sandy and argillaceous loams, in places grading downward into sands or clays. At no place where observations were made did the loess exceed 30 feet in thickness. At numerous places the loess has been entirely eroded away from the crest of the ridge, leaving the gravels of the Lafayette formation as the capping materials.

Western margin of the Mississippi embayment in Arkansas.—Loesslike clays have been observed resting on Paleozoic limestone just west of the ferry over Current River at Tabor, Clay County. They form hills just west of the ferry over Black River at Powhatan, Lawrence County, where they probably rest on Paleozoic rocks. Yellow loams, probably representing the loess, cap the Grandglaise terrace between Strawberry, Lawrence County, and Newark, Independence County, but at many places the loess has been largely eroded away and is now represented only by a thin veneer of sandy loam.

South of Grandglaise in Jackson County, the Grandglaise terrace is capped in places by 10 or 12 feet of reddish, massive, finely arenaceous, argillaceous loam resembling loess; this material strongly suggests certain facies of the loess of Crowleys Ridge. The best exposure of the loam examined in the Grandglaise terrace was in a south-facing bluff one-half mile south of Grandglaise, and just west of the St. Louis, Iron Mountain & Southern Railway; a description of this section is given on page 52 of this report. A statement of the petrographic character of a sample of loess taken from layer No. 5 of this section (sample 26214) and a mechanical analysis of the same sample are given on page 104.

CORRELATION.

The Pleistocene age of the American loess has long been a recognized fact among students of American geology. Chamberlain and Salisbury [1] discuss the age of the loess as follows:

> The relations of the loess to the several drift sheets make it clear that it was accumulated at different stages of the glacial period, but within the glaciated area the accumulation at one of these stages exceeds that at all others, both in volume and areal extent. The loess deposited at this stage is often referred to as "the loess," and is usually correlated in time with the Iowan drift. It is at least later than the Illinois sheet of drift, which it mantles, and earlier than the Wisconsin drift, which overlies it. Locally a thin mantle of loess overlies the Wisconsin drift, even its later parts. No considerable body of loess older than the Illinois drift is known.

In his earlier studies of the loess Salisbury,[2] in terms of the classification then in use, referred the loess of Crowleys Ridge to the first glacial epoch. On the evidence of the soil zone to which reference has previously been made, he subdivided the loess into two parts, the older and lower of which he correlated with the first episode of the first glacial epoch, and the upper and younger of which he referred to the second episode of the first glacial epoch. He regarded the part of the loess above the soil zone as corresponding to the main body of the loess. In terms of the present classification of the glacial drift the main body of loess is correlated in time with either the Iowan drift or with the Peorian interglacial stage,[3] which immediately succeeded the Iowan invasion. In this connection it should be stated that in the southern part of Crowleys Ridge, where the so-called soil zone is most distinctly developed, the thickest body of loess is below and not above the soil zone. The soil zone, at most of the exposures examined, is only 10 or 20 feet below the top of the ridge, while in places the thickness of the loess below the zone is 55 or 60 feet; at one locality a thickness of 40 feet of loess was observed above the soil zone.

If the loess above the soil zone corresponds to the main body of the loess in other parts of the Mississippi basin, that below the soil zone is of course older, though the interval between the deposition of the two parts would not necessarily be of relatively long duration.

[1] A college textbook of geology, p. 888, 1909.

[2] Salisbury, R. D., On the relationship of the Pleistocene to the pre-Pleistocene formations of Crowleys Ridge and adjacent areas south of the limit of glaciation: Arkansas Geol. Survey Ann. Rept., 1889, vol. 2, pp. 232–234, 1891.

[3] Calvin, Samuel, The Iowan drift: Jour. Geology, vol. 19, pp. 599–602, 1911.

The question of the significance to be attached to the so-called soil zone is one to which sufficient attention has probably not been given. On the hypothesis that the upland loess was deposited chiefly through the agency of wind it does not seem improbable that such a zone might be formed within the main body of the loess, due to a temporary change in the prevailing direction of the wind, or to a temporary advantage gained by vegetation in the adjacent area of mud flats from which the materials were supplied to the wind. If this be true, the formation of a soil zone would not necessarily have direct connection with changes taking place in the main area of glaciation farther north.

According to Dr. Paul Bartsch, who determined the species listed on page 108, the contained fossils throw no light on the exact correlation of the loess. Shimek,[1] discussing the same subject, says:

> The fossil mollusks do not enable us to determine the age of any of the Pleistocene formations. The fossils of the Aftonian are not sufficiently distinct from those of modern alluvium to permit the drawing any conclusion other than that the conditions of deposition were much the same. They do not enable us to distinguish between the loesses, for the fossils of the gray and the yellow loesses are, in larger series, essentially the same. * * *
>
> In no known Pleistocene deposit is there a vertical gradation of species which can be accounted for on climatic grounds. * * *
>
> Southward along the Mississippi the loess molluscan fauna changes in essentially the same manner as the modern fauna of the surface. At Hickman, Ky., the larger helices (so prominent in the southeastern modern fauna) already appear in large numbers and *Pyramidula solitaria*, carinate *Pyramidula alternata*, *Polygyra tridentata*, very large *P. albolabris*, large *P. profunda*, a few *P. elevata*, *P. fraterna*, *P. fraudulenta*, *P. appressa*, *Omphalina fuliginosa*, large *Circinaria concava*, more abundant *Pyramidula perspectiva*, and *Gastrodonta ligera*. These species already form the most conspicuous feature of the loess fauna. *Helicina occulta* still appears, though here approaching its southern limit. Still farther south at Dyersburg, Tenn., a similar fauna appears in the loess, but *Helicina occulta* is not common, reaching here its southern limit, and *Pyramidula striatella*, so common in the north, also becomes rare. Still farther south on the west side of Mississippi River at Helena, Ark., the loess fauna becomes still more characteristically southern, and in addition to the larger helices already mentioned the large form of *Succinia ovalis*, *Omphalina kopnodes*, *Vitrea placentula*, and *Helicina orbiculata* appear in conspicuous numbers. The last three species are distinctively southern. *Helicina occulta* has wholly disappeared and its place has been taken by *Helicina orbiculata*. The richly fossiliferous loess of Natchez and Vicksburg, Miss., also contains the forms common at Hickman and Helena, and the presence of *Polygyra obstricta*, *P. inflecta*, and *P. stenotrema* still further stamps the fauna as distinctively southern.

[1] Shimek, Bohumil, The significance of Pleistocene mollusks: Science, new ser., vol. 37, pp. 506, 507, 508, 1913.

ALLUVIUM.

GENERAL FEATURES.

Areal distribution and thickness.—The Advance lowland between Crowleys Ridge on the east, the Ozark province on the northwest, and the Coastal Plain uplands southwest of Arkansas River is underlain by 100 to 200 feet of alluvial deposits, chiefly referable to the Pleistocene epoch. A subordinate portion of the deposits are of Recent age. The Pleistocene alluvium comes to the surface in the interstream areas, or more exactly in the inter-floodplain areas of the lowland.

The Mississippi lowland throughout its extent in Arkansas and the adjoining States of Missouri, Kentucky, Tennessee, and Mississippi is also underlain to depths of 100 to 225 feet by alluvium which belongs to both the Pleistocene and Recent epochs. In this area the deposits of the two epochs have not been so accurately differentiated as have the alluvial deposits of the Advance lowland.

A belt of undulating land a few feet higher than the Mississippi lowland and nowhere more than 5 or 6 miles wide, which borders Crowleys Ridge on the east from Clay County southwestward to the southern part of Craighead County, is believed to be a remnant of a Pleistocene plain or terrace corresponding in age to the interstream plains of the Advance lowland.

Sikeston Ridge or Big Prairie, a narrow ridge about 20 feet high, which extends from south of Lake St. John, Scott County, Mo., to New Madrid, New Madrid County, Mo., is believed to be composed of Pleistocene deposits. A similar low ridge extends with several interruptions from the southern part of Stoddard County, Mo., a little west of south in a slightly sinuous course through Dunklin County, Mo., into the northern part of Mississippi County, Ark.; from north to south the different parts of this ridge are known respectively as Rosebriar Prairie, West Prairie, Grand Prairie, and Big Lake Highlands. This ridge is also believed to be composed of Pleistocene deposits.

The Pleistocene alluvium rests on undifferentiated deposits, chiefly of Eocene age but in part of Cretaceous age.

In the Advance lowland the Pleistocene alluvium comes to the surface in the inter-floodplain areas, but in the broad floodplains of the streams it is overlain by Recent alluvium, the thickness of which has not been determined at any point but which probably nowhere exceeds 75 feet.

Although in the Mississippi lowland the Pleistocene and Recent alluvial deposits have not been satisfactorily differentiated, it is believed that the former are concealed by the latter, except in the few slightly elevated areas previously described, concerning which there is reason, more or less well founded, for believing that the Pleistocene comes to the surface.

Lithologic character.—The Pleistocene alluvium is composed of loams, clays, sands, and gravels, which though irregularly bedded in detail, have in general assumed definite stratigraphic positions. Where the complete sequence of the deposits exists, as in the inter-stream areas of the Advance lowland, there is a downward gradation from fine surface silts or loams through compact clays and fine sands to coarse sands and gravels at the base. This arrangement of the materials has been determined in scores of well borings. Except near the surface the deposits appear to be rather strongly calcareous, as shown by the almost universally hard waters which they yield. The deposits appear also to be rather strongly ferruginous, although the iron is distributed more irregularly than the lime. In the surface materials the iron appears in places in the form of small limonite concretions, and where these are numerous give rise to the so-called "buckshot" soils of the area.

The silty subsoil clays are compact and almost impervious to water and are locally termed "hardpan." They range in thickness from a few feet to a maximum measured thickness of 75 feet, and vary in color from a light ashen gray through yellow and brown to dark red. The subsoil clays and the underlying fine sands are exposed at a few places in river bluffs, gullies, and artificial cuttings. The stream incisions are nowhere deep enough to reveal the coarse sands and gravels which compose the basal portion of the deposits, and the character of these materials has been determined by well borings.

Dark carbonaceous clays, logs and limbs of trees, and peaty accumulations representing buried swamp deposits, are occasionally encountered in well borings. Shells have been reported from a few well borings. With these exceptions, the materials have yielded no fossil remains.

In the northern part of the Advance lowland in Arkansas and along the northwestern border of the lowland are areas characterized by successive low ridges of sand and sandy loam, apparently bearing some close relation to the alluvial lands bordering the rivers. However, many of the ridges rise above the extreme high water level of the present streams and in places the materials appear to rest on the light gray silty clays which constitute the subsoil throughout the greater part of the interflood plain areas of the Advance lowland, and may therefore have been deposited in late Pleistocene time, subsequent to the formation of the clays and prior to the deposition of the Recent flood-plain materials.

Physiographic expression.—The gently undulating prairies and timbered lands of the interstream areas of the Advance lowland are the surface expression of the Pleistocene alluvial deposits. The prairies represent the least altered portions of the original Pleistocene plain; the timbered lands represent various stages in the process of erosion, which on account of the low gradient of the streams, is with extreme slowness reducing the plain to base-level.

LOCAL DETAILS.

As previously stated, the complete sequence of the Pleistocene alluvial deposits is not revealed by natural exposures. The upper portion of the alluvium appears at scattered localities in stream bluffs, gullies, road, and railroad cuttings. A few such sections are described on following pages.

Cloverbend, Lawrence County.—A bluff on Black River at Cloverbend, Lawrence County, reveals the following section:

Section on Black River at Cloverbend, Lawrence County.

	Feet.
Pleistocene alluvium:	
White "buckshot" clay, very hard when dry, containing small limonite concretions	3
Reddish-tinted clay, very hard when dry, becoming sandy at base	3
Reddish fine stratified sand	3
Gray stratified sand, coarser than the overlying layer	3
Concealed to water level	7
	19

Old Grandglaise, Jackson County.—The site of Old Grandglaise is on White River, a few miles northeast of the present village of Grandglaise. The section exposed in the right bank of the river at this place is as follows:

Section on White River at the site of Old Grandglaise, Jackson County.

	Feet.
Soil and Pleistocene alluvium:	
White soil	0.5
White clay, very plastic when wet	4.0
Stratified white, very argillaceous sand or sandy clay, containing great numbers of irregular concretions of calcium carbonate	10.0
	14.5

Colona, Woodruff County.—In a cut of the Chicago, Rock Island & Pacific Railway, south of Colona ($2\frac{1}{2}$ miles south of Grays), Woodruff County, the following section is exposed:

Section in cut of Chicago, Rock Island & Pacific Railway near Colona, Woodruff County.

	Feet.
Soil and Pleistocene alluvium:	
Soil	1.0
Reddish to yellowish argillaceous loam, containing limonite concretions	2.5
White sandy clay, grading downward into harsh reddish sand, which in turn grades downward into soft purplish sand	10.0
	13.5

Augusta, Woodruff County.—Call[1] has described a section on White River, at Augusta, Woodruff County, which is in substance as follows:

Section on White River at Augusta, Woodruff County.

	Feet.
Soil and Pleistocene alluvium:	
Fine light-colored siliceous humus	2
Brownish argillaceous sand, slightly indurated above, grading downward into softer, less argillaceous sand	1
Reddish sand with some clay, regularly stratified; contains irregularly disseminated nodules of argillaceous limonite one-fourth to one-half inch in diameter, which become softer and larger and more numerous toward base; forms an overhanging ledge in places	8
White cross-bedded sand, with occasional patches of clay	10
Indurated fine, somewhat reddish sand, with some clay; contains nodules of sandy, argillaceous limonite near the base	2
Bluish-white, irregularly bedded sand, coarser and more argillaceous than the overlying layer; contains scattered, smoothly rounded pebbles of chert and a few pebbles of waterworn sandstone, averaging about 1 inch in diameter; one mass of flint weighing about 3 pounds noted	4
Slightly indurated reddish sand, becoming brown below; the upper surface is irregular	1
White argillaceous sand	2
	30

[1] Call, R. E., The geology of Crowleys Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 22, 23, 1891.

Phillips County.—The surface in the northwestern half of Phillips County is strongly rolling, presenting a series of low ridges and intervening valleys, a condition believed to have been produced by the erosion effected by the streams where they descend from the Advance lowland to the Mississippi lowland, which lies 25 or 30 feet lower. Along the western side of Crowleys Ridge in this county is a terrace 1 to 3 miles wide and 30 or 40 feet higher than the creek bottom immediately to the west; the terrace is separated from the ridge on the east and the lowland on the west by well-defined escarpments and probably corresponds in elevation to the low ridges in the northwestern part of the county just described. Occasional gullies and road cuttings reveal the character of the materials composing the low ridges and the terrace.

The following section is revealed in a gully cut in the terrace 1½ miles east of Southland and a short distance west of the foot of the west-facing slope of Crowleys Ridge:

Section in gully 1½ miles east of Southland, Phillips County.

	Feet.
Pleistocene alluvium:	
Dark stratified argillaceous loam	4
Layers of fine argillaceous sand, each a few inches in thickness, some containing small, earthy concretions of limonite	4
Yellow argillaceous sand	2
	10

Hickory Ridge, one of the series of ridges west of Crowleys Ridge (see p. 27), is capped with dark loam which, at Marvell, is 10 or 12 feet thick, as shown by exposures in roadside gullies; the loam is underlain by fine gray sand.

A gully in the road leading from Trenton to Turner, about 5 miles south of west of Trenton, reveals a 9-foot section in a ridge similar to but smaller than Hickory Ridge.

Section in public road 5 miles south of west of Trenton, Phillips County.

	Feet.
Pleistocene alluvium:	
Soft dark loam	6
Very fine gray sand	3
	9

Logs of wells.—The most complete data regarding the character and thickness of the Pleistocene alluvium has been afforded by the logs of wells located at various places in the area. The following table contains references to the pages of this report on which logs of wells which penetrate these deposits are given:

References to logs of wells which penetrate Pleistocene alluvium.

Location.	Owner.	Depth (feet).	Depth (in feet) to Eocene (or Cretaceous).	Page on which log of well is given.
ARKANSAS COUNTY.				
Almyra, 2 miles northwest of (SE. ¼ sec. 21, T. 3 S., R. 4 W.).	H. V. Clutter	150	....	153
Booty, ¼ mile west of (W. ½ SE. ¼ sec. 5, T. 8 S., R. 2 W.).	W. N. Carpenter	163	....	153
Stuttgart	Stuttgart Water & Electric Light Co.	131.75	....	151
Stuttgart, 6 miles southwest of (sec. 5, T. 3 S., R. 4 W.).	C. E. Edmund	145	....	152
Tichnor, 4 miles south of (SW. ¼ sec. 16, T. 7 S., R. 2 W.).	J. M. Satchfield	147	....	153
Ulm (Prairie County), ½ mile south of, in Arkansas County (NE. ¼ sec. 6, T. 2 S., R. 4 W.).	Caspar G. Scheiderer, R. D. 3.	110	....	152
CLAY COUNTY.				
Knobel	St. Louis, Iron Mountain & Southern Ry. Co.	50	....	162
Knobel, 5 miles east of (NW. ¼ sec. 10, T. 19 N., R. 5 E.).	Knobel Rice Co	178	....	163
Piggott	Caraway & Friedenburg	74	....	163
Do	Patter & Co	98.5	....	163
CRAIGHEAD COUNTY.				
Bono, 1 mile north of (NE. ¼ sec. 19, T. 15 N., R. 3 E.).	J. E. Bobbitt	78	....	171
Gilkeson, 2½ miles southwest of (SE. ¼ sec. 8, T. 13 N., R. 3 E.).	Burke & Cole, Jonesboro	103	....	171
Gilkeson, 3 miles southeast of (SE. ¼ sec. 9, T. 13 N., R. 3 E.).	C. O. Collins, Jonesboro	113	....	171
Nettleton	St. Louis, Iron Mountain & Southern Ry. Co.	147	....	170
Obear, 3½ miles northwest of (NE. ¼ sec. 18, T. 13 N., R. 3 E.).	Gregg & Houghton Land Co.	102	....	171
CROSS COUNTY.				
Fairoaks	St. Louis & Southwestern Ry. Co.	82	....	183
Fairoaks, 2½ miles east of	T. A. Norviel	65	....	183
Hydrick (near) (NW. ¼ sec. 2, T. 9 N., R. 3 E.).	S. A. Clements	75	....	183
Tilton, 4 miles northeast of (SE. ¼ sec. 11, T. 8 N., R. 1 E.).	Miller & Son	80	....	183
LAWRENCE COUNTY.				
Alicia	St. Louis, Iron Mountain & Southern Ry. Co.	77	....	204
Walnut Ridge, 1 mile northeast of (SE. ¼ sec. 25, T. 17 N., R. 13 E.).	S. C. Dowell	177	....	205
Walnut Ridge, 1½ miles southeast of (NE. ¼ sec. 1, T. 16 N., R. 1 E.).	Robinson & Cornett	81.5	....	205
LEE COUNTY.				
Marianna	Marianna Light & Power Co.	125	....	210
Moro, 2¾ miles northwest of (SW. ¼ sec. 32, T. 2 N., R. 1 E.).	S. D. Johnston, Marianna.	195	....	211
LONOKE COUNTY.				
Carlisle, 1½ miles east of (T. 2 N., R. 7 W.)	Mr. Hubbard	180	....	218
Carlisle, 1½ miles north of (SW. ¼ sec. 10, T. 2 N., R. 7 W.).	Robert Medendorp	158	....	218
Carlisle, 3 miles southwest of (sec. 32, T. 2 N., R. 7 W.).	J. H. Sims	131	....	219
Carlisle, 4½ miles southwest of (W. ½ NW. ¼, T. 1 N., R. 7 W.).	W. H. Fuller, Lonoke	140	....	218
Lonoke	W. Y. Bransford	105	....	216
Lonoke, 4 miles southeast of (SW. ¼ sec. 33, T. 1 N., R. 8 W.).	B. F. Fromholz	300	200	219
MONROE COUNTY.				
Brinkley	Farrell Light, Heat & Water Co.	565	148	231
Brinkley (near) (sec. 4, T. 3 N., R. 2 W.)	J. D. Edmonds	149.75	....	231
Brinkley, 1½ miles northwest of (T. 3 N., R. 2 W.).	H. G. Adams	147.5	....	231

References to logs of wells which penetrate Pleistocene alluvium—Continued.

Location.	Owner.	Depth (feet).	Depth (in feet) to Eocene (or Cretaceous).	Page on which log of well is given.
PHILLIPS COUNTY.				
Southland	William Russell	135		239
POINSETT COUNTY.				
Waldenburg, 2 miles east of north of (NW. ¼ sec. 18, T. 11 N., R. 2 E.).	Scruggs & Swearengin, Mooreville, Ind.	108.5		246
Waldenburg, 2½ miles southwest of (SE. ¼ sec. 35, T. 11 N., R. 1 E.).	Ellis L. Jackson	101		246
Weiner	St. Louis Southwestern Ry.	101.5		246
Weiner, 1 mile north of (SE. ¼ sec. 21, T. 12 N., R. 2 E.).	S. F. Wells	153.5		246
Weiner, 1½ miles south of (NW. ¼ sec. 17, T. 11 N., R. 2 E.).	Charles Thompson	156		247
Weiner, 3 miles northeast of (SE. ¼ sec. 21, T. 12 N., R. 2 E.).	Frank Housman	75		247
Whitehall, 1½ miles west of (sec. 22, T. 10 N., R. 3 E.).	B. A. McKinny	120		247
PRAIRIE COUNTY.				
Des Arc	Peter Deforest	78		252
Des Arc	J. W. Petty	72		252
Devall Bluff, 3½ miles west of (T. 2 N., R. 5 W.).	Thomas Bros	179	176?	253
Hazen, 2 miles southeast of (T. 2 N., R. 5 W.).	Mr. Avery	176		253
ST. FRANCIS COUNTY.				
Wheetley (near) (average log of 9 wells in Tps. 3 and 4 N., R. 1 W.).	A. Boysen & Sons	145		265
Wheetley (near) (sec. 26, T. 4 N., R. 1 W.)	C. E. Patt	186	185?	266
Zent (Monroe County), northeast of, in St. Francis County (SW. ¼ sec. 5, T. 4 N., R. 1 W.).	The Luhallis Co	175		266
Zent (Monroe County), northeast of, in St. Francis County (SW. ¼ sec. 6, T. 4 N., R. 1 W.).	do	155.6	153?	266
Zent (Monroe County), northeast of, in St. Francis County (SE. ¼ sec. 6, T. 4 N., R. 1 W.).	do	147	146	266
Zent (Monroe County), northeast of, in St. Francis County (SE. ¼ sec. 6, T. 4 N., R. 1 W.).	do	462	145	267
Zent (Monroe County), east of, in St. Francis County (SW. ¼ sec. 8, T. 4 N., R. 1 W.).	Norton Bros., Brinkley	180.8	180?	267
Zent (Monroe County), 1½ miles northeast of, in St. Francis County (W. ½ sec. 6, T. 4 N., R. 1 W.).	Mr. Oliphant	125		267
Zent (Monroe County), east of, in St. Francis County (S. ½ sec. 3, T. 4 N., R. 1 W.).	C. E. Barber	151	149?	267
WOODRUFF COUNTY.				
Hunter, southeast of (sec. 34, T. 5 N., R. 1 W.).	Hunter Land & Rice Co. (well No. 1).	127		277
Hunter, southeast of (sec. 34, T. 5 N., R. 1 W.).	Hunter Land & Rice Co. (well No. 2).	156	155?	277
Hunter, 1¾ miles southwest of (sec. 21, T. 5 N., R. 1 W.).	H. L. Baker	108		277

CORRELATION.

The Pleistocene alluvium of eastern and northeastern Arkansas is younger than the loess of Crowleys Ridge and is older than the Recent alluvium. If the main body of the loess was deposited during the time of the Iowan ice invasion (see quotation from Chamberlin and Salisbury on p. 112), then the Pleistocene alluvium was deposited subsequent to that invasion; if the loess was deposited during the

Peorian interglacial stage, which succeeded the Iowan invasion, the Pleistocene alluvium dates from a still later time. Probably most of Pleistocene time subsequent to the Peorian interglacial stage is represented by the Pleistocene alluvial deposits of this area.

RECENT SERIES.

The Recent deposits of eastern and northeastern Arkansas consist mainly of alluvial silts, loams, clays, sands, and gravels; these materials immediately underlie the surface in the flood plains of the streams and rest upon similar deposits of Pleistocene age, except locally along the borders of the uplands where the Recent deposits rest upon Eocene or Cretaceous strata or at a few places upon Paleozoic rocks.

In the Advance lowland the areal distribution and the thickness of the Recent deposits are less than in the Mississippi lowland. The thickness is determined by the depth to which the streams have scoured as they have meandered back and forth across their flood plains. The maximum depth of scour of Arkansas River, the largest stream of the Advance lowland, is probably not greater than 75 feet below the general level of the flood plain. The depth of scour of the other smaller streams of the area is proportionately less, the minimum being that of small creeks which cut only a few feet below their flood plains.

In the Mississippi lowland the Recent and Pleistocene alluvial deposits have not been clearly differentiated. If Mississippi River has in Recent time meandered entirely across the lowland between Crowleys Ridge and the Chickasaw Bluffs, then the surface deposits are all of Recent age. But even if this stream has not covered the entire lowland much of the area not thus occupied has been covered by St. Francis and Little rivers in their meanderings.

Certain small areas in the Mississippi lowland which lie slightly higher than the general level of the lowland are considered probable remnants of Pleistocene deposits. One of these is Sikeston Ridge or Big Prairie, a narrow, low ridge which extends southward from south of Lake St. John in Scott County, Mo., to New Madrid, New Madrid County, Mo.; another, a low ridge which extends with several interruptions from the southern part of Stoddard County, Mo., a little west of south in a slightly sinuous course through Dunklin County, Mo., into Mississippi County, Ark., is known in its various parts, named in order from north to south, as Rosebriar Prairie, West Prairie, Grand Prairie, and Big Lake Highlands. The meaning of these elevations is rendered obscure because of the fact that changes in level accompanying earthquake shocks have taken place in the area.

Mississippi River is at present scouring its channel 100 to 130 feet below the general level of the Mississippi lowland, and the Recent alluvial deposits are therefore at least 100 to 130 feet thick over a part of the area. The materials intervening between the lower limit of scour of the present streams of the lowland and the underlying Eocene deposits are of Pleistocene age.

UNDIFFERENTIATED QUATERNARY ALLUVIUM.

Owing to the difficulty in differentiating the Pleistocene and Recent alluvium in the Mississippi lowland and in certain parts of the Advance lowland, it has been necessary in the interpretation of the logs of numerous wells to class the alluvial deposits as undifferentiated Quaternary alluvium. A list of such wells with references to the pages on which the logs are published is given in the following table:

References to logs of wells which penetrate undifferentiated Quaternary alluvium.

Location.	Owner.	Depth (feet).	Depth (in feet) to Eocene or other older rocks.	Page on which log of well is given.
CRITTENDEN COUNTY.				
Turrell	Baker Lumber Co	864	182	175
CROSS COUNTY.				
Parkin	Northern Ohio Cooperage & Lumber Co.	597	....	182
Cherry Valley, 5 miles east of	Mr. Smith	230	165	183
GREENE COUNTY.				
Beech Grove, 3½ miles north of (SE. ¼ NE. ¼ sec. 11, T. 18 N., R. 4 E.).	Joe Canfee, Lafe	30	....	189
JACKSON COUNTY.				
Newport, 1 mile southwest of (oil-prospecting well).	....	1,000	105	197
JEFFERSON COUNTY.				
Wabbaseka, 5 miles east of (NW. ¼ sec. 17, T. 4 S., R. 7 W.).	John Ingram, sr	66	....	199
MISSISSIPPI COUNTY.				
Ashport Bend, 9 or 10 miles above Osceola	United States Government well No. 1.	164	136.5	227
Do	United States Government well No. 2.	110	....	227
Do	United States Government well No. 3.	166	146	227
Do	United States Government well No. 4.	168	140	227
Blytheville, 2 miles west of	Chicago Mill & Lumber Co.	520	140?	225
Burdette	Three States Lumber Co	1,495.5	123?	226
PHILLIPS COUNTY.				
Helena, 3 miles southeast of	American Cooperage Co	575	160	237
Helena	Mississippi River Commission boring.	206.4	162.3	237

References to logs of wells which penetrate undifferentiated Quaternary alluvium—Continued.

Location.	Owner.	Depth (feet).	Depth (in feet) to Eocene or other older rocks.	Page on which log of well is given.
POINSETT COUNTY.				
Harrisburg		185	40	245
Harrisburg, 11 miles northeast of	C. Ripley	42		245
Marked Tree	Chapman & Dewey Lumber Co.	398	220	245
PULASKI COUNTY.				
Argenta (at site of new shops)	St. Louis, Iron Mountain & Southern Ry. Co.	80		259
Argenta (well No. 1 in group of 8 wells)	do	80		259
Argenta (well No. 4 in group of 8 wells)	do	80		259
Jacksonville	A. J. McBride	82	70	259
Jacksonville, ⅞ mile south of	S. Taylor	24		259
WHITE COUNTY.				
Bald Knob	St. Louis, Iron Mountain & Southern Ry. Co.	225	31?	272
Higginson	do	62.5		272
WOODRUFF COUNTY.				
Augusta		900	145	276

GEOLOGIC HISTORY.

Deposition of Paleozoic sediments.—For the purpose of this report the history of the events leading up to the present geologic conditions of the Mississippi embayment may be assumed to have begun with the deposition of the Paleozoic rocks which outcrop around the rim of the embayment and which form the basement on which the deposits of the Coastal Plain rest.

The deposition of the Paleozoic rocks began in an intercontinental sea in Cambrian time and continued with certain interruptions, a detailed account of which is outside the province of this report, at least until late Carboniferous time.

Post-Paleozoic erosion interval.—The long period of Paleozoic deposition was brought to a close by a general elevation of the region, land appearing where inland seas had previously existed. Then began a long cycle of erosion, indicated by the total absence of deposits of Triassic and Jurassic age, and, so far as known, of Lower Cretaceous age.

Depression in Lower Cretaceous time.—During Lower Cretaceous time areas both east and west of the present Mississippi embayment, and probably the embayment itself to some extent, were depressed, as indicated by the presence of deposits of Lower Cretaceous age in eastern Alabama and in southwestern Arkansas. Although no strata of this age outcrop in the Mississippi embayment, such deposits possibly exist deeply buried beneath younger formations in the south-central portion of the area.

Depression and deposition in Upper Cretaceous time.—During Upper Cretaceous time an area coinciding approximately with the present Mississippi embayment was depressed, probably by downward warping, accompanied by more or less faulting, and was covered by marine waters, which advanced across the area from an open sea on the south. This depression is indicated by the strata of Upper Cretaceous age penetrated in a deep well boring at Memphis, Tenn., and by strata which outcrop along the eastern limb of the embayment as far north as the southern part of Illinois, and which are present at certain places along the western limb of the embayment. The Upper Cretaceous deposits consist of sands, clays, and marls formed as the result of the transportation of materials into the sea by streams flowing from the areas of land surrounding the submerged tract on the west, north, and east. In the central part of the embayment the deposits are more than 1,300 feet in aggregate thickness, and are believed to constitute a conformable series.

Uplift and erosion between the Cretaceous and Eocene.—After the deposition of the Upper Cretaceous series the submerged area was elevated above sea level and subjected to erosion. How great a thickness of strata was removed while land prevailed is not known, but from the approximate correspondence in the stratigraphic position of the eroded Upper Cretaceous surface throughout a vast extent of country in the Atlantic and Gulf Coastal Plain the land was probably reduced nearly to a peneplain. The great importance of this erosion interval is shown by the difference in the paleontologic characters of the upper part of the Upper Cretaceous series and the lower part of the overlying Eocene series, few, if any, of the contained molluscan species being common to the two series. The contact between the two series does not appear at the surface within the area under consideration, but is well exposed at many places in Alabama and Mississippi, and its presence in the vicinity of Little Rock, Ark., is indicated by the paleontologic differences already stated.

Depression and deposition in Eocene time.—The erosion interval succeeding the deposition of the Upper Cretaceous series was brought to a close by a depression of the area which submerged a tract probably corresponding in extent nearly to the present Mississippi embayment, though perhaps somewhat more contracted at the northern extremity and along the eastern side in Mississippi, Tennessee, and Kentucky. The depression was accompanied by renewed deposition which, with two important interruptions, and perhaps other minor interruptions, continued through Eocene time and produced in ascending order the Midway, Wilcox, Claiborne, and Jackson formations, the aggregate thickness of which amounts to between 1,000 and 1,500 feet.

The Midway formation, where typically developed, consists of limestones, calcareous sands, and clays, of marine origin, which show that true marine conditions existed in the southern and central parts of the submerged area at least as far north as the latitude of Newport, Jackson County, Ark. These marine materials merge northward into argillaceous beds of shallow-water origin, which in Tennessee and Kentucky are known as the Porters Creek clay.

The contact between the Midway and Wilcox formations is not exposed in northeastern Arkansas, but Berry [1] has published paleontologic evidence of an unconformity between the two formations in the Mississippi embayment, indicating an important uplift accompanied by erosion.

The Wilcox formation, where exposed in Crowleys Ridge from Craighead northward and also in Mississippi, and deposits of Wilcox age in the Lagrange formation of Tennessee and Kentucky consist of irregularly bedded sands and clays; lignite is common in the formation and in places is segregated into beds; fossil leaves have been collected at numerous places in Mississippi, Tennessee, and Kentucky and at three places in Arkansas. Locally in Crowleys Ridge the sands are indurated to sandstones and quartzites. These characters may perhaps be interpreted to mean that the terrane is a complex of shallow-marine, swamp, and alluvial deposits.

Deposition of the Wilcox formation was followed by uplift which produced a land surface and erosion probably throughout the whole of the embayment. This sequence of events is indicated by the absence of deposits representing the lower part of the Claiborne as developed in Alabama, Louisiana, and east Texas. In upper Claiborne time, however, the area was again depressed and deposition was resumed. The depression probably affected the southern part of the Mississippi embayment more than the northern part, for deposits of the Claiborne formation are not known to extend farther north than Poinsett County, Ark. The northern part of the embayment may have been above water and subjected to erosion. The Claiborne formation in Crowleys Ridge is similar in general lithologic character to the Wilcox formation, but shows a slightly nearer approach to a true marine deposit, as indicated by more massive bedding, particularly in the upper part of the terrane. During Claiborne time subsidence was gaining slightly on sedimentation, and this advantage continued into Jackson time, though, as Berry has shown in the paper just cited,[1] there is evidence of temporary emergence and erosion at the close of the Claiborne.

The Jackson formation consists of sands, clays, and marls of shallow-sea origin. The prevalence of marine conditions during

[1] Berry, E. W., Erosion intervals in the Eocene of the Mississippi embayment: U. S. Geol. Survey Prof. Paper 95, pp. 73–82, 1915 (Prof. Paper 95–F).

the time of deposition of these materials is indicated by the presence in the formation of the remains of mollusks and foraminifera which inhabited shallow seas. During this period also the northern part of the embayment was probably above sea level, for the Jackson formation has been recognized only as far north as the latitude of St. Francis County, Ark.

Post-Eocene erosion.—Succeeding the deposition of the Eocene series, the Mississippi embayment was again elevated above sea level and the upward movement was probably accompanied by a slight tilting toward the south. Erosion was resumed and probably continued until near the close of Tertiary time; that is, during all of Oligocene, Miocene, and a part of Pliocene time; the streams which drained the emerged area attacked the exposed portions of the Eocene strata and began transporting the materials to the sea, which had retreated southward beyond the limits of the embayment area.

The arrangement of the drainage during this erosion interval is not known, but doubtless a large stream corresponding to the present Mississippi River crossed the area, and this stream was probably joined by an ancient Ohio River somewhere in the Mississippi embayment. Streams corresponding to White and Arkansas rivers doubtless existed.

The erosive action of the streams during this period probably resulted in the removal of a relatively large amount of material from the land, which was not reduced to base level, as shown by the irregularities of the surface upon which the next succeeding formation, the Lafayette, was laid down.

Deposition of the Lafayette formation.—The period of land degredation which followed the deposition of the Eocene series was succeeded, probably during late Pliocene time, by a relatively short period of deposition, during which the Lafayette formation, a terrane composed of irregularly bedded sands and gravels, was laid down. The conditions under which this formation was produced were peculiar and are not thoroughly understood. The available facts, however, appear to justify certain deductions.

The materials were transported from an elevated area in which erosion was active and the transporting power of the streams great. The embayment area must have been considerably lower than this elevated tract, and the gradients of the streams were greatly reduced where they passed from the higher to the lower country; the transporting power of the currents was lessened as a result of the lowering of the gradients, and much of the material carried in suspension or rolled along the stream beds was left stranded along the valley bottoms and lower slopes. Since the gravel deposits are composed chiefly of pebbles and cobbles of chert which range from subangular to only partly waterworn, it is evident that they have been transported no great distance, and their source was doubtless the Paleozoic rocks, which are composed in part of cherty limestones and outcrop adjacent to the Mississippi embayment on the west, north, and east. A very small proportion of the gravels consists of small, smoothly rounded quartz pebbles which appear to have been transported a long distance; their history is more complex and is less understood than is that of the chert pebbles and cobbles. The gravels and sands doubtless originally covered much if not all the embayment area.

The chief difficulty in attempting to explain the origin of the deposits of sand and gravel is the fact that the base of the gravel deposits lies at various vertical positions from below the level of the Mississippi lowland to 80 or 100 feet above that datum plane. If the materials were deposited by streams meandering across depositional plains, it would seem that the surface upon which the heavy gravels were laid down would have been reduced to an approximate plain by the lateral cutting of the shifting currents. However, it is probable that the sequence of events was more complicated than can easily be determined from the remnants of the formation available for study. A series of successively younger and lower terraces might account for the observed distribution of the gravels; or the gradual aggradation of valleys permitting the streams to meander over successively higher parts of the adjacent hills might also account for the present position of the gravels.

Post-Lafayette erosion interval.—After the deposition of the Lafayette formation erosion was resumed, either because the streams ceased to carry great loads of coarse material or because there was a general uplift of the area; the resulting dissection produced a surface relief amounting to 100 feet or more.

The arrangement of the drainage during this period of erosion is not known, but doubtless streams existed corresponding to Mississippi, Ohio, White, and Arkansas rivers.

Deposition of the loess.—The erosion interval which succeeded the deposition of the Lafayette formation continued well into Pleistocene time, probably until the second (Kansan) or third (Illinoisan) ice invasion of the Pleistocene epoch, at which time continued erosion was prevented, at least over parts of the area, by deposition of the loess (some of which may be older than the Iowan) upon the sands and gravels of the Lafayette formation.

The loess as it exists to-day is believed to be only a fractional part of that originally deposited, much of it having been since eroded away. The material is now found capping Crowleys Ridge, except in a few places in northern Arkansas and southern Missouri, where it has been eroded from the crest of the ridge; east of the Mississippi lowland the loess occurs in a belt 5 to 25 miles or more in width, paralleling the Chickasaw Bluffs and extending from southern

Illinois southward through Kentucky, Tennessee, and Mississippi to Louisiana; along the western margin of the Mississippi embayment in Arkansas fragmentary remnants of yellowish, reddish, and brownish loam, which probably represent the loess, are found capping the Grandglaise terrace in places and resting upon the east-facing slopes of the hills of the Ozark province. How much of the intervening areas now occupied by the Advance lowland and the Mississippi lowland were originally covered by loess is not known, but doubtless the areal extent of the deposit was much greater than at present.

Several explanations have been given to account for the formation of the loess. These have been summed up by Chamberlin and Salisbury[1] as follows:

By the aqueous hypothesis the loess is assigned to direct deposition by rivers, or their lakelike expansions. To make this possible it is necessary to suppose that the waters stood at elevations 200 to 600 feet higher than now relative to adjacent surfaces, in the Mississippi Basin. This involves difficulties that have never been satisfactorily met. Furthermore, if the waters of rivers or their lake-like expansions were high enough to cover the areas overspread by loess, it is not clear that there could have been an appropriate habitat for the land fauna of the time.

Under the eolian hypothesis, or at least one phase of it, the river flats are supposed to have supplied the material of the loess, which was whipped up by the winds and redeposited on the adjacent uplands. The rivers are thus made essential factors in the distribution, though not the direct agents of deposition. This hypothesis seems on the whole to best fit the phenomena of the larger part of the upland loess of the Mississippi Basin. The constituents of the loess, which appear to have come from the glacial drift, were derived largely from the deposits made by glacial waters or from later flood plain silts derived from the glacial formations, but it is probable that some of the loess was derived from glacial drift directly before it became clothed with vegetation.

In places in Crowleys Ridge the basal portion of the loess shows some evidence of stratification and generally the stratified materials are sandy or argillaceous. The bulk of the loess, however, is massive, though banding is discernible in the more complete exposures. The remains of land shells are numerous in the loess from St. Francis County to the southern extremity of the ridge. One fresh-water form, Sphærium sp.?, has been found associated with land shells at two localities east of Forrest City, in St. Francis County. (See p. 108.) Although locally the basal portion of the loess may have been deposited in ponds or small lakes, the objections to the aqueous hypothesis to account for the origin of the deposits heretofore advanced, seem in the main to be applicable here. Of the explanations that have been offered, the modified eolian hypothesis described in the last paragraph of the quotation just given seems to be most in accord with the known facts. According to this theory fine silts derived

[1] Chamberlin, T. C., and Salisbury, R. D., A college textbook of geology, pp. 889–890, 1909.

from the glacial drift were transported southward by the streams and at flood stages were deposited on the flood plains; these materials, when subsequently dried, were lifted by the winds and spread upon the adjacent slopes and uplands. As the materials accumulated the shells of land mollusks were entombed and in places preserved; occasional slight changes in the prevailing character of the materials transported by the streams or in the character or condition of the vegetable growth resulted in the banding observed in the deposits.

The deposits were spread over a considerable part of the area now occupied by the Advance and Mississippi lowlands and have been subsequently largely removed by the extensive lateral cutting effected by the streams of late Pleistocene and Recent time. The effective deposition of the loess probably ceased before or during the Peorian interglacial stage.

Erosion of the great troughs west and east of Crowleys Ridge and deposition of Pleistocene alluvium.—The distribution of the drainage in the Mississippi embayment during the time of deposition of the loess has not been definitely determined, but the close of that time found Mississippi and Ohio rivers following independent courses southward through the Mississippi embayment, the former west of and the latter east of Crowleys Ridge; the two joined south of the present southern extremity of the ridge. If it be true that the loess was deposited by wind action, this fact would seem to preclude the possibility of the Mississippi having found its way west of Crowleys Ridge during the time of that deposition, because of the topographic obstacles that must have intervened. This arrangement of the drainage is believed, therefore, to date back into the Tertiary period. Mississippi River, as it existed in southeastern Missouri immediately after the deposition of the loess, appears to have been a superimposed stream, which also tends to confirm this view.

The succession of geologic events which transpired in the northern part of the Mississippi embayment from the close of loess deposition to the present time has been determined and described by Marbut.[1]

The brief account which follows is in substance the interpretation of Marbut with the application of his interpretation extended to cover the whole of the embayment, and with such modifications and additions as the conditions existing south of Missouri make necessary.

Shortly subsequent to the close of the deposition of the loess the embayment area was elevated, probably not less than 100 feet above its present position with reference to sea level. Stream erosion was accelerated and the rivers quickly entrenched themselves, their lower

[1] Marbut, C. F., The evolution of the northern part of the lowlands of southeastern Missouri: Missouri Univ. Studies, vol. 1, No. 3, 63 pp., 7 pls., 1902.

limit of scour reaching a level corresponding to the base of the present alluvium of the lowlands. At that time Mississippi River did not follow its present course, but flowed southwestward from Cape Girardeau, Cape Girardeau County, Mo., northwest of the present site of Benton Ridge, and northwest and west of Crowleys Ridge. Ohio River flowed southwestward east of Crowleys Ridge and joined the Mississippi south of the present southern extremity of the ridge.

From Cape Girardeau to Mingo, Stoddard County, Mo., the Mississippi soon found both its downward and lateral cutting hindered by hard Paleozoic rocks, which formed its bed and sides. From Mingo southward through Arkansas the river was entrenched in unconsolidated deposits of the Coastal Plain and quickly reached grade; thereafter the stream meandered, its energies were expended in lateral cutting, and a great, broad trough was, geologically speaking, quickly scoured out. The bottom of this trough was 125 to 200 feet below the present level of the Advance lowland, and the geographic extent coincided with this lowland. The materials removed belonged in descending order to the loess, the Lafayette formation, and to the Eocene and Cretaceous.

Contemporaneous with the lateral cutting the river was redepositing sands, clays, and gravels on the plain across which it meandered, so that as the trough was widened it was refilled with alluvial deposits nearly or quite to the level marked by the present Advance lowland. There is some evidence that before the river was finally diverted from its course west of Crowleys Ridge a slight increase in the thickness of the alluvial deposits was caused by a depression of the area amounting to several feet; the same result might have been accomplished, however, by an increase in the amount of materials carried in suspension by the currents. In the work of cutting and refilling this trough the Mississippi was aided to some extent by Arkansas and White rivers, which entered the valley from the Ozark province.

The ever-broadening flood plains of the Mississippi and its assistants, White and Arkansas rivers, were periodically overflowed by flood waters which spread back across the broad flat tracts from the main channels and deposited their burdens of fine silt, producing the layer of compact, silty clay which nearly everywhere forms the uppermost part of the Pleistocene alluvial deposits. At many places on the level interstream tracts the conditions were favorable for the precipitation of iron oxide as limonite, which took the form of small, impure concretions, or a sort of bog iron ore; these concretions characterize the so-called buckshot soils of the area.

Contemporaneous with the dissection and partial refilling of the great valley west of Crowleys Ridge, Ohio River was accomplishing analogous results east of the ridge. After leaving the Paleozoic rocks above Cairo, Ill., the Ohio encountered only unconsolidated materials and quickly scoured out and partly aggraded a trough nearly coextensive with the present Mississippi lowland. Crowleys Ridge stood between these two great valleys and remains to the present time a remnant of and an index to the deposits that filled the lowlands previous to the cutting of the two great valleys. The flood plain built by the Ohio was similar to that formed by the Mississippi, except that in the northern part of the embayment, the plain of the Ohio stood a few feet lower than that of the Mississippi. Only small remnants of this old Ohio River flood plain testify to its former existence.

Captures of Mississippi River by Ohio River.—At this stage in the evolution of the embayment area an event transpired which caused a radical change in the arrangement of the drainage. A small tributary of Ohio River, the source of which was in the highland that then connected Benton Ridge, Mo., and the northern extremity of Crowleys Ridge, had been gradually pushing its headwaters northward toward Mississippi River. The fact that Ohio River flowed at a lower level than Mississippi River made it possible for this small tributary stream to perform a remarkable feat. Omitting numerous interesting details described by Marbut, the stream cut its headwaters back until one of them finally tapped the Mississippi somewhere in the vicinity of the present village of Delta, and the waters of that great stream, accepting the advantage offered by this steeper and shorter route southward, followed the small valley and quickly carved out a channel suitable to their greater needs. The Mississippi thus abandoned its course west of Crowleys Ridge and joined the Ohio, probably a short distance south of the present site of New Madrid.

The Mississippi occupied this new course until by lateral cutting it produced the gap which now separates Benton and Crowleys ridges, and which forms a part of the Morehouse lowland of Marbut. In the meantime another small tributary of Ohio River had been pushing its headwaters northward from the vicinity of Commerce, Scott County, Mo., toward Grays Point (Graysboro), also in Scott County, and eventually this stream succeeded in tapping the Mississippi and diverting its waters southward to join the Ohio somewhere not far from its present junction at Cairo. Thus twice in a relatively short period this great major stream was diverted from its former course by streams of insignificant size.

After the first capture of the Mississippi, the waters of Castor and St. Francis rivers, former tributaries of the Mississippi, continued to flow west of Crowleys Ridge. Since that time both of these streams have been diverted through Crowleys Ridge by small streams working backward into the ridge in the same manner that the captures of the Mississippi were effected. L'Anguille River, one of the consequent streams of the Advance lowland in Arkansas, was probably diverted through the ridge by capture in Lee County.

Deposition of Recent alluvium.—Except for the changes resulting from the capture of Castor, St. Francis, and L'Anguille rivers, the adjustment of drainage which followed the diversion of Mississippi River from the Advance lowland has remained essentially unchanged to the present time. In comparatively recent times the streams have intrenched themselves a few feet below the old Pleistocene plain represented by the interstream levels of the Advance lowland; this change was probably caused by a slight elevation of the region. At this new level the streams have meandered, cutting laterally and constructing the flood plains as they now exist.

In the Mississippi lowland the old Pleistocene plain has been nearly destroyed by the meandering of the present Mississippi River and its main tributary, St. Francis River.

Late Pleistocene and Recent erosion.—Since the erosion of the great valleys corresponding in geographic extent to the Advance and Mississippi lowlands, which took place shortly after the deposition of the loess, Crowleys Ridge, the upland east of the Mississippi lowland, and the Grandglaise terrace along the western border of the Advance lowland have been partly dissected by erosion.

The old Pleistocene plain represented by the interstream areas of the Advance lowland, owing to its low elevation, has been appreciably though only slightly dissected.

SURFACE WATERS.

STREAMS.

All the large streams of the Coastal Plain of Arkansas rise outside that area and traverse it in their lower reaches. Mississippi River borders Arkansas on the east. St. Francis River enters the State at the northeast corner of Clay County, flows southward east of Crowleys Ridge and joins Mississippi River near Helena, Phillips County. White River enters the area at Batesville, Independence County, flows southward, and joins Mississippi River in Desha County. Arkansas River borders the area on the southwest from Little Rock southeast to Desha County, where it enters the Mississippi. Black River enters the State in Clay County, flows southwestward, and joins White River near Newport. Little Red River flows southeastward from near Searcy, joining White River on the eastern border of White County. Little River rises northwest of the Mississippi embayment, flows southward across the Mississippi lowland from Missouri through Mississippi County, Ark., into St. Francis River, in Poinsett County.

The principal streams that originate within the Mississippi embayment in Arkansas are Bayou Meto, a tributary of Arkansas

River; Cache River, a tributary of White River; Bayou De Vue, a tributary of Cache River; and L'Anguille River, a tributary of St. Francis River. Numerous small creeks and branches feed all the streams.

The gradients of the streams are very low, probably less than a foot a mile, and the streams meander sluggishly in sinuous channels through broad, shallow flood plains. Many of the creeks and branches are locally termed bayous, probably because of their sluggish currents. True bayous, many of them occupying abandoned and partly filled channels, are numerous in the flood plains and connect the ponds and lakes with each other and with the main streams.

The mean annual rainfall of this region, as determined by average results of observation at the stations maintained within the area from 1865 to 1908, inclusive,[1] is approximately 50 inches.

According to data compiled by Henry Gannett,[2] the average annual run-off of the streams is equivalent to a depth of 10 to 20 inches on the drainage area, or between one-fifth and two-fifths of the mean annual rainfall.

LAKES AND PONDS.

Small lakes and ponds are numerous in the broad river flood plains, and many of them occupy abandoned and partly filled channels of meandering streams. Some of the more recently formed lakes obviously had that origin, as shape and position show them to be oxbow bends abandoned by streams that had found a more direct passage to their destination by cutting through the narrow necks of the bows. Recent investigations of the Land Office and the United States Geological Survey, the results of which have not been published, have shown the nonexistence of most of the large lakes in the Mississippi lowland indicated on the old Land Office maps, including Tyronza, Youngs, Wappanocca, and St. Francis lakes, and much of the Hatchie Coon Sunk Lands. These data were received too late for incorporation in the maps accompanying this report. A few small ponds and lakes in the interstream plains west of Crowleys Ridge doubtless occupy original inequalities in the poorly drained Pleistocene plains of the Advance lowland.

SWAMPS.

The poor drainage of the lowland plains which comprise the greater part of the area has resulted in the formation of much heavily timbered swamp land. Many of the swamps occupy the broad, shallow flood plains of the streams, but swampy tracts also exist on the interstream plains.

[1] Only one of the stations was established as early as 1865; the remainder have been established at more recent times, one as late as 1905.

[2] Hoyt, J. C., and Grover, N. C., River discharge, 2d ed., pl. 8, 1912.

ECONOMIC USES.

The surface waters of the area are of suitable quality for use as boiler supplies, for irrigation, and for stock. The waters of the streams are suitable for domestic and municipal water supplies, except those that are polluted or heavily loaded with sediment. As ground waters unobjectionable in these respects are available in most of the area, the surface waters have been adopted only to small extent for domestic and municipal use. Where it is impracticable to obtain adequate supplies of underground water, as at Little Rock, which is on the boundary between the Ozark province and the Gulf Coastal Plain, proper filtration will render the surface waters potable. The city water supplies of Little Rock, Pulaski County; Newport, Jackson County; and Luxora, Mississippi County, are obtained from Arkansas, White, and Mississippi rivers, respectively.

GROUND WATERS.

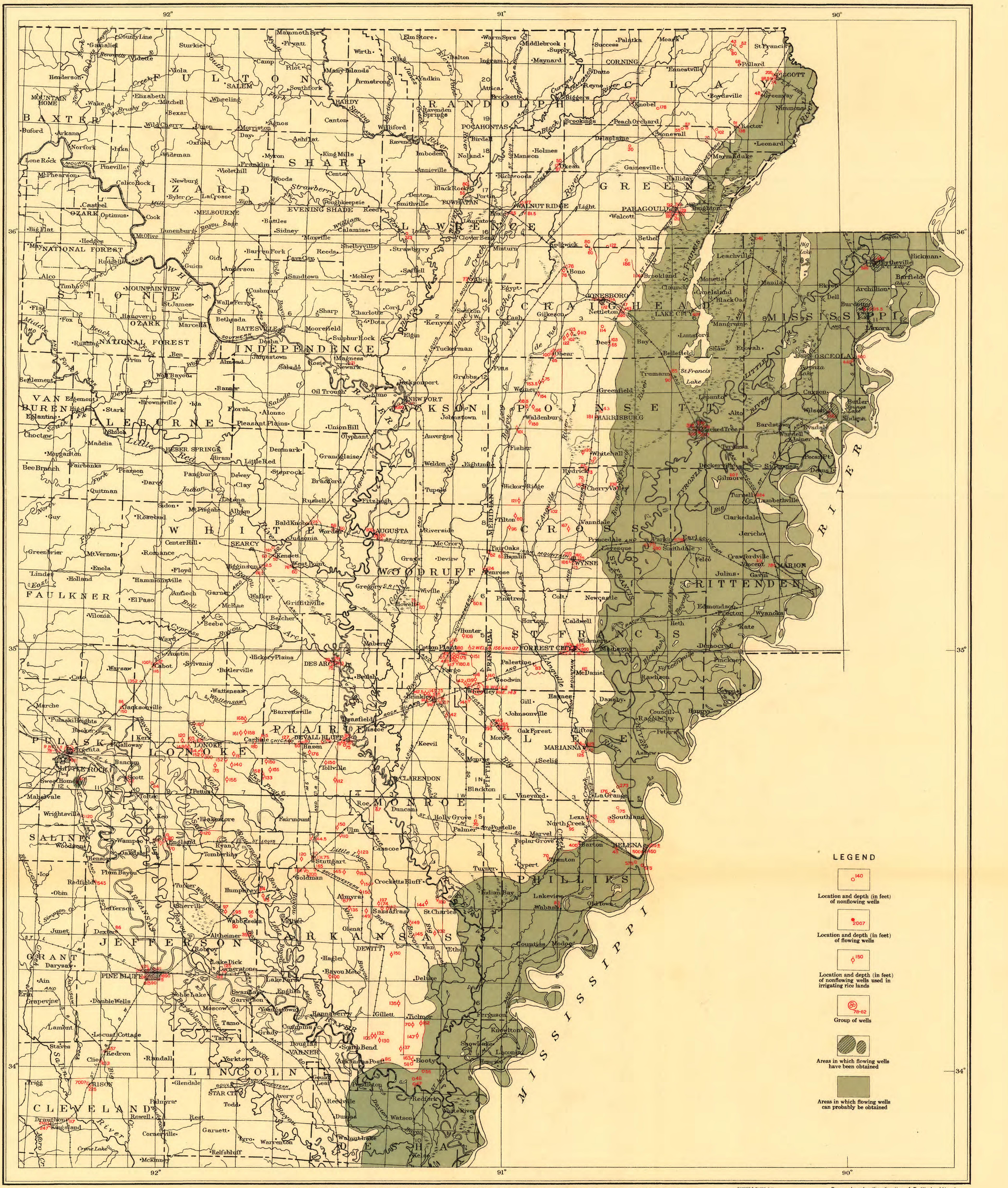
SOURCE.

The strata which underlie northeastern Arkansas are saturated with water below a level, known as the water table, which ranges from the surface to a depth of 100 feet or more. The water table lies deepest in Crowleys Ridge and shallowest in the lowlands east and west of that ridge; in the swamps it lies continuously or intermittently above the surface of the ground. The water table does not occupy a fixed position at any given place but continually fluctuates, being highest at the end of a long period of precipitation and lowest at the end of a long drought.

Although saturated to the level of the water table the various strata do not yield their contained waters to wells with equal readiness. The waters in the more compact layers are so completely locked within the fine interstices as to be practically unobtainable. Only the more porous sands and gravels yield their waters readily and in large quantities; it is to strata composed of these materials that the term water-bearing beds is commonly applied, and these are the strata that the well driller seeks to reach with the drill.

The location and depth of wells concerning which detailed information has been obtained are indicated in Plate XI.

The greater part of the ground water of northeastern Arkansas is derived from rainfall within the borders of the area. The catchment area for the waters of the flowing wells, east of Crowleys Ridge, in the Mississippi lowland, however, lies east of Mississippi River in Mississippi, Tennessee, and Kentucky. There is probably also a general, though extremely slow movement of the ground waters from the head of the Mississippi embayment in Missouri



MAP SHOWING GROUND WATERS OF NORTHEASTERN ARKANSAS

R. B. Marshall, Chief Geographer
A. F. Hassan, Cartographer
Compiled in 1912 and 1913

Prepared under the direction of T. Wayland Vaughan
by L. W. Stephenson and A. F. Crider.

Scale 1/500000

10 0 10 20 30 Miles

10 0 10 20 30 40 Kilometers

1916

southward toward the Gulf. Some water may also leak from the Paleozoic basement rocks to the unconsolidated deposits of the Gulf Coastal Plain, particularly near the outer border of the embayment area.

At certain places elsewhere in the Atlantic and Gulf Coastal Plain waters absorbed by the strata at the time of their deposition on the bottom of the ocean have remained locked in the interstices of the materials to the present time, and unless such waters have been greatly modified by subsequent mixture with waters from other sources, their resemblance to sea water renders it possible for the chemist to detect their marine origin. There is, however, no evidence to show that any of the underground waters of northeastern Arkansas are originally included sea waters, and it may be repeated that nearly all the ground water now recovered by wells in that area is derived from rainfall within the area itself.

DISPOSAL.

Van Hise[1] has estimated that at least 99 per cent of the meteoric waters that enter the earth return to the surface sooner or later, the remaining 1 per cent or less entering into chemical combination with minerals. A large part of the ground water gradually returns to the surface by capillary attraction and is evaporated; a large part is taken up by the roots of plants and is eventually evaporated; and a large part emerges at the surface as springs and flows away in streams. In an area underlain by strata that are inclined slightly toward the ocean, as in the Atlantic and Gulf Coastal Plain, there is probably a constant though extremely slow movement of the ground waters in the direction of the coast, so that a large proportion of these waters may reach the ocean by this course. In some thickly settled regions, where enough water is removed from the earth by wells to lower the water table appreciably, the problem of conserving the ground waters becomes important.

QUANTITY.

In the part of Arkansas included in the Mississippi embayment ground waters are abundant except in certain locally unfavorable areas. The depth to water-bearing strata of large capacity differs, but throughout the lowlands which comprise the greater part of the area, large quantities of water are obtained at depths of 50 to 200 feet. Many wells in the rice-growing areas are pumped at rates between 1,000 and 3,000 gallons a minute, or even more, but reports so far received indicate no appreciable decrease in the underground supplies.

[1] Van Hise, C. R., Treatise on metamorphism: U. S. Geol. Survey Mon. 47, p. 156, 1904.

STRATIGRAPHIC DISTRIBUTION.

CRETACEOUS DEPOSITS.

The beds of porous sand which partly compose the buried Cretaceous deposits of the area constitute an important, though largely undeveloped, source of artesian water. The depth to the Cretaceous deposits has not been determined precisely at any place, but according to the interpretation of the record of a well at Memphis, Tenn., strata of this age were first encountered there at a depth of 1,135 feet. In northeastern Arkansas flowing wells that doubtless tap water-bearing beds of Cretaceous age are in use at Blytheville, Mississippi County (depth 1,448 feet); Burdette, Mississippi County (depth, 1,495.5 feet); Wilson, Mississippi County (depth, 1,567 feet); and Marked Tree, Poinsett County (depth, 2,007 feet). Nonflowing wells that tap beds of this age are located at Jonesboro, Craighead County (1,214 and 1,265 feet deep, respectively), and at Newport, Jackson County (depth to Paleozoic rocks, 655 feet).

TERTIARY DEPOSITS.

EOCENE STRATA.

Basal Eocene strata, which outcrop in the Grandglaise terrace along the western border of the Mississippi embayment, have been correlated with the Midway formation, and the Eocene deposits that compose the core of Crowleys Ridge have been roughly separated in ascending order into the Wilcox, Claiborne, and Jackson formations. With these exceptions, the deposits of Eocene age which underlie practically all eastern and northeastern Arkansas, beneath the Pleistocene and Recent alluvial deposits, remain undifferentiated, and until a large amount of accurate well data has been obtained must be treated as a unit. A few wells scattered over the area have demonstrated that these buried Eocene deposits contain important water-bearing beds and constitute a possible source of artesian water, which is still largely undeveloped.

The Eocene strata dip slightly away from the rim of the Mississippi embayment, and their numerous interbedded layers of porous sand contain waters under sufficient hydrostatic pressure to bring them within easy reach of ordinary force or suction pumps, and perhaps in places in the Mississippi lowland, to produce flows at the surface. Deep wells have not been drilled in sufficient number to determine the vertical positions of the more extensive water-bearing portions of the deposits. Some wells have shown the presence of thick beds of clay which are economically not water bearing; others have encountered sands which, locally at least, are abundantly water bearing.

Concerning a few wells, notably certain ones on or near Crowleys Ridge, the probable subdivision of the Eocene to which the water-bearing beds belong can be indicated.

The wells known to tap water-bearing beds in the Eocene deposits are indicated in the tables of well data accompanying the descriptions of the water resources of the various counties. A few of the more important wells will, however, be mentioned here.

At Marked Tree, Poinsett County, there are four wells, 392 to 400 feet in depth (see wells Nos. 4–7, p. 248), which tap a water-bearing bed of Eocene age, probably belonging to the upper part of the Wilcox formation. The water is obtained between the depths 360 and 400 feet and rises within 1½ to 8 feet of the surface. This stratum is an important aquifer, at least locally, since each of the four wells yields enough water to supply the boilers of a large lumber mill.

At Blytheville, Mississippi County, a well 520 feet deep (see well No. 2, p 228) taps a water-bearing sand at a depth of 500 feet; the water rises within 15 feet of the surface, and the yield is sufficient to supply the boilers of a large lumber mill. This stratum is believed to be in the Wilcox formation of the Eocene.

At Turrell, in Crittenden County, gray water-bearing sand, probably belonging to the basal portion of the Wilcox formation, is encountered in the lower 24 feet of an 864-foot well (well No. 5, p. 178); the static head of the well is 12 feet below the surface.

Wells at Wynne, Cross County, 186, 250, and 360 feet deep, respectively (wells Nos. 15, 16, 19, p. 184), tap water-bearing beds in Eocene deposits, probably belonging to the Wilcox formation of that series.

At Parkin, in Cross County, two wells, 480 and 597 feet deep, respectively, obtain water from beds of sand believed to belong to the upper part of the Wilcox formation (wells Nos. 9, 10, p. 184). In one well (No. 9) the water rises within 10 feet of the surface, and in another (No. 10) within 12 feet of the surface; each well supplies the boilers of a large mill which manufactures wood products.

Another well which taps a coarse, water-bearing sand, probably belonging to the upper part of the Wilcox formation, is at Earl, Crittenden County (well No. 1, p. 178). It is 474 feet deep, and the water-bearing sand makes up the lower 60 feet of the section; the static head is 14½ feet below the surface.

The municipal water supply of Forrest City, St. Francis County, is obtained from three wells, 425, 425+, and 450 feet in depth, respectively, which at a depth of 400 feet tap a coarse, water-bearing sand probably referable to the upper part of the Wilcox formation; the water rises within 70 feet of the surface (wells Nos. 3, 4, 5, p. 268).

The municipal water supply of Marianna, Lee County, is taken from two wells, each 619 feet deep (wells Nos. 3, 4, p. 212). Here the source of the water is white sand of Eocene age; the water rises within 60 feet of the surface.

At and near Helena, Phillips County, numerous wells, including those of the city waterworks, tap clean coarse to fine water-bearing sands at depths of 450 to 575 feet; these sands probably belong to the Claiborne formation (wells Nos. 2–6, p. 240). The water, which is soft and of excellent quality for domestic and industrial supplies, rises within 18 to 40 feet of the surface.

A 400-foot well at Barton, Phillips County, taps a water-bearing sand which probably corresponds to that penetrated by the wells at Helena; the static head is 20 feet below the surface and the water is soft (well No. 1, p. 240).

At Brinkley, in Monroe County, the municipal water supply is obtained from a well (565 feet deep), which penetrates a fine, white, water-bearing sand in the lower 68 feet of the section; the static head is 40 feet below the surface (well No. 1, p. 232).

LAFAYETTE FORMATION (PLIOCENE?).

The Lafayette formation is locally water bearing in Crowleys Ridge, where it is tapped by numerous bored and dug wells; the waters belong to the nonartesian class (p. 139) and are used for house and farm supplies. The formation is the source of the waters of many small springs.

QUATERNARY DEPOSITS.

The loess is not an important water-bearing formation because of its close texture and its elevated topographic position.

The Pleistocene alluvium, which underlies the Advance lowland to an estimated maximum depth of 200 feet, is, from an economic standpoint, the most important water-bearing formation in northeastern Arkansas. In the interstream areas the materials immediately underlying the surface almost everywhere are compact, silty clays that are nearly impervious to water and therefore protect the waters below them from surface pollution. The waters are contained chiefly in the fine to coarse sands and gravels which compose the lower one-half to two-thirds of the deposits.

In the Mississippi lowland the coarse sands and gravels of Pleistocene age, which largely compose the basal portion of the Quaternary alluvial deposits also are abundantly water bearing.

The sands and gravels of the Recent alluvium contain abundant water suitable for use in boilers and other industrial operations. In general, these waters are not considered desirable for domestic use because of the danger of pollution; where local beds of impervious clay overlie the water-bearing beds, the waters may, however be safely used.

SPRINGS.

Numerous small springs in Crowleys Ridge and in the Grand-glaise terrace are used to a small extent as house and farm supplies. In the lowlands seepage springs are common along the stream banks, along the margins of swamps, and at the heads of small branches, but they are of slight importance because of their intermittent character and small yield.

NONARTESIAN WATERS.

DEFINITION AND IMPORTANCE.

The term "nonartesian" is in this report applied to ground waters that are not under sufficient hydrostatic pressure to force them above the containing beds when they are tapped by wells or other excavations. Nonartesian waters are of great economic importance in the Arkansas lowlands because they are used more extensively than those of any other class for domestic and industrial supplies and for irrigation. Their value has become more fully appreciated since their applicability to rice lands has been demonstrated.

The nonartesian waters are contained in the alluvial deposits which underlie the Mississippi lowland and the Advance lowland to depths of 100 to 225 feet. The water table in these deposits ranges in vertical position from the surface to a depth of 65 feet.

Except perhaps locally these waters do not rise at all in wells above the level of the water table or rise only slightly above it. In the tables of well data which accompany the county descriptions the depth to the principal water-bearing bed of most wells is reported as greater than the depth at which the water stands in the wells; but the principal water-bearing bed is generally understood by well owners and drillers to be the coarse, basal sands and gravels which yield their contained waters readily, and the true water table is at a higher level in the finer overlying sands, which are an essential part of the reservoir. The geologic position of the nonartesian waters is graphically represented in *a*, figure 3, p. 142, and *b*, figure 4, p. 143.

METHODS OF DEVELOPMENT.

The nonartesian waters are obtained by means of dug, bored, and driven wells, and are raised by rope and bucket, hand suction or force pumps, windmills, and various types of more powerful steam or gasoline driven pumps. The type of well, its depth and diameter, and the kind of lifting machinery are determined by the purpose to which the waters are to be put and the amount of water required. Wells intended to supply municipalities, large factories, and irrigated lands are equipped with powerful machinery, centrifugal pumps and air lifts being most generally used.[1]

ARTESIAN WATERS.

DEFINITION.

The term "artesian" is applied in this report to ground waters that are under sufficient hydrostatic pressure to force them above the level of the containing beds when they are penetrated by wells or other excavations. Thus artesian water does not necessarily overflow, and an artesian well may be either flowing or nonflowing. The significance of the term "artesian" has been discussed by Fuller.[2]

GENERAL CONDITIONS GOVERNING OCCURRENCE.

Fuller's summary[3] of the essentials and secondary factors of artesian flows, which is applicable also to nonflowing artesian waters, is quoted below:

> The essentials of artesian flows, as recognized by the writer, are as follows:
>
> 1. An adequate source of water supply.
>
> 2. A retaining agent offering more resistance to the passage of water than the well or other opening.
>
> 3. An adequate source of pressure.
>
> The first requisite is not made specific as regards source, because, as has been pointed out, artesian waters are not derived from a single but from a variety of sources. The second requisite—the retaining agent—may be a stratum, a vein or dike wall, a joint, fault, or other fracture plane, a water layer, or some one of a variety of other agents. * * * The pressure, although primarily due to variations in level in the different parts of the artesian system, may be transmitted in so many ways and is subject to so many modifying factors that the postulation of a specific cause is impracticable. * * *
>
> It is believed that the three factors stated in the preceding paragraph are all that can be considered as essential to artesian flows, all other postulated requisites being in reality modifying or accessory rather than essential factors. These secondary factors may be classified as follows:

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[1] Wilson, H. M., Pumping water for irrigation: U. S. Geol. Survey Water-Supply Paper 1, 57 pp., 1896.

Murphy, E. C., Windmills for irrigation: U. S. Geol. Survey Water-Supply Paper 8, 49 pp., 1897.

Hood, O. P., New tests of certain pumps and water lifts used in irrigation: U. S. Geol. Survey Water-Supply Paper 14, 91 pp., 1898.

Perry, T. O., Experiments with windmills: U. S. Geol. Survey Water-Supply Paper 20, 97 pp., 1899.

These reports can be consulted only in libraries, as the editions have long been exhausted.

[2] Fuller, M. L., Underground-water papers: U. S. Geol. Survey Water-Supply Paper 160, pp. 9–15, 1906.

[3] Fuller, M. L., Summary of the controlling factors of artesian flows: U. S. Geol. Survey Bull. 319, pp. 36, 37, 1908.

Secondary factors of artesian flows.

I. Hydrostatic factors (relating to pressure and movement):
   1. Factors mainly affecting pressure—
      (*a*) Barometric pressure.
      (*b*) Temperature.
      (*c*) Density.
      (*d*) Rock pressure.
   2. Factors mainly affecting movement—
      (*a*) Porosity.
      (*b*) Size of pores or openings.
      (*c*) Temperature.

II. Geologic factors (relating to reservoir):
   1. Character of reservoir.
   2. Retaining agents.
   3. Structure of reservoir.
   4. Topographic conditions.
   5. Conditions relating to supply—
      (*a*) Catchment conditions.
      (*b*) Condition of underground feed.
   6. Conditions of leakage.

Hydrostatic pressure in ground waters results from various causes, but any set of conditions that produces such pressure may be termed an artesian system. Fuller[1] has illustrated by diagrams several of the more common artesian systems.

CONDITIONS IN THE ADVANCE LOWLAND.

The artesian and nonartesian conditions from north to south in the Advance lowland west of Crowleys Ridge are shown diagrammatically in figure 3. The Eocene and Cretaceous strata which contain the artesian waters are completely covered by Quaternary alluvial deposits (*a*) which contain nonartesian waters. Rain is absorbed by the alluvium chiefly through the sandy surface materials (*c*) forming the broad flood plains of the present streams, but in part through the slightly pervious silty loams and clays (*b*) which immediately underlie the interstream areas. The alluvial deposits are saturated with water below the level of the water table, which lies from a few feet to 65 feet below the surface; the tendency to develop hydrostatic pressure in the water contained in the alluvial deposits produced by their slight southward tilt is overcome by friction and the waters are therefore nonartesian.

The alluvial deposits serve as a catchment area for the water-bearing beds of the underlying Eocene and Cretaceous strata which dip at a greater angle to the southward; the water gains entrance to these beds at the points indicated by the arrows (*h*). In the pervious stratum (*d*) which lies between two relatively impervious strata, the

[1] Fuller, M. L., Summary of the controlling factors of artesian flows: U. S. Geol. Survey Bull. 319, pp. 38–42, 1908.

only hindrance to the passage of the water down the dip is friction; friction in the bed below the point at which it is tapped by the well produces a certain amount of hydrostatic pressure. In the pervious stratum (*e*) which pinches out down the dip between two relatively impervious strata, hydrostatic pressure is produced by the weight of the confined water. The pervious stratum (*f*) merges down the dip into relatively impervious materials and hydrostatic pressure is produced in the same manner as in stratum (*e*). In the pervious stratum

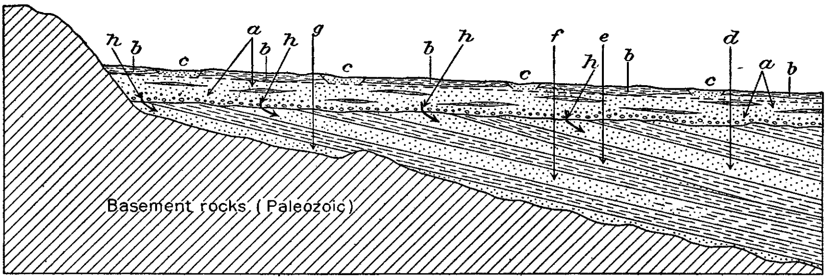

FIGURE 3.—Section to illustrate artesian and nonartesian conditions in the Advance lowland west of Crowleys Ridge, Ark. For explanation see text.

(*g*) the passage of the water down the dip is prevented by an unconformity, and hydrostatic pressure is produced in the same manner as in the two preceding cases.

Although hydrostatic pressure exists in the southward-dipping Cretaceous and Eocene strata of the Advance lowland as represented in figure 3, the conditions, so far as understood and so far as tested, seem to be unfavorable for the development of sufficient pressure to force the water above the surface of the ground.

CONDITIONS IN THE MISSISSIPPI LOWLAND.

In the Mississippi lowland east of Crowleys Ridge the conditions which, when viewed from north to south, appear to be similar to those in the Advance lowland west of the ridge, are modified by a set of east-west conditions favorable to the production of hydrostatic pressure sufficient to cause overflows at the surface in wells 1,000 feet or more in depth. Figure 4 represents these conditions along a line from the vicinity of Lexington, Tenn., westward through Mississippi County, Ark., to Crowleys Ridge, and similar conditions probably exist throughout the greater part of the Mississippi lowland. (See Pl. XI.) This area is underlain beneath 150 to 225 feet of Quaternary alluvial deposits, in descending order, by 2,000 to 3,000 feet or more of Eocene and Cretaceous strata which rise eastward and outcrop in Tennessee and Mississippi at elevations of 400 to 600 feet. On account of the greater elevation of the catchment area and the consequent greater weight of the waters confined in the inclined strata, greater hydrostatic pressure is developed in the deposits underlying the Mississippi lowland. This is believed to be the explanation of the flows obtained in Mississippi County at Blytheville (depth, 1,448 feet), Burdette (depth, 1,495 feet), and Wilson (depth, 1,567 feet), and in Poinsett County at Marked Tree (depth, 2,007 feet).

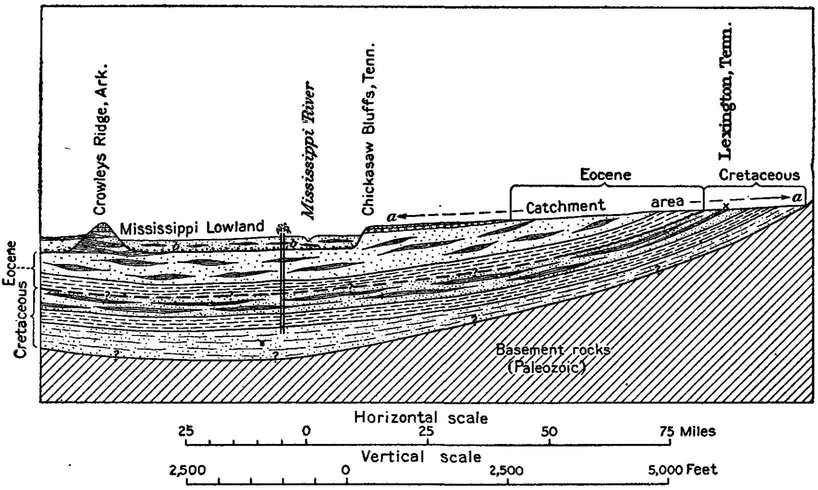

FIGURE 4.—Generalized section to explain the cause of artesian flows in the Mississippi lowland: Water entering the Eocene and Cretaceous deposits in the catchment area *a a* passes down the inclined strata by gravity. Hydrostatic pressure is developed in the several ways explained in figure 3, and because of the greater elevation of the catchment area the pressure is great enough to cause overflows in the Mississippi lowland. *b* is the Quaternary alluvium of the Mississippi Valley.

ECONOMIC USES.

GENERAL USES.

Throughout northeastern Arkansas water for domestic and farm use is obtained chiefly from wells. Except Little Rock, Pulaski County; Newport, Jackson County; and Luxora, Mississippi County; which use the waters of Arkansas, White, and Mississippi rivers, respectively, the towns and cities having municipal waterworks are supplied from wells. Nearly all the manufacturing plants and railroads draw from the same source. The ground waters have been used locally in a small way for irrigating lands devoted to market gardening, but because of the relatively high precipitation the necessity for such irrigation is keenly felt only at occasional intervals. The advantage gained, however, by even distribution of moisture during the growing season would doubtless render profitable the general establishment of pumping plants on garden farms.

RICE CULTURE.[1]

HISTORY.

Rice has been grown commercially in Arkansas since 1904 and conditions are ideal for the rapid development of the industry. The soils of most of the prairie land in the interstream areas of the Advance lowland between Crowleys Ridge and Arkansas River are peculiarly adapted in composition and distribution to the raising of this cereal, and large quantities of the water necessary for irrigation lie at relatively shallow depths beneath the prairies. For the following account of the beginning of the rice-growing industry in the prairies of Arkansas the authors are indebted to Mr. W. H. Fuller, of Lonoke, the pioneer experimenter who raised the first commercially important crop of rice in the State, and to Mr. E. G. Norton, of Brinkley, who has taken special pains to furnish data from reliable sources.

In August and September, 1896, Mr. Fuller and Mr. H. H. Puryear made a wagon trip from Lonoke southward through Arkansas and Louisiana to the Gulf of Mexico. Eight miles north of Crowley, La., they saw rice fields owned and operated by Abbott Bros., of Crowley. As this was the first rice either of them had seen growing, they spent two days studying the plantations of Abbott Bros. and of W. W. Duson, and became convinced that the conditions under which rice was grown in the prairies of southwestern Louisiana were essentially like those existing in the prairies of Lonoke County, Ark.

After his return to Lonoke, Mr. Fuller made preparations to raise an experimental crop of rice on his farm, 8 miles southeast of Lonoke (in the NW. ¼ sec. 8, T. 1 N., R. 7 W.). He drilled two 4-inch wells, installed a pumping plant, and in the spring of 1897 planted 3 acres in rice. Some of the seed germinated, grew, and headed out, but because of an accident to the pumping plant and consequent failure to apply the necessary amount of water to the crop the grain did not reach maturity. Yet the experiment, so far as it went, was successful, for it demonstrated that the grain, if properly irrigated, could be raised on the prairies of Arkansas.

In 1898 Mr. Fuller moved to Louisiana and engaged in rice culture on the prairies of that State for four seasons; he familiarized himself in a practical way with the methods employed in preparing the soil, planting the seed, irrigating the growing plants, and harvesting the grain; he also learned how wells were drilled and equipped for

[1] Literature relating to rice culture in Arkansas, Louisiana, and Texas:

Bond, Frank, Irrigation of rice on the uplands of Louisiana and Texas: U. S. Dept. Agr. Office Exper. Sta. Bull. 113, 19 pls., 9 figs., pp. 1–57, 1902.

Fuller, M. L., Rice irrigation in southern Louisiana: U. S. Geol. Survey Water-Supply Paper 101, pls. 9–11, figs. 13–15, pp. 82–94, 1904.

Knapp, S. A., Rice culture: U. S. Dept. Agr. Farmers' Bull. 417, 30 pp., 1910.

Bonsteel, J. A., The Crowley silt loam: U. S. Dept. Agr. Bur. Soils Circ. 54, 8 pp., 1912.

supplying water for irrigation. During 1903, while Mr. Fuller was in Louisiana, 5 acres of rice were grown in Lonoke County by the Johnson Morris family; no detailed information has been obtained concerning this crop.

In the fall of 1903 Mr. Fuller returned to Arkansas, and with the financial backing of citizens of Carlisle and Hazen, he made preparations to raise a crop of rice on a commercial scale. A well was drilled and equipped for pumping on Mr. Fuller's farm, and 70 acres was planted to rice in the spring of 1904; at the end of the season 5,225 bushels were harvested. The total cost of producing this crop, including the cost of drilling and equipping the well, was $3,147, and the crop sold for $1 a bushel. During the same season a branch station of the Arkansas Agricultural Experiment Station was established 1½ miles west of Lonoke, where 750 bushels of rice were raised on 10 acres of land. Rice was also raised during the same season by the Morris family, but no statistics concerning the crop are available.

PRODUCTION.

The completely successful efforts of Mr. Fuller and of the experiment station to raise rice demonstrated beyond question that this cereal could be grown at a profit on the prairies of Arkansas, and the lessons taught by these demonstrations were quickly learned. The rapid development of the rice-growing industry in Arkansas from 1905 to 1914, inclusive, is shown by the following table compiled by the United States Department of Agriculture:

Acreage and production of rice in Arkansas, 1905 to 1914, inclusive.

Year.	Acreage.	Production.	Average per acre.	Year.	Acreage.	Production.	Average per acre.
		Bushels.	*Bushels.*			*Bushels.*	*Bushels.*
1905	460	22,356	48.6	1910	60,000	2,400,000	40
1906	4,240	131,440	31	1911	71,600	2,792,000	39
1907	6,000	222,000	37	1912	90,800	3,405,000	37.5
1908	11,400	467,400	41	1913	104,700	3,769,000	36
1909	28,000	1,120,000	40	1914	92,580	3,685,000	39.8

In 10 years (1904–1913, inclusive) the acreage devoted to rice culture in Arkansas increased from 80 to 104,700 and the production from 5,975 to 3,769,000 bushels. The rather marked decrease in acreage and production in 1914 was due chiefly to abnormally low prices, but statistics for 1915 compiled by the Department of Agriculture indicate a return to normal conditions.

The cereal was grown chiefly on the prairies of the Advance lowland between Crowleys Ridge on the east, the Ozark province on the northwest, and Arkansas River on the southwest. In 1912 the cereal was successfully grown in 13 counties, as follows: Arkansas, Jefferson, Lonoke, Prairie, Monroe, Lee, St. Francis, Woodruff, Cross, Poinsett, Craighead, Lawrence, and Clay. Since the data on which this report is based were collected the industry has probably spread to several other counties. The chief productive area is at present within the first four counties named, and the greatest development has been in Grand Prairie, which extends from the northern part of Lonoke County southeastward through Prairie and Arkansas counties, and in Prairie Longue, which extends northwest and southeast through the central part of Lonoke County. Another area in which the industry is rapidly developing extends a little east of north from the vicinity of Brinkley and includes part of Monroe, Lee, St. Francis, Woodruff, Cross, Poinsett, and Craighead counties. The grain also is grown in several scattered localities in the above-mentioned counties.

OUTLOOK.

Though the number of acres of land suitable for rice culture in the area under consideration has not been accurately estimated, only a small part, probably less than 5 per cent, of the available land has been put under cultivation. As water for irrigation is present in great abundance at relatively shallow depths throughout the area, the outlook for the development of the industry to large proportions is most promising. The greater part of the potential rice land is in the Advance lowland west of Crowleys Ridge; immediately east of the ridge, however, there is a belt, nowhere more than 5 or 6 miles wide, extending from the northern boundary southward as far as the southern part of Craighead County, in parts of which the conditions of soil, topography, and available water supply are essentially the same as in the area west of the ridge; near Nettleton, Craighead County, which is in this belt, rice has already been successfully grown.

WATER SUPPLY.

Water for irrigating the rice fields is obtained chiefly from the Pleistocene alluvial deposits which underlie the Advance lowland to depths of 100 to 200 feet. Wells 6 to 12 inches in diameter are sunk to the coarse sands and gravels in the lower part of the deposits, which contain large quantities of water. The wells are equipped with powerful pumps, centrifugal pumps being generally used, and yield from 200 to 4,000 gallons a minute. The cost of drilling and equipping a well ranges from $125 to $5,000; the average cost of sinking the wells and installing the pumping machinery, as estimated from statistics regarding 102 wells, is $1,085 per 1,000 gallons of yield per minute.

Though wells are the chief source of water for irrigation, lands near streams and bayous might be irrigated with surface water. Surface waters have been utilized only to a small extent in Arkansas, but they are widely used in Louisiana and eastern Texas, where pumping plants on the banks of the streams lift the water to the canals. Utilization of ground water from porous beds near the surface has the added advantage of reducing danger of damage to the land by water-logging and rise of the alkali, both of which troubles have seriously affected much land in other parts of the United States where the ground water level is normally near the surface. The application of water pumped from beneath the irrigated tract tends not only to lower the water table but also to produce downward circulation that removes the alkali. Such circulation is important in growing a crop like rice, for which the duty of water is very low.

SOIL.

The typical soil of the prairies of Arkansas is known as the Crowley silt loam, the name being derived from Crowley, La., where a similar soil is widely developed. Its physical characteristics and availability have been described by Bonsteel[1] as follows:

> The Crowley silt loam is a brown or ashy gray silt loam ranging in depth from 10 to 16 inches, underlain by a gray or mottled heavy silt loam or silty clay which frequently contains concretions of iron and calcium carbonate. The subsoil ranges in color from gray to reddish yellow, mottled with red and brown, and is stiff and impervious in all localities where it has been encountered. * * *
>
> Before the introduction of rice culture upon this soil type very little agricultural use was made of it. In Arkansas the prairie grasses were used for grazing purposes, and the better drained and higher lying portions of the type were beginning to be cultivated to cereal grains and forage crops. These uses of the type, however, are entirely subordinate to its principal utilization as the chief rice-growing soil of the Western Gulf States. While small areas are annually planted to cotton, corn, cowpeas, and even oats or wheat, the great use of the soil is for the production of the rice crop.
>
> The Crowley silt loam, owing to its flat topography, to its slight elevation above the main drainage channels, and to the impervious nature of both the surface soil and subsoil, is in its natural condition for the most part poorly drained. * * *
>
> The Crowley silt loam is the typical rice land of southwestern Louisiana and east-central Arkansas. It is probable that more rice is grown upon this soil than upon all other rice soils in the United States. In fact, the development of this type for agricultural purposes has been almost coextensive with the development of the rice industry in the Western Gulf States.

Although the Crowley silt loam is best adapted to rice culture in the area under consideration, the cultivation of the cereal has been successfully extended to several closely related soils which, as classified by the Bureau of Soils, possess the qualities essential to the

[1] Bonsteel, J. A., U. S. Dept. Agr. Bur. Soils Circ. 54, pp. 3–5, 1912.

growth of the grain. Knapp,[1] discussing the adaptability of soils to rice culture, states:

The best soil for rice is a medium loam containing about 50 per cent of clay. This allows the presence of sufficient humus for the highest fertility without decreasing too much the compact nature of the soil. * * *

The best rice lands are underlain by a semi-impervious subsoil. Otherwise the land can not be satisfactorily drained at time of harvest in order to permit the use of improved harvesting machinery. The alluvial lands along the Mississippi in Louisiana are not underlain by hardpan, and they can not be drained sufficiently to permit the use of heavy harvesters and teams of horses.

Gravelly or sandy soils are not adapted to rice cultivation because they do not posses the mechanical conditions for the retention of water, and for other reasons above mentioned. Occasionally, on a light sandy soil, underlain by a stiff subsoil, one or two fairly good crops of rice may be grown, but this is the limit.

DUTY OF WATER.

F. H. King,[2] professor of agricultural physics in the University of Wisconsin, states that the usual duty of water for rice in the United States is 38.6 acres per cubic foot per second, which is equivalent to covering the surface with 6.2 inches of water every 10 days. He also states that in Italy the amount of water applied every 10 days is 5.55 inches, while in Egypt only 3.4 inches is provided for the same period.

Brown[3] estimates that in Egypt 1 cubic meter per second is sufficient for 1,440 acres of rice, his estimate being based on the assumption, corroborated by extensive observations, that rice requires twice as much water as most other crops. This duty is equivalent to 40.75 acres irrigated for each cubic foot per second of water. The water is usually applied after intervals of 9 days. He gives the customary duty in India as 50 acres per cubic foot per second, the water being applied after intervals of 12 days. If the interval is 11 days, this duty becomes 51 acres per cubic foot per second.

Buckley[4] states that a rice crop in the Punjab district of India receives 96 inches of water and requires 48 to 72 inches of water during the growing season; he estimates the duty in Spain as 31 acres per cubic foot per second.

Other estimates of the duty of water in rice culture are 50 to 60 acres per cubic foot per second in Egypt;[5] 40 acres per cubic foot per second in Italy;[6] and 43.75 acres per cubic foot per second in the Cavour Canal district of Italy.[7]

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[1] Knapp, S. A., Rice culture: U. S. Dept. Agr. Farmers' Bull. 417, pp. 8, 9, 1910.

[2] King, F. H., Irrigation and drainage, pp. 231–233, New York, 1908.

[3] Brown, Hanbury, Irrigation, its principles and practices as a branch of engineering, pp. 37, 38, London, 1907.

[4] Buckley, R. B., Facts, figures, and formulæ for irrigation engineers, pp. 126, 133, New York, 1908.

[5] Idem, p. 133.

[6] Estimate by Col. Baird Smith, quoted by Buckley, idem, p. 137.

[7] Estimate by Sir S. C. Moncrieff, quoted by Buckley, idem, p. 136.

Reports collected by Collier [1] from members of the Arkansas Rice Growers' Association indicate that 57 per cent of the growers commence applying water four or five weeks and 43 per cent two or three weeks after sowing. Sixty per cent keep the water on the field 3 inches or less deep; 28 per cent 3 to 5 inches deep; and 12 per cent 5 or more inches deep. Somewhat more than half the growers reported that they prefer water pumped from wells to surface water, but the rest expressed no preference. More than nine-tenths stated that cold water direct from wells harms the growing plants.

COUNTY DESCRIPTIONS.[2]

ARKANSAS COUNTY.

PHYSIOGRAPHY.

Arkansas County is in the east-central part of the State between Arkansas and White rivers. Its area is 1,000 square miles and its population was reported by the census of 1910 as 16,103. Stock raising and agriculture, which includes trucking, cotton raising, the cutting of prairie hay, the raising of rice, corn, and other cereals, are the principal industries.

The general surface is a slightly undulating plain sloping from an elevation of about 215 feet above sea level in the northern part to 150 feet in the southern part of the county, and comprising the prairies, which include much of the interstream areas, the timbered lands, which include the remainder of the interstream areas, and the flood plains bordering the streams. The prairies are open, grassy tracts forming part of Grand Prairie (p. 27); they cover the northern part of the county and form interstream areas, a few miles to 10 miles wide, extending southward, the southern limit being 5 or 6 miles south of Gillett. In the east the prairies closely border White River, which has cut into the edge of them in places. The general level of the prairies is 45 or 50 feet above the low-water level of Arkansas and White rivers.

The gently undulating interstream timbered lands border the shallow valleys and intertongue irregularly with the prairie lands The flood plains lie a few feet to 30 feet below the level of the prairies and form poorly drained wooded or cultivated tracts 10 to 12 miles in maximum width. The broadest flood plains are in the west, bordering Arkansas River and Bayou Meto, and in the south where the bottom lands of Arkansas and White rivers merge into Mississippi River bottom.

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[1] Collier, J. S., Report of investigations concerning rice, Arkansas Rice Growers' Assoc., 1910.

[2] This report was transmitted for publication in June, 1913, and the development of the water resources of northeastern Arkansas as herein indicated is based on data collected prior to that date.

Arkansas River and its tributary Bayou Meto form the southwestern boundary of the county and White River the eastern boundary. The principal streams within the county are Mill Creek, a tributary of Bayou Meto, and Lagrue River, a tributary of White River.

GEOLOGY.

The surface is underlain by Pleistocene alluvium consisting of clays, sands, and gravels ranging in thickness from 100 to 180 feet or more. The materials are irregularly bedded, but in general grade downward from fine, compact, gray or reddish clays through fine sands to coarse, water-bearing sands and gravels at the base. The coarse basal materials carry water in practically inexhaustible quantities. The surface distribution of the Pleistocene alluvium is coextensive with the distribution of the interstream lands of the county.

The streams have meandered and eroded away the Pleistocene alluvium to undetermined depths, and the valleys thus formed have been partly refilled with Recent alluvium, which constitutes the material of the present flood plains.

The Pleistocene alluvium rests unconformably on a buried surface of undifferentiated Tertiary strata which are believed to consist of sands, clays, and marls and to contain important water-bearing beds, though no logs have been preserved of the few wells that have been drilled deep enough to enter the Tertiary strata. (See well No. 31, p. 157.)

WATER RESOURCES.

GENERAL CONDITIONS.

Domestic supplies.—Water for household use is obtained chiefly from wells 30 to 150 feet deep drawing from the water-bearing sands and gravels of the Pleistocene and Recent alluvial deposits. The waters, as reported by the well owners, differ in quality, some being soft, some hard, some ferruginous, and a few saline, but with rare exceptions they are suitable for domestic and industrial use. No flowing wells have been reported, the static head ranging from 12 to 65 feet below the surface. The Pleistocene and Recent alluvial deposits which extend from the surface to depths of 150 to 180 feet contain large quantities of water suitable for general use, and the water-bearing beds of the Tertiary deposits which underlie the Pleistocene probably contain water in great abundance.

Irrigation.—Water for irrigating the extensive rice lands is obtained chiefly from wells 70 to 232 feet deep. The average depth of such wells—about 136 feet—is greater than that of domestic wells, most of them reaching the coarser sands and gravels forming the basal beds of the Pleistocene alluvium. The irrigation wells are equipped to yield by pumping 600 to 2,200 gallons a minute. Detailed information has been recorded concerning 33 wells used in irrigation of rice lands (see table on pp. 154–159), but probably more than 250 wells are in use. The cost of drilling and equipping the wells for pumping, according to reports on 29 wells, ranges from $650 to $3,000, the average cost of drilling and equipping the wells being, in round numbers, $1,500 for each 1,000 gallons a minute of water.

LOCAL SUPPLIES.

Stuttgart.—The municipal waterworks of Stuttgart (population 2,740, census of 1910) is owned by the Stuttgart Water & Electric Light Co., and water is obtained from three wells, two of which are 110 and 131.75 feet deep (Nos. 29 and 30, pp. 156, 157). The water is soft and is forced from the wells by an air compressor having a capacity of 400 gallons a minute; it is stored in a 35,000-gallon reservoir and is distributed through 7 miles of mains. The ordinary direct pressure is 40 pounds per square inch, but it can be increased to 110 pounds per square inch for fire protection. The daily consumption is 180,000 gallons for general use and 700,000 gallons for manufacturing.

The following is a log of the 131.75-foot well drilled in 1909:

Log of well owned by the Stuttgart Water & Electric Light Co., Stuttgart.

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil and subsoil	12	12
Sand, clay, and gravel	80	92
Gravel, water bearing	39.75	131.75

The material from a depth of 100 feet in a well owned by G. H. Kline, near Stuttgart, consists of very coarse pebbly sand with numerous angular fragments of gray and brown flint, and Gunter Bros., who furnished the sample, state that this is the kind of material from which water is obtained in the vicinity of Stuttgart. The material from a depth of 95 feet in a well owned by Ed Beity, 8 miles northeast of Stuttgart, consists of chunks of drab, yellow, pink, and red clay, in part finely arenaceous, and one sandstone concretion. Gunter Bros., who furnished this sample also, state that similar clay generally lies between the surface and the water-bearing sand and gravel in the region of Stuttgart. Information is meager regarding the oil-prospecting well drilled 2 miles southwest of Stuttgart (No. 31, pp. 156, 157), but the following partial log of it has been prepared from well borings furnished by Mr. E. J. Balle, of Stuttgart.

Incomplete log of an oil-prospecting well near Stuttgart.

	Thickness.	Depth.
	Feet.	*Feet.*
Not represented by samples	950	950
Fine, dark-gray, micaceous, glauconitic sand	118	1,068
Fine, gray, micaceous, slightly argillaceous sand	10	1,078
Not represented by samples	122	1,200

The materials described are probably of Eocene or Upper Cretaceous age. Mr. G. W. Fagan, of Stuttgart, states that according to the driller, Mr. Schauman, the well was drilled to a depth of 1,200 feet, where hard rock was struck; water-bearing beds were encountered at several levels—one at 800 feet. The waters were cased off without testing their quantity or character.

Irrigation wells.—Wells for irrigating rice lands have been drilled in the vicinity of Stuttgart, Almyra, Dewitt, Gillett, Booty, Arkansas Post, Bayou Meto, Tichnor, St. Charles, Crocketts Bluff, and Humphrey. Logs of the following have been obtained:

Log of well of C. E. Edmund, 6 miles southeast of Stuttgart.

[No. 36, p. 158.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	3	3
Red clay	47	50
Fine sand	55	105
Coarse sand, water bearing	25	130
Gravel, water bearing	15	145

Log of well of Caspar G. Scheiderer, 1¼ miles southwest of Ulm (Prairie County), in Arkansas County.

[No. 42, p. 158.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Tough red clay	60	60
Quicksand	6	66
Tough chocolate-colored clay	14	80
Sand, water bearing	30	110

[No. 1, p. 154.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	3.5	3.5
Red clay	16	19.5
Fine red sand	30	49.5
Red clay	40	89.5
Sand, water bearing	25	114.5
Gravel, water bearing	35.5	150

Log of well of J. M. Satchfield, 4 miles south of Tichnor.

[No. 35, p. 158.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Hard clay	60	60
Sand, water bearing	47	107
Gravel, water bearing	40	147

Log of well of W. N. Carpenter, one-quarter mile west of Booty.

[No. 13, p. 154.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Clay	60	60
Sand	10	70
Gravel, water bearing	93	163

Wells in Arkansas County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Almyra, 2 miles northwest of.	3 S.	4 W.	21, SE. ¼	H. V. Clutter	Layne & Bowler, Stuttgart.	Owner	1909	200±	150	12	90-150	....	Pleistocene alluvium.
2	Almyra, 2½ miles southwest of.	4 S.	4 W.	4, N. ½	P. and A. L. Westerlund, Orion, Ill.	.....do	Wm. Hines	1908	200±	135	10	96-135	....	Do.
3	Almyra, 3 miles southeast of.	4 S.	4 W.	1, SW. ¼	F. E. Hillman	Owner	Owner	......	200±	149	9⅝	110-149	....	Do.
4	Almyra, 4 miles west of.	3 S.	4 W.	29, W. ½	J. M. and W. A. Anderson.	....	W. A. Anderson.	1909	200±	87?	9⅝	50-87?	....	Do.
5	Almyra, 5 miles southeast of.	4 S.	3 W.	5, NE. ¼	G. W. Chambers	Layne & Bowler, Stuttgart.	Owner	1909	190±	174	12	95-131	152-174	Do.
6	Almyra, 6 miles southeast of.	4 S.	3 W.	4, NE. ¼	Austin Rawlings	Owner	.....do	1909	(*a*)	142	10	100-142	65	Do.
7	Almyra, 4 miles east of.	3 S.	3 W.	32, SW. ¼	W. B. Stroud, Stuttgart.	Layne & Bowler, Stuttgart.	.....do	1908	200±	197	9⅝	97	....	Do.
8	Almyra, 4 miles north of	3 S.	4 W.	3, E. ½	S. H. Taggart	.....do	.....do	1908	200±	152	9⅝	90	....	Do.
9	Arkansas Post (Spanish grant 2307).	8 S.	3 W.	....	Fritz Quandt	E. Nichols, Gillett.	.....do	1907	......	85	2	80-85	....	Quaternary alluvium.
10	Arkansas Post, 4 miles north of.	7 S.	3 W.	21, SW. ¼	J. A. Nutter, Gillett.	E. C. Nutter, Gillett.	Driller	1911	(*b*)	130	8¼	95-130	35, 55	Pleistocene alluvium.
11	Bayou Meto, 1½ miles southeast of.	5 S.	5 W.	36, N. ½ SE. ¼.	John Rodgers	L. B. Stephens, De Witt.	Owner	1909	......	100	10	80-100	69	Do.
12	Booty, 2½ miles west of.	7 S.	3 W.	36, NE. ¼	P. Whiting, Arkansas Post; and C. L. Morgan, De Witt.	William Cromwell, Stuttgart.	C. L. & S. A. Morgan.	1910	......	137	12	....	....	Do.
13	Booty, one-fourth mile west of.	8 S.	2 W.	5, SE. ¼	W. N. Carpenter, De Witt.	Owner	Owner	1910	......	163	12	70-163	....	Do.
14	Crocketts Bluff, 3 miles south of.	3 S.	2 W.	34, NW. ¼	A. M. Adams, Rockville, Ind.	A. F. Selig, Stuttgart.	.....do	1911	190±	144	9⅝	....	....	Do.

a Elevation about 50 feet above low-water level of La Grue River.

b Elevation about 25 feet above low-water level of Arkansas River.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Galls.*						
1	Almyra, 2 miles northwest of.	3 S.	4 W.	21, SE. ¼	Sand and gravel	50	1,600		$2,000	$800	Irrigation		100 feet of 24-inch casing; 50 feet of 12-inch casing. Analysis 1, p. 302.
2	Almyra, 2½ miles southwest of.	4 S.	4 W.	4, N. ½	do	48	1,035	Steam	2,000		do		Diameter of well at mouth, 24 inches.
3	Almyra, 3 miles southeast of.	4 S.	4 W.	1, SW. ¼	Coarse gravel	47	900	do	600	400	do	Hard	
4	Almyra, 4 miles west of.	3 S.	4 W.	29, W. ½	Sand and gravel	55	1,100	Gas	2,000	700	do	Soft	87 feet of 24-inch casing; 50 feet of 9⅝-inch casing.
5	Almyra, 5 miles southeast of.	4 S.	3 W.	5, NE. ¼	do	52	1,300	do	2,600		do		From top down, 95 feet of casing, 32 feet of screen, 28 feet of casing and 19½ feet of screen. Analysis 2, p. 302.
6	Almyra, 6 miles southeast of.	4 S.	3 W.	4, NE. ¼	Coarse sand and gravel.	50	600+	do	500	200	do	Soft	Diameter of well at top, 4½ feet.
7	Almyra, 4 miles east of.	3 S.	3 W.	32, SW. ¼	Sand and gravel	53	1,700		1,800	600	Domestic and irrigation.	Medium soft	Diameter at top 24 inches and at bottom 9⅝ inches.
8	Almyra, 4 miles north of.	3 S.	4 W.	3, E. ½	Sand	50	650	Steam	1,200	525	do	Hard and ferruginous.	24-inch pit to depth of 65 feet; 35 feet of 9⅝-inch casing and 52 feet of 9⅝-inch screen.
9	Arkansas Post (Spanish grant 2307).	8 S.	3 W.		do	25		Hand	50		Domestic	Hard	
10	Arkansas Post, 4 miles north of.	7 S.	3 W.	21, SW. ¼	Coarse sand and gravel.	26	700	Steam	800	600	Irrigation	do	
11	Bayou Meto, 1½ miles southeast of.	5 S.	5 W.	36, N. ½ SE. ¼.	Sand and gravel	31	600	do	500	350	do		Pit 6 feet square to depth of 30 feet, and 70 feet of 10-inch casing to bottom of well. Analysis 3, p. 302.
12	Booty, 2½ miles west of.	7 S.	3 W.	36, NE. ¼	do	28±	1,800	do	1,900		do		32-inch steel pit to depth of 60 feet, 37 feet of 12-inch casing to depth of 97 feet, and 40 feet of 12-inch strainer to bottom of well. Analysis 4, p. 302.
13	Booty, one-fourth mile west of.	8 S.	2 W.	5, SE. ¼	do	30	1,500+	do	1,250?	350	do	Hard	
14	Crocketts Bluff, 3 miles south of.	3 S.	2 W.	34, NW. ¼		45		Gas	1,600	1,750	do	Soft	28-inch pit to depth of 70 feet and 9⅝-inch casing to bottom of well.

Wells in Arkansas County—Continued.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*	
15	De Witt, 6 miles northeast of.	....	....	....	F. M. Mitchell....	Elmer Smith, Stuttgart.	R. M. Dickey.	1909	(*a*)	149	10	65–149	....	Pleistocene alluvium.
16	De Witt, one-fourth mile southeast of.	5 S.	3 W.	10, SE. ¼..	W. N. Carpenter..	Owner........	Owner........	1910	186±	150	10	90–150	....	Do.
17	De Witt, 6½ miles east of.	4 S.	2 W.	29, SW. ¼..	George Lacotts....	Elmer Smith, Stuttgart.	.....do........	1909	186±	145	....	....	....	Do.
18	Gillett, 3½ miles south of	....	....	....	S. V. Wise........	A. F. Selig, Stuttgart.	.....do........	1910	180±	105	13	45–105	....	Do.
19	.....do........	....	....	....	Ulrich Bauer......	.....do........	.....do........	1911	180±	132	10	100–132	....	Do.
20	Gillett, 3½ miles northeast of.	6 S.	3 W.	24, SW. ¼..	William Sager.....	....	Andrew Sager.	1910	(*b*)	135	9⅝	35–135	....	Do.
21	Humphrey, 1¾ miles southeast of.	3 S.	6 W.	30, SE. ¼...	Lewis Sachs, Jonesboro.	....	H. Sachs......	1910	190±	115	10	....	....	Quaternary alluvium.
22	Humphrey, 600 feet west of post office.	....	....	....	J. K. Anthony....	Owner........	Owner........	1910	191±	64	8	30–64	....	Do.
23	Nady, 1 mile west of....	8 S.	2 W.	8..........	M. M. Mitchell..	J. M. Satchfield, Tichnor.	.....do........	1902	......	58	8	58	....	Do.
24	Nady, 1½ miles east of (Spanish grant No. 2425).	....	....	....	N. B. Menard.....	Owner........	.....do........	1897	......	56	13	40–56	....	Do.
25	Nady, 2½ miles south of (Spanish grant No. 2303).	....	....	....	.....do........	.....do........	.....do........	1896	......	47	13	37–47	....	Do.
26	Nady, 1½ miles south of (Spanish grant No. 2303).	8 S.	2 W.	....	J. Menard........	J. M. Satchfield, Tichnor.	.....do........	......	(*c*)	48	8	47	....	Do.
27	St. Charles, 3½ miles northwest of.	....	....	....	W. H. Norsworthy & Co.	United Well Works, Stuttgart.	.....do........	1911	......	180	13	....	....	Pleistocene alluvium.
28	St. Charles, 5 miles southwest of.	4 S.	2 W.	26, NE. ¼..	W. H. Norsworthy and W. Hargrave.	Layne & Bowler, Stuttgart.	W. Hargrave..	1910	......	232	9⅝	....	....	Do.
29	Stuttgart........	....	....	....	Stuttgart Water & Electric Light Co.	Charles Williamson.	Sam Harper...	1899	213±	110	3	110	....	Do.
30	.....do........	....	....	....	.....do........	J. W. Beckler....	.....do........	1909	213±	131.75	10	131	110, 120	Do

a Elevation about 60 feet above low-water level of White River.
b Elevation about 50 feet above low-water level of La Grue River.
c Elevation about 40 feet above low-water level of Arkansas River.

No.	Location: Place.	T.	R.	Sec.	Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
						Feet.	*Galls.*						
15	De Witt, 6 miles northeast of.				Gravel and rock	50	2,200	Steam	$2,230		Irrigation	Hard	Diameter at top, 24 inches.
16	De Witt, one-fourth mile southeast of.	5 S.	3 W.	10, SE. ¼	Gravel	50							Intended for irrigation of rice fields, but on account of improper construction will be rebuilt.
17	De Witt, 6½ miles east of.	4 S.	2 W.	29, SW. ¼	Clay and gravel		1,800	Steam	2,300		Irrigation		Pit for pump to depth of 60 feet. Analysis 5, p. 302.
18	Gillett, 3½ miles south of.				Sand and gravel	26		do			do		Irrigates 160 acres of rice land.
19	do				do	32	1,200		1,500		do	Hard	
20	Gillett, 3½ miles northeast of.	6 S.	3 W.	24, SW. ¼	Gravel	38	1,500	Steam	2,000		do	Ferruginous	
21	Humphrey, 1¾ miles southeast of.	3 S.	6 W.	30, SE. ¼	Sand and gravel	18	1,000		$500	$150	do	Hard	
22	Humphrey, 600 feet west of post office.				Coarse sand and gravel.	8	800		43	125	do	do	
23	Nady, 1 mile west of.	8 S.	2 W.	8	Sand	30			25		Domestic	do	
24	Nady, 1½ miles east of (Spanish grant No. 2425).				Gray sand	40		Hand			do	Ferruginous	
25	Nady, 2½ miles south of (Spanish grant No. 2303).				Sand	12		do			do		
26	Nady, 1½ miles south of (Spanish grant No. 2303).	8 S.	2 W.		do	12		do			do		
27	St. Charles, 3½ miles northwest of.				Gravel	65	1,500	Steam	1,850		Irrigation		Analysis 6, p. 302.
28	St. Charles, 5 miles southwest of.	4 S.	2 W.	26, NE. ¼	Sand and gravel	50	1,200	do	3,000		do	Alkaline	9⅝-inch screen in lower 96 feet of well.
29	Stuttgart				Gravel		75	Air			Municipal supply.	Soft	These two wells and another similar well (depth not reported) furnish the municipal water supply.
30	do				do	47	250	do			do	do	

Wells in Arkansas County—Continued.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Water-bearing formation.
	Place.	T.	R.	Sec.					*Feet.*	*Feet.*	*Inches*	*Feet.*	*Feet.*	
31	Stuttgart, 2 miles southwest of.	3 S.	5 W.	5	Stuttgart Oil & Gas Co.	Mr. Schauman	G. W. Fagan	1907	210±	1,200	3			
32	Stuttgart, 3 miles south of.	3 S.	5 W.	4, NE. ¼	J. P. Rich	Layne & Bowler, Stuttgart.	Owner	1909	210±	165	24	90		Pleistocene alluvium.
33	Stuttgart, 2 miles southwest of.	3 S.	5 W.	5, NW. ¼	E. G. Reinsch	do	do	1909	210±	135	9⅝	100		Do.
34	Stuttgart, 1½ miles west of.	2 S.	5 W.	30	G. W. Fagan	do	do	1908	210±	120	9⅝	70		Do.
35	Stuttgart, 4 miles north of.	2 S.	5 W.	4	Pettit & Pettit	do	Edwin Pettit	1910	215±	144.5	10	50		Do.
36	Stuttgart, 6 miles southeast of.	3 S.	4 W.	5	C. E. Edmund	do	Owner	1910	200±	145	12			Do.
37	Stuttgart, 7½ miles east of.	2 S.	4 W.	22, NE. ¼	Mrs. A. F. Duensing.	do	H. E. Duensing.	1909	200±	123	9⅝			Do.
38	Stuttgart, about 12 miles southeast of.				J. M. Ellis	do	Owner	1910	200±	150?	10	110		Do.
39	Tichnor, 4 miles south of	7 S.	2 W.	16, SW. ¼	J. M. Satchfield	William Cromwell, Stuttgart.	do	1910	(a)	147	9⅝	100–147		Do.
40	Tichnor, 2½ miles southeast of.	7 S.	2 W.	4, SE. ¼	August Paulman	Henry Luckett, Stuttgart.	do	1910		162	10	56–162		Do.
41	Tichnor, 1½ miles southeast of.				Botts and Eckles	Beckler Well Co., Stuttgart.	G. W. Botts			70	12			Do.
42	Ulm, 1¼ miles southwest of.	2 S.	4 W.	6, NE. ¼	C. G. Scheiderer, Stuttgart.	W. H. Wheeler, Devall Bluff.	Owner	1910	209±	110	8	80–110		Do.

a Elevation about 30 feet above low-water level of Arkansas River.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.		Feet.	Galls.						
31	Stuttgart, 2 miles southwest of.	3 S.	5 W.	5									Drilled as an oil-prospecting well; diameter at top, 10 inches, at bottom, 3 inches; water-bearing beds at several levels, one at a depth of 800 feet.
32	Stuttgart, 3 miles south of.	3 S.	5 W.	4, NE. ¼	Gray sand		1,550	Steam.	$2,100		Irrigation	Soft	
33	Stuttgart, 2 miles southwest of.	3 S.	5 W.	5, NW. ¼	Sand and gravel	35	1,200	do			do	do	
34	Stuttgart, 1½ miles west of.	2 S.	5 W.	30	Clear gravel	30	1,500	do	1,500	500	Domestic and irrigation.	Medium hard.	24-inch pit to depth of about 70 feet; 9⅝-inch casing and screen extend to bottom of well; length of screen about 40 feet.
35	Stuttgart, 4 miles north of.	2 S.	5 W.	4	Gravel	40	1,000	do			do		
36	Stuttgart, 6 miles southeast of	3 S.	4 W.	5	Sand and gravel	45	1,000	Gas	1,600	600	do	Soft	24-inch pit to depth of 103 feet; 42 feet of 12-inch casing and screen to bottom of well.
37	Stuttgart, 7½ miles east of.	2 S.	4 W.	22, NE. ¼	Coarse gravel	40	1,500	Steam.	2,250		Irrigation		24-inch pit.
38	Stuttgart, about 12 miles southeast of.				Gravel	45?	1,200	do	2,500		Domestic, irrigation, manufacture of ice, and bottling.	Soft	
39	Tichnor, 4 miles south of.	7 S.	2 W.	16, SW. ¼	do	34	2,000	do	2,000		Irrigation	Salty, ferruginous, and very hard.	11⅝-inch strainer in lower 40 feet of well.
40	Tichnor, 2½ miles southeast of.	7 S.	2 W.	4, SE. ¼	do	30	1,800	do	1,900	760	do		13-inch screen from depth of 85 to 155 feet. Analysis 7, p. 302.
41	Tichnor, 1½ miles southeast of.				Sand and gravel	33	1,000		1,500	600	do	Hard and salty	
42	Ulm, 1¼ miles southwest of.	2 S.	4 W.	6, NE. ¼	Sand	54	210	Steam.	650		do		Analysis 8, p. 302.

CLAY COUNTY.

PHYSIOGRAPHY.

Clay County, in the extreme northeastern part of the State, comprises an area of 654 square miles. The census of 1910 reported its population as 23,690. Agriculture, including trucking, the raising of cotton and of cereals, and horticulture, including the growing of the common fruits, are the principal industries.

Except for a few square miles of the Ozark province included in its extreme northwestern section, the county comprises parts of the three topographic divisions—Crowleys Ridge, the Advance lowland, and the Mississippi lowland—into which the Mississippi embayment of the Gulf Coastal Plain is separable.

Crowleys Ridge is a broken, hilly area, 5 to 10 miles wide, extending from the northeastern corner of the county southwestward to and beyond the county line. Its maximum elevation is about 550 feet above sea level, or 250 feet above the level of the Advance lowland to the west. The highest part of the ridge lies somewhat west of the center, the drainage being chiefly to the east into St. Francis River; along the divide and west of the divide the surface is characterized by narrow ridges and steep slopes, many of which are wooded; west of the divide the drainage is into Cache River. To the east the hills are lower, their tops are broader, and their slopes more rounded, so that more extensive cultivation is possible here than in the more rugged area to the west.

The Advance lowland, which includes practically all the county west of Crowleys Ridge, is a nearly level plain 275 to 300 feet above sea level. Current River, in the northwest, which flows southward, Black River, which flows southwestward through the central part of the lowland, and Cache River which flows southwestward near the foot of Crowleys Ridge, traverse shallow, swampy, and wooded valleys several miles in width, lying only a few feet below the level of the plain. The interstream areas are characterized by low, parallel sand ridges and ancient abandoned stream channels.

That part of the county lying east of Crowleys Ridge is included in the Mississippi lowland and lies 275 to 300 feet above sea level. St. Francis River, which forms the eastern boundary, flows through a broad, shallow, partly wooded, and swampy valley known as the "sunk lands," lying only a few feet below the general level of the Mississippi lowland. The lowland plain slopes gradually upward from the river to the foot of Crowleys Ridge, a strip several miles wide just east of and bordering the ridge being a few feet higher and therefore better drained than the lowland to the east.

GEOLOGY.

Paleozoic rocks of pre-Carboniferous age outcrop in an area a few miles square in the extreme northwestern section and lie buried beneath deposits of the Coastal Plain throughout the remainder of the county; their upper eroded surface inclines eastward, probably reaching a maximum depth of 1,000 feet or more in the extreme east.

Sands and clays of Eocene age belonging to the Wilcox formation form the body of Crowleys Ridge and outcrop in places on the sides and slopes of the hills. The sands are locally indurated to sandstones and quartzites; fossil leaves of Wilcox age have been found in a soft sandstone 3 or 4 miles southwest of Boydsville. (See p. 58.) The beds are lignitic in places, and southwest of Boydsville lignite is exposed near the base of the west slope of the ridge. In a well dug near the same place lignitic beds were encountered to a depth of 40 feet below the level of the plain to the west. It is reasonably certain that strata of Eocene age underlie the remainder of the county beneath the Pleistocene and Recent alluvium, and that at an unknown depth the Eocene is underlain by strata of Cretaceous age. The deposits of the Coastal Plain rest on a basement of Paleozoic rocks.

The Eocene strata in Crowleys Ridge are unconformably overlain by a few feet to 30 feet or more of sands and gravels of late Pliocene (?) age belonging to the Lafayette formation. The gravels consist chiefly of partly rounded chert pebbles and cobbles, with subordinate amounts of smoothly rounded quartz pebbles, locally cemented by iron oxide to form hard conglomerates.

The light yellow or brown to dark-red noncalcareous loess and loesslike clay of Pleistocene age that overlie the gravels and cap the ridge have in places been eroded entirely away from above the gravels. Both the loess and the gravels have been in part reworked and redeposited on the sides of the hills or have found their way down the slopes by creep.

The Advance lowland west of Crowleys Ridge is underlain to a depth of 150 or 200 feet by alluvial sands, clays, and gravels, chiefly of Pleistocene age but in part of Recent age. In general the coarser sands and gravels occur toward the basal portion and carry large quantities of water. The alluvium is believed to rest on a buried eroded surface of Tertiary strata.

The Mississippi lowland east of Crowleys Ridge is underlain to a depth of 150 feet or more by alluvial sands, clays, and gravels, probably for the most part of Recent age, but perhaps in part of Pleistocene age, which also carry large quantities of water.

WATER RESOURCES.

GENERAL CONDITIONS.

An abundant supply of water for domestic and industrial use is obtained throughout the county from wells ranging in depth from 10 to 200 feet. In the lowlands the water is derived principally from the sands and gravels of the Pleistocene and Recent alluvium; in Crowleys Ridge the wells tap the water-bearing sands of the underlying Tertiary deposits. According to the reports of well owners, the quality of the well waters varies considerably from place to place, some being hard, some soft, and some ferruginous.

Small springs are numerous in Crowleys Ridge, and some of them are utilized for domestic supplies. They emerge from the gravel beds of the Lafayette formation or from the underlying Tertiary sands, and many of them yield waters made turbid or milky by fine suspended particles of clay.

In the eastern half of the county artesian water could probably be obtained from the deeply buried Tertiary and Cretaceous deposits at an estimated maximum depth of 1,000 feet. Wells sunk in the Mississippi lowlands east of Crowleys Ridge will probably yield flowing water.

LOCAL SUPPLIES.

Source.—None of the towns and villages of the county has a water-supply system, although three of them, according to the census of 1910, have populations exceeding 1,000, as follows: Rector, 1,859; Corning, 1,439; and Piggott, 1,150. Water for domestic and industrial use is obtained chiefly from wells. (See table on p. 164.)

The strata penetrated by several wells are indicated as follows:

Logs of several wells furnishing local water supply.

St. Louis, Iron Mountain & Southern Ry. Co., Knobel.

[Authority, C. H. Winters, driller, Harrisburg, Ark.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Clay	8	8
Sand and clay	12	20
Fine yellow sand, water bearing	12	32
Coarse sand and gravel, water bearing (see analysis No. 9 on p. 302)	18	50

Caraway & Freidenburg, Piggott (No. 6, p. 164).

Soil and Pleistocene alluvium:		
Alluvial soil	30	30
Blue clay; well stopped on water-bearing gravel	44	74

Patter & Co., Piggott (No. 7, p. 164).

Pleistocene alluvium:		
Irregularly bedded sands and clays	30	30
Tough blue material with a mixture of shells and fossil wood, becoming a pinkish color toward base; water bearing	65	95
Gravel, water bearing	3.5	98.5

Well at Campbell, Mo.—The following record of a well at Campbell, Dunklin County, Mo., quoted from a report by Shepard,[1] is of interest in connection with the deep-seated waters of Clay County:

At Campbell, Dunklin County, a well is located on the land of the Campbell Lumber Co. Depth, 960 feet; elevation above tide, about 310 feet; casing, 4-inch, to 910 feet; temperature of water, 72° F.; flow, 16 gallons per minute; date of completion, September, 1902; drillers, Johnson & Fleming, Memphis, Tenn.; cost, $3,000. The principal source of water was found at 490 feet in sand, and another water-bearing horizon was found at 145 feet. The water is somewhat soft, though rather saline, and contains sulphureted hydrogen. The following log of this well was furnished by Mr. William B. Johnson, of Memphis, Tenn.:

Log of well of Campbell Lumber Co., Campbell, Dunklin County, Mo.

	Thickness.	Depth.
	Feet.	*Feet.*
Loess ? (112 feet):		
Yellow clay, a little darker than that on Crowleys Ridge	112	112
Lafayette (43 feet):		
Orange sand and gravel; the sand has many white loamy clay nodules mixed in it	43	155
Lagrange formation (785 feet):		
Very hard black and brown clay or marl, with numerous very hard strata from 1 to 23 inches thick, composed largely of iron pyrites. At some point between 700 and 750 feet a bed of logs 10 or 12 feet thick was penetrated. This clay differed from any other bed struck in the bottoms in containing no sand strata, and not even a trace of the "gray sand" found in other wells was noted	785	940
Ripley sands (20 feet):		
Very fine black sand, with a large percentage of mica in small grains. Water headed about 7 feet above surface and flowed 16 gallons per minute; had brackish taste	20	960

The water from this well is used for boiler and drinking purposes. It is probable that the bottom of the well is not far from bedrock.

The yellow clay correlated by the author questionably with the loess, and the sand and gravel correlated with the Lafayette, are probably Pleistocene alluvial deposits. The correlations indicated for the remainder of the section are not based on paleontologic evidence and can scarcely be considered conclusive. The section is important chiefly as showing the great thickness of clay at this place (785 feet) and the presence of a water-bearing sand beneath the clay.

Well water for irrigation.—A well 5 miles east of Knobel (No. 3, p. 164) is used for irrigating 52 acres of rice land. This well penetrated the material shown by the following log:

Log of well of the Knobel Rice Co., 5 miles east of Knobel.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene alluvium:		
Clay, commonly called hardpan	28	28
Sand becoming coarser toward base; water bearing throughout	150	178

[1] Shepard, Edward M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, pp. 174, 175, 1907.

Wells in Clay County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.					*Feet.*	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Greenway	20 N.	8 E.	28	M. R. Stone		Owner	1909	290±	48		48	26	Pleistocene.
2	Knobel				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.		287	97	10			Do.
3	Knobel, 5 miles east of	19 N.	5 E.	10, NW. ¼	Knobel Rice Co	Layne & Bowler, Stuttgart.	Joseph Sellmeyer.	1910	287±	178	9⅝	28–178		Do.
4	Piggott	20 N.	8 E.	11	J. K. Browning		Owner	1905	298±	70	8	50	16	Do.
5	do	20 N.	8 E.	11	Piggott special school district.		M. T. Pope	1910	360±	200	3			Eocene.
6	do	20 N.	8 E.	11, SW. ¼	Caraway & Freidenburg.	O. S. Mayfield	M. D. Green	1904	298±	74	8	74	30	Pleistocene alluvium.
7	do	20 N.	8 E.	10, SE. ¼	Patter & Co	do	Driller	1905	290±	98.5	8	30–95	97	Do.
8	Pollard, one-fourth mile west of.				Alexander Forrest.	Owner	Owner	1904		69	16	63–69		Wilcox formation (?).
9	Pollard, 3 miles northwest of.	21 N.	7 E.	14, NE. ¼ SE. ¼.	A. Trailer		do	1904		52	1¼			Do.
10	Pollard	21 N.	7 E.	22	E. Forrest		R. B. Settlemair.	1894		43	12	43		Quaternary alluvium.
11	Pollard, 3 miles northwest of.						do	1900		80	1¼			Do.
12	Rector, one-half mile west of.				V. O. Cudd	H. S. Cudd	Owner	1909	297	91	2	50–91		Eocene.
13	Rector				H. A. Bennett Heading Co.		D. C. Bennett.		287±	138				Eocene (?).

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.		*Feet.*	*Galls.*						
1	Greenway	20 N.	8 E.	28		20	5	Hand			Domestic	Ferruginous(?)	
2	Knobel						23+				Boilers		This and another similar well together yield 2,000,000 gallons monthly. Analysis 9, p. 302.
3	Knobel, 5 miles east of.	19 N.	5 E.	10, NW. ¼	Sand	14	2,000	Steam.	$1,500	$750	Irrigation	Soft	Irrigates 52 acres.
4	Piggott	20 N.	8 E.	11	Gravel	35		Hand	35	18	Domestic	Hard	Bored type, tile cribbing.
5	do	20 N.	8 E.	11			10	do			Drinking	Soft, slightly ferruginous.	
6	do	20 N.	8 E.	11, SW. ¼	Gravel	20		do	25	18	do	Ferruginous	Bored type; wood cribbing extends to 74 feet.
7	do	20 N.	8 E.	10, SE. ¼	Sand and gravel	12	10		70		Domestic	Hard	Bored type; tile cribbing.
8	Pollard, one-fourth mile west of.				do	63					do		Bored type.
9	Pollard, 3 miles northwest of.	21 N.	7 E.	14, NE. ¼ SE. ¼.	White sand	16		Hand			do	Ferruginous	Driven type. Four similar wells, depths 49, 51, 51, and 53 feet.
10	Pollard	21 N.	7 E.	22	do			do	20	18	Domestic and boiler.	Soft	
11	Pollard, 3 miles northwest of.				do			Flows.	35		do	do	80 feet of 1½-inch casing; water will rise to or slightly above surface; it is cut off by an elbow 10 feet below surface and flows into a pit.
12	Rector, one-half mile west of.				Sand	48	9	Gas			Domestic	do	Bored type.
13	Rector										Drinking, boilers.		Yields abundant supply.

CRAIGHEAD COUNTY.

PHYSIOGRAPHY.

Craighead County comprises an area of 687 square miles. At the time of the census of 1910 its population was 27,627. Lumbering and agriculture, including the raising of cotton, cereals, vegetables, and hay are the chief industries. Fruits, such as peaches, apples, and pears are also grown. Jonesboro, the county seat, is a shipping point for hardwood timber.

The county includes parts of the three main topographic divisions—Crowleys Ridge, the Advance lowland, and the Mississippi lowland—into which the Mississippi embayment is divisible.

Crowleys Ridge, a belt of hilly, partly wooded country, extends north and south through the county a little west of the center, rising to a maximum elevation of 475 or 500 feet above sea level, or 200 to 250 feet above the level of the lowlands to the east and west. From the northern boundary southward the ridge is 10 to 12 miles wide to a point 3 or 4 miles south of Jonesboro, where it narrows abruptly to a width ranging from one-half mile to 4 miles. A deep gap in the ridge in the vicinity of Dee is traversed by the Helena branch of the St. Louis, Iron Mountain & Southern Railway. The ridge has been strongly dissected, chiefly by the headwater streams of Bayou De Vue, a tributary of Cache River. A few small streams flow eastward into the Hatchie Coon Sunk Lands. The larger streams flow through rather broad valleys with smoothly rounded slopes, and many of the smaller headwater streams occupy deep, steep-sided ravines, producing a rugged topography along the main divides.

The Advance lowland, a plain lying 250 to 260 feet above sea level and inclining slightly to the southward, includes all the county west of Crowleys Ridge; this lowland is characterized by irregularly distributed patches of grass-covered, gently undulating prairie land and tracts of wooded land. The valley of Cache River, which crosses the western part of the county from northeast to southwest, is 8 to 10 feet lower than the general level and is 1 to 4 miles wide. The valley of Bayou De Vue, which heads in Crowleys Ridge north of Jonesboro and flows across the plain from northeast to southwest, west of the St. Louis Southwestern Railway, is also broad and very shallow.

All the county east of Crowleys Ridge is included in the Mississippi lowland which is divisible into the post-oak flats, a narrow strip of slightly undulating land bordering Crowleys Ridge and lying 255 to 260 feet above sea level, and the "sunk lands," which lie 10 to 15 feet lower and embrace the remainder of the county to the east. The "sunk lands" are gently undulating, the partly wooded, swampy depressions being separated by low ridges of dark sandy loam dotted with the so-called sand blows of the region. The sand blows are low circular or irregular patches of clean white sand, supposed to have been discharged from underground sources through crevices during the time of the New Madrid earthquake shocks (1811–12). The ridges have been partly cleared and cultivated.

GEOLOGY.

Irregularly bedded sands and clays belonging to the Wilcox formation of the Eocene make up the body of Crowleys Ridge to a maximum height of 100 feet or more above the level of the lowlands to the east and west. Along the western border of the ridge the sands have been locally indurated to hard quartzites. In Crowleys Ridge the Eocene deposits extend to an unknown depth, and are believed to underlie the alluvial deposits both to the east and west of the ridge, where they would be encountered at depths of 130 to 150 feet; they contain important water-bearing beds.

From general considerations it is believed that the Eocene deposits are underlain by sands and clays of Cretaceous age, though no data for definitely differentiating the deeply buried deposits of these ages have been obtained within the county.

The Wilcox formation of Crowleys Ridge is unconformably overlain by irregularly bedded gravels and reddish sands reaching a maximum thickness of 50 feet or more; these materials cap the tops of the hills and mantle their slopes, almost completely covering the Wilcox strata; they are in part water bearing. These gravels and sands belong to the Lafayette formation and are of late Pliocene or early Pleistocene age. The Lafayette formation is overlain by material ranging in composition from typical loess to reddish loesslike clays and in thickness from a few feet to 40 feet; the loess is of Pleistocene age.

The advance lowland west of Crowleys Ridge is underlain by 130 to 150 feet of alluvial sands, clays, and gravels of Pleistocene age, which rest upon Tertiary strata; the sands and gravels contain water in large quantities. The flood plains of Cache River and Bayou De Vue are underlain by Recent alluvial sands and clays of undetermined thickness which rest upon the Pleistocene alluvium. The Mississippi lowland east of Crowleys Ridge is underlain to an estimated depth of 130 to 200 feet by undifferentiated alluvial sands, clays, and gravels of Pleistocene and Recent age, which rest on Eocene strata and are abundantly water bearing.

WATER RESOURCES.

GENERAL CONDITIONS.

Domestic supplies.—Water for domestic and industrial use is obtained chiefly from wells 10 to 200 feet deep and from springs. In the lowlands east and west of Crowleys Ridge the waters are derived chiefly from the Pleistocene and Recent alluvial sands and gravels and stand in the wells 10 to 35 feet below the surface. In Crowleys Ridge the wells tap the water-bearing sands and gravels of the Lafayette formation and the water-bearing sands of the underlying Wilcox formation; the waters from the Wilcox formation rise within 25 to 100 feet of the surface. Most of the well waters are soft, though a few are reported to be moderately hard. Wells exceeding 200 feet in depth have been drilled at Jonesboro and at Lake City (Nos. 10, 11, and 15, p. 172). Small springs are numerous in Crowleys Ridge and afford clear, soft, or only moderately hard waters; some are sulphurous or ferruginous.

In the lowlands west and east of Crowleys Ridge water in abundance is contained in the sands and gravels of the Pleistocene and Recent alluvial deposits at depths of 30 to 150 feet. In Crowleys Ridge moderate or large quantities of artesian water can be obtained from the Eocene deposits and from the deeply buried Cretaceous deposits by wells 70 to 1,500 feet or more in depth. In the lowlands artesian waters can be obtained from the same deposits by drilling through the overlying Recent or Pleistocene alluvium.

None of the wells in this county yield flowing water, but the fact that flows have been obtained in Mississippi County at Blythesville (depth, 1,448 feet), at Burdette (depth, 1,495.5 feet), and at Wilson (depth, 1,568 feet), and in Poinsett County at Marked Tree (depth, 2,007 feet) justifies the prediction that flows are obtainable in Craighead County in the Mississippi lowlands east of Crowleys Ridge.

Irrigation.—The rice-growing industry has been introduced in the county in recent years and on the Advance lowland west of Crowleys Ridge is rapidly becoming important. Rice has also been grown east of Crowleys Ridge near Nettleton. Water for irrigating the rice fields is obtained chiefly from wells 75 to 150 feet deep, the source being the Pleistocene alluvial sands and gravels underlying the lowlands. Heavy machinery is used for pumping the wells, the yield ranging from 400 to 1,600 gallons per minute. The wells are drilled and equipped at costs ranging from $1,000 to $1,500, the average cost based on six wells being in round numbers $1,400 for each 1,000 gallons of yield per minute, or at the rate of $1.40 for each gallon of yield per minute. Detailed information concerning nine wells used for irrigating rice lands is given in the table on page 172.

LOCAL SUPPLIES.

Jonesboro.—The municipal water supply of Jonesboro (population 7,123, census of 1910) is taken from deep wells. Information concerning the system has been obtained from Mr. Jeffrey A. Houghton, postmaster of Jonesboro; from the superintendent of the waterworks plant; and from Mr. Lee Stone, who drilled the two deepest wells. There are six wells, four of which are 300 to 500 feet deep, and two respectively 1,214 and 1,265 feet deep. One of the deepest wells is cased to a depth of 500 feet with 8-inch casing and the rest of the way with 6-inch casing; the other is cased to a depth of 500 feet with 6-inch casing and the remainder of the depth with 4-inch casing; in these wells the water rises to within 60 feet of the surface.

The water is pumped from the wells to a standpipe, the base of which is 372 feet above sea level and 70 feet above the level of the St. Louis Southwestern Railway track at the station. The water is distributed through nearly 15 miles of mains. The standpipe pressure is 72 pounds per square inch and the possible direct pressure for fire protection is 110 pounds per square inch. The daily capacity of the plant is 2,000,000 gallons.

An approximate log of one of the deep wells (No. 10, p. 172) is as follows:

Log of deep well at the city waterworks plant, Jonesboro.

	Thickness.	Depth.
Pleistocene:	*Feet.*	*Feet.*
Red clay (a facies of the loess)	20	20
Pliocene (?) (Lafayette formation):		
Gravel mixed with red clay	4	24
Joint clay	10	34
Coarse yellow sand	1	35
Eocene and probably Cretaceous (undifferentiated):		
Pipe clay	25	60
Gumbo	10	70
Very fine quicksand, grading downward to a coarse sand and gravel, the latter abundantly water bearing	60	130
Very tough black gumbo	50	180
Blue mud, soft in places, containing iron concretions called "niggerheads"	1,020	1,200
Very hard rock	4	1,204
Alternating layers of water-bearing sand and hard rock, the sand layers being about 14 feet thick and the rock layers 1 to 2 feet thick	61	1,265

The log of a well owned by Mr. C. N. Carson, 4 miles south of Jonesboro, on the east side of Crowleys Ridge (No. 12, p. 172), is as follows:

Log of well of C. N. Carson, 4 miles south of Jonesboro.

	Thickness.	Depth.
Pleistocene (?):	*Feet.*	*Feet.*
Red clay	7	7
Eocene (Wilcox formation):		
White sand, water bearing in basal portion	107	114

Nettleton.—Detailed information concerning several wells at Nettleton (population 1,080, census of 1910) is given in the table on page 172 (Nos. 16, 17, 18). A log of the well owned by the St. Louis, Iron Mountain & Southern Railway is as follows:

Log of well of St. Louis, Iron Mountain & Southern Railway, Nettleton.

	Thickness.	Depth.
Pleistocene alluvium (?):	*Feet.*	*Feet.*
Yellowish clay	24	24
Fine white sand, water bearing	40	64
Coarse sand and gravel	3	67
Yellowish, tough clay	20	87
Yellowish, white, pink, and gray sand, gravel at bottom, water bearing throughout	60	147

Greensboro.—The log of a well (No. 9, p. 172) owned by J. W. Johnson at Greensboro, a small village on Crowleys Ridge, 8 miles northeast of Jonesboro, is as follows:

Log of well of J. W. Johnson, Greensboro.

	Thickness.	Depth.
Soil and Pleistocene (a facies of loess):	*Feet.*	*Feet.*
Soil and underlying loess	10	10
Pliocene (?) (Lafayette formation):		
Gravel	1	11
Tertiary (Eocene, Wilcox formation):		
Clay ("hardpan")	30	41
Sand, reddish at top, becoming white toward base; water bearing in basal portion	145	186

Lake City.—A 400-foot oil-prospecting well was drilled at Lake City in 1900 (?), concerning which the following information has been furnished by Mr. A. J. Bates: Sands and clays in alternating layers, with the sands predominating, were penetrated to the bottom of the well, with the exception of a bed of gravel encountered at a depth of 300 feet. An incomplete set of samples from the well was examined by the senior author. From the surface to a depth of 130 feet the materials appear to be alluvial sands and clays. A sample from a depth of 160 feet is medium-grained white sand; one from a depth of 220 feet is hard white clay breaking with a conchoidal fracture; and one from a depth of 280 feet is black, shiny lignite. The strata from 160 feet to 400 feet probably belong to the Wilcox formation.

Wells for irrigation.—Wells used for irrigating rice lands have been drilled in the vicinity of Bono, Gilkeson, Obear, and Nettleton; nine of them are described in detail in the table on pages 172–173. The logs of four of them are as follows:

Log of well of J. E. Bobbitt, 1 mile north of Bono.

[No. 1, p. 172.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	2	2
"Hardpan"	18	20
Gravel, water bearing	58	78

Log of well of Burk & Cole, 2½ miles southwest of Gilkeson.

[No. 7, p. 172.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	2.5	2.5
"Hardpan"	18	20.5
Quicksand	35	55.5
Coarse sand, water bearing	10	65.5
Gravel, water bearing	37.5	103

Log of well of C. O. Collins, 7 miles southwest of Jonesboro (3 miles southeast of Gilkeson).

[No. 13, p. 172.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	2	2
Hard clay called "hardpan"	20	22
Soft friable clay	10	32
Fine sand	5	37
Sand, increasing in coarseness to a very coarse gravel at base, water bearing throughout	76	113

Log of well of the Gregg & Houghton Land Co., 3½ miles northwest of Obear.

[No. 22, p. 172.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	2	2
"Hardpan" clay	18	20
Fine quicksand	15	35
Coarse sand, water bearing	67	102

Wells in Craighead County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	Feet.	Inches	Feet.	Feet.	
1	Bono, 1 mile north of	15 N.	3 E.	19, NE. ¼ of NE. ¼.	J. E. Bobbitt	Weiner Well Co., Weiner.	Owner	1910	265±	78	9⅝	70–78		Pleistocene alluvium.
2	Bono, 5½ miles northeast of.				W. R. Schisler		J. Q. Schisler		265±	60	12			Wilcox (?) formation.
3	Bono, one-half mile northwest of.	15 N.	3 E.	19	J. D. Stringer	Weiner Well Co., Weiner.	Owner	1910	265±	76	12			Pleistocene alluvium.
4	Brookland				Town	Stone Bros., Jonesboro.			290±	154				Wilcox formation.
5	Dee, one-fourth mile southeast of.	13 N.	4 E.	20, NE. ¼	Wm. Woodard	John Martin, Jonesboro.	Owner	1902	(a)	103	6	100–103		Wilcox (?) formation.
6	Dee				J. F. McCarty					65				Do.
7	Gilkeson, 2½ miles southeast of.	13 N.	3 E.	8, SE. ¼	Burk & Cole, Jonesboro.	George Fogle, Jonesboro.	J. W. H. Cole.	1911	287±	103	9⅝	63–103	35	Pleistocene alluvium.
8	Gilkeson, 3½ miles southeast of.	13 N.	3 E.	18, NE. ¼ of SW. ¼.	Ellis & Peters, Jonesboro.	do	G. C. Peters	1909	287±	122	10	92–122		Do.
9	Greenboro				J. W. Johnson	John Martin, Jonesboro.	Owner		370±	186				Wilcox formation.
10	Jonesboro				Town	Lee Stone			300±	1,265	6(?)			Cretaceous.
11	do				do	do			300±	1,214	4(?)			Do.
12	Jonesboro, 4 miles south of.				C. N. Carson					114				Wilcox formation.
13	Jonesboro, 7 miles southwest of.	13 N.	3 E.	9, SE. ¼	C. O. Collins	F. L. Casper, Weiner.	Owner	1911	290±	113	7¼	37–113		Pleistocene alluvium.
14	Jonesboro				Warner Hotel					172				Wilcox formation.
15	Lake City						A. J. Bates			400				
16	Nettleton				St. Louis, Iron Mountain & Southern Ry. Co.		Frank Kiech		259	147		87–147	24–64	Pleistocene alluvium (?).
17	do				do		do		259	200				Do.
18	Nettleton, one-fourth mile east of.	14 N.	4 E.	26	F. Kiech Mfg. Co	C. H. Winters, Harrisburg.	C. W. Kiech	1910	260±	143	10	75–143		Do.
19	Obear, one-fourth mile northwest of.				J. L. Burns, Jonesboro.	Craighead County Well Co., Jonesboro.	Owner	1910	253±	100	10	90–100		Pleistocene alluvium.
20	do				do	F. L. Casper, Weiner.	do	1911	253±	148	10	90–148		Do.
21	Obear				Barger Bros.					65				Do.
22	Obear, 3½ miles northeast of.	13 N.	3 E.	18, NE. ¼	Gregg & Houghton Land Co., Jonesboro.	George Fogle, Jonesboro.	C. B. Gregg	1910	250±	102	9⅝	33–102		Do.

a Elevation about 40 feet above the level of the St. Louis, Iron Mountain & Southern Ry. track at the station.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Galls.*						
1	Bono, 1 mile north of.	15 N.	3 E.	19, NE. ¼ of NE. ¼.	Gravel	17	400±		$1,500		Irrigation		Analysis 10, p. 302.
2	Bono, 5½ miles northeast of.				Sand						Domestic	Hard	Bored type.
3	Bono, one-half mile northwest of.	15 N.	3 E.	19		10	1,200				Domestic and irrigation.		
4	Brookland				Sand and gravel	25					Domestic		Driven type. Assay 5, p. 304.
5	Dee, one-fourth mile southeast of.	13 N.	4 E.	20, NE. ¼	Sand	97					do	Soft	Bored type. Cribbed with wood.
6	Dee										do		Assay 7, p. 304.
7	Gilkeson, 2½ miles southeast of.	13 N.	3 E.	8, SE. ¼	Coarse sand and gravel.	26	1,600	Steam.	1,028		Domestic and irrigation.		53 feet of 9⅝-inch casing and 9⅝-inch brass screen, analysis 11, p. 302.
8	Gilkeson, 3½ miles southeast of.	13 N.	3 E.	18, NE. ¼ of SW. ¼.	Sand and gravel	27	1,200	do	1,300		do	Hard	72 feet of 10-inch casing and 50 feet of 10-inch Stancliff strainer No. 17. Irrigates 165 acres.
9	Greenboro					36					Domestic		Assay 8, p. 304.
10	Jonesboro					60(?)					Municipal supply.		These wells and 4 others, ranging in depth from 300 to 500 feet, furnish the municipal water supply. Assay 10, p. 304.
11	do					60					do		
12	Jonesboro, 4 miles south of.				White sand	90					Domestic	Soft	
13	Jonesboro, 7 miles southwest of.	13 N.	3 E.	9, SE. ¼	Coarse sand and gravel.	35	800	Gas	1,000	1,000	Domestic and irrigation.		20 feet of 7¼-inch casing and 55 feet of 7¼-inch screen.
14	Jonesboro										Domestic		Assay 11, p. 304.
15	Lake City												Oil prospecting well.
16	Nettleton				Sand and gravel						Boilers		Assay 14, p. 304.
17	do				do						do		
18	Nettleton, one-fourth mile east of.	14 N.	4 E.	26	Sand	15	500+		1,400+		Irrigation		Analysis 12, p. 302.
19	Obear, one-fourth mile northwest of.				Sand and gravel	30.5	600				do		60 feet of 10-inch casing and 40 feet of 10-inch strainer.
20	do				do	30.5	1,000	Steam.			do		98 feet of 10-inch casing and 50 feet of 10-inch strainer. Analysis 13, p. 302.
21	Obear					30					Boilers		Assay 15, p. 304.
22	Obear, 3½ miles northeast of.	13 N.	3 E.	18, NE. ¼	Sand		800	Steam.	1,000	250	Irrigation		52 feet of 9⅝-inch casing and 50 feet of 9⅝-inch screen. Analysis 14, p. 302.

CRITTENDEN COUNTY.

PHYSIOGRAPHY.

Crittenden County, in the eastern part of the State, adjacent to the southwestern part of Tennessee, comprises an area of 582 square miles. The population was reported by the census of 1910 as 22,447. Lumbering and agriculture, including trucking and the raising of cotton and cereals, are the chief industries. Fruit is also grown. The county is heavily timbered and large sawmills are numerous.

The county is included in the Mississippi lowland, the general surface lying 200 to 236 feet above sea level. Mississippi River forms the eastern boundary; the highest land lies immediately west of the river, from which there is a slight inclination to the west and southwest. Ponds, abandoned stream channels, and bayous are numerous, and much of the surface is swampy and covered with forest. The area is subject in part to overflow from Mississippi River. Some of the higher land has been cleared and cultivated. The drainage is chiefly to the southwest into St. Francis River.

GEOLOGY.

The surface materials throughout the county consist of Recent alluvial sands and clays deposited from the waters of Mississippi River. Data concerning the age of the materials below the Recent deposits are meager. It is possible that the Recent alluvium rests on alluvial sands, clays, and gravels of Pleistocene age, which in turn rest on an eroded surface of Tertiary (Eocene) strata. The depth to the Eocene strata has not been determined, but data afforded by several wells probably indicate that the Eocene lies 150 to 225 feet below the general surface.

The undifferentiated Eocene strata are believed to be about 1,000 feet thick and they are underlain by strata of Cretaceous age. According to Ashley's interpretation[1] of the record of a well on Hen and Chicken Island, near Memphis, the Ripley formation of the Upper Cretaceous was first encountered at a depth of 1,135 feet (see section, p. 177), and clay representing the Selma chalk, also Upper Cretaceous, was reached at a depth of 1,589 feet, and had not been completely penetrated when drilling was discontinued at a depth of 1,793 feet. At an unknown depth, probably between 2,500 and 3,000 feet, the Cretaceous deposits are believed to rest upon a basement of Paleozoic rocks.

[1] Ashley, G. H., Recent drilling for oil and gas at Memphis, Tenn.: Preliminary report upon the oil and gas developments in Tennessee: Tennessee Geol. Survey, Appendix A, pp. 40–42, 1911.

WATER RESOURCES.

GENERAL CONDITIONS.

The domestic water supplies of this county are obtained chiefly from wells 10 to 100 feet deep, the strata drawn upon being the alluvial sands. The water in the wells stands 10 to 30 feet below the surface. As reported by the well owners, some of the waters are soft, some are hard, and some are ferruginous. Wells more than 100 feet deep have been drilled at Earl and Turrell. Cisterns are in use at a few places in the county.

Water in great abundance is obtainable from the sands and gravels of the Recent and Pleistocene alluvial deposits to depths of 150 to 225 feet. The Eocene deposits which underlie the alluvial materials to depths of 1,100 or 1,150 feet contain important water-bearing beds, the waters of which are under hydrostatic pressure and will rise within 5 to 15 feet of the surface or may even overflow at the surface; they will be found potable and suitable for domestic and most other ordinary purposes, but some of them are apt to be moderately hard or ferruginous. The Cretaceous deposits which underlie the Eocene strata also contain water-bearing beds and probably the waters are under sufficient hydrostatic pressure to overflow at the surface.

LOCAL SUPPLIES.

Earl.—The town of Earl (population 1,542, census of 1910) owns a municipal water-supply system and obtains water from a 474-foot well (No. 1, p. 178). The water is lifted from the well by a pump, having a capacity of 17,000 gallons an hour, into a tank holding 40,000 gallons. The tank pressure is 35 pounds per square inch, and the direct pressure for fire protection is 60 pounds per square inch. Three miles of mains distribute the water to the consumers. The daily consumption is 70,000 gallons for domestic use and 50,000 gallons for manufacturing. (See incomplete analysis No. 15, p. 302.)

Turrell.—The following is the log of a deep well at Turrell owned by the Baker Lumber Co.[1] (No. 5, p. 178):

Log of well of Baker Lumber Co., Turrell.

	Thickness.	Depth.
Quaternary alluvium (Pleistocene and Recent):	*Feet.*	*Feet.*
"Buckshot" grading downward into sand	16	16
Sand and gravel with thin clay partings	166	182
Tertiary (Eocene):		
Blue clay with enough fine sand to make sinking by hydraulic process easy	658	840
Gray sand like that at Memphis, containing lignite in large quantities	24	864

[1] Shepard, E. M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, p. 187, 1907.

Wells at and near Memphis, Tenn.—Several deep wells have been drilled in areas adjacent to Crittenden County, at and near Memphis, Tenn.; the materials penetrated in them are essentially the same as would be encountered by deep drilling anywhere in Crittenden County. Logs of the two deepest wells reported are included here.

Log of municipal well No. 109, Memphis.[a]

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay	27	27
Hard brown clay	10	37
Slightly soft brown clay	8.4	45.4
Gravel and sand	4	49.4
Soft brown clay and sand	14	63.4
Slightly hard brown clay	12.5	75.9
Stiff blue clay	3	78.9
Soft blue clay	4.4	83.3
Stiff blue clay and sand	2.6	85.9
Soft brown clay and sand	1	86.9
Very hard brown clay	2	88.9
Very reddish clay	1.5	90.4
Hard blue clay	15.5	105.9
Soft blue clay	15.1	121
Stiff blue clay	1	122
Soft brown clay	4	126
Slightly hard brown clay	1.3	127.3
Stiff brown clay	1	128.3
Hard brown clay	1	129.3
Very hard brown clay	5.7	135
Hard brown clay	61	196
Slightly hard blue clay	18	214
Hard blue clay	9	223
Sandy blue clay	53	276
Fine sand and clay	27	303
Fine sand	35.4	338.4
Fine sand and lumps of blue clay	41.6	380
Coarse sand and lumps of blue clay	10	390
Soft blue clay	17	407
Sandy blue clay	10	417
Fine sand and clay	15	432
Sandy blue clay	13	445
Fine sand and clay	7	452
Sandy blue clay	22	474
Fine sand	2.6	476.6
Sandy blue clay	6.6	483.2
Fine sand	.8	484
Coarse sand and clay	6	490
Soft blue clay	2.3	492.3
Clay and sand	17.7	510
Very fine sand	25	535
Very fine sand and clay	38.2	573.2
Very fine sand	16.8	590
Very coarse sand with lignite	8	598
Lignite, pyrite, and clay	2	600
Very fine sand and lignite	195	795
Soft white clay	17	812
Very fine sand	53	865
Hard brown clay	31	896
Fine white sand	30	926
Hard brown clay	24	950
Fine sand	50	1,000
Stiff brown clay	25.6	1,025.6
Very hard, substantial rock	.5	1,026.1
Very stiff blue clay	27.9	1,054
Blue clay, slightly sandy	106	1,160
Shale	.5	1,160.5
Sandy clay	3.5	1,164
Gravel	6	1,170
Blue clay and sand	26	1,196
Sand and rock	7	1,203
Sand and blue clay	6	1,209
Sand and clay and rock	23	1,232
Fine sand and clay	8	1,240
Blue clay and sand	46	1,286
Sand and clay	79	1,365
Fine sand	35	1,400
White sand (water flowed to surface)	4	1,404
White sand	38	1,442

[a] Glenn, L. C., U. S. Geol. Survey Water-Supply Paper 164, pp. 114, 115, 1906. (Gives a partial log of the well to a depth of 1,147.5 feet.) Munn, M. J., Resources of Tennessee, vol. 2, No. 2, pp. 55–57, Tennessee Geol. Survey, Feb., 1912. (Gives a complete log of the well to a depth of 1,583 feet.)

Log of municipal well No. 109, Memphis—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Blue clay	95	1,537
Good sand	20	1,557
Black sand	6	1,563
Blue clay and sand	3	1,566
Clay	16	1,582
Fine gray sand	1	1,583

Log of Memphis Natural Gas & Oil Co.'s oil-prospecting well No. 1, on Hen and Chicken Island.[a]

	Thickness.	Depth.
	Feet.	*Feet.*
Gray sand	35	35
Clay	3	38
Gas sand	20	58
Blue gumbo	4	62
Fine gray sand	43	105
Fine gravel	4	109
Coarse gravel	12	121
White sand	4	125
Clay and lignite	130	255
Gray water-bearing sand and lignite	221	476
Blue clay (chunks)	70	546
Gray sand and lignite	154	700
Gray coarse water sand	45	745
Gray sand and lignite	225	970
Blue clay	155	1,125
Brown sand (good showing of oil)	10	1,135
Black gas sand (gas and oil showing)	12	1,147
Cemented rock and gravel	1	1,148
Gas sand	24	1,172
Blue rock	3	1,175
Green clay	2	1,177
Brown clay	7	1,184
Lignite	5	1,189
Blue clay	33	1,222
Fine sand	10	1,232
Green clay	23	1,255
Hard clay	45	1,300
Fine sand	4	1,304
Gumbo	20	1,324
Fine sand	27	1,351
Gumbo	8	1,359
Artesian sand	230	1,589
Clay	86	1,675
Fine sand	9	1,684
Clay	16	1,700
Blue rock	5	1,705
Fine sand	3	1,708
Clay	38	1,746
Fine sand	17	1,763
Clay	8	1,771
Fine sand	9	1,780
Gumbo, strong showing of oil; stops on rock	14	1,794

[a] Ashley, G. H., Recent drilling for oil and gas at Memphis: Preliminary report upon the oil and gas developments in Tennessee, Appendix A, pp. 40–42, Tennessee Geol. Survey, 1911.

Ashley says:

Well No. 1 passed through 155 feet of blue clay between 980 feet and 1,135 feet. Apparently this is the Porters Creek clay [basal Eocene]; then comes sand, clay, and lignite, the sand predominating, to 1,589 feet, or for a thickness of 454 feet. As clays predominate below, and as this is about the thickness of the Ripley formation [Upper Cretaceous], it may be assumed to represent that formation; below would come the Selma clay [Upper Cretaceous], and as that formation has a thickness of 300 to 400 feet to the east, it would appear that the well stopped in that formation. The Selma clay is a light leaden gray or greenish clay when dry, and somewhat darker when wet. It will be noted that of the 204 feet of strata at the bottom of the well below 1,589 feet all but 43 feet are clay.

Wells in Crittenden County.

	Location. Place.	T.	R.	Sec.	Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Geologic name of water-bearing formation.
									Feet.	Feet.	In.	Feet.	
1	Earl				Town	Johnson & Fleming, Memphis, Tenn.	Sam Boone	1905	231	474	4	414–474	Wilcox (?) formation.
2	Ebony, one-eighth mile north of.	7 N.	8 E.	21, SE. ¼	The Ebony Co	Owner	H. D. Drane		230±	50	1¼	50	Quaternary alluvium.
3	Gilmore, 2½ miles west of	9 N.	7 E.	3	W. A. Dudley	do	Owner	1910	236±	60(?)	1¼	50-60(?)	Do.
4	Marion				L. D. Bland		do		231±	78			Do.
5	Turrell	9 N.	8 E.	29	Baker Lumber Co.	Johnson & Fleming, Memphis, Tenn.	W. B. Johnson [a]	1901	236±	864	4	840–864	Wilcox (?) formation.

	Location. Place.	T.	R.	Sec.	Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
						Feet.	Galls.						
1	Earl				Coarse sand	14½	70+				Municipal supply, manufacturing.		Analysis 15, p. 302.
2	Ebony, one-eighth mile north of.	7 N.	8 E.	21, SE. ¼		20		Gas	$20		Domestic and boilers.		Driven type; on the land owned by the company there are numerous similar wells at the houses of tenants.
3	Gilmore, 2½ miles west of.	9 N.	7 E.	3	Sand			Hand	15		Domestic	Hard	
4	Marion										do		Driven type. Assay 18, p. 304.
5	Turrell	9 N.	8 E.	29	Gray sand	12					do		See log of well on p. 175. Assay 21, p. 304.

[a] Shepard, E. M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, p. 187, 1907.

CROSS COUNTY.

PHYSIOGRAPHY.

Cross County lies west of Crittenden County and north of St. Francis County. Its area is 619 square miles. Its population at the time of the census of 1910 was 14,042. Lumbering, agriculture, fruit growing, and stock raising are important industries. At Wynne, the county seat, there are several sawmills and mills which manufacture wood products.

The county includes parts of three recognizable physiographic subdivisions—Crowleys Ridge, the Advance lowland, and the Mississippi lowland.

Crowleys Ridge is a belt of hilly, partly wooded land, 3 to 6 miles wide, extending north and south through the center of the county and rising 350 to 380 feet above sea level, or 120 to 150 feet above the lowlands to the east and west. Small intermittent and perennial streams flow at right angles to the trend of the ridge and discharge into St. Francis River or St. Francis Bayou on the east and into L'Anguille River on the west. The surface has been considerably dissected by these streams. The eastern slope is somewhat more abrupt than the western slope, but both margins of the ridge are separated from the bordering lowlands by sharply defined escarpments.

The Advance lowland includes the area west of Crowleys Ridge, a nearly level plain lying 230 to 245 feet above sea level and sloping slightly to the south. It is drained chiefly by L'Anguille River (flowing southward) and its tributaries, which occupy shallow valleys that are only a few feet lower than the general level, are in part swampy, and are heavily timbered except where locally cleared for cultivation. In the interstream areas west of L'Anguille River the surface is gently rolling and presents irregularly distributed tracts of open grass-covered prairie, separated by slightly lower wooded areas. East of L'Anguille River the surface slopes gradually upward from the river bank to the foot of Crowleys Ridge; here the land is more fertile than the land west of the river and is forested, except where locally cleared for cultivation.

The Mississippi lowland east of Crowleys Ridge is within the flood plain of St. Francis River and is 220 to 235 feet above sea level. St. Francis River enters the county at the northeast corner and flows sinuously across it in a general southwesterly direction. Bayou St. Francis enters the county in the north, flows southward near the foot of Crowleys Ridge, and joins St. Francis River near Levesque. The surface of the lowland is diversified by numerous ponds and abandoned stream channels, separated by wooded areas of low swamp land and low ridges.

GEOLOGY.

The core of Crowleys Ridge to a height of 50 to 100 feet above the lowlands to the east and west is composed of regularly and irregularly bedded fine sands and clays of Eocene age, belonging mainly to the Claiborne formation. The clays are light to dark in color and in places are lignitic. Well-preserved fossil leaves of Claiborne age have been found in clays and nodules of iron carbonate in an exposure near Cherry Valley. (See p. 69.) The Eocene deposits underlie Crowleys Ridge to an undetermined depth, estimated to be at least 1,000 feet; they also underlie the alluvial deposits in the lowlands, both to the east and west of the ridge; they contain important water-bearing beds.

The Eocene deposits are underlain by strata of Cretaceous age, doubtless in part water bearing, which at an unknown depth rest upon a basement of Paleozoic rocks. The Eocene strata in Crowleys Ridge are unconformably overlain by 10 to 40 feet of irregularly bedded sands and gravels of late Pliocene or early Pleistocene age belonging to the Lafayette formation; they are in part water bearing. Locally the gravels have been indurated to a conglomerate. The gravels and sands are overlain by 20 to 60 feet of yellowish, reddish, and brownish massive loess, in part calcareous, which forms the capping material of Crowleys Ridge.

The gravels, sands, and loess extend down over the slopes of the ridge, and doubtless they have been reworked in part from their original position, or have found their way downward by creep or landslides.

The Advance lowland west of Crowleys Ridge is underlain by 140 to 160 feet of alluvial gravels, sands, clays, and loams of Pleistocene age, unconformably overlying Eocene strata. In general the materials grade downward from fine clays and loams to coarse water-bearing sands and gravels at the base. The flood plains of L'Anguille River and its tributaries are underlain by Recent alluvial sands, clays, and loams of undetermined thickness. The Mississippi lowland east of Crowleys Ridge is underlain by 150 to 225 feet of undifferentiated Recent and Pleistocene loams, clays, sands, and gravels which rest unconformably upon Eocene strata. The sands and gravels carry large quantities of water.

WATER RESOURCES.

GENERAL CONDITIONS.

Domestic supplies.—Water for domestic and industrial uses is obtained chiefly from wells 10 to 200 feet deep, and from springs. In the lowlands the sands and gravels of the alluvial deposits form the principal source of the waters; the static head of the wells is 10 to 35 feet below the surface. In Crowleys Ridge the sands and gravels of the Lafayette formation and beds of sand in the underlying Eocene deposits yield waters which here rise within 30 to 100 feet of the surface. Wells exceeding 200 feet in depth have been drilled at Wynne, at Parkin, and 5 miles east of Cherry Valley. As reported by the well owners, some of the well waters are soft, some are hard, and some are ferruginous. With perhaps a few exceptions they are potable and are suitable for most ordinary purposes. Numerous small springs in Crowleys Ridge yield soft moderately mineralized waters.

The Pleistocene alluvial deposits, which underlie the Advance lowland west of Crowleys Ridge to depths of 140 to 160 feet, and the undifferentiated Pleistocene and Recent alluvial deposits, which underlie the Mississippi lowland east of the ridge to depths of 150 to 225 feet, contain in their sandy and gravelly layers great quantities of water suitable for domestic and industrial supplies and for irrigation. The Tertiary strata which underlie Crowleys Ridge and upon which rest the alluvial deposits east and west of the ridge contain important water-bearing beds that may be reached by wells at estimated depths of 1,000 to 1,200 feet below the lowland levels. These are underlain to unknown depths by deposits of Cretaceous age which also contain water-bearing beds.

There are no flowing wells in the county. In the two deep wells at Parkin (480 and 597 feet, respectively), the water rises within 10 to 12 feet of the surface and a well 2,007 feet deep at Marked Tree, Poinsett County, overflows at the surface, facts which seem to show that flows could be obtained in this county in the Mississippi lowland east of Crowleys Ridge at depths of 1,800 to 2,500 feet.

Irrigation.—The rice-growing industry has been introduced into the county and in the flat lands west of Crowleys Ridge is rapidly becoming important. Water for irrigation is obtained chiefly from wells 65 to 170 feet deep which tap the water-bearing alluvial sands and gravels underlying the Advance lowland, and yield from 500 to 2,000 gallons per minute. The cost of drilling and equipping the wells ranges from $550 to $1,200 per well, the average cost for five wells being $1,100 for each 1,000 gallons of yield per minute, or at the rate of $1.10 for each gallon of yield. Six irrigation wells are described in the table on page 184.

LOCAL SUPPLIES.

Wynne.—The town of Wynne (population 2,353, census of 1910) owns a municipal water-supply system and obtains water from two 125-foot wells (Nos. 17, 18, p. 184). C. M. Crain, mayor, has furnished the following information in regard to the wells and plant: The water is pumped from the wells to a standpipe having a capacity of 75,000 gallons and furnishing a standpipe pressure of 75 pounds per square inch. The water is distributed to the consumers through 4 miles of mains, the daily consumption for domestic purposes being approximately 65,000 gallons.

One well at Wynne has been sunk to a depth of 360 feet. The name of the owner and other details have not been obtained, but a citizen has furnished the following log which, since it is given from memory, must be understood as only approximately correct:

Log of well at Wynne.

	Thickness.	Depth.
Pleistocene (a facies of loess):	*Feet.*	*Feet.*
Yellow loam	40	40
Tertiary (Eocene):		
White to gray, tough clay	15	55
Red "buckshot" clay	9	64
Red, blue, and white sand, very fine on top and becoming coarse below; water bearing. Water potable but hard and scales boilers	25	89
Fine white sand	25	114
Black and white sand, water bearing; water hard, but scales boilers less than that from layer 5; fossils reported from the sand	20	134
Coarse white sand with a layer of gravel within 5 feet of top, water bearing; water of better quality for drinking and for boiler-supply purposes than that from layers 3 and 5	30	164
Gray, tough "pipe" clay	196	360

The Wynne Brick Co. owns a well 250 feet deep (No. 19, p. 184) and the St. Louis, Iron Mountain & Southern Railway Co. owns a well 186 feet deep (No. 16, p. 184).

Parkin.—Two deep wells, the deepest in the county, have been drilled at Parkin. One, owned by the Northern Ohio Cooperage & Lumber Co., is 597 feet deep (No. 10, p. 184), the log of which is as follows:

Log of well of the Northern Ohio Cooperage & Lumber Co., Parkin.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Not reported	80	80
Sand	100	180
Gravel, water bearing	40	220
Tertiary (Eocene—probably in part Claiborne and in part Wilcox):		
Clay	375	595
Sand, water bearing	2	597

The other well, owned by the Lansing Wheelbarrow Co., is 480 feet deep (well 9, p. 184).

Vanndale.—A 167-foot well at Vanndale is owned by the York Lumber Co. (No. 13, p. 184). The following log has been furnished by Mr. Wiley, of the firm of Layne & Bowler, drillers, Stuttgart, Ark., through Mr. E. G. Norton, of Brinkley, Ark.:

Log of well of the York Lumber Co., Vanndale.

	Thickness.	Depth.
[Pleistocene alluvium]:	*Feet.*	*Feet.*
Clay	65	65
Fine sand	52	117
Fine gravel	12	129
Coarse gravel, water bearing; stopped drilling on blue clay	38	167

Five miles east of Cherry Valley.—A well located near the east foot of Crowleys Ridge, owned by Mr. Smith, is 230 feet deep. The owner has furnished the following log from memory:

Log of well owned by Mr. Smith, 5 miles east of Cherry Valley.

[No. 3, p. 184.]

	Thickness.	Depth.
	Feet.	*Feet.*
[Quaternary (alluvium)]:		
Sandy loam	1.5	1.5
Sand and gravel	15	16.5
[Tertiary (Eocene)]:		
Sand, alternating with layers of sticky clay	213.5	230

Fairoaks.—A well at Fairoaks, 82 feet deep, is owned by the St. Louis Southwestern Railway Co. (No. 4, p. 184). The log is as follows:

Log of well of the St. Louis Southwestern Railway Co., Fairoaks.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene alluvium:		
White earth	3	3
"Hardpan"	9	12
Gray medium fine sand, water bearing	70	82

Wells for irrigation.—Wells for irrigating rice lands have been drilled in the vicinity of Cherry Valley, Fairoaks, Hickory Ridge, Hydrick, Tilton, and Vanndale; six of the wells are described in detail in the table on page 184. Logs of three of them are as follows:

Log of well of T. A. Norviel, 2.5 miles east of Fairoaks.

[No. 5, p. 184.]

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene alluvium:		
Clay	14	14
Sand, water bearing	26	40
Coarse gravel, water bearing	25	65

Log of well owned by W. F. Clements, near Hydrick.

[No. 7, p. 184.]

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene alluvium:		
Whitish colored clay	40	40
Sand, water bearing, especially in lower 15 feet	35	75

Log of well owned by Miller & Son, 4 miles northeast of Tilton.

[No. 11, p. 184.]

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene alluvium:		
Clay and sand	23	23
Quicksand, water bearing	30	53
Sand and gravel, water bearing	27	80

Wells in Cross County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.					*Feet.*	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Cherry Valley				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.		292±	140	10			Pleistocene alluvium.
2	Cherry Valley, one-half mile north of.	9 N.	3 E.	15, NW. ¼ of NE. ¼.	J. O. Halk	J. M. Stacey	Owner	1911		70	2			Pleistocene alluvium (?).
3	Cherry Valley, 5 miles east of.				Mr. Smith	C. H. Winters	....do			230				Eocene.
4	Fairoaks				St. Louis Southwestern Ry. Co.	Homer Shults, Pine Bluff.	Driller	1909	218	82	8	21–82		Pleistocene alluvium.
5	Fairoaks, 2½ miles east of.				T. A. Norviel	F. A. Schairman, Jonesboro.	Owner		220±	65	10	18–65		Do.
6	Hickory Ridge, 3½ miles southeast of.	9 N.	1 E.	36, NW. ¼.	Love Banks, Smithdale.	J. E. Gidrey, Rayne, La.	....do	1910	235±	121	9⅝	82–121	45	Do.
7	Hydrick	9 N.	3 E.	2, NW. ¼	S. A. Clements	S. J. Hodges, Harrisburg.	....do	1891	(*a*)	85	2	20–85		Do.
8	....do	9 N.	3 E.	2, NW. ¼	W. F. Clements		....do	1908	(*b*)	75	2½	60–75		Do.
9	Parkin, one-fourth mile south of.	7 N.	5 E.	3, NW. ¼	Lansing Wheelbarrow Co.		D. S. Watrons.	1902. (?)	220±	480	6			Wilcox (?) formation.
10	Parkin, one-fourth mile north of.	7 N.	5 E.	3, E. ½	Northern Ohio Cooperage & Lumber Co.	W. G. Lanham, Memphis, Tenn.	S. W. Sterling		230±	597	5⅝	597	180–220	Do.
11	Tilton, 4 miles northeast of.	8 N.	1 E.	11, SE. ¼	Miller & Son	Owner	E. M. Miller	1911	222±	80	6	23–80		Pleistocene alluvium.
12	Tilton, 3½ miles southeast of.	8 N.	1 E.	22, SE. ¼	B. V. Rogers	Jesse Rogers	Owner	1911	222±	96	8¼	31½–96		Do.
13	Vanndale, 2 miles southwest of.				York Lumber Co.	Layne & Bowler, Stuttgart.	E. G. Norton, Brinkley.		260±	167				Do.
14	Vanndale, 7 miles west of.	8 N.	2 E.	2, SW. ¼	J. W. Blue	Owner	Owner	1910		102	10	80–102		Do.
15	Wynne									360				Wilcox (?) formation.
16	....do				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.		259±	186	10			Do.
17	....do				Town		C. M. Crain	1900	260±	125	6	100		Pleistocene alluvium (?).
18	....do				....do		....do	1900	260±	125	6	100		Do.
19	....do				Wynne Brick Co.				260±	250				Wilcox (?) formation.

a Elevation about 35 feet above low-water level of L'Anguille River.

b Elevation about 25 feet above low-water level of L'Anguille River.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Gallons.*						
1	Cherry Valley										Boilers		Analysis 16, p. 302.
2	Cherry Valley, one-half mile north of.	9 N.	3 E.	15, NW. ¼ of NE. ¼.	Sand			Hand.	$20	$30	Domestic	Hard	
3	Cherry Valley, 5 miles east of.				do	30					do		
4	Fairoaks				Fine sand	21	300	Steam.			Domestic and boilers.	Ferruginous	Pit 21 feet deep and 12 feet in diameter, lined with cast-iron curbing; 61 feet of 8-inch casing.
5	Fairoaks, 2½ miles east of.				Sand and gravel	18	500		1,000		Irrigation		Analysis 17, p. 302.
6	Hickory Ridge, 3½ miles southeast of.	9 N.	1 E.	36, NW. ¼.	Coarse sand and gravel.	26	1,500	Steam.	1,050	700	Domestic and irrigation.		Analysis 18, p. 302.
7	Hydrick	9 N.	3 E.	2, NW. ¼					35		Domestic	Hard	
8	do	9 N.	3 E.	2, NW. ¼	Fine sand	60	10	Hand.	10	25	do	Ferruginous	
9	Parkin, one-fourth mile south of.	7 N.	5 E.	3, NW. ¼		10		Steam.			Domestic and boilers.		Supplies 35 buildings and 600 people.
10	Parkin, one-fourth mile north of.	7 N.	5 E.	3, E. ½	Sand	12	200	do			do	Sulphurous	Supplies 75 buildings and 250 people.
11	Tilton, 4 miles northeast of.	8 N.	1 E.	11, SE. ¼	Sand and gravel		500		400	150	Irrigation	Hard	57 feet of 6-inch casing and 20 feet of 6-inch screen.
12	Tilton, 3½ miles southeast of.	8 N.	1 E.	22, SE. ¼	do	31½	1,200	Steam.	500	225	do		Pit 35 feet deep and 5½ feet square; 42 feet of 8¼-inch casing, and 19 feet of 8¼-inch Keystone screen.
13	Vanndale, 2 miles southwest of.				Coarse gravel						do		
14	Vanndale, 7 miles west of.	8 N.	2 E.	2, SW. ¼	Sand and gravel	30	2,000	Steam.	1,000	185	Drinking and irrigation.		Analysis 21, p. 302.
15	Wynne				Sand							Hard	
16	do										Boilers		This well and 2 similar wells yield 3,000,000 gallons per month. Analysis 22, p. 302.
17	do				Gravel and sand	90		Steam.			Municipal supply.	Alkaline	The amount used daily is approximately 65,000 gallons.
18	do				do	90		do			do	do	
19	do					100						Hard	

GREENE COUNTY.

PHYSIOGRAPHY.

Greene County lies immediately south of Clay County, in the northeastern part of the State. The area of the county is 561 square miles, and the population was reported by the census of 1910 as 23,852. Agriculture and lumbering are the chief industries, and stock raising is growing in importance. At Paragould, the county seat, are several sawmills and mills manufacturing wood products.

The county includes parts of Crowleys Ridge, the Advance lowland, and the Mississippi lowland, the three main topographic divisions recognizable in the Mississippi embayment.

Crowleys Ridge forms a belt of hilly, partly cultivated and partly wooded land, 8 to 12 miles wide, extending northeast and southwest through the center of the county, attaining a maximum elevation of 500 to 525 feet above sea level, or 200 to 250 feet above the lowlands to the east and west. The ridge is drained by numerous small perennial and intermittent streams which flow either eastward into the Hatchie Coon Sunk Lands or westward into Cache River. The surface has been strongly dissected by these streams, the main ones flowing through rather broad valleys with smoothly rounded slopes; many of the small headwater branches occupy narrow, steep-sided gorges. The main divide of the ridge is a little west of the center and the western slope is in general more rugged than the eastern.

The county west of Crowleys Ridge is included within the Advance lowland, a gently undulating plain lying 260 to 275 feet above sea level and inclining slightly to the south. Cache River flows southwestward in the northwestern part of the county, south of which it forms the western boundary for about 15 miles; the river valley, which is 3 to 5 miles wide and is 8 or 10 feet lower than the general level, is in part swampy and is largely covered with a growth of timber. The interstream areas belong chiefly to the post-oak flat type and are poorly drained. In the northwest, between Cache River and the St. Louis, Iron Mountain & Southern Railway, the otherwise nearly level surface is broken by Jones Ridge, a ridge 3 or 4 miles long, one-quarter to one-half mile wide, and 30 to 40 feet high, which trends northeast-southwest. Between Cache River and the foot of Crowleys Ridge the soil is more fertile than west of the river because of the loams brought down from Crowleys Ridge and deposited on the plain.

All the county east of Crowleys Ridge is included in the Mississippi lowland; immediately east of and bordering the ridge is a belt of post-oak flats, several miles wide, lying 270 to 275 feet above sea level, and crossed by the numerous shallow valleys of the small streams from Crowleys Ridge. East of these flats is the "sunk lands" of St. Francis River bottom, a swampy, timber-covered tract several feet lower than the post-oak flats, interspersed with low ridges of sandy loam trending northeast and southwest; the ridges, which have been partly cleared for cultivation, are dotted with the so-called sand blows of the region, which consist of irregularly distributed small patches of clean white sand believed to have been ejected from fissures at the time of the New Madrid earthquake in 1811–12. The "Hatchie Coon Sunk Lands" form the eastern boundary of the county.

GEOLOGY.

The core of Crowleys Ridge to a height of 75 to 100 feet or more is composed of irregularly bedded sands and clays belonging to the Wilcox formation (Eocene). The sands have been locally indurated to sandstones of all grades of hardness from soft, friable rocks to hard quartzites, which outcrop at numerous places along the western slope of the ridge; fossil leaves of Wilcox age have been collected from soft sandstone near Hardys Mill, about 4 miles west of Gainesville. (See p. 59.) Lignite has been encountered in wells drilled at numerous places on the ridge. Eocene strata underlie Crowleys Ridge to a depth estimated to be not less than 400 or 500 feet, and are also present beneath the alluvial deposits both to the east and west of the ridge, where their upper surface lies at depths of 150 to 200 feet; they contain important water-bearing beds. The Eocene strata are believed to be underlain by strata of Cretaceous age, doubtless in part water bearing, which at an undetermined depth, probably not exceeding 1,200 feet, rest on a basement of Paleozoic rocks.

The Eocene strata in Crowleys Ridge are overlain unconformably by a few feet to 50 feet of gravels and reddish sands belonging to the Lafayette formation (Pliocene?); these are in part water bearing. The gravels are locally indurated to conglomerates. The Lafayette formation is overlain by 10 to 30 feet or more of loess presenting various facies of reddish and yellowish argillaceous loam and sandy clay. In places on the crest of the ridge the loess has been completely removed from above the gravels by erosion. Both the loess and gravels extend down over the slopes of the ridge, probably in part reworked and in part as creep materials, almost completely concealing the Eocene strata.

The Advance lowland west of Crowleys Ridge is underlain to an estimated depth of 150 to 175 feet by alluvial gravels, sands, clays, and loams, for the most part of Pleistocene age but in part of Recent age, which rest upon Eocene strata. The Recent alluvium underlies the bottom lands of Cache River to an undetermined depth and the Pleistocene alluvium outcrops in the interstream areas. In general, the Pleistocene deposits grade downward from fine clays and silts at the surface through fine sands to coarse sands and gravels at the base, which are abundantly water bearing. The Mississippi lowland is underlain to an estimated depth of 150 to 200 feet by alluvial loams, clays, sands, and gravels of undifferentiated Pleistocene and Recent age. The coarser materials carry water in large quantities.

WATER RESOURCES.

GENERAL CONDITIONS.

Domestic water supplies are obtained chiefly from wells 10 to 130 feet deep. In Crowleys Ridge the wells tap the water-bearing sands and gravels of the Lafayette formation or the water-bearing sands of the underlying Eocene deposits; in the lowlands the alluvial sands and gravels of Pleistocene and Recent age form the source. The waters are generally soft, but according to the statements of well owners some are moderately hard and some are ferruginous. Detailed information concerning wells at or in the vicinity of Lorado, Marmaduke, and Paragould is given in the table on page 190.

The sands and gravels which largely compose the alluvial deposits below the surface clays in the lowlands west and east of Crowleys Ridge contain water in large quantities; these beds may be tapped by wells from 10 to 175 feet deep. The Eocene strata which underlie Crowleys Ridge and which are present beneath the alluvial deposits of the lowlands, and the Cretaceous strata which underlie the Eocene deposits, contain important water-bearing beds; these may be tapped at depths of 100 feet and over in Crowleys Ridge, and at depths of 200 feet and over in the lowlands. The lower limit of possible water-bearing beds found in the Eocene and Cretaceous deposits is the Paleozoic basement rocks, which lie at an estimated maximum depth of 1,200 feet or more in the extreme east. The waters of the Eocene and Cretaceous deposits are under hydrostatic pressure, which in the Mississippi lowland may be sufficient to produce flows.

Small springs are numerous in Crowleys Ridge and are utilized to some extent for domestic and farm supplies. As reported by the owners, some of the spring waters are soft, some are hard, and some are ferruginous; a few are rendered turbid by suspended particles of clay.

LOCAL SUPPLIES.

Paragould.—The municipal water supply of Paragould (population 5,248, census of 1910) is obtained from two wells. Detailed information concerning the system has been furnished by A. P. Mack, mayor, and L. Stedman, superintendent of waterworks. The wells are 512 feet deep and 6 inches in diameter (Nos. 7 and 8, p. 190).

The water is raised by air lift at the rate of 353 gallons a minute from each well. The water is stored in two 120,000-gallon reservoirs at the pump station and is distributed through 5 miles of mains. The maximum direct pressure is 120 pounds per square inch. The daily consumption for all purposes is between 400,000 and 500,000 gallons.

Detailed information concerning wells at Paragould owned by the Crystal Ice Co., the Paragould Brick Co., and the St. Louis, Iron Mountain & Southern Railway Co. is given in the table on page 190.

Rural supplies.—Several typical wells used for domestic and farm supplies are described in the table on page 190. Logs or incomplete logs of several such wells are as follows:

Incomplete log of well of S. P. Weigart, 5½ miles north of Marmaduke.

[No. 6, p. 190.]

	Feet.
Eocene (Wilcox formation):	
White sand	26
Sand, water bearing	50
Coarse white sand, water bearing	85
Red sand with some red clay, 8 inches thick	93
Sand, water bearing; water red when first pumped but clears on continued pumping. After standing or boiling, water becomes red	98
Layer of "pipe" clay 1 inch thick	98
Not reported to	102

Log of well of R. A. Dortch, 12 miles northwest of Marmaduke, in the NE. ¼ sec. 8, T. 19 N., R. 6 E.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	1	1
Red clay	2	3
Sand	2	5
Blue clay	14	19
Sand, water bearing	20	39

Log of well of Joe Canfee, of Lafe, 3½ miles north of Beech Grove, in the SE ¼ NE. ¼ sec. 11, T. 18 N., R. 4 E.

	Thickness.	Depth.
Quaternary (alluvium):	*Feet.*	*Feet.*
Loam	3.5	3.5
Clay	4	7.5
Fine sand, water bearing	7.5	15
Blue mud	12	27
Sand and gravel, water bearing	3	30

Wells in Greene County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.					Feet.	Feet.	Inches.	Feet.	Feet.	
1	Lorado, 1½ miles southwest of.	16 N.	3 E.	35	W. C. Nutt	Allen Daniels	J. M. Rhea	1904		80	8	60-80		Wilcox (?) formation.
2	Lorado, 3 miles southeast of.				D. M. Powers		Owner	1905		122	6			Do.
3	Marmaduke, 9 miles northwest of.				W. Y. Smith		do	1911		57	10	50-57		Do.
4	Marmaduke, 10 miles northwest of.				J. A. Smith	Tobe Hamilton	do	1909	(a)	55	10	50-55		Do.
5	Marmaduke, 2½ miles north of.	18 N.	6 E.	1, N. ½, SW. ¼.	Arch McBride, Rector.	H. Johnson, Rector.	do	1908	290±	70	4	60-70		Do.
6	Marmaduke, 5½ miles north of.	19 N.	7 E.	30 W. ½, NE. ¼.	S. P. Weigart, Rector.	W. D. Cudd, Rector.	do	1911		102	2	50-98		Do.
7	Paragould				Town	Thos. Fleming, Pine Bluff.	L. Stedman	1910	276±	512	6	472	135	Wilcox formation.
8	do				do	do	do	1910	276±	512	6	472	135	Do.
9	do				Paragould Brick Co.				276±	120		120	60	Wilcox (?) formation.
10	do				Crystal Ice Co.				276±	120	6			Do.
11	do				do				276±	120	6			Do.
12	do				do				276±	120	6			Do.
13	do				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.		276	180	10			Do.

a Elevation about 55 feet above low-water level of Cache River.

	Location. Place.	T.	R.	Sec.	Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
						Feet.	Gallons.						
1	Lorado, 1½ miles southwest of.	16 N.	3 E.	35	Yellow sand	65			$25		Domestic	Soft	
2	Lorado, 3 miles southeast of.				Sand	109					do		Bored type.
3	Marmaduke, 9 miles northwest of.								15		do	Soft	Do.
4	Marmaduke, 10 miles northwest of.				Sand	40		Hand	16		do	do	Do.
5	Marmaduke, 2½ miles north of.	18 N.	6 E.	1, N. ½, SW. ¼.	Sand and gravel	50			30		do	Aklaline	
6	Marmaduke, 5½ miles north of.	19 N.	7 E.	30, W. ½ NE. ¼.	Sand	50		Hand	65		do	Soft, ferruginous.	
7	Paragould				Coarse sand	32	353	Air	4,000		Municipal supply.	Soft and sulphurous.	Combined yield of 2 wells used for municipal supply.
8	do				do	32	353	do			do	do	
9	do										Boilers and mud-mixing.		Yields an abundant supply.
10	do					20	200				Manufacture of ice.		
11	do					20					do		
12	do					20					do		
13	do						50				Boilers		

INDEPENDENCE COUNTY.

PHYSIOGRAPHY.

Independence County is in the northeast-central part of the State, west of Jackson County, and is on the border between the Coastal Plain and the Ozark province. The area is 762 square miles and the population, according to the census of 1910, is 24,776.

The greater part of the county is included within the Ozark province, a rugged, deeply dissected plateau which, within the county limits, lies 500 to 1,150 feet above sea level. This plateau is crossed from northwest to southeast by White River, which flows through a narrow gorge 200 to 500 feet deep.

The remainder of the county, embracing a strip 3 to 6 miles wide bordering the county on the east and an area a few miles wide extending up the valley of White River as far as Batesville, is included in the Mississippi embayment, which is a part of the Gulf Coastal Plain. The greater part of the Coastal Plain portion lies 240 to 250 feet above sea level and is a part of the subdivision known as the Advance lowland; a smaller part is a narrow, more or less clearly defined terrace bordering the Ozark province 40 to 100 feet or more above the bottom lands of Black River; this is the northern extension of the Grandglaise terrace of Lonoke County (p. 23). White River flows out from the Ozark province into the Advance lowland a little south of the center of the county. Black River forms the eastern boundary of the county from the northeastern corner southward to Jacksonport, where it joins White River.

Only that part of the county included in the Coastal Plain is treated in this report; here lumbering and agriculture are the chief industries.

GEOLOGY.

The Ozark province is underlain by Paleozoic limestones, cherts, shales, and sandstones of Ordovician, Mississippian, and Pennsylvanian age. The contact between these rocks and the unconsolidated sedimentary materials composing the Coastal Plain is marked by an abrupt erosion escarpment. Along the line of this escarpment the upper eroded surface of the older rocks passes to the eastward at a steep angle beneath the younger materials.

The oldest post-Paleozoic strata outcropping in the area are glauconitic sands interbedded with laminated clays and subordinate lenses of shell marl of Upper Cretaceous age and are probably referable to the Nacatoch sand; these form the body of the Grandglaise terrace in the vicinity of Newark and northward probably to and beyond the county line. Limestones of Eocene age belonging to the Midway formation appear in the Grandglaise terrace along the margin of the Ozark province in the extreme southeast. Undifferentiated Eocene and Cretaceous strata underlie the remainder of the lowland area beneath an estimated thickness of 100 to 150 feet of alluvial deposits. Little is known about these buried deposits, but they are believed to consist chiefly of sands, clays, and perhaps limestones, the thickness probably not exceeding 200 or 300 feet within the county. They rest upon the eastward-sloping surface of the buried Paleozoic rocks, the depth to which probably does not exceed 400 feet.

On the hills along the eastern margin of the Ozark province and on the Grandglaise terrace are scattered deposits of gravel, which probably represent the Lafayette formation (Pliocene?).

The alluvial deposits which cover the Eocene and Cretaceous consist of sands, clays, loams, and gravels. In the flood plains of the streams the alluvial materials immediately underlying the surface to an undetermined depth are of Recent age; in the level interstream areas they are of Pleistocene age. The Pleistocene alluvial deposits are irregularly bedded, but in general grade downward from light-colored, compact, silty clays at the surface through fine sands to coarse, water-bearing sands and gravels at the base, the total thickness, though undetermined, probably not exceeding 150 feet. They rest upon strata of Eocene age.

WATER RESOURCES.

GENERAL CONDITIONS.

The statements which follow apply only to the small area in the east included in the Advance lowland. Here the domestic water supplies are obtained chiefly from wells 10 to 100 feet deep. Except in the narrow terrace along the western margin of the lowland, where only moderate amounts of water are obtained from strata of Eocene and Cretaceous age, the wells tap the abundantly water-bearing sands and gravels of the alluvial deposits, the waters of which are soft to moderately hard. The undifferentiated Eocene and Cretaceous deposits which underlie the alluvial deposits also contain water-bearing beds which may be tapped by wells 150 to 400 feet deep. Flowing wells probably can not be obtained within the county.

LOCAL SUPPLIES.

The town of Newark (population 595, census of 1910) is on the Grandglaise terrace bordering the Ozark province along the western margin of the lowland. Shale of Paleozoic age lies 30 to 40 feet beneath the surface. The beds overlying the shale consist in descending order of light brown, yellow, and red loam and clay, gray marl containing shells and shark teeth, and coarse basal water-bearing sands and gravels which are the main source of domestic water supplies. The fossiliferous marls probably belong to the Nacatoch sand of the Upper Cretaceous.

The log of one well has been furnished by J. W. Sisk as follows:

Log of well at Newark, Independence County.

	Thickness.	Depth.
[Pleistocene?]:	*Feet.*	*Feet.*
Yellow loam (loess?)	8	8
Black loam or clay (loess?)	8	16
[Upper Cretaceous (Nacatoch sand?)]:		
Yellow sand	1	17
Black mud	1	18
Gray, soft limestone or marl containing mollusks and shark teeth	2	20
Sand	1	21
Black mud containing wood and leaves	⅓	21⅓

JACKSON COUNTY.

PHYSIOGRAPHY.

Jackson County comprises 632 square miles in the northeast-central part of the State, between Independence County on the west and Poinsett County on the east. Its population at the time of the census of 1910 was 23,501. Agriculture is the chief industry and includes the raising of cereals, fruits, and hay. Two cotton compresses, an oil mill, and several sawmills and mills which manufacture wood products are located at Newport. Lumbering is also an important industry.

A relatively small area in the southwestern part of the county is included in the Ozark province, a rugged, broken area lying 400 to 600 feet above sea level. The remainder of the county is included in the Advance lowland and Grandglaise terrace of the Mississippi embayment which is a part of the Gulf Coastal Plain. The Grandglaise terrace is a narrow ridge or dissected terrace bordering the Ozark province just west of the St. Louis, Iron Mountain & Southern Railway, the crest of which is approximately 300 feet above sea level. The Advance lowland is a plain lying 200 to 260 feet above sea level and sloping slightly to the southward. In the interstream areas the surface is gently undulating and partly timbered and the soil and subsoil are loam or silty clay. The broad flood plains of the streams are a few feet lower than the interstream areas, are in part swampy, and are traversed by numerous bayous. Between the swamps and bayous are fertile heavily timbered ridges of sand or sandy loam, some rising a few feet higher than the general level of the lowland.

Black River forms the western boundary from the northwestern corner of the county to Jacksonport, where it joins White River—a stream which flows in a general southerly direction from Jacksonport to the southern boundary of the county. Cache River enters the county on the east and flows a little west of south to the southern boundary.

GEOLOGY.

In the Ozark province in the southwestern part of the county the surface is immediately underlain by Paleozoic rocks of Pennsylvanian age. Along their eastern border the Paleozoic rocks are separated from the materials of the Coastal Plain by an abrupt erosion escarpment along which their eroded surface passes beneath the deposits of the Coastal Plain and extends to the eastward to increasing depths, forming the basement upon which the latter rest; these basement rocks were encountered in a well at Newport at a depth of 655 feet. (See section, p. 197.)

Pebbly fossiliferous limestones interbedded with gray to yellowish sands belonging to the Midway formation (Eocene) outcrop in the basal 20 or 25 feet of the east-facing escarpment of the Grandglaise terrace. The Midway is overlain by reddish, pebbly sands, probably of the same age as the similar sands (Lafayette formation) overlying the Eocene strata of Crowleys Ridge; the red sands are overlain by dark and light, more or less sandy loams resembling certain facies of the loess of Crowleys Ridge and probably of the same age (middle Pleistocene). Scattered patches of gravel on the Paleozoic hills west of the Grandglaise terrace probably also represent the Lafayette formation. The Midway formation is separated from the alluvial deposits of the Advance lowland to the east by an abrupt erosion escarpment. Eocene and Cretaceous strata are believed to underlie the Advance lowland beneath 100 to 150 feet of alluvial deposits of Quaternary age; they probably consist mainly of sands and clays, in part water-bearing, and rest upon the Paleozoic basement rocks. At Newport the basement rocks were struck in a well at a depth of 655 feet and their upper surface probably inclines to greater depths to the eastward.

The alluvial deposits which immediately underlie the Advance lowland to estimated depths of 100 to 150 feet consist of loams, clays, sands, and gravels of Pleistocene and Recent age. The Pleistocene deposits, which outcrop in the nearly level interstream areas, are irregularly bedded, but in general grade downward from fine compact loams or silty clays at the surface through fine sands to coarse water-bearing sands and gravels at the base. Paralleling the streams are numerous ridges of sand and sandy loam which rise above high-water level of the present streams and are probably of Pleistocene age. The flood plains of the streams are underlain to undetermined depths by Recent alluvial sands, clays, and loams.

WATER RESOURCES.

GENERAL CONDITIONS.

Wells 10 to 100 feet deep furnish the principal domestic water supplies in the Advance lowland, which includes the greater part of the county. The wells tap the abundantly water-bearing sands and gravels of the alluvial deposits, the water standing within 10 to 30 feet of the surface. As reported by the well owners some of the well waters are soft, some are hard, and some are ferruginous; with perhaps a few exceptions they are potable and are suitable for domestic and industrial purposes. The undifferentiated Tertiary and Cretaceous strata which underlie the alluvial deposits contain water-bearing beds and constitute an important undeveloped source of artesian water. Flowing wells probably can not be obtained in the Advance lowland in this county. Small springs are numerous in the Grandglaise terrace and in the Ozark province in the southwestern part of the county.

LOCAL SUPPLIES.

The waterworks plant of Newport (population 3,557, census of 1910) is owned by the Newport Water, Light & Power Co., concerning which information has been furnished by S. Blackburn. Water from White River is filtered by means of a Roberts pressure filter having a daily capacity of 500,000 gallons and is distributed to the consumers from a standpipe having a capacity of 70,000 gallons. The direct pressure is about 45 pounds per square inch, and the maximum pressure from the pumps for fire protection is 135 pounds per square inch. The total length of the distributing mains is 6 miles, and the daily consumption is approximately 30,000 gallons for domestic use and 50,000 gallons for manufacturing.

The Newport Ice Co. owns a well 100 feet deep and 6 inches in diameter, completed in 1898. Mr. R. J. Hugully, the informant, states that a 6-inch casing extends to a depth of 85 feet, and the water, which comes from gravel penetrated in the bottom of the well, stands within 12 feet of the surface. The water is soft and is used for the manufacture of ice. The cost of the well and a pump operated by steam was $500.

In 1900 (?) an oil-prospecting well was drilled 1 mile southwest of Newport (sec. 10, T. 11 N., R. 3 W.) to a depth of 1,000 feet. The following log has been published by Purdue:[1]

Log of oil-prospecting well 1 mile southwest of Newport.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and sand	30	30
Sand	75	105
"Soapstone"	50	155
Quicksand	500	655
Rock of different kinds, ending in flint	345	1,000

Purdue says:

The 105 feet of clay and sand at the top are of Recent [and Pleistocene] age; the rocks from the base of the quicksand downward are supposedly Paleozoic. The 550 feet between the Recent and the Paleozoic may all be Cretaceous, though it is possible that the upper 50 feet, reported as "soapstone," is Tertiary.

JEFFERSON COUNTY.

PHYSIOGRAPHY.

Jefferson County comprises 903 square miles in the southeast-central part of the State, west of Arkansas County. Its population at the time of the census of 1910 was 52,734. Only that part of the county lying north and east of Arkansas River is in the area covered by this report. The chief industry is agriculture and the leading crop is cotton, although cereals are grown to an important extent. The rice-growing industry has been introduced in recent years, and in certain places in the northeast is rapidly growing in importance.

The county is included within two well-defined topographic divisions of the Gulf Coastal Plain. In the west an area varying in width from 3 miles in the north to 16 miles in the south forms part of an upland which is extensively developed in the interstream areas of southwestern Arkansas; within this county the upland lies 300 to 350 feet above sea level. The remainder of the county is included within the Advance lowland, the general surface of which is a plain 190 to 235 feet above sea level sloping slightly to the south. Arkansas River traverses the lowland from northwest to southeast and forms the southwestern boundary of the area here treated. Nearly all the land northeast of the river is included within the gently undulating flood plain of Arkansas River, is in part swampy, and is traversed by numerous bayous and abandoned stream channels. The soil is fertile and, except where cleared for cultivation, is heavily timbered;

[1] Purdue, A. H., U. S. Geol. Survey Water-Supply Paper 145, pp. 96, 97, 1905.

the areas above high-water level and the areas protected from overflow by levees produce large crops, particularly of cotton.

GEOLOGY.

Strata of Eocene age, referable chiefly to the Jackson formation, outcrop in the upland area in the western part of the county; undifferentiated Eocene deposits underlie the remainder of the county beneath 125 feet or more of Quaternary alluvium. Although nothing definite is known concerning the Eocene deposits beneath the alluvium, they are believed to consist of 500 feet or more of sands, clays, and marls, in part water bearing. The Eocene deposits are probably underlain by similar deposits of Cretaceous age, which doubtless also contain water-bearing beds. The Cretaceous strata are believed to rest on a deeply buried basement of Paleozoic rocks. The alluvial deposits in the Advance lowland northeast of Arkansas River have an estimated thickness of 125 to 150 feet and consist of alluvial loams, clays, sands, and gravels. The surface materials are probably for the most part of Recent age, but some of the higher interstream areas may be of Pleistocene age. The thickness of the Recent deposits has not been determined, but it is probable that Pleistocene deposits underlie them and intervene between them and the Eocene deposits. The sands and gravels of the alluvial deposits are abundantly water bearing.

WATER RESOURCES.

Domestic supplies.—In the area northeast of Arkansas River water for domestic use is obtained chiefly from wells 15 to 125 feet deep, which tap the abundantly water-bearing sands and gravels of the alluvial deposits; the waters stand in the wells 5 to 20 feet below the surface. According to the reports received from well owners, most of the waters are hard, but some are soft, and a few are ferruginous. The undifferentiated Eocene and Cretaceous deposits which intervene between the alluvial deposits and the deeply buried Paleozoic basement rocks also contain important water-bearing beds, the waters of which are under sufficient hydrostatic pressure to bring them nearly to the surface, and in wells 1,000 feet or more deep perhaps above the surface. At Lake Dick wells have been drilled as deep as 350 feet and at Langford as deep as 274 feet.

In the part of the county southwest of Arkansas River wells 50 to 100 feet in depth are common, and the deep wells listed in the table on page 200 (Nos. 4–11) have been drilled at and near Pine Bluff and at Redfield.

Wells for irrigation.—Wells for irrigating rice lands have been drilled in the vicinity of McGrew, New Gascony, and Wabbaseka, detailed information concerning seven of which is given on page 200. The wells are 35 to 125 feet deep and yield 390 to 2,000 gallons of water a minute. The cost of sinking the wells and erecting pumping plants ranges from $450 to $1,550 per well, the average cost of production based on five wells being $600 for each 1,000 gallons of yield per minute, or at the rate of 60 cents for each gallon of yield a minute. Incomplete analyses of samples of water from two irrigation wells near Wabbaseka are given in the table opposite page 302 (Nos. 23 and 24).

The following is the log of an irrigation well owned by John Ingram, sr., 5 miles east of Wabbaseka (No. 15, p. 200):

Log of well of John Ingram, sr., 5 miles east of Wabbaseka.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Not reported	19	19
Argillaceous sand and gravel, water bearing	16	35
Sand	8	43
Red sand grading into white sand below, bearing a dark-colored water	8	51
Coarse sand, water bearing	8	59
Gravel, water bearing	2	61
Sand, water bearing	5	66

Wells in Jefferson County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.					*Feet.*	*Feet.*	*Inches*	*Feet.*	
1	McGrew (near)	4 S.	7 W.		John Ingram, sr.		J. S. Jones	1910		35	4	25–35	Quaternary alluvium.
2	New Gascony, 2 miles northwest of.	5 S.	7 W.	31, NE. ¼	John M. Gracie	Layne & Bowler, Stuttgart.	Owner	1910		125	24	35–125	Do.
3	....do	5 S.	7 W.	31, NE. ¼	....do	United Well Co., Stuttgart.	....do	1911		125	24	35–125	Do.
4	Pine Bluff				S. Geirreiter		J. J. Martin [a]			300			
5	....do				St. Louis Southwestern Ry.		J. S. Berry [a]	1897	216	840	5½	840	Wilcox formation.
6	....do				....do	W. B. S. Sharpe & Bro.	R. M. Galbraith.[a]	1898	216	890	8		Do.
7	....do				Pine Bluff Water & Light Co.	....do	F. G. Bridges [a]	1898		915	6	864–915	Do.
8	....do				Sawyer-Austin Lumber Co.	W. B. Sharpe	Owner [a]	1899		915	8		Do.
9	....do				Pine Bluff Ice Co.		Jeff Hicks [a]			300	10	26–100	Quaternary.
10	....do				Arkansas Cotton Oil Co.	Johnson & Fleming, Memphis, Tenn.	Owner [a]	1904	215	826	4	806–826	
10a	Pine Bluff, 7 miles southeast of.	6 S.	8 W.	33, NE. ¼ NW. ¼.	B. L. Rutherford	T. Fleming	Owner	1908	200±	167	13	125–167	Quaternary alluvium.
11	Redfield				St. Louis, Iron Mountain & Southern Ry.	C. H. Winters	C. H. Winters [a]			545	6	404–412	Wilcox formation.
12	Wabbaseka, 1 mile northeast of.				W. L. Davis	George Hestand, Pine Bluff.	Owner	1910	198±	95	25		Quaternary alluvium.
13	Wabbaseka, 1½ miles southeast of.	4 S.	7 W.	21	Shelby Bros.	Owners	G. A. Shelby	1910	198±	90	9⅝	65–90	Do.
14	Wabbaseka, three-fourths mile north of.	4 S.	7 W.	7	N. T. Roberts, Pine Bluff, Ark.	A. D. Bunn	Owner	1911	198±	97	10		Do.
15	Wabbaseka, 5 miles east of.	4 S.	7 W.	13, NW. ¼	John Ingram, sr.	John Ingram & Bros.	Hezekiah Ingram.		200±	66	4	61–66	Do.

[a] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 174–175, 1906.

No.	Location: Place.	T.	R.	Sec.	Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
						Feet.	*Galls.*						
1	McGrew (near)	4 S.	7 W.				2,000				Irrigation	Soft	
2	New Gascony, 2 miles northwest of.	5 S.	7 W.	31, NE. ¼	Sand and gravel	17	2,000	Steam	$750	$800	do	Hard and sulphurous.	
3	do	5 S.	7 W.	31, NE. ¼	do	17	2,000	do	750	800	do	do	
4	Pine Bluff												
5	do					20						Soft	
6	do					22	650					do	Length of strainer, 60 feet.
7	do					31							Yield of this and another similar well, 600 gallons per minute. In 1902 the static head had decreased to —46 feet.
8	do					47						Soft	Forms a soft red scale.
9	do					26						Hard, ferruginous.	
10	do					28	30+					Soft	
10a	Pine Bluff, 7 miles southeast of.	6 S.	8 W.	33, NE. ¼ NW. ¼.	Sand and gravel	4	4,000	Steam	3,000		Irrigation		
11	Redfield					60	20						
12	Wabbaseka, 1 mile northeast of.				Sand	15		Steam	1,000	800	Irrigation	Soft and ferruginous.	
13	Wabbaseka, 1½ miles southeast of.	4 S.	7 W.	21	Coarse sand and gravel.	7	1,500	do	300	150	do		Analysis 23, p. 302.
14	Wabbaseka, three-fourths mile north of.	4 S.	7 W.	7	Sand and gravel	15	2,000	do	1,000		do	Alkaline	
15	Wabbaseka, 5 miles east of.	4 S.	7 W.	13, NW. ¼.	White sand	8	390	do	41	85	Domestic and irrigation.		Analysis 24, p. 302.

LAWRENCE COUNTY.

PHYSIOGRAPHY.

Lawrence County lies west of Green and Craighead counties, on the border between the Ozark province and the Gulf Coastal Plain. Its area is 592 square miles, and its population was given by the census of 1910 as 20,001. The western part of the county, embracing a little less than half of the total area, forms a part of the Ozark province, a rugged, dissected area 400 feet or more above sea level; the remainder of the county is included in the Mississippi embayment, which is a part of the Gulf Coastal Plain, and only this part is here considered. In this section agriculture is the chief industry, and includes the raising of cotton, the common cereals, rice, hay, and vegetables.

Along the western margin of the Coastal Plain, in the southern part of the county, is a narrow terrace lying 330 or 340 feet above sea level and 70 to 100 feet above the level of the lowland to the east, which is the northward extension of the Grandglaise terrace of Independence and Jackson counties.

The remainder of the county to the east is included in the Advance lowland, a nearly level or gently rolling plain lying 260 to 280 feet above sea level and sloping slightly to the south. The interstream areas of this lowland are white clay flats, poorly drained and partly wooded. The flood plains bordering the streams are 3 to 6 miles wide and present networks of bayous, abandoned channels, and swamps, separated by higher, rolling, partly forested tracts of sand and sandy loam. Black River flows across the Advance lowland from north of Black Rock a little west of south to the southern boundary, where it is joined by Strawberry River, which flows in from the northwest. Cache River forms the eastern boundary.

GEOLOGY.

The Ozark province in the western part of the county is underlain by Paleozoic rocks of Mississippian and pre-Carboniferous age; the contact between these rocks and the deposits of the Gulf Coastal Plain is a steep, eastward-facing erosion escarpment against which the younger deposits rest; the older rocks extend eastward beneath the younger deposits, reaching greater depths in that direction; they form the basement upon which the deposits of the Coastal Plain rest.

The Grandglaise terrace, which extends from Independence County a short distance into Lawrence County, is composed chiefly of stratified sands and clays probably belonging to the Nacatoch sand of the Upper Cretaceous. These beds, however, are capped by 3 to 10 feet of pebbly sands and loams, probably corresponding in part to the Lafayette formation (Pliocene?) and in part to the loess of Crowleys Ridge. On the crest of the hills immediately west of the Grandglaise area are scattered patches of gravel deposits, probably also representing the Lafayette formation.

Beneath 150 to 180 feet of alluvial deposits the Advance lowland is underlain in descending order by undifferentiated strata of Eocene and Cretaceous age, which at an undetermined depth rest on a basement of Paleozoic rocks; the Eocene and Cretaceous deposits contain water-bearing beds. The alluvial deposits which immediately underlie the Advance lowland consist of loams, clays, sands, and gravels of Pleistocene and Recent age. The Pleistocene deposits which outcrop in the interstream areas, though irregularly bedded, in general grade downward from light-gray silty clays or loams at the surface through fine sands to coarse, water-bearing sands and gravels at the base. At many places, however, low ridges of sand or sandy loam rise above the level of the white clay flats and are probably of Pleistocene age. The flood plains of the streams are underlain to an undetermined depth by Recent alluvial sands, clays, and loams, which probably rest upon the Pleistocene alluvium.

WATER RESOURCES.

GENERAL CONDITIONS.

In the Advance lowland water for domestic and industrial purposes is obtained chiefly from wells, 15 to 100 feet deep, which tap the abundantly water-bearing sands and gravels of the alluvial deposits, though a few wells have been sunk to greater depths. According to the reports of well owners many of the waters are moderately hard, but some are soft and a few are ferruginous. The waters stand in the wells within 5 to 20 feet of the surface.

The strata beneath the alluvial deposits, which (in descending order) are believed to be of Eocene and Cretaceous age and which rest upon a basement of Paleozoic rocks, probably contain important water-bearing beds that would be tapped by wells ranging in depth from 200 feet to an estimated maximum depth of 600 or 700 feet. The upper surface of the basement Paleozoic rocks lies at its greatest depth in the extreme eastern part of the county. Flowing wells probably can not be obtained from the deposits of the Coastal Plain within the limits of the county.

A few small springs issuing from the Eocene deposits which outcrop along the western border of the Advance lowland are used to a small extent for domestic supplies.

LOCAL SUPPLIES.

Walnut Ridge.—At Walnut Ridge (population 1,798, census of 1910) water for domestic and industrial uses is obtained chiefly from wells 30 to 100 feet deep. The general character of the strata underlying the town and the surrounding country may be understood by referring to the logs of two wells used for irrigation (p. 205).

Alicia.—At Alicia (population 168, census of 1910) the St. Louis, Iron Mountain & Southern Railway obtains water for the boiler supply of locomotives from a well 77 feet deep (No. 1, p. 206), a log of which is given as follows:

Log of well of the St. Louis, Iron Mountain & Southern Railway at Alicia.

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Tough clay	8	8
Yellow quicksand	55	63
Sand and gravel, water bearing	14	77

Black Rock.—Black Rock (population 1,078, census of 1910) is on the border between the Ozark province and the Gulf Coastal Plain. Many of the wells in the vicinity pass through a thin covering of deposits of the Coastal Plain and enter the underlying Paleozoic rocks, but some obtain water from sands and gravels at the base of the deposits of the Coastal Plain. A well of the latter kind is owned by Clay Sloan, who has furnished the following log:

Log of well of Clay Sloan, 1 mile west of Black Rock.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	52	52
Argillaceous sand and gravel	3	55

Lynn.—Lynn is also on the border between the Ozark province and the Gulf Coastal Plain; the Paleozoic rocks are overlain by 20 to 50 feet of clays, sands, and gravels of post-Paleozoic age; many of the wells tap the sands and gravels which are water bearing. The log of a well owned by O. F. Rider, which entered the Paleozoic rocks at a depth of 46 feet, is as follows:

Log of well of O. F. Rider, 1 mile west of Lynn.

	Thickness.	Depth.
Tertiary:	*Feet.*	*Feet.*
Unconsolidated materials, character not reported	46	46
Paleozoic:		
Limestone	277	323

Wells for irrigation.—In the Advance lowland the soil, topography, and water supply afford favorable conditions for the rapid growth of the rice-growing industry, and water for irrigating rice lands is obtained from wells tapping the water-bearing sands and gravels of the alluvial deposits and yielding 800 to 2,500 gallons a minute. Detailed information concerning two irrigation wells near Walnut Ridge is given in the table on page 206 (Nos. 6 and 7), and the logs are as follows:

Log of well of S. C. Dowell, 1 mile northeast of Walnut Ridge.

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Gray gumbo soil	6	6
Clay	15	21
Fine sand	15	36
Clay	10	46
Coarse sand and fine gravel	19	65
Coarse gravel, water bearing	112	177

Log of well of Robinson & Cornett, 1½ miles southeast of Walnut Ridge.

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Clay	3	3
Hardpan	11	14
Sand, quicksand, and fine gravel	51	65
Coarse gravel, water bearing	16.5	81.5

Wells in Lawrence County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Alicia				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.	1902	259±	77	6	63-77		Pleistocene alluvium.
2	Black Rock				C. H. Martin	Chas. Smith and Geo. Shale.	Owner	1906	265±	80	6	70		Paleozoic (?) rocks.
3	Black Rock, 1 mile west of.				Clay Sloan	Geo. Henderson	do	1901		55	6	67-70		Lafayette (?) formation.
4	Hoxie				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.		274	65	10			Pleistocene alluvium.
5	Lynn, 1¼ miles west of	16 N.	3 W.	23, SE. ¼	O. F. Rider	Worth Drilling Co., Worth.	Owner	1910		323	5	319		Paleozoic rocks.
6	Walnut Ridge, 1 mile northeast of.	17 N.	1 E.	25, SE. ¼	S. C. Dowell	Layne & Bowler, Stuttgart.	do	1910	277	177	11⅝	65-177		Pleistocene alluvium.
7	Walnut Ridge, 1½ miles southeast of.	16 N.	1 E.	1, NE. ¼	Robinson & Cornett.	J. E. Brown and A. D. Cornett.	A. D. Cornett	1911	276±	81½	9⅝	65-81½		Do.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Galls.*						
1	Alicia				Sand and gravel	15					Boilers		13.5 feet of $5\frac{1}{2}$-inch No. 6 Cook strainer in lower part of well. Well yields 1,500,000 gallons per month. Analysis 25, p. 302.
2	Black Rock				Limestone	70		Wind.	$250		Domestic	Hard	Entered rock at a depth of 12 or 15 feet.
3	Black Rock, 1 mile west of.				Gravel	20		Hand.	75		do	do	
4	Hoxie										Boilers		Well yields 7,000,000 gallons per month. Analysis 26, p. 302.
5	Lynn, $1\frac{1}{4}$ miles west of.	16 N.	3 W.	23, SE. $\frac{1}{4}$	Limestone	80			350		Domestic	Hard	Entered rock at a depth of 46 feet.
6	Walnut Ridge, 1 mile northeast of.	17 N.	1 E.	25, SE. $\frac{1}{4}$	Coarse gravel	12	2,500	Steam.	2,700		Irrigation		65 feet of 24-inch steel pit; 22 feet of $11\frac{5}{8}$-inch casing, and 90 feet of $11\frac{5}{8}$-inch strainer. Analysis 27, p. 302.
7	Walnut Ridge, $1\frac{1}{2}$ miles southeast of.	16 N.	1 E.	1, NE. $\frac{1}{4}$	Gravel	14	800	Gas.	400	510	do	Hard	

LEE COUNTY.

PHYSIOGRAPHY.

Lee County, in the eastern part of the State adjacent to the northwestern part of the State of Mississippi, has an area of 601 square miles and a population, according to the census of 1910, of 24,252. Agriculture, which includes the raising of cotton, cereals, and in lesser quantities potatoes, tobacco, and sorghum, is one of the principal industries; rice growing has been introduced in the county and in the area west of Crowleys Ridge will probably become important. Lumbering is another important industry. At Marianna, the county seat, there are several large lumber mills, a spoke factory, a brick-making plant, and a large cottonseed-oil mill.

The county is in the Mississippi embayment of the Gulf Coastal Plain and is topographically subdivisible into three parts, as follows: Crowleys Ridge, the Advance lowland, and the Mississippi lowland.

Crowleys Ridge, which trends north and south a little east of the center of the county, is interrupted by a gap 6 to 8 miles wide through which L'Anguille River flows from northwest to southeast. Only the southern nose of the part of the ridge north of the gap appears in this county. The part of the ridge south of the gap is a hilly, partly wooded area, 3 to 5 miles wide, extending from the southern boundary northward to Marianna, a distance of 6 miles; the maximum elevation of the ridge has not been exactly determined, but is probably between 325 and 375 feet above sea level, or 125 to 150 feet above the lowlands to the east and west; the eastward-facing slope of the ridge is steeper than the westward-facing slope, though both are sharply defined. The Advance lowland, which includes the part of the county west of Crowleys Ridge, is in general a plain 200 to 230 feet above sea level. The interstream areas are gently undulating, being in part wooded and in part open, grass-covered prairies. The broad, slightly depressed flood plains of the streams are heavily timbered and are interspersed with swamps, shallow lakes, and bayous. The Mississippi lowland includes the part of the county east of Crowleys Ridge, a poorly drained, heavily timbered plain lying 200 to 220 feet above sea level; swamps, bayous, and abandoned stream channels are numerous.

Mississippi River forms the eastern boundary of the county; St. Francis River flows from north to south, east of Crowleys Ridge, and joins the Mississippi just south of the southern boundary in Phillips County. L'Anguille River enters the county west of Crowleys Ridge, flows from northwest to southeast through a gap in the ridge and joins St. Francis River. The western part of the county is drained by Big Creek, a tributary of White River.

GEOLOGY.

Crowleys Ridge, to a height of 50 to 80 feet or more above its base, is composed of irregularly bedded sands and clays, in part lignitic, belonging to the Jackson formation of the Eocene. Eocene deposits representing the Jackson formation, and in descending order several formations older than the Jackson, underlie Crowleys Ridge to an estimated depth of 1,200 feet or more; they are underlain by deposits of Cretaceous age, which at an estimated depth of 3,000 feet or more rest upon a basement of rocks believed to be of Paleozoic age. The Eocene and Cretaceous deposits underlie the remainder of the county beneath 125 to 200 feet of alluvial deposits and contain important water-bearing beds. In Crowleys Ridge the Eocene strata are overlain unconformably by 10 feet or more of coarse sands and gravels belonging to the Lafayette formation (Pliocene?), above which are 50 to 100 feet of calcareous loess forming the capping material of the ridge. In places the loess contains numerous fossil remains of land shells.

The Advance lowland west of Crowleys Ridge is underlain to a depth of 125 to 200 feet by loams, clays, sands, and gravels of Pleistocene and Recent age. The Pleistocene deposits rest unconformably upon Eocene strata throughout the area, and outcrop in the interstream areas; although irregularly bedded, in general they grade downward from silty clays, loams, or fine sands at the surface through fine sands to coarse, water-bearing sands and gravels at the base. In the flood plains of the streams the Pleistocene deposits are overlain by an undetermined thickness of alluvial loams, clays, sands, and gravel. The Mississippi lowland east of Crowleys Ridge is underlain to an estimated depth of 150 to 225 feet by Quaternary alluvial loams, clays, sands, and gravels. Here the surface materials are probably of Recent age, but Pleistocene alluvium may intervene between the Recent and the underlying Eocene deposits. The coarser phases of the alluvium contain water in great quantities.

WATER RESOURCES.

GENERAL CONDITIONS.

Domestic water supplies are obtained chiefly from wells 25 to 150 feet deep. In the lowlands they tap the abundantly water-bearing sands and gravels of the Quaternary alluvium, the waters of which stand in the wells 10 to 50 feet below the surface. In Crowleys Ridge the source is either the sands and gravels of the Lafayette formation (Pliocene?) or the sands of the underlying Jackson formation (Eocene) the waters of which will rise to within 30 to 140 feet of the surface, depending upon the depth and the elevation of the mouth of the well. In the lowlands the hydrostatic pressure of the deeply buried Eocene and Cretaceous waters is sufficient to bring them within less than 100 feet of the surface, and in the Mississippi lowland wells 1,000 feet or more in depth will probably flow. As reported by the well owners, some of the well waters are soft, some are hard, and some are ferruginous; in general they are suitable for all ordinary domestic and industrial uses. Small springs are fairly common in Crowleys Ridge, particularly at the foot of the steep, east-facing slopes, and are utilized to a small extent for domestic and farm supplies.

LOCAL SUPPLIES.

Marianna.—Marianna (population 4,810, census of 1910), the county seat, owns a municipal water-supply system, information concerning which has been furnished by the mayor, T. E. Wood. Water is obtained from two 6-inch wells 619 feet deep (Nos. 3 and 4, p. 212); the water rises within 60 feet of the surface and is forced to a small reservoir by means of two air compressors having a combined capacity of 1,000 gallons a minute, whence it is pumped to an elevated tank having a capacity of 70,000 gallons, from which it is distributed through 5 miles of mains. The tank pressure is 60 pounds per square inch and the direct pressure from the pumps for fire protection is 150 pounds per square inch. The daily consumption is 235,000 gallons for domestic use and 15,000 gallons for manufacturing. The water is soft.

A well, 125 feet deep and 3 inches in diameter, is owned by the Marianna Light & Power Co. (No. 5, p. 212), the log of which is as follows:

Log of well of Marianna Light & Power Co., Marianna.

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Loam	1	1
Clay	3	4
Blue mud	86	90
Blue mud and quicksand	10	100
Clay	10	110
Sand and gravel, water bearing	15	125

Lagrange.—A well owned by the Kennedy Heading Co., 4 miles east of Lagrange, is 176 feet deep (No. 1, p. 212); the log is as follows:

Log of well of Kennedy Heading Co., 4 miles east of Lagrange.

	Thickness.	Depth.
Pleistocene (?):	*Feet.*	*Feet.*
Red clay (loess?)	40	40
Interbedded layers of blue, brown, and white clay	40	80
Pliocene (?) (Lafayette formation?):		
Sand, gravel, and clay	90	170
Gravel, water bearing	6	176

The following is the log of a 273-foot well about 5 miles east of Lagrange owned by J. O. Hale, of Marianna (well No. 2, p. 212):

Log of well of J. O. Hale, about 5 miles east of Lagrange.

	Thickness.	Depth.
Pleistocene (?):	*Feet.*	*Feet.*
Red clay (loess?)	50	50
Blue clay (loess?)	50	100
Pliocene (?) (Lafayette formation?):		
Sand, gravel, and blue clay, mixed	10	110
Eocene:		
Interbedded blue, white, and brown clays	90	200
Fine sand and clay, mixed, with a layer of hard sand a few inches thick at top	68	268
White sand, water bearing; stopped drilling on hard rock	5	273

Wells for irrigation.—Rice has been successfully grown on the prairies in the western part of the county. Detailed information concerning several wells in the vicinity of Moro, used for irrigating rice lands, is given on pages 212–213 (wells Nos. 7–11). The wells range in depth from 145 to 195 feet and yield from 2,000 to 3,500 gallons a minute. The water is obtained from the Pleistocene alluvial sands and gravels underlying the Advance lowland. The log of S. D. Johnston's irrigation well is as follows:

Log of well of S. D. Johnston, 2¾ miles northwest of Moro.

(No. 10, p. 212.)

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Fee*
Hard clay or "hardpan"	15	15
Very fine sand gradually increasing in coarseness to coarse gravel, water bearing; stopped drilling on clay	180	195

Wells in Lee County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Lagrange, 4 miles east of	1 N.	4 E.	28?	Kennedy Heading Co.	E. C. Guerrant, Marianna.	O. C. Norment, Marianna.			176	2½	170		Eocene (?) deposits.
2	Lagrange, 5 miles east of	1 N.	4 E.	23	J. O. Hale, Marianna.	do	do	1912		273	2	268		Eocene deposits.
3	Marianna (well No. 1)				Town	do	T. E. Wood		236±	619	6			Do.
4	Marianna (well No. 2)				do	do	do		236±	619	6			Do.
5	Marianna, one-half mile south of post office.				Marianna Light & Power Co.	do	Owners	1909	236	125	3	125	30–100	Pleistocene alluvium.
6	Marianna, 3 blocks from post office.				Marianna Ice & Storage Co.	do	do	1908	236±	116	6	110		Do.
7	Moro	3 N.	1 E.	33, SE. ¼	Johnston Stock Co., Marianna.	Layne & Bowler, Stuttgart.	A. W. Bonner.	1909		165	10			Do.
8	Moro, 2 miles northwest of.	3 N.	1 E.	33, SW. ¼	do	do	do	1911		145	16			Do.
9	Moro, 2 miles north of	2 N.	1 E.	4, NW. ¼	do	do	S. D. Johnston	1909		145	13	129–145		Do.
10	Moro, 2¾ miles northwest of.	3 N.	1 E.	32, SW. ¼	S. D. Johnston, Marianna.	do	Owner	1911		195	13	178–195		Do.
11	Moro, 7½ miles northwest of.	3 N.	1 W.	10	C. E. Rimmer, Wheetley.	Arkansas Well Co., Brinkley.	do	1910	200±	148	12	125–148		Do.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Galls.*						
1	Lagrange, 4 miles east of.	1 N.	4 E.	28?	Gravel	125		Steam.			Boilers		170 feet of 2½-inch casing.
2	Lagrange, 5 miles east of.	1 N.	4 E.	23	White sand	140		Gas			Domestic		265 feet of 2-inch casing, followed by 8 feet of strainer.
3	Marianna (well No. 1)				do	60	400	Air			Municipal supply.		Combined yield is used for municipal supply; total daily consumption, 250,000 gallons. Analysis 28, p. 302.
4	Marianna (well No. 2)				do	60	600	do			do		
5	Marianna, one-half mile south of post office.				Gravel	30		Steam.	$200		Boilers	Soft with magnesium carbonate.	
6	Marianna, 3 blocks from post office.					50?	35		600		Manufacture of ice.	Ferruginous	
7	Moro	3 N.	1 E.	33, SE. ¼	Sand and gravel	26	2,000	Steam.	1,750	750	Irrigation	Hard	
8	Moro, 2 miles northwest of.	3 N.	1 E.	33, SW. ¼	do	26	3,000	do	1,750	750	do	do	
9	Moro, 2 miles north of	2 N.	1 E.	4, NW. ¼	do	26	3,500	do	2,300		do		24-inch steel pit to depth of 65 feet, followed by 13-inch casing, then 40 feet or more of 13-inch strainer to bottom of well. Analysis 29, p. 302.
10	Moro, 2¾ miles northwest of.	3 N.	1 E.	32, SW. ¼	do	26	3,500	do	2,300		do		24-inch steel pit to depth of 65 feet, followed by 13-inch casing, then by 40 feet or more of 13-inch strainer to bottom of well. Analysis 30, p. 302.
11	Moro, 7½ miles northwest of.	3 N.	1 W.	10	Gravel	32	800		1,400	764	do	Hard	Pit 60 feet deep and 30 inches in diameter, and 88 feet of 12-inch casing and strainer.

LONOKE COUNTY.

PHYSIOGRAPHY.

Lonoke County, in the east-central part of the State, comprises an area of 794 square miles and has a population (census of 1910) of 27,983. Agriculture, lumbering, and stock raising are the chief industries. The first commercial crop of rice produced in the State was raised near Lonoke, the county seat, in 1904, since which time the industry has rapidly grown.

A few square miles in the northwestern part of the county, included in the Ozark province, is hilly, the tops of the hills and ridges lying 400 to 600 feet above sea level. The remainder of the county is included in the Gulf Coastal Plain, which is here separable into Chinquapin Ridge and the Advance lowland.

Chinquapin Ridge, or the "sandhills" lying just east of the Ozark province and east of Austin and Cabot, is a sandy ridge having a maximum width of several miles, a north-south extent of approximately 12 miles, and an elevation of 375 or 400 feet above sea level. The Advance lowland is a nearly level or gently rolling plain, 200 to 250 feet above sea level, and sloping slightly to the south. The interstream areas present numerous tracts of open, grass-covered prairies, separated by slightly lower timbered lands. Grand Prairie, an irregular but in general continuous tract of prairie, lies northeast of Bayou Two Prairie and extends from a point 6 miles northwest of Lonoke southeastward through Lonoke, Prairie, and Arkansas counties (p. 27); Prairie Longue, a similar prairie, extends southeastward through Lonoke County south of Bayou Two Prairie, and parallel to Grand Prairie (p. 27). The broad flood plains of the streams, for the most part swampy and heavily timbered, are characterized by numerous ponds, abandoned stream channels, and bayous. The southwestern part of the county falls within the flood plain of Arkansas River and supports a vigorous growth of timber.

The county is drained chiefly by Cypress Bayou, Wattensas Bayou, Bayou Two Prairie, Bayou Meto, and Indian Bayou.

GEOLOGY.

Paleozoic rocks of Pennsylvanian age outcrop in the Ozark province in the northwest and are present beneath deposits of the Coastal Plain throughout the remainder of the county. The Paleozoic rocks are separated from the deposits of the Coastal Plain by a relatively steep southeastward-facing erosion escarpment along the line of which the eroded surface of the Paleozoic rocks passes under the deposits of the Coastal Plain and extends to the eastward beneath them, reaching greater depths in that direction.

Strata of Cretaceous age, dipping slightly to the southeast, rest upon the Paleozoic basement rocks, but so far as known do not outcrop in this county; the Upper Cretaceous fossils *Exogyra costata* Say and *Cardium eufaulense* Conrad have been recognized in a calcareous sandstone taken from a depth of 15 or 20 feet in a well at Cabot (p. 40). The Cretaceous deposits are overlain by southeastward-dipping strata of Eocene age; limestones of the Midway formation have been observed in outcrops near Cabot (p. 49), and probably the beds composing Chinquapin Ridge east of Austin and Cabot belong to the Eocene.

Throughout the Advance lowland the Eocene deposits are overlain and concealed by 125 to 200 feet of Quaternary alluvial loams, clays, sands, and gravels of Pleistocene and Recent age. The Pleistocene alluvium, which rests upon the Eocene strata and outcrops in the interstream areas, though irregularly bedded grades downward in general from gray compact silty clays at the surface through fine sands to coarse water-bearing sands and gravels at the base. The Recent alluvium immediately underlies the flood plains of the present streams.

WATER RESOURCES.

GENERAL CONDITIONS.

Ordinary supplies.—In the Advance lowland water for domestic, industrial, and irrigation uses is obtained chiefly from wells 15 to 180 feet deep, tapping the abundantly water-bearing sands and gravels of the Quaternary alluvial deposits, the waters of which stand in the wells 10 to 50 feet below the surface. As reported by the well owners, some of the waters are soft, some are hard, and some are ferruginous; with an occasional exception, they are suitable for all ordinary uses. The undifferentiated Eocene and Cretaceous deposits, which in the southeastern part of the county probably reach a thickness of 1,000 feet or more, contain important water-bearing beds, the waters of which are probably under sufficient hydrostatic pressure to bring them within less than 100 feet of the surface, but not sufficient to cause overflows at the surface. Cisterns are in use at some places along the western border of the Gulf Coastal Plain, and particularly at Cabot.

Irrigation.—The rice-growing industry in Arkansas had its beginning in this county (pp. 144–149). From the first water for irrigating the rice lands has been obtained from wells, and because of the great quantities of water obtainable from the sands and gravels of the Quaternary deposits at depths of 25 to 180 feet wells have continued to be used. The water stands in the wells at depths of 10 to 50 feet and is lifted by means of powerful machinery, the yield per minute ranging from 600 to 4,000 gallons for each well. The cost of drilling and equipping the wells ranges from $580 to $5,000, the difference in cost depending chiefly on the depth and diameter of the wells and on the capacity of the pumping machinery. The average cost, based on 15 wells, is about $811 for each 1,000 gallons of yield per minute, or at the rate of 81 cents for each gallon of yield per minute. Detailed information concerning 21 irrigation wells is given in the table on pages 220–223.

LOCAL SUPPLIES.

Lonoke.—Lonoke (population 1,547, census of 1910), the county seat, is equipped with a municipal water-supply system, owned by W. Y. Bransford, information concerning which has been furnished by the owner and by the postmaster. Water is obtained from two wells, one of which is 103 feet deep and the other 105 feet deep (Nos. 23, 24, p. 222). The water is distributed from a tank having a capacity of 18,000 gallons, and the daily consumption is about 36,000 gallons; the water is ferruginous.

A log of the 105-foot well, the figures in which are approximations, is as follows:

Log of 105-foot well at waterworks plant, Lonoke.

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Yellowish clay	27	27
Reddish clay, rather hard	3	30
Sand and gravel	18	48
Reddish, sticky clay	28	76
Thin layers of blue clay	4	80
Sand and gravel, water bearing	25	105

Holland.—At Holland station, 4 miles southwest of Cabot, the St. Louis, Iron Mountain & Southern Railway Co. drilled in 1911 a 1,352-foot well, the log of which is as follows:

Log of well owned by the St. Louis, Iron Mountain & Southern Railway Co., Holland.

[No. 16, p. 220.]

	Thickness.	Depth.
Quaternary or Tertiary:	*Feet.*	*Feet.*
Surface material, character not stated	36	36
Paleozoic:		
Black shale	789	825
Dark-gray sand	57	882
Light shale	11	893
Black sand	14	907
Shale and hard shells	6	913
Hard black sand	14	927
Brown shale	78	1,005
Brown sand	80	1,085
Black shale	90	1,175
Black sand	50	1,225
Light shale	127	1,352

A 12½-inch casing was used to a depth of 141 feet and a 10-inch casing to a depth of 365 feet. As no water was obtained, the casings were withdrawn and the well abandoned.

Cabot.—Branner[1] has published the two following logs of wells at and near Cabot:

Log of well at Neeley & Neeley's ginhouse, Cabot.

[No. 2, p. 220.]

	Thickness.	Depth.
	Feet.	*Feet.*
Red and sandy clays	39	39
Calcareous clay (Cretaceous) [or Midway (Eocene)]	1	40
Marl (Cretaceous)	6	46
Carboniferous shale to the bottom of the well	70	116

Log of well in NE. ¼ SW. ¼ sec. 25, T. 4 N., R. 10 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	2	2
Red clay	10	12
Sandy clay	16	28
Calcareous clay (Cretaceous) [or Midway (Eocene)]	1	29
Marl (Cretaceous); stopped on Carboniferous shale	8	37

The log of another well, of interest chiefly because of the geologic information it affords, is as follows:

Log of well, known as the Nursery well, owned by J. P. Murrel, Cabot.

	Thickness.	Depth.
	Feet.	*Feet.*
Not reported	15	15
Gray calcareous clay	5	20
Black clay and gray calcareous sandstone, with shells; contained iron-stained gravel at depth not stated; stopped digging on hard blue rock (Paleozoic)	26	46

Materials collected between the depths of 20 and 46 feet in this well consist in part of dark-gray calcareous clay, with numerous fragments of shells, some of which are arranged in seams and pockets, and in part of gray calcareous fossiliferous sandstone, with fragments of lignite. Both the clay and sandstone contain Upper Cretaceous fossils, probably belonging to the Nacatoch sand. (See p. 40.)

[1] Branner, J. C., The clays of Arkansas: U. S. Geol. Survey Bull. 351, p. 133, 1908.

Wells for irrigation.—Wells for irrigating rice lands have been drilled at many places on the prairies, particularly in the vicinity of Carlisle, Lonoke, England, Cobb, and Scott. Detailed information concerning 21 of them is given in the table on pages 220–223. The following are logs of irrigation wells:

Log of well of W. H. Fuller, 4½ miles southwest of Carlisle.

[No. 3, p. 220.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
In descending order, hard clay, yellow clay, red clay, and white clay	25	25
Quicksand and gravel	40	65
Gravel and small bowlders	75	140

Log of well of Mr. Hubbard, 1½ miles east of Carlisle.

[No. 6, p. 220.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Red clay	19	19
Fine sand and thin strata of clay	19	38
Quicksand	40	78
Fine and coarse sand containing logs of wood	62	140
Gravel and bowlders, water bearing; stopped on blue clay, probably of Eocene age	40	180

Log of well of Robert Medendorp, 1½ miles north of Carlisle.

[No. 5, p. 220.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1	1
Yellow subsoil	2	3
Clay	12	15
Fine yellow sand	85	100
Blue clay	5	105
Mixed clay	15	120
Coarse sand, water bearing	5	125
Gravel	21	146
Gravel and bowlders	4	150
Blue clay	1	151
Sand, gravel, and bowlders	5	156
Blue clay	2	158

Log of well of J. H. Sims, 3 miles southwest of Carlisle.

[No. 8, p. 220.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Sandy loam	2	2
Hard red clay	18	20
Sand	10	30
Sand and fine gravel	40	70
Gravel, water bearing	20	90
Coarse gravel, water bearing; stopped on clay	41	131

Log of well of B. F. Fromholz, 4 miles southeast of Lonoke.

[No. 21, p. 220.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Clay	33	33
Quicksand	10	43
Clay	10	53
Quicksand and gravel	40	93
Gravel, water bearing	37	130
Clay, containing a mixture of gravel and bowlders	70	200
Eocene:		
Hard sand	40	240
Sand and clay	60	300

Wells in Lonoke County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.					Feet.	Feet.	Inches	Feet.	Feet.	
1	Cabot				O. H. Beasley		Owner		260±	100?	48			Nacatoch sand?
2	Cabot (at ginhouse)				Neeley and Neeley		J. C. Branner [a]		275±	116				
3	Carlisle, 4½ miles southwest of.	1 N.	7 W.	8, W. ½ of NW. ¼.	W. H. Fuller, Lonoke.	Owner	Owner			140	9⅝	25–140		Pleistocene alluvium.
4	Carlisle (near)	2 N.	7 W.	9	W. N. Hilbert	S. Jordon	do	1910		161	9⅝	60–161		Do.
5	Carlisle, 1½ miles north of.	2 N.	7 W.	10, SW. ¼	Robert Medendorp	F. A. Raprich, Lonoke.	do	1907		158	9⅝	125–156		Do.
6	Carlisle, 1½ miles east of.	2 N.	7 W.		Mr. Hubbard	Joe Peters, Brinkley.	F. G. Norton, Brinkley.			180				Do.
7	Carlisle, 3 miles east of.	2 N.	7 W.	24, NE. ¼	C. E. Smiley	Mark Brown	Owner	1911		165	13			Do.
8	Carlisle, 3 miles southwest of.	2 N.	7 W.	32	J. H. Sims	Elmer Morris	do	1911		131	10	70–131	50	Do.
9	Carlisle, 3 miles north of.	3 N.	7 W.	34, W. ½ of SW. ¼.	W. J. D. Alexander.	Mr. Bitzler	do			168	8¼			Do.
10	Carlisle, 6 miles southwest of.	1 N.	7 W.	6, NW. ¼	Elmer Morris	Owner	do	1910		152	10	80–152		Do.
11	Carlisle, 6½ miles west of south of.	1 N.	7 W.	19	Wm. Zimmerman, Burnside, Ill.	Fuller & Morris	J. R. Moery	1905		155	10	90–155		Do.
12	England, 1 mile west of.				Morris & Gray	Layne & Bowler, Stuttgart.	G. W. Morris	1909	228±	165	11	60–165		Do.
13	England, one-half mile northwest of.	2 S.	9 W.		Arkansas Cotton Oil Co.	Corless Well Co., Memphis, Tenn.	R. J. Lanford	1902	228±	110	6			Do.
14	England, 600 yards northwest of post office.	2 S.	9 W.	10	do	Cook Well Co., St. Louis, Mo.	do	1902	227±	80	5			Do.
15	England, one-half mile southeast of.				R. J. Lanford	J. H. Massey	Owner	1911	231±	70	1¼	50–70	20, 35	Do.
16	Holland				St. Louis, Iron Mountain & Southern Ry.		J. R. Stephens, chief engineer.	1911	250±	1,352	10			Do.

[a] Branner, J. C., The clays of Arkansas: U. S. Geol. Survey Bull. 351, p. 133, 1908.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Galls.*						
1	Cabot										Domestic	Hard	Dug type, curbed with brick. Used by railroad employees.
2	Cabot (at ginhouse)												Encountered Carboniferous shale at depth of 46 feet.
3	Carlisle, 4½ miles southwest of.	1 N.	7 W.	8, W. ½ of NW. ¼.	Sand and gravel	25	2,000	Steam.	$560	$160	Domestic and irrigation.	Soft	
4	Carlisle (near)	2 N.	7 W.	9		45		do			Irrigation		50 feet of pit and 110 feet of 9⅝-inch casing and strainer.
5	Carlisle, 1½ miles north of.	2 N.	7 W.	10, SW. ¼	Sand and gravel	44	2,500	do	1,000		do		Pit 50 feet deep and 6 feet square. Analysis 31, p. 302.
6	Carlisle, 1½ miles east of.	2 N.	7 W.		do						do		
7	Carlisle, 3 miles east of.	2 N.	7 W.	24, NE. ¼		45	1,700	Steam.	2,200		do	Sulphurous	
8	Carlisle, 3 miles southwest of.	2 N.	7 W.	32	Gravel	31		do	520	190	do	Hard	
9	Carlisle, 3 miles north of.	3 N.	7 W.	34, W. ½ of SW. ¼.	do	28	750	do	550	125	Domestic and irrigation.	Soft	
10	Carlisle, 6 miles southwest of.	1 N.	7 W.	6, NW. ¼	Sand and gravel	27	1,500	do	600	125	do		
11	Carlisle, 6¼ miles west of south of.	1 N.	7 W.	19	Gravel	30	2,100	do	620	175	Irrigation	Soft	
12	England, 1 mile west of.					10	2,500	do	2,300		do	Ferruginous	
13	England, one-half mile northwest of.	2 S.	9 W.		Sand and gravel			do			do	do	
14	England, 600 yards northwest of post office.	2 S.	9 W.	10				do			Boilers		Analysis 32, p. 302.
15	England, one-half mile southeast of.							Hand.	35	3	Domestic		Driven type; 1¼-inch casing extends to depth of 70 feet. Analysis 33, p. 302.
16	Holland												No water obtained and well abandoned; rocks of Paleozoic age were penetrated from a depth of 36 feet to the bottom of the well.

Wells in Lonoke County—Continued.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
								Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*		
17	Jebb, 1½ miles northeast of.	2 S.	8 W.	4	J. E. Biscoe	Layne & Bowler, Stuttgart.	Owner	1910		120	24			
18	Lonoke, 1¼ miles southwest of.				W. E. & J. N. Wheat.	W. H. Fuller	W. E. Wheat			154	9⅝			Pleistocene alluvium.
19	Lonoke, 1½ miles west of	2 N.	9 W.	24, NW. ¼	W. P. Fletcher		Owner	1904	240±	120	8	65–120	24	Do.
20	Lonoke, 3 miles north of				Rowena Rice Co	W. B. Johnson, Memphis, Tenn.	Duff Green	1909		160	11⅝	90–160		Do.
21	Lonoke, 4 miles southeast of.	2 N.	8 W.	33, SW. ¼	B. F. Fromholz	F. A. Raprich, Lonoke.	Owner	1906		300	9⅝	100–130		Do.
22	Lonoke, 6 miles southeast of.	1 N.	8 W.	11, NE. ¼	W. H. Hicks	United Well Co., Stuttgart.	do	1912		175	9⅝	75–175		Do.
23	Lonoke				W. Y. Bransford		do	1901		103	3	78–103		Do.
24	do				do		do	1902		105	4	80–105		Do.
25	Lonoke, 1½ miles southwest of.	2 N.	9 W.	24, NW. ¼	W. H. Fuller	Owner	do	1908		148	10	26–148		Do.
26	Lonoke, 2¼ miles southeast of.	2 N.	8 W.	28, SW. ¼	do	do	do	1907		152	10	26–152		Do.
27	Scott (Pulaski County), 5 miles east of (in Lonoke County).	1 N.	9 W.	30	T. W. Steele	John Graham	do	1907		84	10	70–84	23	Do.

	Location. Place.	T.	R.	Sec.	Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
						Feet.	*Galls.*						
17	Jebb, 1½ miles northeast of.	2 S.	8 W.	4		10	1,500	Steam.	$2,300		Domestic and irrigation.	Hard	
18	Lonoke, 1¼ miles southwest of.				Gravel	32	1,500	...do...			Irrigation	...do...	
19	Lonoke, 1½ miles west of.	2 N.	9 W.	24, NW. ¼.	Sand and gravel	24	1,200	...do...	500	160	Domestic and irrigation.	Soft	100 feet of 8-inch casing and 20 feet of 6-inch Cook strainer. Irrigates 100 acres.
20	Lonoke, 3 miles north of.				...do...	41	800		1,500	250	Irrigation		Analysis 35, p. 302.
21	Lonoke, 4 miles southeast of.	2 N.	8 W.	33, SW. ¼.	Gravel	40	700		1,000		...do...	Soft	
22	Lonoke, 6 miles southeast of.	1 N.	8 W.	11, NE. ¼.	Sand and gravel	35	2,000	Steam.	2,300		Domestic and irrigation.		24-inch pit to depth of 90 feet. Within the pit is 80 feet of 10-inch casing, followed by 20 feet of 13-inch casing, followed by 75 feet of 13-inch strainer to bottom of well. Analysis 37, p. 302.
23	Lonoke				Gravel	30					Municipal supply.	Ferruginous	The combined yield of these wells furnishes the municipal water supply; the daily consumption is 36,000 gallons.
24	...do...				...do...	30					...do...	...do...	
25	Lonoke, 1½ miles southwest of.	2 N.	9 W.	24, NW. ¼.	Sand and gravel	26	2,000	Steam.	572	125	Domestic and irrigation.		Analysis 34, p. 302.
26	Lonoke, 2¼ miles southeast of.	2 N.	8 W.	28, SW. ¼.	...do...	26	2,000	...do...	608	125	...do...	Soft	
27	Scott (Pulaski County), 5 miles east of (in Lonoke County).	1 N.	9 W.	30	Fine gravel	12	600				Irrigation	Hard	Abandoned.

MISSISSIPPI COUNTY.

PHYSIOGRAPHY.

Lying between Craighead and Poinsett counties on the west, Tennessee on the east, and Missouri on the north, Mississippi County comprises an area of 792 square miles; Mississippi River forms its eastern boundary. At the time of the census of 1910 the population of the county was 30,468. Agriculture and lumbering are the chief industries. The soil is very fertile and produces large crops of cotton, corn, and hay. Except where cleared for cultivation, the surface is heavily timbered, and much lumber is produced.

The county is entirely within the Mississippi lowland. The surface is a nearly level or gently rolling alluvial plain lying 235 to 260 feet above sea level and sloping slightly to the south and west. The highest land in the county, with the exception of Big Lake highlands, a tract of slightly elevated land 2 to 3 miles wide lying west of Big Lake and extending northward into Missouri, is immediately west of the river. Swamps, bayous, and abandoned stream channels are numerous and much of the area is subject to overflow. The greater part of the drainage passes westward into St. Francis River. The western half of the county, with the exception of Big Lake highlands, is included in the area known as the St. Francis Sunk Lands, where the bayous and swamps are separated by low ridges of sandy loam dotted with the so-called "sand blows" of the region. The sand blows are low circular or irregular mounds of clean white sand supposed to have been discharged from underground sources through crevices during the time of the New Madrid earthquake in 1811–12.

GEOLOGY.

The materials underlying the surface of this county to depths estimated at 150 to 225 feet are Quaternary alluvial loams, clays, sands, and gravels. The immediate surface materials are probably all of Recent age, though in some of the higher swells, such as Big Lake highlands west of Big Lake, deposits of Pleistocene age may come to the surface. It is probable that strata of Pleistocene age intervene between the Recent deposits and the underlying older deposits, but this has not been definitely proved. Buried logs are encountered in many wells.

The alluvial deposits are underlain by an estimated thickness of 600 to 1,000 feet of Eocene sands and clays, and the latter are in turn underlain by Cretaceous strata. At an undetermined depth, probably 2,000 feet or more, the Cretaceous deposits rest on a basement of rocks believed to be of Paleozoic age.

WATER RESOURCES.

GENERAL CONDITIONS.

Water for domestic and industrial supplies is obtained chiefly from wells 10 to 100 feet deep, which tap the abundantly water-bearing sands of the alluvial deposits the waters of which stand in the wells 1 to 30 feet below the surface. According to the reports of well owners, many of the waters are hard and ferruginous, but some are soft.

Both Eocene deposits and the underlying Cretaceous deposits contain important water-bearing beds the waters of which are under sufficient hydrostatic pressure to bring them nearly to or above the surface. Water has been obtained by wells at Blytheville (1,448 feet), Burdette (1,495.5 feet), and at Wilson (1,567 feet), and probably can be obtained anywhere in the county at depths of 1,400 to 2,000 feet.

LOCAL SUPPLIES.

Osceola.—Osceola (population 1,679, census of 1910), the county seat, owns its municipal water plant and obtains water from an 800-foot well (No. 5, p. 228) information concerning which has been furnished by N. B. Baldwin. The water is forced to a standpipe holding 5,000 gallons by a pump having a capacity of 500 gallons a minute. The standpipe pressure is 55 pounds per square inch and the direct pressure from the pump for fire protection is 90 pounds. The daily consumption is between 50,000 and 60,000 gallons.

Blytheville.—T. W. Davis, mayor, states that the town of Blytheville (population 3,849, census of 1910) has drilled a flowing well 1,448 feet deep (No. 1, p. 228) to supply a proposed municipal water plant. The Chicago Mill & Lumber Co. owns a well 520 feet deep 2 miles west of Blytheville (No. 2, p. 228) a partial log of which follows:

Partial log of well of the Chicago Mill & Lumber Co., 2 miles west of Blytheville.

[Authority, W. P. Orr, chief engineer for the company.]

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	20	20
Quicksand	10	30
Not reported	20	50
Fine sand	10	60
Not reported	20	80
Coarse sand yielding hard water	10	90
Not reported	10	100
Fine sand and small pebbles	10	110
Not reported	30	140
Black material resembling lignite	30	170
Not reported	60	230
Fine, gray quicksand	60	290
Not reported	110	400
Fine sandy material	10	410
Not reported	80	490
Coarse white sand becoming coarser in lower 20 feet	30	520

The materials described to a depth of 140 feet are probably referable to the Quaternary alluvium, and the remainder to the bottom of the well are of Eocene age.

Luxora.—The village of Luxora is equipped with a water-supply system owned by Wood Bros., information concerning which has been furnished by John B. Driver. Water is obtained from Mississippi River and is pumped to a tank having a capacity of 10,000 gallons, from which it is distributed to the consumers through 2 miles of mains. The daily consumption is 10,000 gallons.

Burdette.—A flowing well, owned by the Three States Lumber Co., at Burdette is 1,495 feet deep (No. 4, p. 228). The following is an incomplete log of the well:

Incomplete log of well of the Three States Lumber Co., Burdette.

	Feet.
Sand and gravel at	123
Sand, lignite, and clay	123–1,060
Clay	1,060–1,067
Rock at	1,398
Fine white sand, gravel, and hard clay from the rock to the bottom of the well	1,495.5

The sand and gravel reached at a depth of 123 feet probably represents the basal portion of the Quaternary alluvial deposits. The well probably passed entirely through the Eocene strata which underlie the Quaternary deposits and entered the Cretaceous deposits, although the data are not sufficient to differentiate the beds of the two ages.

Wilson.—A flowing well, owned by Lee Wilson & Co., at Wilson is 1,567 feet deep (No. 7, p. 228). The water is used in boilers at several large sawmills and is the principal domestic supply of the town. No log of the well has been obtained, but according to the informant, Miss June Blackwell, postmistress, rock was struck at a depth of 1,500 feet, and the water, which flows at the surface at the rate of 208 gallons per minute, was obtained from a coarse sand beneath this rock.

Ashport Bend, Mississippi River.—In 1893 four borings were made at Ashport Bend, Mississippi River, Ark., 9 or 10 miles above Osceola, under the auspices of the Mississippi River Commission, the logs of which follow:

Log of boring No. 1, Ashport Bend, Mississippi River, Ark.

[Elevation of mouth of boring about 32.5 feet above extreme low-water level.]

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Sandy loam	10	10
Blue clay	10	20
Silt	15	35
Fine sand	13	48
Sand and gravel	34	82
Silt	9	91
Very fine sand	9	100
Coarse sand and gravel	36.5	136.5
Eocene (?):		
Fine sand	27.5	164

Log of boring No. 2, Ashport Bend, Mississippi River, Ark.

[Elevation of mouth of boring 30 feet above low-water level.]

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Sandy loam	5	5
Blue clay	15	20
Fine sand	5	25
Blue clay	10	35
Sand and gravel	50	85
Coarse sand	15	100
Fine sand	10	110

Log of boring No. 3, Ashport Bend, Mississippi River, Ark.

[Elevation of mouth of boring 30 feet above low-water level.]

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Sandy loam	5	5
Silt	11	16
Blue clay	38	54
Fine sand	11	65
Sand and gravel	40	105
Fine sand	9	114
Coarse sand	20	134
Coarse sand and gravel	12	146
Eocene (?):		
Fine sand	20	166

Log of boring No. 4, Ashport Bend, Mississippi River, Ark.

[Elevation of mouth of boring 28 feet above low water level.]

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Sandy loam	4	4
Blue clay	38	42
Fine sand	33	75
Coarse sand and gravel	12	87
Blue clay	2	89
Very fine sand	6	95
Coarse sand and gravel	30	125
Fine sand	10	135
Sand and gravel	5	140
Eocene (?):		
Fine sand	28	168

Wells in Mississippi County.

No.	Location: Place.	T.	R.	Sec.	Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter, inches.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
									Feet.	Feet.		Feet.	Feet.	
1	Blytheville	15 N.	11 E.		Town		T. W. Davis	1911		1,448	8			Cretaceous.
2	Blytheville, about 2 miles west of, near Chickasawba.	15 N.	11 E.	17, NE. ¼	Chicago Mill & Lumber Co.	Johnson & Fleming, Memphis, Tenn.	W. P. Orr	1906	259	520	6	500		Wilcox (?) formation.
3	Boynton	16 N.	8 E.	29, NE. ¼	Mill Shoals Cooperage Co.		P. E. Files	1907	(a)	41	3	24–41		Quaternary alluvium.
4	Burdette, 400 yards south of post office.	14 N.	11 E.	20, SW. ¼	Three States Lumber Co.	Johnson & Fleming, Memphis, Tenn.	Mr. Gilchrist	1910		1,495.5	6	1,420–1,495.5		Cretaceous.
5	Osceola	13 N.	10 E.		Town		N. B. Baldwin		255	800				Cretaceous (?).
6	Osceola (at hotel)				Mr. Beal		A. F. Crider			440+				Wilcox (?) formation.
7	Wilson	11 N.	10 E.		Lee Wilson & Co.	Johnson & Fleming, Memphis, Tenn.	June Blackwell.		245	1,567				Cretaceous.

No.	Location: Place.	T.	R.	Sec.	Character of principal water-bearing bed.	Level of water above or below surface.	Yield per minute.	Method of lift.	Use.	Quality of water.	Remarks.
						Feet.	Gallons.				
1	Blytheville	15 N.	11 E.			+10	300	Flows.			
2	Blytheville, about 2 miles west of, near Chickasawba.	15 N.	11 E.	17, NE. ¼	Sand	−15			Boilers	Ferruginous	
3	Boynton	16 N.	8 E.	29, NE. ¼	do	−12		Steam	do		Driven type; analysis, 38, p. 302.
4	Burdette, 400 yards south of post office.	14 N.	11 E.	20, SW. ¼		+17		Flows.	Domestic and boilers.		1,420 feet 6-inch casing; 54 feet 5-inch cook strainer; and 21.5 feet of pipe at bottom of strainer; analysis 39, p. 302.
5	Osceola	13 N.	10 E.				500		Municipal supply.		
6	Osceola (at hotel)								Domestic		Assay 37, p. 304.
7	Wilson	11 N.	10 E.		Coarse white sand.	+15(?)	208	Flows.	Domestic and boilers.		

a Elevation, 2 feet below the level of the St. Louis, Iron Mountain & Southern Ry. track.

MONROE COUNTY.

PHYSIOGRAPHY.

Monroe County, in the east-central part of the State, comprises an area of 603 square miles and has a population of 19,907 (census of 1910). Agriculture, lumbering, and stock raising are the chief industries. The agricultural products include cotton, cereals, and vegetables. Rice growing is rapidly becoming important. Wood products are manufactured at several mills at Clarendon, the county seat, and at Brinkley; at the latter place there is also a cottonseed-oil mill.

The county lies within the Advance lowland, one of the topographic divisions of the Gulf Coastal Plain. The surface is, in general, a slightly undulating plain 170 to 210 feet above sea level, sloping slightly to the south. Throughout the greater part of the county east of White River are numerous swamps, bayous, and abandoned stream channels, separated by low, rolling ridges of sand or sandy loam. Much of the surface is poorly drained, and the greater part of the area is wooded; there are a few small tracts of prairie-like land in the northeast. A relatively small area in the west-central part of the county lies west of White River, and about 15 square miles of this section is open, grass-covered prairie, forming a part of Grand Prairie (p. 27). White River enters the county in the northwest and forms the southwestern boundary for a distance of about 18 miles. Cache River flows from north to south in the northwestern part of the county and joins White River at Clarendon.

GEOLOGY.

Throughout the county the materials underlying the surface to estimated depths of 125 to 175 feet are Quaternary alluvial loams, clays, sands, and gravels of Recent and Pleistocene age. The Pleistocene deposits outcrop in the prairies west of White River and probably also in the higher areas east of White River and underlie the remainder of the county beneath Recent deposits. Although irregularly bedded, in general they grade downward from loams or fine, silty clays at the surface, through fine sands to coarse water-bearing sands and gravels at the base. The Recent deposits form the surface materials in the broad, rolling flood plains of White and Cache rivers.

The alluvial deposits rest unconformably on strata of Eocene age, the only definite data concerning which have been furnished by a well at Brinkley, owned by the Farrell Light, Heat & Water Co. Here sands, clays, and gravels, probably referable to the Eocene, were penetrated from a depth of 148 to 565 feet; blue clay containing oyster shells was penetrated between the depths 411 and 415 feet, and lignite between the depths 411 and 416 feet. From general considerations it is believed that the Eocene deposits are underlain at some depth, probably not exceeding 1,000 or 1,200 feet, by strata of Cretaceous age, and at an undetermined depth, probably, however, not exceeding 2,500 feet, the Cretaceous deposits are believed to rest on a basement of Paleozoic rocks. Both the Eocene and Cretaceous deposits contain water-bearing beds.

WATER RESOURCES.

GENERAL CONDITIONS.

Domestic water supplies are obtained chiefly from wells 15 to 85 feet deep, tapping the water-bearing sands and gravels of the alluvial deposits, the waters of which stand in the wells at depths of 10 to 30 feet. According to the reports of well owners, some of the waters are hard and some are soft, but with an occasional exception they are suitable for household and farm use. A few wells used for industrial supplies and for irrigation range in depth from 100 to 150 feet, and draw their supplies from the coarse, abundantly water-bearing sands and gravels at the base of the alluvial deposits.

The Eocene strata, which underlie the alluvial deposits, contain important water-bearing beds, as shown by the yield of the 565-foot well at Brinkley (No. 1, p. 232). The Cretaceous deposits, which underlie the Eocene at an undetermined depth, probably contain water-bearing beds. The Eocene and Cretaceous waters are under sufficient hydrostatic pressure to bring them within less than 50 feet of the surface; flowing wells probably can not be obtained except in the low alluvial lands in the southern part of the county, where wells 1,500 feet or more in depth might overflow at the surface.

LOCAL SUPPLIES.

Brinkley.—The municipal water supply of Brinkley (population 1,740, census of 1910) is obtained from a well 565 feet deep (No. 1, p. 232). Information concerning the system has been furnished by Elmo Chaney, manager, through the mayor, R. M. Henderson. The water is forced into a reservoir holding 100,000 gallons by an air compressor having a capacity of 250 gallons a minute. From the reservoir the water is pumped to an elevated tank, holding 60,000 gallons, from which it is distributed through 3 miles of mains. The standpipe pressure is 40 pounds per square inch, though a direct pressure of 100 pounds per square inch can be obtained in case of fire by cutting out the standpipe. The daily consumption for domestic purposes is 70,000 gallons. The water is slightly brackish. The following is a log of the well:

Log of well of the Farrell Light, Heat & Water Co., Brinkley.

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Clay	25	25
Sand	123	148
Eocene:		
Clay	2	150
Sand	255	405
Hard blue clay, with oyster shells	6	411
Lignite	4	415
Fine sand and gravel	80	495
Blue clay	2	497
Fine white sand and gravel, water bearing	68	565

Other wells at Brinkley, owned by the Brinkley Ice Co., the Arkansas Cotton Oil Co., and the Brinkley Car Works, are described in the table on page 232.

Wells for irrigation.—Several wells in the vicinity of Brinkley for irrigating rice lands are described in the table on page 232. They range in depth from 140 to 150 feet and tap the coarse water-bearing sands and gravels in the basal portion of the Quaternary alluvium; they yield from 2,000 to 3,500 gallons per minute.

Logs of two irrigation wells are as follows:

Log of well of J. D. Edmunds, near Brinkley.

[No. 5, p. 232.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Hardpan	6	6
Sand	7.75	13.75
Sand and gravel, water bearing	124	137.75
Blue clay	12	149.75

Log of well of H. G. Adams, 1½ miles northwest of Brinkley.

[No. 7, p. 232.]

	Thickness.	Depth.
Soil and Pleistocene alluvium (approximate thickness):	*Feet.*	*Feet.*
Soil and subsoil	13	13
Sand	64	77
Gravel, water bearing	70.5	147.5

Log of well of Harshberger & Staley, 2½ miles southeast of Brinkley, Ark.

[No. 8, p. 232.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Red and yellow clay	20	20
Quicksand	10	30
Sand	10	40
Gumbo and shale	20	60
Sand and gravel, water bearing	82	142

Wells in Monroe County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.									
									Feet.	*Feet.*	*In.*	*Feet.*	
1	Brinkley	3 N.	2 W.		Farrell Light, Heat & Water Co.	Corless Well Co., Memphis, Tenn.	E. G. Norton	1904	208	565		497–565	Eocene.
2	do	3 N.	2 W.		Brinkley Ice Co.	do			±206	114			Pleistocene alluvium.
3	do	3 N.	2 W.		Arkansas Cotton Oil Co.	Cook Well Co., St. Louis, Mo.			±206	100(?)			Do.
4	do	3 N.	2 W.		Brinkley Car Works.	do			±206	98			Do.
5	do	3 N.	2 W.	4, S. ½	J. D. Edmunds	Layne & Bowler, Stuttgart.	E. G. Norton	1910	±189	149.75	9⅝	14–138	Do.
6	Brinkley, one-half mile northwest of.	3 N.	2 W.	9, NE. ¼	Donnelly & Federer.	Chas. Golieke, Garden City, Kans.	Frank Federer	1910	190	142	12	112	Do.
7	Brinkley, 1½ miles northwest of.	3 N.	2 W.		H. G. Adams	Layne & Bowler, Stuttgart.	Owner	1910	±200	147.5	13		Do.
8	Brinkley, 2½ miles southeast of.	3 N.	2 W.	25, NE. ¼	Harshberger & Staley, Tippecanoe City, Ohio.	Oscar Lowe, Jennings, La.	H. J. Harshberger	1910		142	11⅝	60–142	Do.
9	Palmer, 1 mile northwest of.	1 S.	1 W.	23, SE. ¼	Tim Williams		Owner	1909		70	1¼	70	Do.
10	Roe, 1 mile east of (at the Poor Farm).				County	H. H. Rittmann, Stuttgart.	Driller	1904	±200	67	2	60	Do.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.		Feet.	Gallons.						
1	Brinkley	3 N.	2 W.		Fine white sand	40		Air			Municipal supply.		Analysis 42, p. 302.
2	do	3 N.	2 W.								Manufacture of ice.		
3	do	3 N.	2 W.								Boilers		
4	do	3 N.	2 W.								do		
5	do	3 N.	2 W.	4, S. ½	Sand and gravel	14		Steam			Irrigation		Analysis 43, p. 302.
6	Brinkley, one-half mile northwest of.	3 N.	2 W.	9, NE. ¼	do	20	3,500	do	$2,200	$1,600.00	do	Alkaline	24-inch pit extends to depth of 60 feet.
7	Brinkley, 1½ miles northwest of.	3 N.	2 W.		do	13	2,000		2,500	750.00	Domestic and irrigation.	Hard	
8	Brinkley, 2½ miles southeast of.	3 N.	2 W.	25, NE. ¼	do	18	1,500	Steam	1,500	900.00	Drinking and irrigation.		Analysis 44, p. 302.
9	Palmer, 1 mile northwest of.	1 S.	1 W.	23, SE. ¼		10		Hand	13		Domestic	Hard	
10	Roe, 1 mile east of (at the Poor Farm).				Gravel	60(?)	7	do	50	5.50	do	do	

PHILLIPS COUNTY.

PHYSIOGRAPHY.

Phillips County comprises an area of 692 square miles, lying south of Lee County and east of Monroe and Arkansas counties; Mississippi River borders the county on the east. Its population was 33,535 in 1910. Agriculture is the chief industry, but lumbering is also important. The agricultural products include cotton, cereals, and hay. At Helena, the county seat, there are several cotton compresses, cottonseed oil mills, and mills manufacturing wood products.

The three topographic subdivisions of the Mississippi embayment—Crowleys Ridge, the Advance lowland, and the Mississippi lowland—are represented in the county.

Crowleys Ridge includes a small tract of hilly, partly wooded, partly cultivated land in the northeastern part of the county; its maximum elevation is about 400 feet above sea level or about 210 feet above the surrounding lowlands. The east-facing slope is rugged and presents numerous deep, steep-sided gullies; along the western slope the hills are more smoothly rounded and the valleys of the small streams are broader and shallower. The southern terminus of the ridge is about 2 miles southwest of Helena.

The Advance lowland comprises the area lying between Crowleys Ridge and the western boundary of the county and extending southward a maximum of 14 miles from the northern boundary. The surface is a rolling plain 170 to 240 feet above sea level, mostly timbered, with a general slope to the south. The creeks and bayous flow through poorly drained shallow valleys and are separated by low ridges of light to dark loam. One of the more prominent ridges, known as Hickory Ridge, is 20 to 30 feet higher than the surface to the west and extends from a short distance south of Marvel northwestward to the county line. Along the western side of Crowleys Ridge is a well-defined terrace, 1 to 3 miles wide, lying 30 or 40 feet above the lowland immediately to the west, from which it is separated by an abrupt escarpment; it is also separated from Crowleys Ridge on the east by a plainly defined escarpment.

The Mississippi lowland is an area 1 to 12 miles wide, bordering Mississippi River along the entire southeastern side of the county; a few square miles of the area lies east of the southern part of Crowleys Ridge and north of Helena. The lowland slopes from about 200 feet above sea level in the northern part of the county to about 170 feet above sea level in the south. Swamps, lakes, abandoned stream channels, and bayous are numerous, and much of the surface is heavily timbered.

West of Crowleys Ridge the county is drained by Big Creek, a tributary of White River, and White River forms the boundary of the county for a distance of about 15 miles on the southwest.

GEOLOGY.

The core of Crowleys Ridge to a maximum height of 80 or 90 feet above the level of the Mississippi bottom is composed of Tertiary sands, clays, and gravels referable to the Jackson formation of the Eocene. Undifferentiated deposits of Eocene age underlie the ridge to an estimated depth of 1,200 feet or more and contain important water-bearing beds. The Eocene is underlain by deposits of Cretaceous age, which, at an undetermined depth, probably 3,000 feet or more, are believed to rest on a basement of Paleozoic rocks. The Cretaceous deposits contain water-bearing beds, but their character is not definitely known. Throughout the remainder of the county the Eocene and the subjacent Cretaceous deposits are present beneath Quaternary alluvial deposits estimated to be 120 to 200 feet thick.

In Crowleys Ridge the Eocene sands and clays are overlain unconformably by a known maximum thickness of 80 feet of sands and gravels belonging to the Lafayette formation (Pliocene?), which is in turn overlain by typical loess (Pleistocene), having a maximum measured thickness of approximately 140 feet. The loess caps the ridge, and materials derived from both the Lafayette formation and the loess mantle down over the slopes of the ridge and in most places completely cover the Eocene strata. It is difficult at some places to determine whether these mantling materials are in their original position or have subsequently come to their present position by redeposition or by creep. Fossil land shells are numerous in the loess.

Along the western side of Crowleys Ridge is a terrace 30 to 40 feet above the lowland to the west, the deposits composing which are probably the reworked loess, sands, and gravels of Crowleys Ridge. This terrace is of Pleistocene age, is younger than the loess capping Crowleys Ridge, and older than the alluvium underlying the lowland immediately to the west. The Advance lowland west of Crowleys Ridge is underlain to estimated depths of 125 to 200 feet by Quaternary alluvial loams, clays, sands, and gravels of Pleistocene and Recent age. The Pleistocene alluvium rests on Eocene strata and appears at the surface in the interstream areas. Although irregularly bedded, the materials in general grade downward from fine silts or loams at the surface through fine sands to coarse, water-bearing sands and gravels at the base. Recent stream alluvium immediately underlies the surface in the flood plains of Big Creek and White River. The Mississippi lowland is underlain by alluvial clays and water-bearing sands and gravels to estimated depths of 150 to 200 feet.

WATER RESOURCES.

GENERAL CONDITIONS.

Water for domestic supplies is derived chiefly from wells 15 to 150 feet deep. In the Advance and Mississippi lowlands the water is obtained from the sands and gravels of the Quaternary alluvium and stands within 10 to 50 feet of the surface. In Crowleys Ridge the wells tap either the water-bearing sands and gravels of the Lafayette formation or the water-bearing sands of the underlying Eocene deposits. Wells on the higher parts of the ridge generally exceed 100 feet in depth and yield waters that rise within 80 to 130 feet of the surface. As reported by the owners, the waters of wells less than 150 feet deep are nearly all hard and some have a distinct taste of iron.

The Eocene strata beneath the alluvial deposits contain water-bearing beds which at Helena have been tapped by numerous wells 450 to 575 feet deep, and by one well 400 feet deep at Barton. The waters rise within 15 to 40 feet of the surface of the lowland, are soft, and of suitable quality for all ordinary domestic and industrial uses. No tests have been made of the character of the Eocene waters at depths exceeding 575 feet or of the deeply buried Cretaceous waters. Waters from depths of 1,000 feet or more are probably under sufficient hydrostatic pressure to produce flows.

Cisterns are used in a few places on the bottom lands. Springs are numerous among the hills of Crowleys Ridge, especially along the foot of the east-facing slope; some of them are used for domestic and farm supplies.

LOCAL SUPPLIES.

Helena.—The city of Helena (population 8,772, census of 1910) is equipped with a water-supply system owned by the Helena Water Co., concerning which information has been furnished by T. J. Mitchell, superintendent. The supply is obtained from four wells about 500 feet in average depth, two being 8 inches and two 10 inches in diameter. The water comes from a bed of coarse, sharp sand between the depths 437 and 500 feet. Several air lifts, each having a daily capacity of 2,000,000 gallons, are used to force the water from the wells to a concrete reservoir holding 1,000,000 gallons, from which it is distributed through 18 miles of mains. The reservoir, which is on Crowleys Ridge west of the town, affords a pressure of 60 pounds per square inch. The daily consumption is 12,000,000 gallons, about one-third of which is used in factories.

Three samples of material from one of the wells of the Helena Water Co., furnished by A. Goldsberg, are on file in the office of the United States Geological Survey (U. S. G. S., well No. 424). One sample from a depth of 350 feet is a drab clay, and two from depths of 455 and 492 feet consist of light-gray clean, sharp quartz sand.

Detailed information concerning wells at and near Helena owned by the W. D. Reeves Lumber Co. (depth 450 feet), the New South Oil Co. (depth 575 feet), and S. B. Carpenter (depth 575 feet), is given in the table on page 240.

An incomplete log of the well owned by the American Cooperage Co. is given below.

Log of well of American Cooperage Co., 3 miles southwest of the post-office building at Helena.

	Thickness.[a]	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Not reported	50	50
Brown sand and gravel, water bearing	110	160
Eocene:		
Firm clay	60	220
White sand, water bearing	12	232
Clay	118	350
White sand, water bearing	40	390
Clay	135	525
White sand, water bearing	50	575

[a] The thicknesses were given from memory and are therefore only approximately correct.

The well was originally drilled to a depth of 700 feet, but the casing was pulled back and the lower 125 feet became filled with sand. The materials between the depths of 575 and 700 feet consisted of white sand with thin, interbedded layers of clay.

In 1879 two borings were made near Helena under the auspices of the United States Mississippi River Commission. One of them (No. 1) was sunk on the Mississippi lowland east of Crowleys Ridge and shows the thickness of the alluvial deposits and the character of the underlying Eocene strata to a depth of 206.4 feet. The other (No. 2) was sunk on Crowleys Ridge and shows the nature of the materials composing the ridge and underlying the ridge to a depth of 236.8 feet. The logs of these borings are repeated here with the age designations modified to accord with present usage.[1]

Log of boring No. 1 in bottom land, Helena.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Not reported	31	31
Fine sand	56.4	87.4
Coarser sand with gravel	29	116.4
Clean sand with gravel	26.3	142.7
Coarse sand	14.1	156.8
Finer sand	4.7	161.5
Coarse sand	.8	162.3
Eocene (Jackson formation):		
Smooth blue clay	27.2	189.5
Lignite in mass	.2	189.7
Smooth blue clay	16.7	206.4

[1] Report of Profs. E. W. Hilgard and F. V. Hopkins upon the examination of specimens from borings on Mississippi River between Memphis and Vicksburg: Mississippi River Commission Ann. Rept. for 1883, 48th Cong., 1st sess., House Ex. Doc. No. 37, pp. 479–497; logs, pp. 485–488.

Log of boring No. 2 on Crowleys Ridge, near Helena.

	Thickness.	Depth.
Pleistocene:	*Feet.*	*Feet.*
Brownish-yellow loam, noncalcareous (loess)	0.5	0.5
Yellow silt, calcareous, and full of snail shells and concretions of lime called "loess puppets" (loess)	139.2	139.7
Yellowish clay	28.1	167.8
Pliocene (?) (Lafayette formation?):		
Chert pebbles	3.5	171.3
Eocene (Jackson formation):		
Stiff blue clay with green sand and lignitized seaweed; fossiliferous	27.7	199
Stiff blue clay, calcareous; a clayey greensand marl; fossiliferous	12.2	211.2
Ferruginous concretions of stony hardness	.2	211.4
Clayey greensand marl, with a clay-colored calcareous rock at base; fossiliferous	19.9	231.3
Dark, pebbly, sandy clay with a layer of clay-colored fossiliferous sand at base	5.5	236.8

The molluscan fossils from this well between the depths 171.3 and 236.3 feet, as redetermined by Harris,[1] are:

Helena (boring No. 2): Dentalium (very nearly smooth, but with traces of longitudinal striation); *Volutilithes petrosus* (fragments); *Corbula wailesiana;* Corbula sp.: *Phos hilli* var.; *Pseudoliva vetusta; Pleurotoma denticula;* Actæon; Natica.

According to Harris, these fossils indicate the Jackson age of the containing beds.

In the same boring numerous foraminifers were obtained between the depths 229.5 and 236.8 feet. These were identified and listed by F. V. Hopkins.[2]

The following is the record of a boring at Helena, Ark., made in 1904, under the direction of Capt. E. W. Van C. Lucas, Corps of Engineers, United States Army, by W. M. Rees, assistant engineer:

Log of a boring on the levee at Helena, Ark.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Artificial fill (levee)	16	16
Blue mud or clay	26	42
Fine blue sand	6	48
Bluish sandy clay	20	68
Fine blue sand, slightly coarser at bottom	8	76
Coarse gray sand with red grains	1.6	77.6
Eocene (?) (Jackson formation?):		
Stiff dark-greenish sandy clay, containing shells and pebbles	1.2	78.8
Hard clay with layers of shale	1.1	79.9
Stiff dark-green sandy clay with shells	3	82.9
Gravel, containing some large pebbles	.6	83.5
Dark-greenish stiff sandy clay, containing shells and large pebbles	1.5	85
Hard brown clay with large pebbles, and with a layer of hard yellow clay at base	19.4	104.4
Hard green clay or marl	1.4	105.8
Siliceous quartzitic rock	.2	106
Dark-green clay with a layer of hard yellow clay at base	2	108
Dark-green clay	1.2	109.2
Hard dark-brown clay	3.6	112.8
Coarse sand, containing shells and lignite	1	113.8
Stiff brown clay with small pebbles and seams of white sand	5.7	119.5
Soft gray sandy clay or fine gray sand	1.5	121

[1] Harris, Gilbert D., The geology of the Mississippi embayment with special reference to the State of Louisiana: Louisiana Geol. Survey, pt. 6, 1902, p. 22 (footnote).
[2] Hilgard, E. W., and Hopkins, F. V., op. cit., pp. 485–488.

The preceding log, together with the logs of 11 other Government wells bored near the river at Helena and ranging in depth from 50.8 to 90 feet, have been furnished by Capt. Lucas. The elevation of the ground at the points where borings were made ranges from 163 to 192 feet above sea level; all penetrated alluvial sands and clays ranging in total thickness from 50.5 to 89 feet, beneath which hard, green, gray, blue, or dark-brown clay was encountered. The level at which the hard clay was struck ranged from about 99 to 112 feet above sea level. The clay, which is believed to be the upper eroded surface of the Jackson formation (Eocene), corresponds to the uppermost layer of the Eocene in the log just given.

Barton.—At Barton, 13 miles west of Helena, a well drilled to a depth of 926 feet yielded hard water obtained in Quaternary sand and gravel at a depth of 110 feet, and soft water in Eocene sand at a depth of 400 feet. A layer of sandstone was penetrated at a depth of 800 feet and at 926 feet the drill was broken in attempting to penetrate a layer of hard rock. The well was then abandoned and another well was drilled to the 400-foot stratum (No. 1, p. 240) from which an abundant supply of water was obtained.

Southland.—In the vicinity of Southland, which is on the terrace bordering Crowleys Ridge on the west, are several wells ranging in depth from 130 to 140 feet. The log of a well owned by William Russell is as follows (No. 12, p. 240):

Log of well of William Russell, Southland.

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Red clay	12	12
Blue clay	55	67
Quicksand	65	132
Gravel, water bearing	3	135

Wells in Phillips County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	Feet.	Inches	Feet.	Feet.	
1	Barton (at cotton mill).									400		400	100	Claiborne formation.
2	Helena				Helena Water Co.		T. I. Mitchell.		200±	500±	8	480		Do.
3	Helena, 1 mile south of post office.	2 S.	5 E.	9, SE. ¼	W. D. Reeves Lumber Co.	Corless Well Co., Memphis, Tenn.	Owners	1901	200±	450	6			Do.
4	Helena, 3 miles southwest of post office.				American Cooperage Co.	W. P. Maingault, Memphis, Tenn.	Driller	1909	200±	575	4	525	110–160, 220–232, 350–390	Do.
5	Helena, 3 miles south of (Spanish grant on private survey No. 496).				S. B. Carpenter	W. B. Johnson, Memphis, Tenn.	Dale Welsh	1910	200±	575	4	540	65, 450	Do.
6	Helena, 1 mile south of post office (O'Connor Street and St. Louis, Iron Mountain & Southern Ry.).				New South Oil Co.	J. A. Thedeis, Clarksdale, Miss.	R. T. Doughtie	1911	200±	500	8			Do.
7	Helena, 5 miles west of.				C. R. Coolidge	H. H. Rittmann, Stuttgart, Ark.	Driller	1887		43	2			Quaternary alluvium.
8	Helena, 8 miles northwest of.				Dr. Horner	do	do	1887		175	2	175		Eocene.
9	Lexa				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.			175	10			Pleistocene alluvium.
10	do				do		do			175	10			Do.
11	North Creek, one-fourth mile northeast of.	1 S.	3 E.		G. F. Foster, Lagrange, Ark.	David Phillips, Lagrange, Ark.	T. W. Foster		210±	95				Do.
12	Southland	1 S.	4 E.		William Russell		Owner		205±	135		70		Eocene.
13	Trenton	2 S.	2 E.	23, SE. ¼	J. L. Kendall	Owner	do			70		70		Pleistocene alluvium.
14	Wabash, one-quarter mile west of.	3 S.	3 E.	31, NW. ¼	Howe Lumber Co.	W. E. Winters, Harrisburg, Ark.	O. D. Howe	1907		50	6	40	20	Quaternary alluvium.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.		*Feet.*	*Gallons.*						
1	Barton (at cotton mill).				Sand	20						Soft	
2	Helena				Coarse sand	18	250?	Air			Municipal supply.		This well and three other similar wells, having an average depth of 500 feet, furnish the municipal water supply; estimated daily consumption 18,000,000 gallons; analysis 45, p. 302.
3	Helena, 1 mile south of post office.	2 S.	5 E.	9, SE. ¼		20		do	$2,500	$350	Boilers and drinkiug.	Soft	
4	Helena, 3 miles southwest of post office.				White sand	20					Domestic and boilers.	do	
5	Helena, 3 miles south of (Spanish grant on private survey No. 496).				Fine sand	27	36	Steam.	1,350		Domestic and manufacturing.	do	Used for steam production and in vats at plant of American Cooperage Co.
6	Helena, 1 mile south of post office (O'Connor Street and St. Louis, Iron Mountain & Southern Ry.					38		do	2,200	182	Domestic and boilers.	do	
7	Helena, 5 miles west of.				Sand	4	7	Hand.	43	5.50	Domestic	Hard	
8	Helena, 8 miles northwest of.					130	7	Wind.	180		do	do	Well is located on Crowleys Ridge.
9	Lexa						45				Boilers		Analysis 46, p. 302.
10	do										do		
11	North Creek, one-fourth mile northeast of.	1 S.	3 E.			25		Hand.	50		Domestic	Hard	
12	Southland	1 S.	4 E.		Gravel	38					do	do	
13	Trenton	2 S.	2 E.	23, SE. ¼	do			Gas	35		do	do	
14	Wabash, one-quarter mile west of.	3 S.	3 E.	31, NW. ¼.	Sand and gravel	7		Steam.	150	150	Domestic and boilers.		Analysis 47, p. 302.

POINSETT COUNTY.

PHYSIOGRAPHY.

Poinsett County, situated south of Craighead County and east of the northern third of Jackson County, embraces an area of 721 square miles. Its population at the time of the census of 1910 was 12,791. The chief industries are agriculture and lumbering. The agricultural products include cotton, corn, rice, and hay, and such fruits as apples, peaches, and grapes. Rice is grown chiefly on the prairie lands west of Crowleys Ridge. There are numerous sawmills in the county. At Harrisburg are several mills which manufacture wood products.

The county includes parts of the three topographic subdivisions of the Mississippi embayment, Crowleys Ridge, the Advance lowland, and the Mississippi lowland.

Crowleys Ridge is a belt of hilly, partly timbered land, 1 to 3 miles wide, extending in a north-south direction slightly west of the center of the county, and separated from the adjacent plains by sharply defined escarpments; the top of the ridge is 350 to 400 feet above sea level or 100 to 150 feet above the lowlands to the east and west.

West of Crowleys Ridge is a nearly level or gently rolling plain which forms part of the Advance lowland; it is 230 to 290 feet above sea level and slopes slightly to the south. The plain is drained by L'Anguille River, which heads just north of the county and flows southward west of Crowleys Ridge and by Bayou de Vue, which flows from north to south in the western part of the county. The interstream areas present irregularly distributed tracts of open, grass-covered prairies, separated by slightly lower wooded lands. The broad, shallow, flood plains of the streams are in part swampy and, except where cleared for cultivation, are heavily timbered.

East of Crowleys Ridge is the gently undulating, heavily timbered plain of the Mississippi lowland, lying 225 to 240 feet above sea level, sloping slightly to the west and south. This part of the county is drained by St. Francis River, which flows in a sinuous course in a general southerly direction in the eastern part of the county. Much of the surface is swampy, and bayous and ponds are common.

GEOLOGY.

The core of Crowleys Ridge, to a maximum height of 85 to 100 feet above the level of the lowlands, is composed of irregularly bedded sands and clays, with occasional interstratified layers of lignite, referable to the Wilcox and Claiborne formations of the Eocene; the former outcrops at the base of the ridge from the northern boundary southward to about the middle of the county, and the latter appears at the base of the ridge for the remainder of the distance to the southern boundary. Undifferentiated Eocene deposits containing important water-bearing beds underlie the ridge to an estimated depth of 500 feet or more and extend out to the east and west beneath the alluvial deposits of the lowlands, the thickness of which ranges from 125 to 225 feet.

The Eocene deposits are underlain by strata of Cretaceous age which also contain water-bearing beds. At an unknown depth, estimated, however, to be between 2,000 and 3,000 feet, the Cretaceous deposits rest on a basement of older rocks, probably of Paleozoic age.

In Crowleys Ridge the Eocene strata are overlain unconformably by a few feet to 40 feet of sands and gravels, locally indurated to hard conglomerates, belonging to the Lafayette formation (Pliocene?); these materials are water bearing in many places. The Lafayette is in turn overlain in part by deposits of loess (Pleistocene) reaching 20 feet or more in thickness, which, where present, forms the capping material of the ridge. In this county the loess has in places been removed from the crest of the ridge by erosion, leaving the gravels of the Lafayette as the capping material.

In the Advance lowland the Eocene strata are overlain by an estimated thickness of 125 to 175 feet of Quaternary alluvium of Pleistocene and Recent age. The Pleistocene deposits rest unconformably on the Eocene strata and outcrop at the surface in the interstream areas; they are irregularly bedded, but in general grade downward from loams and silty clays at the surface through fine sands to coarse, water-bearing sands and gravels at the base. The Recent alluvium immediately underlies the flood plains of the present streams. The Mississippi lowland is underlain by 150 to 225 feet of Quaternary alluvial loams, clays, and water-bearing sands and gravels of undifferentiated Pleistocene and Recent age.

WATER RESOURCES.

GENERAL CONDITIONS.

Ordinary supplies.—Water for domestic and industrial uses is obtained chiefly from wells 10 to 160 feet deep; those on the lowlands tap the abundantly water-bearing sands and gravels of the Quaternary alluvial deposits, the waters of which stand 3 to 50 feet below the surface. As reported by the well owners, some of the waters are soft, some are hard, and some are ferruginous. The wells in Crowleys Ridge tap either the water-bearing sands and gravels of the Lafayette formation or the water-bearing sands of the underlying Eocene deposits.

The beds of sand that compose in part the Eocene deposits beneath Crowleys Ridge and underlying the alluvial deposits of the lowlands to an estimated depth of 500 feet or more contain water-bearing beds of importance, the waters of which are under sufficient hydrostatic pressure to lift them within less than 50 feet of the surface, except in the higher parts of Crowleys Ridge; in the Mississippi lowland they rise within a few feet of the surface. The deeply buried Cretaceous water-bearing beds are under hydrostatic pressure, which in the Mississippi lowland is sufficient to cause strong flows at the surface, as shown by the 2,007-foot well at Marked Tree (No. 3, p. 248).

There are a few small springs in Crowleys Ridge, but these do not form an important source of water.

Irrigation.—Wells for irrigating rice lands in the vicinity of Waldenburg, Weiner, and Whitehall (Nos. 11–19, p. 248) range in depth from 75 to 156 feet and yield 300 to 3,000 gallons a minute. The cost of drilling the wells and installing machinery ranges from $500 to $2,800, the average cost based on seven wells being at the rate of $787 for each 1,000 gallons of yield a minute, or at the rate of 79 cents for each gallon of yield a minute.

LOCAL SUPPLIES.

Harrisburg.—The following is the log of a 181-foot well at Harrisburg (population 942, census of 1910); this well is on Crowleys Ridge at the Vandiver Hotel.

Log of well at Vandiver Hotel, Harrisburg.

	Thickness.[a]	Depth.
Pliocene (?) (Lafayette formation):	*Feet.*	*Feet.*
Sand and gravel	20	20
Eocene (Claiborne formation?):		
Hard blue "dry" clay, lignitic near base	80	100
Very fine blue sand, water bearing	80	180

[a] Thicknesses approximate.

Mr. C. H. Winters, a well driller of Harrisburg, has furnished the following log of a well that he drilled on the lowland about one-quarter mile west of the foot of Crowleys Ridge at Harrisburg:

Log of well in western part of the town of Harrisburg.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Red clay with loose gravel; contains water in small quantities at base	40	40
Eocene (Wilcox formation):		
Blue "gumbo" clay	25	65
Red sand, very fine and dry, caves easily	40	105
Dark-blue sandy clay containing small fragments of leaves, lignite, shells (?), and decayed wood; emits an unpleasant odor	50	155
Very fine blue sand, water bearing	30	185

The following incomplete log of a well 11 miles northeast of Harrisburg, owned by C. Ripley, has been prepared from a set of well borings, which were furnished by the driller, C. H. Winters, and are now on file in the office of the United States Geological Survey (well No. 1542).

Incomplete log of well of C. Ripley, 11 miles northeast of Harrisburg.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Gray sandy clay mottled with yellow	20	20
Chunks of drab, slickensided clay	15	35
Same as preceding	(?)	39
Dark shaly carbonaceous clay full of lignitized fragments of vegetation	(?)	42

Marked Tree.—A flowing well, 2,007 feet deep, owned by the town of Marked Tree (population 2,026, census of 1910), was completed in 1911 (No. 3, p. 248). No municipal water-supply system had been installed at the time the information was obtained. Several wells, approximately 400 feet deep, have been drilled at this place (Nos. 4, 5, 6, 7, p. 248). The log of one of them follows:

Log of well of Chapman & Dewey Lumber Co., Marked Tree.

[No. 7, p. 248.]

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
"Buckshot" soil grading downward into sand	27	27
Yellowish sand and gravel	193	220
Eocene:		
Soft white clay	12	232
Very hard blue clay	63	295
Soft sandy blue clay with thin layers of sand	71	366
Gray sand	32	398

Weiner.—Mr. John White, a driller, has furnished the following log of a well owned by the St. Louis Southwestern Railway at Weiner (population 232, census of 1910):

Log of well of the St. Louis Southwestern Railway at Weiner.

	Thickness.	Depth.
[Soil and Pleistocene alluvium]:	*Feet.*	*Feet.*
Soil	0.5	0.5
Light-colored clay	2	2.5
"Hardpan" (clay)	10	12.5
Sand	16	28.5
Quicksand grading downward into coarse sand and gravel, water bearing	22	50.5
Very hard clay	1	51.5
Gravel, becoming coarser as the depth increases, water bearing	50	101.5

Wells for irrigation.—Wells for irrigating rice lands have been drilled in the vicinity of Waldenburg, Weiner, and Whitehall (Nos. 11–19, p. 248); the logs of six irrigation wells follow:

Log of well of Scruggs & Swearengin, 2 miles east of north of Waldenburg.

[No. 11, p. 248.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	3	3
"Hardpan"	9	12
Fine white sand, water bearing in lower 20 feet	36.5	48.5
Coarse sand grading down into gravel containing scattered fragments of lignite, water bearing	60	108.5

Partial log of well of E. L. Jackson, 2½ miles southwest of Waldenburg.

[No. 12, p. 248.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Not reported	25	25
Fine white sand, becoming coarser, water bearing	30	55
Gravel, water bearing	46	101

Log of well of S. F. Wells, 1 mile north of Weiner.

[No. 14, p. 248.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Subsoil	1	1
"Hardpan"	30	31
Fine sand, becoming coarser and grading downward into coarse gravel	122	153
Rock	.5	153.5

Log of well of Chas. Thompson, 1½ miles south of Weiner.

[No. 15, p. 248.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Loam	4	4
"Hardpan"	10	14
Yellow sand	10	24
Fine sand, becoming coarser to a coarse gravel at base, water bearing below the depth of 27 feet	76	100
Coarse gravel with cobbles 6 to 8 inches in diameter, water bearing	56	156

Log of well of Frank Housman, 3 miles northeast of Weiner.

[No. 16, p. 248.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Light-gray soil	2	2
"Hardpan"	10	12
Fine sand, not water bearing	18	30
Fine sand, becoming coarser to a coarse gravel at base, water bearing	45	75

Log of well of B. A. McKinny, 1½ miles west of Whitehall.

[No. 18, p. 248.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	2	2
Red "hardpan"	18	20
Gray "hardpan"	6	26
Blue earth, gradually turning to sand	14±	40?
Fine sand, becoming coarser and grading downward into fine gravel, water bearing	80±	120

Wells in Poinsett County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Harrisburg				Vandiver Hotel					181		100–180		Wilcox formation.
2	Harrisburg, 1½ miles northeast of.				C. W. Spencer	Owner	Owner	1904	(*a*)	43	10	37		Lafayette (?) formation.
3	Marked Tree	11 N.	6 E.		Town			1911	236	2,007				Cretaceous.
4	do	11 N.	6 E.		Marked Tree Lumber Co.				236	392	6			Wilcox (?) formation.
5	do	11 N.	6 E.		E. Ritter & Co.				236	400	6			Do.
6	do	11 N.	6 E.		Chicago Mill & Lumber Co., Blytheville.	W. B. Johnson, Memphis, Tenn.	W. B. Johnson, Memphis, Tenn.[b]		236	398		366–398		Do.
7	Marked Tree, ¾ mile northwest of post office.	11 N.	6 E.	34, NE. ¼ SE. ¼.	Chapman & Dewey Lumber Co.	Johnson & Fleming, Memphis, Tenn.	D. P. Mann and T. G. Staton.	1903	236±	398	6	366–398		Do.
8	Marked Tree, 7 miles southeast of.	10 N.	7 E.	12, NE. ¼.	E. B. Boyd, Monmouth, Ill.		Frank Vollmer, Tyronza.	1908	230±	100	1½	90	45	Quaternary alluvium.
9	Trumann	12 N.	5 E.		Springfield Lumber & Cooperage Co.				237	85	3			Do.
10	do	12 N.	5 E.		do				237	90	4			Do.
11	Waldenburg, 2 miles east of north of.	11 N.	2 E.	18, NW. ¼.	Scruggs & Swearengin, Mooreville, Ind.	Henry Elliott	U. C. Allan	1911	240±	108.5	12	28.5–108.5		Pleistocene alluvium.
12	Waldenburg, 2½ miles southwest of.	11 N.	1 E.	35, SE. ¼.	E. L. Jackson		Owner	1910	235±	101	10	60–101	25	Do.
13	Waldenburg, 1½ miles southeast of.	11 N.	2 E.	30, SE. ¼.	John Fahrm	F. L. Casper, Weiner.	do		235±	150	10	32–150		Do.
14	Weiner, 1 mile north of.	12 N.	2 E.	28	S. F. Wells	J. P. Nicholas, Stuttgart.	Driller	1911	240±	153.5	9⅝	80–153.5		Do.
15	Weiner, 1½ miles south of	11 N.	2 E.	17, NW. ¼.	Chas. Thompson	F. L. Casper	Owner	1910	240±	156	10	27–156		Do.
16	Weiner, 3 miles northeast of.	12 N.	2 E.	21, SE. ¼.	Frank Housman	Owner	do	1909	240±	75	4	28–75		Do.
17	Weiner, ¼ mile east of.	11 N.	2 E.	4, NW. ¼.	A. L. Wood	F. L. Casper	do	1911	240±	154	9⅝	30–154		Do.
18	Whitehall, 1½ miles west of.	10 N.	3 E.	22	B. A. McKinney	W. C. Winters, Harrisburg.	do	1911		120	8	40–120		Do.
19	Whitehall, 1 mile southeast of.	10 N.	3 E.		Joe Speakes		do			72	30	68–72		Claiborne (?) formation.

[a] Elevation about 100 feet above the level of the St. Louis, Iron Mountain & Southern Ry.
[b] Shepard, E. M., Underground waters of Missouri: U. S. Geol. Survey Water-Supply Paper 195, p. 182, 1907.

	Location.				Character of principal water-bearing bed.	Level of water above or below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.		*Feet.*	*Galls.*						
1	Harrisburg				Fine blue sand	−81					Domestic	Soft	
2	Harrisburg, 1½ miles northeast of.					−37		Hand			Drinking	Sulphurous	Bored type.
3	Marked Tree	11 N.	6 E.		Sand	+26	300	Flows				Soft	
4	do	11 N.	6 E.			− 1.5					Domestic and boilers.		
5	do	11 N.	6 E.		Sand	− 8	300(?)	Pump			Domestic and manufacture of ice.	Medium soft	
6	do	11 N.	6 E.		Gray sand	− 3	3				Boilers		
7	Marked tree, ¾ mile northwest of post office.	11 N.	6 E.	34, NE. ¼ SE. ¼.	Sand	− 2		Steam			Domestic and boilers.		Analysis 48, p. 302.
8	Marked tree, 7 miles southeast of.	10 N.	7 E.	12, NE. ¼	Sand and gravel	−15		Wind	$136.50		Domestic	Ferruginous	
9	Trumann	12 N.	5 E.		Gravel						Boilers	Hard	
10	do	12 N.	5 E.		do						do	do	
11	Waldenburg, 2 miles east of north of.	11 N.	2 E.	18, NW. ¼	Sand	−28.5	3,000	Steam	2,800		Irrigation		Analysis 49, p. 302. 28 feet, 14-inch casing; 20 feet, 12-inch casing; and 60 feet, 12-inch Stancliff strainer.
12	Waldenburg, 2½ miles southwest of.	11 N.	1 E.	35, SE. ¼	Gravel	−25	1,400	do	1,000		Domestic and irrigation.		Analysis 50, p. 302.
13	Waldenburg, 1½ miles southeast of.	11 N.	2 E.	30, SE. ¼	Sand and gravel			do	1,000		Irrigation	Hard	74 feet of casing and 76 feet of screen.
14	Weiner, 1 mile north of.	12 N.	2 E.	28	Gravel	−32	2,000	do	1,350		Domestic and irrigation.	do	103.5 feet of casing and 50 feet of strainer.
15	Weiner, 1½ miles south of.	11 N.	2 E.	17, NW. ¼	Sand and gravel	−27	2,500	do	1,400	150	do	Soft	76 feet of 10-inch casing and 80 feet of 10-inch strainer.
16	Weiner, 3 miles northeast of.	12 N.	2 E.	21, SE. ¼	Sand	−28	300	Gas	500		do	do	30 feet of 5-inch casing, 20 feet of 4-inch casing, and 25 feet of 4-inch screen.
17	Weiner, ¼ mile east of	11 N.	2 E.	4, NW. ¼	Sand and gravel	−30	2,000	Steam	900	125	Irrigation	Medium hard	
18	Whitehall, 1½ miles west of.	10 N.	3 E.	22	do	−40	800		1,225		Domestic and irrigation.		Analysis 51, p. 302; pit 6 feet square to depth of 40 feet.
19	Whitehall, 1 mile southeast of.	10 N.	3 E.								Domestic	Soft	Dug type.

PRAIRIE COUNTY.

PHYSIOGRAPHY.

Prairie County, in the east-central part of the State, comprises an area of 675 square miles. Its population was 13,853 in 1910. Agriculture, stock raising, and lumbering are the chief industries. The agricultural products include vegetables, hay, cotton, cereals, and fruits, such as apples, peaches, pears, plums, and berries. Rice is grown extensively and the crop is rapidly increasing in importance.

The county is included within the Advance lowland (see p. 25), the surface of which is in general a gently undulating or rolling plain lying 200 to 240 feet above sea level, and sloping slightly to the south. White River flows a little east of south across the county and leaves it about 10 miles north of the southeastern corner; Cache River forms the eastern boundary for a few miles. The channel of White River is near the western edge of the flood plain, and all the county east of this river is in the heavily timbered flood plain of either White or Cache River, an area characterized by numerous bayous, lakes, and abandoned stream channels. West of White River and north of the Chicago, Rock Island & Pacific Railway much of the surface is timbered land lying a few feet higher than the flood plains and slightly lower than the prairies. South of this railroad and west of the wooded belt bordering White River are broad stretches of grass-covered prairie separated by patches and belts of slightly lower timbered lands.

The principal western tributaries of White River, in order from north to south, are Cypress Creek and its eastward extension, Bayou Des Arc, Wattensaw Bayou, and Bayou Lagrue. Bayou Two Prairie forms the western boundary for a distance of a few miles in the extreme southwest.

GEOLOGY.

Quaternary alluvial deposits of Pleistocene and Recent age immediately underlie the surface of the county to depths of 125 to 180 feet, and rest unconformably on strata of Eocene age. The Pleistocene deposits immediately overlie the Eocene strata and outcrop in the interstream areas; they are irregularly bedded but in general grade downward from fine silty loams and clays at the surface through fine sands to coarse water-bearing sands and gravels at the base. Fossil logs have been encountered in well borings at several places in the county. Loams, clays, sands, and gravels of Recent age constitute the flood-plain materials of the present streams.

Only meager data are available concerning the character of the Eocene strata underlying the alluvial deposits, but from general considerations it is believed that they consist predominantly of sands and clays, and doubtless they contain water-bearing beds. The Eocene strata are believed to be underlain by strata of Cretaceous age, also in part water bearing, which at an undetermined depth, probably not exceeding 1,200 or 1,500 feet, rest upon a basement of Paleozoic rocks.

WATER RESOURCES.

GENERAL CONDITIONS.

Ordinary supplies.—Water for domestic and industrial uses is obtained chiefly from wells 25 to 180 feet deep that tap the abundantly water-bearing sands and gravels of the Quaternary alluvial deposits, the waters of which stand 10 to 55 feet below the surface. According to the reports of well owners, some of the waters are hard, some are soft, and an occasional one is ferruginous; in general they are of suitable quality for ordinary uses. Well waters having a salty taste have been reported from the northern part of the county in the western half of T. 5 N., R. 5 W.

The waters of the undifferentiated Eocene and Cretaceous deposits, which intervene between the alluvial deposits and the deeply buried Paleozoic basement rocks, may be obtained by means of wells ranging in depth from 200 to an estimated maximum depth of 1,200 or 1,500 feet. These are under hydrostatic pressure sufficient to bring them within less than 50 feet of the surface but not sufficient to cause flows.

Irrigation.—Rice culture was begun in this county shortly after the grain was first successfully grown in the adjoining county of Lonoke and the industry rapidly increased in importance. Water for irrigating the rice lands is obtained from wells 100 to 180 feet deep tapping the water-bearing beds of the alluvial deposits. The water level in these wells is 30 to 55 feet below the surface, and the water is lifted to the surface by means of pumps of large capacity. The cost of sinking the wells and installing pumping plants varies from $750 to $2,200 per well, and the yield ranges from 700 to 3,000 gallons a minute. The average cost based on six wells is at the rate of $1,180 for each 1,000 gallons of yield a minute, or $1.18 for each gallon of yield a minute. Detailed information in regard to nine irrigation wells is given in the table on page 254.

LOCAL SUPPLIES.

Hazen.—The town of Hazen (population, 687, census of 1910) is equipped with a water-supply system owned by the Hazen Power & Light Co., information concerning which has been furnished by Messrs. W. H. and W. L. Fox. Water is obtained from two wells 60 and 80 feet deep, respectively (Nos. 13 and 14, p. 254). The water, which is hard, is lifted by a pump having a daily capacity of 15,000 gallons and is distributed through 8,000 feet of mains.

The standpipe pressure is 30 pounds per square inch and the direct pressure from the pumps for fire protection is 80 pounds per square inch. The daily consumption is 13,000 gallons for domestic use and 2,000 gallons for manufacturing.

Des Arc.—Logs of two wells at Des Arc (population 1,061, census of 1910) are as follows:

Log of well of Peter Deforest, Des Arc.

[No. 2, p. 254.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	3.5	3.5
Clay	35	38.5
"Seepy" earth	8	46.5
Red clay	10	56.5
Blue clay	7.5	64
Sand and gravel, water bearing	14	78

Log of well owned by J. W. Pettey, Des Arc.

[No. 3, p. 254.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1	1
Clay	3	4
Quicksand	25	29
Joint clay	10	39
Blue clay	8	47
Gray sand	5	52
Sand and gravel, water bearing	20	72

Wells for irrigation.—Wells for irrigating rice lands have been drilled in the vicinity of Devall Bluff, Hazon, and Ulm, detailed information concerning some of which is given in the table on page 254. The following are logs of two irrigation wells:

Log of well of Thomas Bros., 3½ miles west of Devall Bluff.

[No. 10, p. 254.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1	1
Red clay	59	60
Blue clay	33	93
Sand	22	115
Sand and gravel, water bearing	61	176
Eocene:		
Blue clay	3	179

Log of well of Mr. Avery, 2 miles southeast of Hazen.

[No. 15, p. 254.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil and red clay	25	25
Fine red sand	46	71
Blue clay	29	100
Fine sand	6	106
Sand and gravel	15	121
Fine hard sand	13	134
Sand and gravel, water bearing; stopped on blue clay which is probably of Eocene age	42	176

Wells in Prairie County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Carlisle (Lonoke Co.), 8 miles southeast of (in Prairie Co.).	1 N.	6 W.	8, SW. ¼	Hubbard & Sons	M. Brown	W. O. Hubbard.	1910		155	24	70–155		Pleistocene alluvium.
2	Des Arc, ¼ mile north of post office.	4 N.	5 W.		Peter Deforest	J. W. Pettey	Owner	1909		78	2	64–78		Do.
3	Des Arc				J. W. Pettey	Owner	do	1908	(a)	72	2	50–72	30	Do.
4	do	4 N.	5 W.	14, NE. ¼	G. W. Edmondson	J. W. Pettey	do	1906		75	2	65–75		Do.
5	Des Arc, ¼ mile southeast of post office.				McQueen & Fink	do	J. H. McQueen	1908	(b)	70	4	55–70		Do.
6	Devall Bluff				F. Gates					95				Do.
7	do				E. L. Sanders					75				Do.
8	Devall Bluff, ½ mile south of.				Jacob Frohlich					75				Do.
9	Devall Bluff				W. B. Coyle					85				Do.
10	Devall Bluff, 3½ miles west of.				Thomas Bros., Hazen.	Wm. Guntzenhouser, Stuttgart.	Clay Thomas, Hazen.	1911	230±	179	12	130–179		Do.
11	Devall Bluff, 5 miles southwest of.				Mrs. Geo. Lawman, Hazen.	Ralph Canyon, Hazen.	Owner		300±	150	12	90–150		Do.
12	Devall Bluff, 8½ miles south of.	1 N.	5 W.	24, E. ½	Chas. Strohl, Hazen.	Wheeler & Pettey, Devall Bluff.	do	1910		112	8¼	75–112		Do.
13	Hazen				Hazen Power & Light Co.	J. J. Paduska	W. L. Fox	1908		60	4			Do.
14	do				do	do	do	1911		80	6			Do.
15	Hazen, 2 miles southeast of.				Mr. Avery		E. G. Norton, Brinkley.		235±	176				Do.
16	Hazen, 2½ miles west of.	2 N.	6 W.	23, NW. ¼	E. W. Crouch	W. M. Scheck, Memphis, Tenn.	Owner	1909		127	8	80–127		Do.
17	Hazen, 8 miles southwest of.	1 N.	6 W.	18, SW. ¼	W. A. Shaw	Layne & Bowler, Stuttgart.	do	1910		133	11⅝	77–133		Do.
18	Hazen, 6 miles southwest of.	1 N.	6 W.	6	T. E. Downs, Carlisle.	J. E. Gidrey, Rayne, La.	do			150	8			Do.
19	Hazen, 8 miles southwest of.	1 N.	6 W.	18, SW. ¼	C. H. Chapman	Lonoke	E. L. Chapman.	1904	212±	158	9⅝			Do.
20	Ulm, 1 mile west of	1 S.	4 W.		A. J. Liedtke, Stuttgart.	Layne & Bowler, Stuttgart.	Owner	1910	209±	150	11⅝	45–150		Do.

a Elevation about 40 feet above low-water level of White River.

b Elevation about 20 feet above low-water level of White River.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.		Feet.	Galls.						
1	Carlisle (Lonoke Co.), 8 miles southeast of (in Prairie Co.).	1 N.	6 W.	8, SW. ¼	Sand and gravel	28	4,000		$5,000		Irrigation	Soft	
2	Des Arc, ¼ mile north of post office.	4 N.	5 W.		do	35			50	18	Domestic		
3	Des Arc				do	35		Hand.	50		do		
4	do	4 N.	5 W.	14, NE. ¼	Gray sand	40		do	55	6	do	Soft and ferruginous.	
5	Des Arc, ¼ mile southeast of post office.				Sand	20		Steam.	125	110	Domestic and manufacture of ice.	Soft	
6	Devall Bluff										Domestic		Assay 44, p. 304.
7	do										do		Assay 45, p. 304.
8	Devall Bluff, ½ mile south of.										do		Assay 46, p. 304.
9	Devall Bluff										do		Assay 47, p. 304.
10	Devall Bluff, 3½ miles west of.				Sand and gravel	50	1,800	Steam.	1,850		Irrigation		At top 80 feet of 10-inch casing and at bottom 99 feet of 12-inch casing and screen. Analysis 52, p. 302.
11	Devall Bluff, 5 miles southwest of.				Gravel	47	3,000				Domestic and irrigation.	Hard	Steel pit 95 feet deep and 28 inches in diameter; 60 feet of 12-inch strainer.
12	Devall Bluff, 8½ miles south of.	1 N.	5 W.	24, E. ½	Sand and gravel	48		Steam.	600		do	Soft	102 feet of 8¼-inch casing.
13	Hazen						200	Gas			Municipal supply.		Combined yield of these 2 wells furnishes the municipal water supply. For well No. 14, see analysis 53, p. 302.
14	do						250	do	400		do		
15	Hazen, 2 miles southeast of.					55		Electricity.			Irrigation		
16	Hazen, 2½ miles west of	2 N.	6 W.	23, NW. ¼	Sand and gravel	47½	700	Steam.	600	150	do		Analysis 54, p. 302.
17	Hazen, 8 miles southwest of.	1 N.	6 W.	18, SW. ¼	do	34	1,800		1,300	650	do	Soft	
18	Hazen, 6 miles southwest of.	1 N.	6 W.	6	Gravel	35	700	Air	600	1,000	do	Hard	
19	Hazen, 8 miles southwest of.	1 N.	6 W.	18, SW. ¼	do	33	2,000		1,200	125	Domestic and irrigation.		Irrigates 300 acres. Analysis 55, p. 302.
20	Ulm, 1 mile west of	1 S.	4 W.		Fine sand	40	1,200	Steam.	2,200		do	Soft	110 feet of casing and 40 feet of screen.

PULASKI COUNTY.

PHYSIOGRAPHY.

Pulaski County, in the central part of the State, has an area of 747 square miles and a population, according to the census of 1910, of 86,751. Only that part of the county lying east of Arkansas River and east of the Ozark province is treated in detail in this report. Agriculture is the chief industry and the principal crops are cotton, cereals, vegetables, and hay

The greater part of the county lying west of the St. Louis, Iron Mountain & Southern Railway is included in the Ozark province, an area characterized by hills and ridges which trend in general east and west, the summits of which are 500 to 1,000 feet or more above sea level. The remainder of the county is part of the Gulf Coastal Plain, here topographically subdivisible into the upland west of the Arkansas River bottom, a small area of Tertiary upland near Jacksonville, and the Advance lowland. The hills of the upland west of Arkansas River are 400 to 500 feet above sea level, but the upland has been strongly dissected by Fourche and Loran creeks and their tributaries.

The Arkansas River flood plain forms the greater part of the Advance lowland, a flat or gently rolling, heavily timbered plain, which stands 230 to 250 feet above sea level, and in which swamps, lakes, abandoned stream channels, and bayous are numerous. Arkansas River crosses the county, flowing southeastward to a point a few miles beyond Little Rock, where its general course becomes southerly.

In the northern part of the lowland small interstream areas rise a few feet above the flood-plain level.

GEOLOGY.

Paleozoic rocks of Ordovician and Carboniferous age outcrop in the Ozark province. They are separated from the deposits of the Coastal Plain by a steep southeastward-dipping erosion escarpment which trends northeast-southwest within a few miles west of the St. Louis, Iron Mountain & Southern Railway. Along the line of this escarpment the upper eroded surface of the Paleozoic rocks passes under the deposits of the Coastal Plain and extends southeastward beneath them.

Strata of Tertiary age, including the Midway formation (Eocene) and overlying undifferentiated Eocene deposits, outcrop in the Coastal Plain upland west of Arkansas River. The Midway formation, which consists of 25 feet or more of limestones, calcareous sandstones, sands, and clays, outcrops in a narrow area along the northwestern margin of the Coastal Plain, where it rests unconformably on Paleozoic rocks. The undifferentiated Eocene deposits, which consist of unconsolidated sands and clays, overlie the Midway formation and come to the surface in the upland southeast of the Midway area and also in a small area in the vicinity of Jacksonville, in the northeastern part of the county. Two to 5 miles south of Little Rock is a hill composed of igneous rocks which project through the Tertiary deposits. The summit of the hill is about 500 feet above sea level.

The Tertiary deposits are underlain by strata of Cretaceous age which at Little Rock have been recognized in well excavations and questionably recognized in a few poorly exposed outcrops. The materials immediately underlying the Arkansas River bottom to estimated depths of 100 to 200 feet consist of Quaternary alluvial loams, clays, sands, and gravels which contain large quantities of water. These deposits rest on undifferentiated strata of Cretaceous and Eocene age which at undetermined depths rest on the southeastward-sloping Paleozoic basement rocks.

WATER RESOURCES.

GENERAL CONDITIONS.

East of Arkansas River water for domestic and industrial uses is obtained chiefly from wells 15 to 100 feet deep that tap the sands and gravels of the Quaternary alluvium the waters of which stand 8 to 30 feet below the surface. According to well owners, many of the waters are hard, but some are soft and some are ferruginous. Detailed information concerning wells at Argenta and at Jacksonville is given in the table on page 260. A flowing well 140 feet deep has been obtained at Sweet Home, a village west of Arkansas River on the St. Louis, Iron Mountain & Southern Railway, about 6½ miles southeast of Little Rock (No. 14, p. 260).

The undifferentiated Eocene and Cretaceous deposits intervening between the alluvial deposits and the buried Paleozoic basement rocks, except in close proximity to the margin of the Ozark province, doubtless contain water-bearing beds that are a probable source of artesian waters. These waters are under hydrostatic pressure probably sufficient to bring them within less than 50 feet of the surface, but it is doubtful if flowing wells can be obtained in the Advance lowland east of Arkansas River. The static head of the flowing well at Sweet Home is believed to be due to conditions that are only of local extent.

LOCAL SUPPLIES.

Little Rock.—The municipal water supply of Little Rock (population 45,914, census of 1910) is obtained from Arkansas River. Information concerning the system has been furnished by Mr. G. M. Gadsby, superintendent of the waterworks, and by Mr. George P. Brown, secretary of the board of trade. The raw water is first pumped into a preliminary sedimentation basin (holding 2,500,000 gallons) where 20 to 60 per cent of the suspended matter is removed by subsidence. The water drawn from the top of this basin at one end is led into a coagulating basin having a capacity of 5,000,000 gallons, arranged with baffles and weirs so as to allow the most efficient settling of the coagulated water. From this coagulating basin the water is drawn by floating outlets to the filters, the pressure filters being placed at a lower elevation so that the water flows through them into the clear-water basin by gravity. The clear-water basin has a capacity of 5,300,000 gallons and is situated at such elevation that the city is supplied therefrom by gravity. Twenty-five closed pressure filters and four open gravity filters, all of the rapid-sand type, have been installed, the pressure filters having a total sand surface of 2,284 square feet and the gravity filters a total sand surface of 704 square feet. The sand is agitated during washing by the wash water, which is forced in from the bottom of the filter at sufficient pressure to float the sand almost to the top of the outlet trough. The normal capacity of the plant is 8,504,000 gallons and the daily consumption is about 4,000,000 gallons. Alum and iron and lime are used as coagulants, the kind and quantity of the coagulant varying with the quality of the raw water. The filtered water is also treated with calcium hypochlorite as it enters the clear-water basin. Though it is not intended to soften the water it is frequently necessary at low stages to use sufficient lime to have some softening effect. The water varies widely in its mineral content, but though enough chlorine has been present at times to be slightly noticeable the water has never been reported as brackish. It is generally used in boilers and is reported to be satisfactory with moderate use of boiler compound. There are 90 miles of mains, about 8,000 taps, and about 450 fire hydrants.

Argenta.—The town of Argenta (population, 11,138, census of 1910) is equipped with a water-supply system owned by the American Waterworks & Guaranty Co. Information concerning it has been obtained from F. G. Smith, acting superintendent. The supply is obtained from wells that tap the Quaternary alluvial deposits and are capable of yielding 2,000,000 gallons daily. There are 25 miles of mains. A pressure of 55 pounds per square inch is ordinarily maintained, but this can be raised for fire protection to 100 pounds per square inch. The daily consumption is 500,000 gallons.

The St. Louis, Iron Mountain & Southern Railway Co. owns nine wells at Argenta, all of which are described in detail in the table on page 260 (Nos. 1–9). One well is at the site of the new shops and the other eight form a group used in furnishing the boiler supply of locomotives. The logs of three of these wells are as follows:

Logs of wells of St. Louis, Iron Mountain & Southern Railway, Argenta.

At site of new shops.

[No. 1, p. 260.]

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Loam	4	4
Quicksand	3	7
Red clay	10	17
"Hardpan" or clay	20	37
Sandy clay	13	50
Quicksand	20	70
Gravel, water bearing	4	74
Coarse sand and bowlders, water bearing	6	80

Well No. 1 in group.

[No. 2, p. 260.]

	Thickness.	Depth.
Artificial fill:	*Feet.*	*Feet.*
Cinders and clay	10	10
Quaternary alluvium:		
"Dry" sand and clay	30	40
Sand and gravel, water bearing	40	80

Well No. 4 in group.

[No. 5, p. 260.]

Artificial fill:		
Cinders and clay	10	10
Quaternary alluvium:		
Fine sand	25	35
Very fine sand	20	55
Sand and gravel	25	80

The materials penetrated in wells Nos. 2, 3, 6, 7, and 8 of the group were of the same character as those encountered in well No. 1, and those in well No. 5 of the group were of the same character as those in well No. 4.

Jacksonville.—The log of a well owned by S. Taylor, seven-eighths of a mile south of Jacksonville, is as follows:

Log of well of S. Taylor, seven-eighths of a mile south of Jacksonville (SE. ¼ sec. 30, T. 3 N., R. 10 W.).

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Hard red clay	7	7
White clay	4	11
Variegated clay; stopped on soft, water-bearing sand	13	24

The log of an 82-foot well at Jacksonville, on the property of A. J. McBride, drilled in 1904, has been furnished by the owner as follows:

Log of well of A. J. McBride, Jacksonville.

	Thickness.	Depth.
[Quaternary alluvium]:	*Feet.*	*Feet.*
Red gumbo	10	10
Gray clay	20	30
Black clay	40	70
[Eocene (Midway formation ?)]:		
Limestone (?), water bearing	12	82

Wells in Pulaski County.

	Location.	Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Geologic name of water-bearing formation.	Character of principal water-bearing bed.	Level of water below surface.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
						Feet.	*Ft.*	*In.*	*Feet.*			*Ft.*						
1	Argenta (at site of railroad shops).	St. Louis, Iron Mountain & Southern Ry. Co.	....	J. R. Stephens, chief engineer.	....	255±	80	....	50-80	Quaternary alluvium.	Sand and gravel.	32	......	....	....	....	......	
2	Argenta (well No. 1)	.....do.......	....	...do.....	1907	255±	80	10	40-80	...do.....	...do.....	....	......	....	....	Boilers...	......	The combined yield of these 8 wells is 60,000,000 gallons per month. They are equipped with No. 8 and No. 10 Cook strainers, 15 to 20 feet in length.
3	Argenta (well No. 2)	.....do.......	....	...do.....	1907	255±	79	10	40-80	...do.....	...do.....	....	......	....	....	...do.....	......	
4	Argenta (well No. 3)	.....do.......	....	...do.....	1907	255±	80	10	40-80	...do.....	...do.....	....	......	....	....	...do.....	......	
5	Argenta (well No. 4)	.....do.......	....	...do.....	1907	255±	80	10	55-80	...do.....	...do.....	....	......	....	....	...do.....	......	
6	Argenta (well No. 5)	.....do.......	....	...do.....	1907	255±	81	10	55-80	...do.....	...do.....	....	......	....	....	...do.....	......	
7	Argenta (well No. 6)	.....do.......	....	...do.....	1907	255±	82	10	40-80	...do.....	...do.....	....	......	....	....	...do.....	......	
8	Argenta (well No. 7)	.....do.......	....	...do.....	1907	255±	80	10	40-80	...do.....	...do.....	....	......	....	....	...do.....	......	
9	Argenta (well No. 8)	.....do.......	....	...do.....	1907	255±	78	10	40-80	...do.....	...do.....	....	......	....	....	...do.....	......	
10	East Little Rock....	.....do.......	C. H. Winters.	Driller[a]..	....	268	66	8	......	Quaternary	....	27	......	....	....	....	Hard	Paleozoic rock struck at depth of 66 feet.
11	Jacksonville........	Mrs. P. T. Murtishaw.	B. Wood..	S. W. Murtishaw.	1881	288±	86	4	......	Quaternary alluvium.	Sand......	30	Hand	$160	$60	Domestic	..do.	
12	.....do............	Jacksonville Gin Co.	H. L. Huff, Little Rock.	J. H. Ramsey.	....	288±	150	8	......	...do.....	....	....	......	....	....	....	......	This well entered rock, probably of Paleozoic age, at a depth of 30 feet. An insufficient supply of water was obtained.
13	Scott..............	C. F. Chaer...	....	....	....	......	42	....	......	...do.....	....	....	......	....	....	Domestic	......	Assay 52, p. 304.
14	Sweet Home (at mill)	Mr. Bowman.	J. P. Clifford.	Driller[a]..	....	250?	140	....	......	Eocene.	....	....	Flows	....	....	....	Soft.	Water from below a bed of black clay.
15	Wrightsville........	Wm. Ferral...	...do.....	...do.....	....	257	120	....	......	...do.....	....	....	......	....	....	....	..do.	

[a] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 194–195, 1906.

RANDOLPH COUNTY.

PHYSIOGRAPHY.

Randolph County, which lies west of Clay and Green counties and north of Lawrence County, embraces an area of 674 square miles. Its population at the time of the census of 1910 was 18,987. Agriculture is the chief industry, the products including cotton, cereals, vegetables, and hay.

About three-quarters of the total area of the county is included in the Ozark province, a hilly upland lying 400 feet or more above sea level. A triangular area in the southeast, embracing about one-fourth of the county, is included in the Advance lowland, a topographic subdivision of the Mississippi embayment. Only that part of the county east of the Ozark province, including approximately one-third of the area, is treated in this report.

The surface of the Advance lowland is a nearly level or gently rolling plain, 270 to 280 feet above sea level, separated from the Ozark province on the west by a well-defined escarpment. Black River flows across the plain from the eastern border of the county westward to Pocahontas, and thence follows along the foot of the Ozark Hills to the southern boundary of the county. Near Pocahontas Black River is joined by Current River, which flows across the plain from northeast to southwest. The greater part of the Advance lowland is included in the broad timbered flood plains of these two streams, although in the extreme southeastern part of the county is a small area of gently rolling white clay land having the characteristics of the interstream areas.

GEOLOGY.

The Ozark province is underlain by Paleozoic rocks of Cambrian and Lower Ordovician age, which are separated from the deposits of the Coastal Plain on the east by a steep, southeastward-dipping, erosion escarpment, trending northeast-southwest. The older rocks pass under the deposits of the Coastal Plain and extend eastward beneath them, reaching greater depths in that direction.

The Advance lowland is underlain by an estimated thickness of 150 to 180 feet of Quaternary alluvial deposits of Pleistocene and Recent age. The Pleistocene deposits rest on strata of Eocene or Cretaceous age and outcrop in the interstream areas. In general they grade downward from silty loams or clays at the surface through fine sands to coarse, water-bearing sands and gravels at the base. The Recent alluvium appears at the surface in the flood plains of Black and Current rivers.

The strata of Eocene or Cretaceous age do not outcrop in the county. They underlie the alluvium which is underlain in turn by a basement of Paleozoic rocks the depth of which has not been determined by borings but probably nowhere exceeds 500 or 600 feet. The Eocene and Cretaceous deposits consist chiefly of unconsolidated sands and clays.

WATER RESOURCES.

In the Advance lowland water for domestic use is obtained chiefly from wells 15 to 100 feet deep, which tap the water-bearing sands and gravels of the Quaternary alluvium. The water stands in the wells 10 to 30 feet below the surface. As reported by the owners the well waters are in general soft but locally they are ferruginous.

Two wells owned by the St. Louis, Iron Mountain & Southern Railway Co. at O'Kean are, respectively, 50 and 97 feet deep, and 8 and 10 inches in diameter; the water is used in the boilers of locomotives, the consumption being 1,200,000 gallons per month. An analysis of the mixed waters from the two wells is given in the table opposite page 302 (No. 57).

The Eocene and Cretaceous deposits which underlie the alluvium are believed to contain water-bearing beds which could be reached by wells ranging in depth from 180 to 500 or 600 feet as a probable maximum. The hydrostatic pressure would probably be sufficient in most places to bring the waters within less than 50 feet of the surface but not sufficient to cause flows.

ST. FRANCIS COUNTY.[1]

PHYSIOGRAPHY.

St. Francis County, in the eastern part of the State, comprises an area of 628 square miles and has a population, according to the census of 1910, of 22,548. Agriculture and lumbering are the principal industries. The agricultural products include cotton, cereals, and hay. Sawmills are numerous.

Three topographic subdivisions of the Gulf Coastal Plain are represented in the county—Crowleys Ridge, the Advance lowland, and the Mississippi lowland.

Crowleys Ridge is a belt of hilly, partly wooded land, 1½ to 6 miles wide, trending north and south a little west of the center of the county; the crest of the ridge is about 370 feet above sea level, or 140 to 160 feet above the lowlands to the east and west. The drainage is effected chiefly by small streams that flow either eastward into St. Francis River or westward into L'Anguille River, but Big Crow Creek heads in the ridge near the northern boundary of the county, flows due south for about 9 miles, and leaves the ridge to join St.

[1] A detailed account of the surface features and the geology of St. Francis County, accompanied by a topographic and a geologic map, is given by R. E. Call in Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 143–183.

Francis River near Madison. Both the eastern and western slopes of the ridge are sharply defined, but the eastern slope is the steeper.

The part of the county west of Crowleys Ridge is included in the Advance lowland, a gently undulating plain 230 to 260 feet above sea level. L'Anguille River traverses this plain from north to south at a distance of 3 to 6 miles west of Crowleys Ridge. From the foot of the ridge westward to L'Anguille River the plain is heavily timbered, except where cleared for cultivation, and slopes gradually from an elevation of about 260 feet to about 220 feet. West of the river the plain slopes from an elevation of about 250 feet in the north to about 230 feet in the south. A small area in the southwestern part of the county is drained by Big Creek, a tributary of White River. The flood plains of the streams are heavily timbered and in part swampy. The interstream areas west of L'Anguille River present irregular patches of open, grass-covered prairie land, separated by slightly depressed patches and belts of timbered land.

The part of the county east of Crowleys Ridge is included in the Mississippi lowland, a heavily timbered, nearly level or gently undulating plain, 220 to 230 feet above sea level; swamps, lakes, bayous, and abandoned stream channels are numerous. The drainage is effected by St. Francis River, which flows from north to south in the western part of the lowland, following a course which in detail is very sinuous. Much of the area is subject to overflow from St. Francis and Mississippi rivers.

GEOLOGY.

Strata of Eocene age compose the core of Crowleys Ridge to a height of 20 to 70 feet above the level of the lowlands to the east and west. The deposits are irregularly bedded, dark to light clays, in part lignitic, and subordinate beds of dark to light-colored sands, in part glauconitic. Locally, the clays contain large numbers of invertebrate fossils, of which *Ostrea alabamiensis* Lea is the most abundant and most conspicuous species. The fossiliferous stratum has been determined by Vaughan to be of lower Jackson age. (See p. 82.) Undifferentiated strata of Eocene age underlie Crowleys Ridge to an estimated depth of 800 or 1,000 feet, and beds of this age extend out under the lowlands both to the east and west of the ridge, where they are overlain by Quaternary alluvium, whose estimated thickness ranges from 125 to 225 feet. The Eocene deposits contain important water-bearing beds, that have been tapped by deep wells at Forrest City. The Eocene deposits are underlain by deposits of Cretaceous age, which are thought to contain water-bearing beds; at an undetermined depth, probably, however, not exceeding 3,000 feet, the Cretaceous strata rest upon a basement of rocks believed to be of Paleozoic age.

The Eocene strata of Crowleys Ridge are unconformably overlain by 10 to 40 feet of coarse sands and gravels, in part water-bearing, belonging to the Lafayette formation (Pliocene?) and this formation is in turn overlain by loess of Pleistocene age, ranging in thickness from a few feet to 80 feet or more. The loess is the capping material of the ridge. Both the Lafayette and the loess are found blanketing the slopes of the ridge; in places these materials have reached their present position either by redeposition, landslides, or creep, but at many places it is difficult to distinguish between the original and the disturbed deposits.

The Quaternary alluvium which immediately underlies the surface in the Advance lowland west of Crowleys Ridge to depths of 140 to 200 feet is in part of Pleistocene and in part of Recent age. The Pleistocene deposits which outcrop in the interstream areas are irregularly bedded but in general grade downward from fine loams and silty clays through fine sands to coarse, abundantly water-bearing sands and gravels which rest unconformably on Eocene strata. The Recent deposits are loams, clays, sands, and gravels forming the flood-plain materials of the present streams.

The Quaternary alluvium, which underlies the Mississippi lowland to depths estimated at 125 to 225 feet, consists of loams, clays, and gravels, the coarser portions of which are abundantly water bearing. The materials immediately beneath the surface are probably entirely of Recent age, but Pleistocene beds probably intervene between the Recent and the underlying Eocene strata.

WATER RESOURCES.

GENERAL CONDITIONS.

Ordinary supplies.—Water for domestic and industrial use is obtained chiefly from wells 20 to 200 feet deep. Wells in Crowleys Ridge tap either the water-bearing sands and gravels of the Lafayette formation or the water-bearing sands of the underlying Eocene deposits, the waters of which rise within 20 to 125 feet of the surface. Wells in the lowlands tap the water-bearing sands and gravels of the Quaternary alluvium. According to the reports of the owners most of the well waters are hard and some are strongly ferruginous, but a few are soft.

The Eocene strata that underlie Crowleys Ridge to an estimated depth of 800 to 1,000 feet and extend out to the east and west of the ridge beneath the Quaternary alluvium, contain water-bearing beds in which the waters are under hydrostatic pressure; in Crowleys Ridge they will rise within less than 150 feet of the surface, in the lowland east of the ridge within less than 20 feet of the surface, and in the lowland west of the ridge within 30 to 60 feet of the surface.

The deeply buried Cretaceous deposits are believed to contain water-bearing beds which would be reached by wells 1,000 feet or more in depth. In the Mississippi lowland waters from depths of 1,200 feet or more would probably be under sufficient hydrostatic pressure to flow at the surface.

Small springs are numerous in Crowleys Ridge and are utilized to some extent for domestic and farm supplies.

Irrigation.—Rice culture has become an important industry on the prairies in the western part of the county, and water for irrigating the rice lands is obtained from wells 125 to 190 feet deep. The cost of sinking the wells and installing pumping plants ranges from $1,000 to $3,500 per well, and the yield ranges from 600 to 2,500 gallons a minute. The average cost based on nine wells is at the rate of $1,276 for each 1,000 gallons of yield a minute, or $1.28 for each gallon of yield a minute.

Detailed information concerning 14 irrigation wells is given in the table on page 268.

LOCAL SUPPLIES.

Forrest City.—Forrest City (population, 2,484, census of 1910) is equipped with a water supply drawn from three wells, respectively, 425, 425+, and 450 feet in depth (Nos. 3–5, p. 268). The principal water-bearing bed is in Eocene deposits at a depth of 400 feet, and the water rises within 70 feet of the surface. The standpipe pressure is 70 pounds per square inch. The wells yield an adequate supply of water of satisfactory quality.

A well at the Choctaw Brick Plant, three-quarters of a mile east of the town, is 600 feet deep and taps a water-bearing bed in the Eocene deposits (No. 6, p. 268).

Wells for irrigation.—Wells for irrigating rice lands have been drilled in the western part of the county in the vicinity of Goodwin, Wheetley, and east and northeast of Zent (Monroe County). A. Boysen & Sons own nine wells near Wheetley, in Tps. 3 and 4 N., R. 1 W. (See No. 11, p. 268.) Mr. A. Boysen states that the wells pass through essentially the succession of strata given in the following log:

Average log of nine wells of A. Boysen & Sons near Wheetley.

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	3	3
Hard clay, almost impervious to water	12	15
Sand, slightly argillaceous	15	30
Quicksand	10	40
Sand, becoming coarser toward base, water bearing	30	70
Gravel, becoming coarser toward base, water bearing; drilling is discontinued when clay is struck at a depth of 145 feet	75	145

The following is the log of an irrigation well near Wheetley, owned by C. E. Patt:

Log of well of C. E. Patt near Wheetley.

[No. 13, p. 268.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	2	2
Clay	16	18
Fine sand	7	25
Clay	5	30
Fine sand, water bearing in lower 20 feet	50	80
Coarse sand, water bearing	20	100
Fine sand, water bearing	15	115
Gravel and bowlders, water bearing	35	150
Gravel, water bearing	35	185
Eocene (?):		
Blue clay	1	186

Several irrigation wells are owned by the Luhallis Co. of Brinkley, detailed information concerning five of which is given on pages 268–269 (Nos. 15–19), and the logs of four of them follow:

Log of well of the Luhallis Co., in the SW. ¼ sec. 5, T. 4 N., R. 1 W.

[No. 16, p. 268.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1.5	1.5
Clay	14.5	16
Sand, water bearing	85	101
Sand and gravel, water bearing	74	175

Log of well of the Luhallis Co., in the SW. ¼ sec. 6, T. 4 N., R. 1 W.

[No. 17, p. 268.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1.5	1.5
Clay	15.5	17
Quicksand	43	60
Fine sand, water bearing	20	80
Sand, water bearing	73	153
Eocene (?):		
Blue clay	2.6	155.6

Log of well of the Luhallis Co., in the SE. ¼ sec. 6, T. 4 N., R. 1 W.

[No. 18, p. 268.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1	1
Clay	13	14
Sand, water bearing	97	111
Sand, gravel, and bowlders, water bearing	35	146
Eocene:		
Blue clay	1	147

Log of well of the Luhallis Co., in the SE. ¼ sec. 6, T. 4 N., R. 1 W.

[No. 19, p. 268.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1.5	1.5
Clay	14.5	16
Quicksand	39	55
Fine sand, water bearing	30	85
Fine sand and fine gravel, water bearing	60	145
Eocene:		
Blue clay	2	147
Blue sand	16	163
Blue clay	165	328
Sand, water bearing	50	378
Blue shale	84	462

The last well was drilled to the depth indicated (462 feet) to determine if larger quantities of water could be obtained from deeper water-bearing beds than from the sands and gravels of the alluvial deposits, with negative results.

The logs of three other irrigation wells (Nos. 20–22, p. 268) in T. 3 N., R. 1 W., are as follows:

Log of well of Norton Bros., of Brinkley, Ark., in the SW. ¼ sec. 8, T. 4 N., R. 1 W.

[No. 20, p. 268.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1.5	1.5
Clay	16.5	18
Quicksand	32	50
Fine sand	25	75
Sand, water bearing	25	100
Gravel, bowlders, water bearing	63	163
Gravel ("dead")	17	180
Eocene (?):		
Blue clay	.8	180.8

Log of well of C. E. Barber, in the S. ½ sec. 3, T. 4 N., R. 1 W.

[No. 21, p. 268.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1	1
Clay	14	15
Sand and gravel, water bearing	134	149
Eocene (?):		
Blue clay	2	151

Log of well of Mr. Oliphant, 1¼ miles northeast of Zent, in the W. ½ sec. 6, T. 4 N., R. 1 W.

[No. 22, p. 268.]

	Thickness.	Depth.
Pleistocene alluvium:	*Feet.*	*Feet.*
Clay	12	12
Fine sand	52	64
Coarse sand and gravel, water bearing	45	109
Coarse, bluish sand, water bearing	16	125

Wells in St. Francis County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Water-bearing formation.
	Place.	T.	R.	Sec.					Feet.	Feet.	Inches	Feet.	Feet.	
1	Forrest City				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.			170	10			Eocene.
2	do				do		do			170	10			Do.
3	do				Town				280±	425	4	400		Wilcox formation.
4	do				do				280±	425+	6	400		Do.
5	do				do				280±	450	8	400		Do.
6	Forrest City, ¾ mile east of.				Choctaw Brick Plant.				280±	600				Do.
7	Goodwin, 1½ miles west of.	4 N.	1 E.		Riley-Harrison Co.	Layne & Bowler, Stuttgart.	George Riley	1908	200±	160	11	85–160		Pleistocene alluvium.
8	Hunter (Woodruff County), 3½ miles south of.	4 N.	1 W.	5, N. ½	J. M. Brichler, Belleville, Ill.		Owner	1911	200±	160	9⅝	100–160		Do.
9	McDaniel, 1 mile east of.	4 N.	3 E.	22, NE. ¼	A. D. McDaniel	Gus Carpenter, Forrest City.	do	1904	250±	113	2	73–113	63	Eocene?
10	Palestine	4 N.	2 E.	9, SW. ¼	J. A. Sulcer	O. S. Abels	do			83	2	83	35	Pleistocene alluvium.
11	Wheetley				A. Boysen & Sons.		A. Boysen		214±	145		80–145		Do.
12	do	4 N.	1 W.	33, NE. ¼	Alex. Oehlschlager.	Layne & Bowler, Stuttgart.	Owner	1909	214±	142	9⅝	57–142		Do.
13	do	4 N.	1 W.	26	C. E. Patt, Kansas City, Mo.	C. Golieke, Garden City, Kans.	E. G. Norton, Brinkley.		214±	186				Do.
14	do				Wm. Fisher		Owner		214±	139	10	30–139		Do.
15	Zent (Monroe County), 1¼ miles east of.	4 N.	1 W.	6	The Luhallis Co., Brinkley.	Arkansas Well Co., Brinkley.	J. L. Norton, Brinkley.	1910	200±	180	12	70–180		Do.
16	Zent, northeast of	4 N.	1 W.	5, SW. ¼	do	C. Golieke, Garden City, Kans.	E. G. Norton, Brinkley.	1910	218±	175	9⅝	33–175		Do.
17	do	4 N.	1 W.	6, SW. ¼	do	do	do	1910	218±	155.6	9⅝	33–153		Do.
18	do	4 N.	1 W.	6, SE. ¼	do	do	do	1911	217±	147	9⅝	33–146		Do.
19	do	4 N.	1 W.	6, SE. ¼	do	do	do	1910	218±	462		55–145	328–378	Do.
20	Zent, east of	4 N.	1 W.	8, SW. ¼	Norton Bros., Brinkley.	do	do	1910	218±	180.8	9⅝	33–180		Do.
21	do	4 N.	1 W.	3, S. ½	C. E. Barber, Wheetley.	Layne & Bowler, Stuttgart.	do		218±	151	9⅝			Do.
22	Zent, 1¼ miles northeast of.	4 N.	1 W.	6, W. ½	Mr. Oliphant	Jerome Fesperman	do	1912	200±	125	9⅝	36–125		Do.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.		*Feet.*	*Galls.*						
1	Forrest City										Boilers		Combined monthly yield, 1,200,000 gallons. Analysis 58, p. 302.
2	do										do		
3	do				Coarse sand	70	100+				Municipal supply.		The three wells operated in combination are the source of the municipal water supply.
4	do				do	70	100+				do		
5	do				do	70	100+				do		
6	Forrest City, ¾ mile east of.										Boilers		
7	Goodwin, 1½ miles west of.	4 N.	1 E.		Gravel	4	2,500		$3,500		Irrigation		Analysis 59, p. 302.
8	Hunter (Woodruff County), 3½ miles south of.	4 N.	1 W.	5, N. ½	do	27	2,500	Steam			Domestic and irrigation.		
9	McDaniel, 1 mile east of.	4 N.	3 E.	22, NE. ¼	Fine sand	36		Wind.	75	206	Domestic	Medium soft	
10	Palestine	4 N.	2 E.	9, SW. ¼	Gravel	20		Hand.	50		do	Hard	
11	Wheetley				do	30	1,500	Steam	1,500	500	Domestic and irrigation.		There are 8 similar wells on this property used for irrigating rice fields. Analysis 61, p. 302.
12	do	4 N.	1 W.	33, NE. ¼	do	32	1,200	do	2,000		Irrigation	Hard	85 feet of 9⅝-inch casing and 57 feet of 9⅝-inch strainer.
13	do	4 N.	1 W.	26	Sand and gravel			do			do		
14	do				Quicksand	30	1,500	do	1,750		do		Analysis 60, p. 302.
15	Zent (Monroe County), 1¼ miles east of.	4 N.	1 W.	6	Sand and gravel	30	2,000	do	2,500		do		70 feet of 24-inch casing and 110 feet of 12-inch casing and screen. Analysis 63, p. 302.
16	Zent, northeast of	4 N.	1 W.	5, SW. ¼	do	33	1,100	do	1,800	700	do	Alkaline	70 feet of 24-inch steel pit and 105 feet of 9⅝-inch casing and screen.
17	do	4 N.	1 W.	6, SW. ¼	Sand	33	600	do	1,800	700	do	do	50 feet of 24-inch steel pit and 105.6 feet of 9⅝-inch casing and screen.
18	do	4 N.	1 W.	6, SE. ¼	Sand and gravel	33	2,500	do	1,800	700	do	do	70 feet of 24-inch steel pit and 77 feet of 9⅝-inch casing and screen.
19	do	4 N.	1 W.	6, SE. ¼	Fine sand	33						do	Drilled as a test well.
20	Zent, east of	4 N.	1 W.	8, SW. ¼	Sand and gravel	33	1,100	Steam.	1,800	700	Irrigation		54 feet of 24-inch steel pit and 126.8 feet of 9⅝-inch casing and screen. Analysis 62, p. 302.
21	do	4 N.	1 W.	3, S. ½	do		2,000	do			do		
22	Zent, 1¼ miles northeast of.	4 N.	1 W.	6, W. ½	do	36		do			do		

WHITE COUNTY.

PHYSIOGRAPHY.

White County, in the northeast-central part of the State, comprises an area of 1,037 square miles. Its population at the time of the census of 1910 was 28,574. The principal industry is agriculture, the products including cotton, cereals, vegetables, and hay.

The county is topographically divisible into two parts. The part west of a line running northeast-southwest a few miles west of the St. Louis, Iron Mountain & Southern Railway is the Ozark province, a strongly dissected upland lying 400 to 1,000 feet or more above sea level and containing about three-fifths of the total area of the county. The remainder of the county is included in the Gulf Coastal Plain, the greater part of which is a nearly level or gently rolling plain known as the Advance lowland, lying 215 to 230 feet above sea level. Only that part of the county lying east of the Ozark province is treated in this report.

Along the western margin of the Coastal Plain in the northern part of the county bordering the Ozark province is a narrow terrace or ridge more or less clearly defined, forming the southern extremity of the Grandglaise terrace, the crest of which is 250 to 300 feet above sea level, or 40 to 50 feet above the lowland to the east. Bordering the Ozark province, southwest of Beebe in the southern part of the county, there is also a small hilly tract, which rises somewhat above the level of the Advance lowland.

White River forms the eastern boundary of the county. Little Red River leaves the Ozark province near Searcy, flows a little south of east, and joins White River about 6 miles north of the southeastern corner of the county. Bayou des Arc, a tributary of White River, forms the greater part of the southern boundary. The broad flood plains of these streams are heavily timbered, and swamps, bayous, and abandoned stream channels are numerous. The interstream areas are gently rolling and are for the most part timbered except where cleared for cultivation. There are a few patches of prairie land in the southern part of the county.

GEOLOGY.

The Ozark province is underlain by undifferentiated Paleozoic sandstones and shales of Pennsylvanian age. They are separated from the deposits of the Coastal Plain on the east by a relatively steep, eastward-facing erosion escarpment along the line of which the older rocks pass under the deposits of the Coastal Plain and extend eastward beneath them, lying deeper in that direction. The Paleozoic rocks have been reached in wells east of the escarpment at a few places along the St. Louis, Iron Mountain & Southern Railway. (See logs of wells, p. 272.)

The deposits of the Coastal Plain are of Cretaceous, Tertiary, and Quaternary age. So far as known Cretaceous strata do not outcrop within the county, but marl containing characteristic Cretaceous fossils has been taken from a well at Beebe between the depths 29 and 64 feet.[1] Strata of this age are believed to underlie all the Coastal Plain portion of the county. They rest upon the rocks of the Paleozoic basement and are overlain by Eocene and younger deposits.

Marls and limestone belonging to the Midway formation of the Eocene outcrop at a few places in the Grandglaise terrace and marls, probably of Midway age, have been recognized in well borings near Beebe. Undifferentiated strata of Eocene age are believed to make up the body of some low hills southwest of Beebe. East of the Grandglaise terrace in the Advance lowland undifferentiated strata of Eocene age are believed to be present, resting upon the deeply buried Cretaceous strata and overlain by 100 to 150 feet of Quaternary alluvial deposits. Both the Eocene and underlying Cretaceous deposits probably contain important water-bearing beds.

The Quaternary alluvium, which immediately underlies the Advance lowland to estimated depths of 100 to 150 feet, is of Pleistocene and Recent age. The Pleistocene deposits, though irregularly bedded, in general grade downward from fine silty clays or sands at the surface through fine sands to coarse abundantly water-bearing sands and gravels at the base. They rest unconformably upon Paleozoic, Cretaceous, and Eocene strata and outcrop in the interstream areas. Recent loams, clays, sands, and gravels compose the flood-plain deposits of the present streams.

WATER RESOURCES.

GENERAL CONDITIONS.

In the Coastal Plain area water for domestic and industrial uses is obtained chiefly from wells 15 to 80 feet deep. In the Advance lowland wells that yield sufficient water for ordinary domestic supplies tap the water-bearing sands and gravels of the Quaternary alluvial deposits, and in the Grandglaise terrace beds belonging to the Midway formation are the source of supply. The waters stand in the wells 10 to 50 feet below the surface and, according to the reports of well owners, many are hard, some are soft, and some are ferruginous. In a considerable area in the eastern part of the county, particularly in the vicinity of West Point, Worden, and east of Russell, waters having a distinct brackish taste, probably due to common salt, are obtained.

Small springs which emerge from strata of the Midway formation are numerous along the narrow ridge or terrace known as the

[1] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept., vol. 2, pp. 10, 11, 1892.

Grandglaise terrace, and are utilized to some extent for domestic supplies.

The undifferentiated Cretaceous and Eocene deposits which intervene between the Quaternary alluvium and the Paleozoic basement rocks are believed to contain important water-bearing beds that would be reached by wells ranging in depth from 150 to 200 feet near the western part of the area to a maximum of 800 or 1,000 feet in the extreme southeastern part. These waters are under hydrostatic pressure probably sufficient to bring them within 50 feet or less of the surface.

LOCAL SUPPLIES.

Bald Knob.—At Bald Knob (population 617, census of 1910) the St. Louis, Iron Mountain & Southern Railway Co. obtains water for locomotives from a well 225 feet deep (No. 1, p. 273), which enters Paleozoic rocks at a depth of 31 feet; the water, which rises within 38 feet of the surface, comes from a crevice in these rocks at a depth of 193 feet. The well yields 4,000,000 gallons a month. When pumped at the rate of 5,000 gallons an hour the static head is reduced 4 feet and 5 inches. (See analysis 64, p. 302.)

The following is a log of the well:

Log of well of the St. Louis, Iron Mountain & Southern Railway, Bald Knob.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Yellow clay	30	30
Sand and gravel	1	31
Paleozoic:		
Hard rock	30	61
Soft blue rock	9	70
Hard rock	70	140
Soft black rock	12	152
Hard rock; at a depth of 193 feet a crevice was struck, which is believed to furnish the principal water supply	73	225

Higginson.—The St. Louis, Iron Mountain & Southern Railway Co. owns two wells at Higginson (population 192, census of 1910), each 62.5 feet deep (Nos. 2 and 3, p. 273). They tap the coarse sands and gravels at the base of the Quaternary alluvium and yield at the rate of 3,500,000 gallons a month. An analysis of the mixed water from the two wells is given in the table opposite page 302 (No. 65). The following is a log of one of the wells:

Log of well of the St. Louis, Iron Mountain & Southern Railway, Higginson.

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Clay	30	30
Fine sand	20	50
Coarse sand with pebbles and cobbles, water bearing; stopped drilling on rock	12.5	62.5

Wells in White County.

No.	Location: Place.	T.	R.	Sec.	Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
									Feet.	*Feet.*	*In.*	*Feet.*	*Feet.*	
1	Bald Knob				St. Louis, Iron Mountain & Southern Ry. Co.		J. R. Stephens, chief engineer.		231	225	6	193		Carboniferous.
2	Higginson				do		do		226±	62.5	10	50–62.5		Pleistocene alluvium.
3	do				do		do		226±	62.5	10	50–62.5		Do.
4	Kensett				Kensett Ice Co		H. E. Watson.		230±	63		60	34	Quaternary alluvium.
5	Kensett, 1½ miles north of.	7 N.	6 W.	8, NW. ¼	Doniphar Lumber Co.	Thos. F. Hughes.	H. Kilpatrick.	1910	230±	165	7			Pleistocene alluvium.
6	Kensett				Geo. F. Meyer		Owner	1911	230±	50	1¾	50	35	Quaternary alluvium.
7	West Point	7 N.	6 W.	26, NE. ¼	S. N. Wright	Owner	do	1911		76	2	72		Pleistocene alluvium.
8	do	7 N.	6 W.	25, SW. ¼	M. B. Johnson	C. K. Williams	do	1902		60	12	55		Do.
9	Worden	8 N.	5 W.	25, NW. ¼	W. H. Davidson		do	1901	216±	60	1¼	35		Do.
10	Worden, ¼ mile west of.	8 N.	5 W.	25	O. R. Root		do	1907	216±	58	1¼	45–58		Do.

Wells in White County—Continued.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Galls.*						
1	Bald Knob				Crevice in hard rock.	38	90+				Boilers		$12\frac{1}{4}$-inch casing extends to depth of 43 feet; 12-inch bore from depth of 43 feet to depth of 112 feet; 8-inch bore from depth of 112 feet to depth of 155 feet; 6-inch bore from depth of 155 feet to depth of 255 feet. Monthly yield, 4,000,000 gallons. Analysis 64, p. 302.
2	Higginson				Coarse sand with pebbles and cobbles.	10	80 (2 and 3)				do		Analysis 65, p. 302.
3	do				do	10					do		
4	Kensett				Coarse sand and gravel.	23	35+	Steam	$80	$154	Domestic and manufacture of ice.	Soft	Dug type.
5	Kensett, $1\frac{1}{2}$ miles north of.	7 N.	6 W.	8, NW. $\frac{1}{4}$	Gravel			Hand			Drinking	Ferruginous	50 feet of 7-inch casing; well enters Paleozoic rock at depth of 50 feet.
6	Kensett				Coarse sand			do	9	9	Domestic	do	Driven type.
7	West Point	7 N.	6 W.	26, NE. $\frac{1}{4}$	Gravel	50			25	15	Drinking and boilers.	Slightly brackish (?), hard (?).	
8	do	7 N.	6 W.	25, SW. $\frac{1}{4}$	Sand	50		Hand	10	20	Domestic		Bored type.
9	Worden	8 N.	5 W.	25, NW. $\frac{1}{4}$		20		do	9	6	Boilers and domestic.	Hard	
10	Worden, $\frac{1}{4}$ mile west of.	8 N.	5 W.	25	Sand	20		do			do	Slightly brackish.	

WOODRUFF COUNTY.

PHYSIOGRAPHY.

Woodruff County, in the northeast-central part of the State, embraces an area of 577 square miles. The census of 1910 reported its population to be 20,049. Agriculture is the chief industry, the principal crops being cotton, corn, rice, and hay.

The county is included in the topographic subdivision of the Gulf Coastal Plain known as the Advance lowland, the surface of which is in general a gently undulating plain 190 to 235 feet above sea level and sloping slightly to the south. White River forms the western boundary; Cache River enters the county in the north and flows a little west of south entirely across the county. The area between White and Cache rivers is heavily timbered and is nearly all included in the flood plain of the two streams; it is characterized by swamps, bayous, and lakes, separated by low ridges of sand or sandy loam. Bayou De Vue enters the county in the northeastern corner and flows a little west of south to the southern boundary. Between Cache River and Bayou De Vue and 15 or 20 feet higher than the flood plain to the west is a belt of land locally known as Nubbin Ridge, which has been largely cleared for cultivation. East of Bayou De Vue the surface presents irregular patches of grass-covered prairie separated by tracts of slightly depressed timbered lands.

GEOLOGY.

Quaternary alluvium of Pleistocene and Recent age underlies the surface to depths estimated at 125 to 165 feet. The Pleistocene deposits rest unconformably upon Eocene strata and outcrop in the higher interstream areas in the eastern half of the county and to a small extent in the northern part of the county. Although irregularly bedded they grade downward in general from fine silty loams or clays at the surface, through fine sands to coarse water-bearing sands and gravels at the base. Recent alluvial loams, clays, sands, and gravels underlie the flood plains of the present streams to an undetermined depth.

The Eocene strata which underlie the Quaternary alluvium are probably several hundred feet thick and are in turn underlain by Cretaceous deposits which, at a depth of 900 to 1,200 feet or more, rest upon Paleozoic basement rocks. The only definite information available concerning the character of the undifferentiated Eocene and Cretaceous strata is furnished by a 900-foot well at Augusta, which is reported to have penetrated "dry" blue clay from a depth of 145 feet to a depth of 900 feet, where hard rock, probably Paleozoic basement rock, was struck.

WATER RESOURCES.

GENERAL CONDITIONS.

Water for domestic, industrial, and irrigation supplies is obtained chiefly from wells 10 to 165 feet deep which tap the abundantly water-bearing sands and gravels of the Quaternary alluvium. The water stands in the wells a few feet to 40 feet below the surface, and, according to the reports of the well owners, most of the waters are soft but a few are hard.

Although the 900-foot well at Augusta is reported to have encountered only non water-bearing clays from a depth of 145 to 900 feet, it is believed that this condition, if accurately reported, is of local extent and that elsewhere the prospects are good for obtaining water from interbedded sandy layers in these undifferentiated Eocene and Cretaceous deposits. Such waters would be under hydrostatic pressure which would probably bring them within less than 50 feet of the surface.

LOCAL SUPPLIES.

Augusta.—The municipal water supply of Augusta (population 1,520, census of 1910), the county seat, is owned by Campbell & Vinson. The water is obtained from two wells, 100 feet deep (Nos. 1 and 2, p. 278), whose combined daily yield is 200,000 gallons. A Cook strainer is inserted in the lower 20 feet of each well. The water is distributed at a pressure of 40 pounds per square inch from a standpipe holding 50,000 gallons. The level of the water in the wells is said to fluctuate with the level of White River, the maximum range being from 20 to 40 feet below the surface. The water is strongly ferruginous.

The following log of a 900-foot well drilled at Augusta some time ago is based on the oral statements of citizens, and the character and thickness of the strata are therefore given only approximately.

Log of 900-foot well at Augusta.

[No. 3, p. 278.]

	Thickness.	Depth.
Quaternary alluvium:	*Feet.*	*Feet.*
Yellow clay loam	30	30
Sand, water bearing	70	100
Not reported	45	145
Undifferentiated Eocene and Cretaceous:		
"Dry" blue clay; stopped drilling on hard rock	755	900

Cotton Plant.—The municipal water supply of Cotton Plant (population 1,081, census of 1910), information concerning which has been furnished by F. H. Kennedy, postmaster, is obtained from a shallow well 36 (?) feet deep and is distributed from a 50,000-gallon tank. The water is soft and the daily consumption is 15,000 gallons.

Wells for irrigation.—Rice is grown on the prairies in the eastern part of the county and water for irrigation is obtained from wells 100 to 160 feet deep, yielding 1,500 to 2,500 gallons a minute. Detailed information concerning five irrigation wells is given in the table on page 278 (Nos. 7–11). The logs of three of these wells follow:

Log of well of the Hunter Land & Rice Co., near Hunter.

[No. 8, p. 278.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1.25	1.25
Clay	.75	2
"Hardpan"	16	18
Quicksand	22	40
Fine sand, water bearing	30	70
Coarse sand, water bearing	20	90
Gravel and bowlders, water bearing; stopped on blue clay, probably of Eocene age	37	127

The driller states that gas was encountered in this well with pressure sufficient to lift the tools 4 inches.

Log of well No. 2 of the Hunter Land & Rice Co., near Hunter.

[No. 7, p. 278.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	1.5	1.5
Clay	1	2.5
"Hardpan"	14.5	17
Quicksand	33	50
Fine sand, water bearing	30	80
Coarse sand, water bearing	20	100
Gravel and bowlders, water bearing	55	155
Eocene (?):		
Blue clay	1	156

Log of well of H. L. Baker, 1¾ miles southwest of Hunter.

[No. 9, p. 278.]

	Thickness.	Depth.
Soil and Pleistocene alluvium:	*Feet.*	*Feet.*
Soil	3	3
Bluish-white clay	12	15
Quicksand	8	23
Character not stated but the materials are slightly water bearing	42	65
Fine gravel, water bearing	9	74
Coarser gravel, water bearing	16	90
Sand and gravel, water bearing	18	108

Wells in Woodruff County.

	Location.				Owner.	Driller.	Authority.	Date completed.	Approximate elevation above sea level.	Depth.	Diameter.	Depth to principal water-bearing bed.	Depth to other water-bearing beds.	Geologic name of water-bearing formation.
	Place.	T.	R.	Sec.										
									Feet.	*Feet.*	*Inches*	*Feet.*	*Feet.*	
1	Augusta				Augusta Waterworks Co.			1903		100	6			Quaternary alluvium.
2	do				do			1903		100	6			Do.
3	do									900				
4	Hilleman	6 N.	1 W.	22, SE. ¼	Geo. Hillemann, Altamont, Ill.		J. L. Stair	1907	210±	60±	2½	30–60±		Pleistocene alluvium.
5	Howell	6 N.	2 W.	30, NW. ¼	T. A. Smith		Owner	1890	216±	76	1¼	76	47.5	Do.
6	do	6 N.	2 W.	30, NE. ¼	Town	John Jacobs, Judsonia.	R. T. Martin	1905	216±	80	1¼	45–80		Do.
7	Hunter, southeast of	5 N.	1 W.	34	Hunter Land & Rice Co. (well No. 2).	C. Golieke, Garden City, Kans.	E. G. Norton, Brinkley.		212±	156		50–105		Do.
8	do	5 N.	1 W.	34	Hunter Land & Rice Co. (well No. 1).	do	do		212±	127		40–127		Do.
9	Hunter, 1¾ miles southeast of.	5 N.	1 W.	21	H. L. Baker	Oscar Lowe, Jennings, La.	Owner	1910	212±	108	12	75–108	23–48	Do.
10	Hunter, 3 miles south of	5 N.	1 W.	30, SW. ¼	I. N. Strickler		do	1906	210±	115	8	30–115		Do.
11	Penrose	7 N.	1 W.	25, SE. ¼	McCleery & Son	Walters & Baker, Hunter.	R. W. McCleery.	1911	215±	124	10	60–124		Do.

	Location.				Character of principal water-bearing bed.	Level of water below surface.	Yield per minute.	Method of lift.	Cost of well.	Cost of machinery.	Use.	Quality of water.	Remarks.
	Place.	T.	R.	Sec.									
						Feet.	*Galls.*						
1	Augusta					20–40	70				Municipal supply.	Ferruginous	
2	do					20–40	70					do	
3	do												Hard rock (Paleozoic ?) struck at 900 feet.
4	Hilleman	6 N.	1 W.	22, SE. ¼	Sand	20		Steam.			Boilers	Alkaline	
5	Howell	6 N.	2 W.	30, NW. ¼	do	28		Hand.	$45		Domestic	Soft	
6	do	6 N.	2 W.	30, NE. ¼	Gravel	40	2	do	80		do	do	
7	Hunter, southeast of.	5 N.	1 W.	34	Sand and gravel						Irrigation		Analysis 66, p. 302.
8	do	5 N.	1 W.	34	do						do		Analysis 67, p. 302.
9	Hunter, 1¾ miles southeast of.	5 N.	1 W.	21	Coarse gravel	23	1,600	Steam.	1,100	625	do		Pit 50 feet deep, 18 feet of 12-inch casing and 40 feet of 12-inch screen.
10	Hunter, 3 miles south of.	5 N.	1 W.	30, SW. ¼	Sand	30	2,500	do	1,000	200	Domestic and irrigation.		
11	Penrose	7 N.	1 W.	25, SE. ¼	Gravel	19	2,000		1,000		do		Analysis 68, p. 302.

CHEMICAL CHARACTER OF THE WATERS OF NORTH-EASTERN ARKANSAS.

By R. B. Dole.

STANDARDS OF CLASSIFICATION.

MINERAL CONSTITUENTS OF WATER.

The substances that may be present in natural waters are classified for analysis as suspended matter, such as particles of clay or leaves; dissolved matter, either of mineral or organic origin; microscopic animals or plants; and bacteria. The presence of very small animals and plants likely to affect the quality of waters is determined by microscopic examination, and the chance of contracting disease by drinking the water is studied by bacteriologic processes. The amount and nature of the mineral ingredients are most commonly determined by estimating the total suspended matter, total dissolved matter, total hardness, total alkalinity, silica, iron, aluminum, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, nitrate, chloride, free carbon dioxide, and free hydrogen sulphide. These estimates are a measure of the materials most commonly present and most likely to affect the value of the waters.

WATER FOR BOILER USE.

FORMATION OF SCALE.

The most common trouble in boilers is formation of scale, for when the water is heated under pressure and concentrated certain substances are thrown out of solution and form an incrustation on the flues or crown sheets or within the tubes. This scale or incrustation includes practically all the suspended matter or mud; the silica, probably precipitated as the oxide (SiO_2); the iron and aluminum, appearing in the scale as oxides or hydrated oxides; the calcium, precipitated principally in the form of carbonate and sulphate; and the magnesium, found in the deposits principally as the oxide but partly as the carbonate. The scale is therefore a mixture, which varies in amount, density, hardness, and composition with different conditions of water supply, steam pressure, type of boiler, and other circumstances. Calcium and magnesium are the principal basic substances in the scale, over 90 per cent of which usually is calcium, magnesium, carbonate, and sulphate. If much organic matter is present, part of it is precipitated with the mineral scale, as the organic matter is decomposed by heat or by reaction with other substances. If magnesium and sulphate are comparatively low, or if suspended matter is comparatively high, the scale is soft and bulky and may be in the form of sludge that can be blown or washed from the boiler. On the other hand, a clear water relatively high in magnesium and sulphate may produce a hard, compact scale that is nearly as dense as porcelain, clings to the tubes, and offers great resistance to the transmission of heat.

CORROSION.

Corrosion or "pitting" is caused chiefly by the solvent action of acids on the iron of the boiler. Organic matter is probably a source of acids, for it is well known that waters high in organic matter and low in calcium and magnesium are corrosive, though the exact nature and the action of the organic bodies are not well understood. Acids freed in the boiler by the deposition of iron, aluminum, and magnesium as hydrates are the chief cause of corrosion, and magnesium deserves particular attention, as it is the most abundant of the three. The acid radicles that were in equilibrium with these bases may do one or all of three things, according to the chemical composition of the water: They may pass into equilibrium with other bases, displacing equivalent quantities of carbonate and bicarbonate; they may decompose carbonate that has been precipitated as scale; or they may combine with the iron of the boiler, thus causing corrosion. Which of these reactions will occur can be expressed even with the most complete analyses only as a probability. If the acid thus freed exceeds the amount required to decompose the carbonate and bicarbonate, the iron of the boiler is attacked and pits or tuberculations of the interior surface, leaks, particularly around rivets, and consequent deterioration of the boiler result.

FOAMING.

Foaming is the formation of masses of bubbles on the surface of the water in the boiler and in the steam space above the water, and it is intimately connected with priming, which is the passage from the boiler of water mixed with steam. The principal cause of foaming is usually believed to be an excess of dissolved matter; consequently, as sodium and potassium remain dissolved in the boiler water while the greater portion of the other bases is precipitated, the foaming tendency is commonly measured by the degree of concentration of the alkaline salts in solution, because this figure, in connection with the type of boiler, determines to great extent the length of time that a boiler may run without danger of foaming. It is a fact that the worst foaming waters in railroad practice are encountered in the arid and semiarid regions of the Southwest, where the quantity of dissolved alkali is greatest. However, it is well known that suspended matter can cause foaming, for certain surface waters that when clear do not foam, but deposit a moderate amount of scale, foam badly whenever they carry a great quantity of mud. The design of the boiler, irregular blowing off, neglect to change water periodically, introduction of oil into the feed water from the exhaust steam, and improper firing and feeding are doubtless factors in foaming.

REMEDIES FOR BOILER TROUBLES.

It is best to treat feed waters before they enter boilers, but when such treatment can not be given there are various ways of obviating trouble. Low-pressure, large-flue boilers are frequently used in many stationary plants with hard waters, and it is said that the scale formed in them is softer and more flocculent and can therefore be more readily removed than that in high-pressure boilers. Blowing off is about the only practical means of preventing foaming, because this trouble is due principally to concentration of substances in the residual water of the boilers. Accumulated sludge, or soft scale, is removed by blowing, particularly in locomotive practice.

BOILER COMPOUNDS.

Boiler compounds are widely used in regions where hard waters abound, but treatment within the boiler should be given only when it is impossible to purify the supply before it enters the boiler or when the relatively pure condition of the supply requires only minor correction. If previous purification is not practicable, some feed waters can be improved by judicious addition of chemicals. Though many substances have been recommended for such use, only a few have proved to be really efficient. Soda ash, the commercial form of sodium carbonate, containing about 95 per cent Na_2CO_3, is most valuable for attacking chemically the scaling and corroding constituents, precipitating the incrusting matter, and neutralizing acids because it is cheap and its use is attended with the least objectionable results. The proper amount of it to be used depends on the chemical composition of the water and the type of boiler. Tannin and tannin compounds are also used for the same purpose. The addition of limewater to some feed waters high in organic matter and free carbon dioxide and very low in incrustants effectively prevents corrosion and foaming. Certain other boiler compounds act mechanically on the precipitated crystals of scale-making matter soon after they are formed, surrounding them and robbing them of their cement-like action. Glutinous, starchy, and oily substances belong to this class, but they are not now used to any considerable extent because they thicken and foul the water more than they prevent the formation of hard scale. Kerosene is effective in partly dissolving deposited scale, thus loosening it and permitting its ready removal, and graphite is extensively used to prevent formation of hard scale and sticking of particles to the boiler tubes or shell.

Many boiler compounds possessing or supposed to possess one or more of the functions just described are on the market and are widely sold. Some are effective and some are positively injurious. Most of them depend for their chief action on soda ash, petroleum, or a vegetable extract, but all are costly compared with lime and soda ash. Boiler compounds can not reduce the amount of scale, but may increase it. Their only legitimate functions are to prevent corrosion and deposition of hard scale and to remove accumulations of scale that have become attached to the boiler. Every engineer should bear in mind that a steam boiler is an expensive piece of apparatus and that fuel and boiler repairs also are expensive. Therefore he should hesitate to add substances to his feed water without competent advice regarding their effect. It is far more economical to have the water supply analyzed and to treat it effectively by well-known chemicals in proper proportion, either within or without the boiler, than to experiment with compounds of unknown composition.

NUMERICAL STANDARDS.

The probable quantities of scale-forming and foaming ingredients and the probability of corrosion when the waters are used in boilers have been computed for the analyses published in this report by means of modifications of certain formulas published in Stabler's excellent discussion[1] of the quality of mineral waters. His terms involving iron, aluminum, and free acids have been omitted because the amount of these substances in the waters of Arkansas is usually too small to necessitate consideration in such approximate rating; the terms involving sodium and potassium have been united for sim-

[1] Stabler, Herman, The mineral analysis of water for industrial purposes and its interpretation by the engineer: Eng. News, vol. 60, p. 355, 1908; also U. S. Geol. Survey Water-Supply Paper 274, p. 165, 1911.

plicity. The coefficients have been recomputed to give the estimates in parts per million.

(1) $s = Sm + Cm + 2.95\ Ca + 1.66\ Mg$.
(2) $h = SiO_2 + 1.66\ Mg + 1.92\ Cl + 1.42\ SO_4 - 2.95\ Na$.
(3) $f = 2.7\ Na$.
(4) $c = 0.0821\ Mg - 0.333\ CO_3 - 0.0164\ HCO_3$.

These equations express numerically some of the relations that have been discussed in the preceding sections on scale, corrosion, and priming. Sm, Cm, SiO_2, Ca, Mg, Na, Cl, SO_4, CO_3, and HCO_3 represent the amounts in parts per million, respectively, of suspended matter, colloidal matter (oxides of silicon, iron, and aluminum), silica, calcium, magnesium, alkalies, chlorine, sulphate, carbonate, and bicarbonate. The first formula gives the amount of scale-forming ingredients (s) under ordinary conditions of boiler operation. As values for silica (SiO_2) are given in only a few of the analyses in this report, 35 has been taken as a fair average value for that substance in computing the value of s. Fortunately, silica is a relatively constant ingredient, its values ranging within comparatively narrow limits irrespective of the abundance of other ingredients. As most of the ground waters of Arkansas carry practically no suspended matter, Sm generally has the value of zero, but the term can not be disregarded in estimating the value of raw surface waters, which frequently contain more suspended than dissolved matter.

The hard-scale-forming ingredients (h) may be estimated by formula 3; therefore the ratio, $\frac{h}{s}$, expresses the relative hardness of the scale. If $\frac{h}{s}$ is greater than 0.5 the scale may properly be called hard; if it is less than 0.25 the scale may be called soft. The third formula gives an estimate of the foaming ingredients (f) based on the probable amount of alkali salts dissolved in the water.

Formula 4 has been used to calculate the corrosive tendency of the water (c), and it can be readily seen from the coefficients that it expresses the relation between the reacting values of magnesium and the radicles involving carbonic acid outlined in the discussion of corrosion. If c is positive the water is corrosive. If $c + 0.0499$ Ca, the reacting value of calcium, is negative, corrosion due to the mineral constituents will not take place; whether organic matter or electrolysis can then cause corrosion is uncertain. If $c + 0.0499$ Ca is positive the probability of corrosion is uncertain.

After these three attributes of boiler feed have been computed it is largely a matter of judgment based on experience to rate the water. The value of natural waters for use in boilers depends primarily on their corroding and foaming tendencies and on the amount and character of scale likely to be deposited by them, but this value should always be considered in connection with local standards, for no matter how low a water may be in undesirable constituents it can not be classed as good if it is poorer in quality than the average water of the region in which it occurs, and, on the other hand, if the best available supply is poor the economy of purifying it, even at large expense, is obvious.

Waters of poor quality can be improved by treatment in softening plants. The question how bad a water may be used without treatment can be answered by comparing the cost of artificially softening the water with the saving effected by the use of softened water. The benefits of softening include saving in boiler cleaning, in repairs, and in fuel, increased number of boilers in service, decreased depreciation of boilers, and the value of the materials removed by softening. The cost of softening includes labor and power for the softening apparatus, value of softening chemicals, interest on cost of installation, depreciation in value of softening plant, and waste in changing boiler feed due to increased foaming tendency. In general, it is economical in locomotive service to treat waters containing 250 to 850 parts per million of incrustants and those containing less than the lower amount if the scale formed contains much sulphate.[1]

The amount of mineral matter that makes a water absolutely unfit for boiler use depends on the combined effect in boilers of the softening reagents used with such waters and of the constituents not removed by softening. Sodium salts added to remove incrustants or to prevent corrosion increase the foaming tendency and this increase may be great enough to render a water useless for steaming. It is not of much benefit to soften a water containing more than 850 parts per million of nonincrusting material and much incrusting sulphate.[1] Though waters containing as high as 1,700 parts per million of foaming constituents have been used in locomotives, it is usually more economical to incur considerable expense in replacing such supplies by better ones. A concentration of about 7,000 parts is considered the limit of safety for stationary boilers.

The ratings of the committee on water service of the American Railway Engineering and Maintenance of Way Association given in the following table have been used for classifying the Arkansas waters in respect to boiler use. These limits are obviously only approximate and the classifications must therefore not be taken too literally. They are given rather to indicate the limits of usefulness than to define rigidly the value of the waters.

[1] Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 6, p. 610, 1905.

Rating of waters for boiler use according to proportion of incrusting and corroding constituents and according to proportion of foaming constituents.

Incrusting and corroding constituents (parts per million).			Foaming constituents (parts per million).		
More than—	Not more than—	Classification.[a]	More than—	Not more than—	Classification.[b]
....	90	Good.	....	150	Good.
90	200	Fair.	150	250	Fair.
200	430	Poor.	250	400	Bad.
430	680	Bad.	400	....	Very bad.

[a] Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 5, p. 595, 1904.
[b] Idem, vol. 9, p. 134, 1908.

WATER FOR IRRIGATION.

RELATION BETWEEN APPLIED WATER AND SOILS.

When water evaporates from the surface of soil it leaves its content of salts. If all the water applied in irrigating were to evaporate, the constant use of any supply, no matter how good it might be, would eventually result in an accumulation of alkali that would render the soil unproductive. If, on the other hand, all of a water not too high in mineral content were to seep downward into the deep-lying strata it would gradually leach out the soluble salts of a highly charged area. Such extreme conditions, however, are not normal, for seepage from irrigated tracts carries with it a load of dissolved salts; various amounts of mineral matter are also taken up by crops and are removed during harvesting; then, too, proper methods of irrigation and drainage will prevent alkali from accumulating where it will damage the delicate feeding roots of crops. Consequently, waters of relatively low mineral content may be applied year after year without inflicting damage, but those exceeding a certain limit of mineral content are useless for irrigation; waters of an intermediate class, normally capable of increasing the alkali in the soil, may be harmless under judicious usage.

NUMERICAL STANDARDS.

The value of a water for irrigation is measured primarily by its content of alkali and by the probable form in which the alkali will be deposited in the soil. Experience has shown that sodium carbonate is most harmful to crops, sodium chloride less so, and sodium sulphate least harmful of all. Basing his computations on determinations of the alkali-resisting qualities of certain cultures in

California,[1] Stabler has developed formulas[2] for rating waters in respect to their value for irrigation. His comparison is made by means of an "alkali coefficient" (k), which is defined as the depth in inches of water which would yield on evaporation sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops. The sodium equivalents of the three common salts of sodium, the sulphate, chloride, and carbonate, are assigned relative toxicities of 1, 5, and 10, respectively, and the maximum tolerance of sensitive cultures is taken as 1,500 pounds of sodium in the form of sulphate per acre-4-feet. The correctness of the latter assumption by itself might be questioned, but it does not lead to appreciable error, as the chief value of the formulas rests with the ratio of toxicities and the interpretation of the computed value of k.

$$k = \frac{2{,}040}{Cl} \text{ if } Na-0.65\ Cl \text{ is zero or negative.}$$

$$k = \frac{6{,}620}{Na+2.6\,Cl} \text{ if } Na-0.65\ Cl \text{ is positive but not greater than } 0.48\ SO_4.$$

$$k = \frac{662}{Na-0.33\ Cl-0.43\ SO_4} \text{ if } Na-0.65\ Cl-0.48\ SO_4 \text{ is positive.}$$

The symbols SO_4, Cl, and Na represent, respectively, the amounts in parts per million in the water of sulphate, chlorine, and alkali, the latter being commonly grouped under the name of sodium. The three formulas represent the different relations between the alkali and the acid radicles. Under the first condition, with enough or more than enough chlorine to satisfy sodium, it is assumed that the chlorides other than that of sodium are as harmful as that compound. Under the second condition, where the chloride and sulphate radicles together are sufficient to satisfy sodium, and under the third, where both chlorine and sulphate are insufficient to satisfy sodium, magnesium is assumed to have no deleterious effect. This base loses the greater part of its toxic power when much calcium is present and therefore this assumption seems justifiable, as not only is calcium usually high in all soils, but also it commonly exceeds the proportion of magnesium in natural waters. Though the formulas are based on the relative predominance of the radicles they should not be interpreted as signifying that the acids and bases are combined but as presenting the maximum possibilities of the deposition of harmful alkali salts in the soil layer.

[1] Loughridge, R. H., Tolerance of alkali by various cultures: California Univ. Agr. Exp. Sta. Bull. 133, 1901. Quoted by E. W. Hilgard, Soils, p. 467, Macmillan Co., New York, 1906. See also California Univ. Agr. Exp. Sta. Bulls. 128, 140, and 169.

[2] Stabler, Herman, Some stream waters of the western United States, with chapters on sediment carried by the Rio Grande and the industrial application of water analyses: U. S. Geol. Survey Water-Supply Paper 174, p. 177, 1911; also Eng. News, vol. 64, p. 57, 1910.

The following ratings for interpreting values of the alkali coefficient are proposed by Stabler:

Classification of water for irrigation.

Value of k.	Classification.
Greater than 18	Good.
6 to 18	Fair.
1.2 to 5.9	Poor.
Less than 1.2	Bad.

The value of k, showing the number of inches of water that would yield on evaporation sufficient alkali to inhibit the growth of very sensitive plants, indicates the relative degree of care that is essential in applying a water to irrigated tracts. As defined by Stabler, "good" waters are those that can be used for many years without special care to prevent alkali accumulation. Waters classed as "fair" require special care to prevent gradual concentration of alkali, except in loose soils with free natural drainage. Care in selection of soils has been imperative and artificial drainage has frequently been necessary in using waters classed as "poor." The "bad" waters contain so much harmful matter in solution that they are practically valueless for irrigation.

This rating, like any other that might be devised, should be liberally interpreted. It signifies only a comparison of the waters themselves on the basis of their mineral content. It does not signify the possibility of raising good crops on land to which the waters may be applied, because it does not take into account the alkali content and the texture of the soil, conditions of drainage, the method of irrigation, the duty of the water, or the other factors on which agricultural success depends. As the rating is based on common irrigation practice in the arid and semiarid regions of the United States, it is probably too severe for a well-watered region like eastern Arkansas; therefore, it may safely be concluded that waters of eastern Arkansas that have been classified as good on the basis of this rating will give no trouble whatever by deposition of alkali.

WATER FOR DOMESTIC USE.

PHYSICAL QUALITIES.

Entirely acceptable domestic waters are free from suspended matter, color, odor, and taste, and are fairly cool when they reach the consumer. The nearer waters approach these conditions the more satisfactory they are for general use. Suspended mineral matter clogs pipes, valves, and faucets. Growths of microscopic plants form tufts or layers in pipes and well casings and sometimes clog them, and detached particles give the water an unsightly appearance and stain clothes washed in it. So far as is known such growths do not cause disease, but some of them impart unpleasant odors to water. True color is usually due to dissolved vegetable matter and causes serious objection only when it exceeds 20 or 30 parts per million.

BACTERIOLOGICAL QUALITIES.

Before a water is used for domestic purposes there should be reasonable certainty that it is free from disease-bearing organisms and that it can be guarded against all chances of infection. Water from ponds, rivers, sloughs, and bayous liable to contamination by drainage from houses, privies, cesspools, stables, or irrigated fields should not be used for drinking without thorough purification. Wells should be so placed that their waters are guarded against the entrance of filth of any kind, either over the top or by infiltration. Pumps and piping in the system should also be protected. Water from a carefully cased well more than 20 or 30 feet deep is acceptable if the well is at a reasonable distance from privies, cesspools, and other sources of pollution. Many open dug wells and the pits constructed as reservoirs around the tops of many casings are frequently exposed to fecal contamination from above or through cracks in poorly built side walls. Care should be taken that the casings of deep wells do not become leaky near the surface of the ground so as to allow pollution to enter. As a matter of ordinary precaution the ground should be kept clean and water should not be allowed to become foul or stagnant near any well, no matter how deep. If shallow dug wells are necessary they should be constructed with water-tight walls extending as far as practicable into the well and also a short distance above ground. The floor or curbing should be water-tight and pumps should be used in preference to buckets for raising the water. Every possible precaution should be taken to prevent feet scrapings and similar dirt from getting into the well. Underground water is not only less likely to become contaminated if protected from surface washings, air, and light, but it keeps better and is less likely to develop microscopic plants that give it an unpleasant taste.

CHEMICAL QUALITIES.

Amounts of dissolved substances permissible in a domestic supply depend much on their nature. No more than traces of barium, copper, zinc, or lead should be present because these substances are poisonous. The occurrence of these elements in measurable amounts in ordinary waters is so rare that tests for them are not usually made. Any constituent present in sufficient amount to be clearly perceptible to the taste is objectionable. Water containing 2 parts per million of iron is unpalatable to many people, and even this small amount can cause trouble by discoloring washbowls and tubs and by producing rusty stains on clothes. Tea and coffee can not be made satisfactorily with water containing much iron, because a black inky compound is formed. Four or five parts of hydrogen sulphide makes a water unpleasant to the taste, and this dissolved gas is objectionable also because it corrodes well strainers and other metal fittings. The amounts of silica and aluminum ordinarily present in well waters have no special significance in relation to domestic supply. Approximately 250 parts of chlorine make a water "salty," and less than that amount may cause corrosion. Calcium and magnesium are the chief causes of the hardness of water, which is indicated by increased consumption of soap and by deposition of scale on kettles. Calcium and magnesium unite with soap, forming insuluble curdy compounds with no cleansing value and preventing the formation of a lather until these two basic radicles have been precipitated. Hardness can be measured by testing a water with a standard solution of soap, but as that test was not made in analyzing Arkansas waters the total hardness has been computed from the amounts of calcium (Ca) and magnesium (Mg) by means of the following formula:

$$\text{Total hardness as } Ca\,CO_3 = 2.5\ Ca + 4.1\ Mg.$$

The lower waters are in mineral content the more acceptable they are as sources of domestic supply; yet the amount of dissolved substances that can be tolerated in drinking water is much greater than that allowable in city supplies, for which problems of hardness, corrosion, pipe clogging, and general utility have to be considered, inasmuch as rather high concentrations of the common mineral ingredients have no apparent physiologic effect. Detailed inquiries by the writer in arid districts where strongly mineralized waters have to be drunk because no better supplies are available indicate that waters exceeding in strength 300 parts per million of carbonate, 1,500 parts of chloride, or 2,000 parts of sulphate are intolerable to most persons. These limits are fortunately far beyond the points where the substances in solution are clearly perceptible to taste. Though individuals are differently susceptible to the effects of such mineral matter it may be concluded that in general water without a disagreeable taste may be drunk without fear of harmful effect by its mineral ingredients. This comment does not of course take into consideration the possibility of contamination by organic matter or infection by disease germs.

PURIFICATION OF WATER.

GENERAL REQUIREMENTS.

Purification of water is the removal or reduction in amount of substances that render waters in their raw state unsuitable for use, and it is practiced on a large scale to render the supplies safe and unobjectionable for drinking, to reduce the amount of the mineral ingredients injurious to boilers, or to remove substances injurious to machinery or to industrial products.

Removal of bacteria, especially those causing disease, and removal of turbidity, odor, taste, and iron are the principal requirements in purification of a municipal supply, elimination of bacteria and turbidity being the most important. The common methods of effecting such purification are slow filtration through sand and rapid filtration through sand after coagulation, both methods usually being combined with sedimentation.[1] Thoroughly efficient filters of either type remove 98 per cent or more of the bacteria.

Removal of scale-forming and neutralization of corrosive constituents are the chief aims in preparing water for steam making. For this two general methods are employed—precipitation by chemicals followed by sedimentation and heating with or without chemicals, usually followed by rapid filtration. The first process is carried on in cold-water softening plants and the second in feed-water heaters. Some waters that have to be used because no better supplies are available are so bad that neither of these processes is practicable, and such supplies are distilled. Distilled water, which is practically free from all dissolved and suspended matter, must also be used in certain industries. Recent improvements in multiple-effect evaporators have greatly reduced the cost of distillation, so that it is now economical to distill for industrial and domestic use many waters heretofore considered too highly mineralized to be treatable, and large factories, hotels, and even municipalities have installed multiple-effect stills.

METHODS OF PURIFICATION.

Besides the above-mentioned systems of purification many minor processes are used, sometimes alone, but more frequently as adjuncts to filters or softeners. Coarse suspended matter can be removed by rapid filtration through ground quartz or similar material in units of convenient size provided with arrangements for washing the filtering medium similar to those used in mechanical filters. Very turbid waters may be first allowed to stand in large sedimentation basins to reduce the cost of operating the filters by removing a large part

[1] For descriptions of filters see Johnson, G. A., The purification of public water supplies: U. S. Geol. Survey Water-Supply Paper 315, 1913.

of the suspended solids. Supplies containing much iron are aerated by being sprayed into the air or by being allowed to trickle over rocks, thus precipitating the iron so that it can readily be removed by rapid filtration.

Calcium hypochlorite, sodium hypochlorite, and free chlorine gas are used to disinfect drinking water, and treatment with these substances is now widely practiced, either as an adjunct to filtration or as an emergency precaution where supplies otherwise untreated are believed to be contaminated. Disinfection by this method is not a substitute for purification by filtration for it does not remove suspended matter nor appreciable amounts of color, organic matter, swampy tastes, or odors, and it does not soften water.[1]

SLOW SAND FILTRATION.

Slow sand filtration consists in causing the water to pass downward through an artificial layer of fine sand.

On the bottom of a water-tight basin commonly constructed of concrete, perforated tiles or pipes laid in the form of a grid are covered with a foot of gravel graded in size from 25 to 3 millimeters in diameter from bottom to top. A layer of fine sand 3 to 4 feet in depth is put over the gravel, which serves only to support the sand. When water is applied on the surface it passes through the sand and the gravel and flows away through the underdrain of tiles. The suspended materials, including bacteria, are removed by the sand, the action of which is rendered more efficient by the rapid formation of a mat of finely divided sediment on the surface. When this film has become so thick that filtration is unduly retarded, the water is allowed to subside below the surface and about half an inch of sand is removed, after which filtration is resumed. The sand thus taken off is washed to free it from the collected impurities and is replaced on the beds after they have been reduced about a foot in thickness by successive scrapings. As cleaning necessitates temporary withdrawal of filters from service, they are divided into units of convenient size, usually one-half to 1 acre each, so that the operation of the entire system may not be interrupted. Most modern filters are roofed and sodded, as this practice facilitates cleaning by preventing the formation of ice, permits work on the filter beds in all kinds of weather, inhibits algæ growths, and prevents agitation of the water by wind and rain.

The foregoing paragraphs describe the esential features of a slow sand filter, but several adjuncts render this system more efficient. A clear-water basin for the filtered supply, covered to prevent dete-

[1] Johnson, G. A., op. cit., p. 71.

rioration of the water, is provided in order that the varying rate of consumption may not affect the rate of filtration. Clarification of turbid water is rendered more economical by allowing it to stand for one to three days, during which a large portion of the suspended matter is deposited, so that the time between sand scrapings is lengthened. Objectionable odors and tastes may be removed by aeration before or after filtration. Killing the bacteria before filtration by use of chlorine or other germicides is practiced.

Slow sand filtration removes practically all the suspended matter and the bacteria. Color is only slightly reduced, and the hardness is not changed. The process is specially adapted to waters low in color, suspended matter, and animal pollution. Very small particles of clay are not removed by these filters and for water carrying such particles only for short periods occasional addition of a coagulant before filtration is advisable.

RAPID SAND FILTRATION.

The distinctive features of the rapid sand process are the coagulant and the high rate of filtration. While the raw water is entering the sedimentation basin, which is smaller than that used with slow sand filters, it is treated with a definite proportion of some coagulant, usually aluminum sulphate, which forms a gelatinous precipitate that unites and incloses the suspended material, including the bacteria, and absorbs the organic coloring matter. This combined action destroys color and makes suspended particles larger and therefore more readily removable. The proper amount of coagulant to be used is determined by the amounts of color, organic matter, and suspended matter, and by the fineness of the suspended matter, and it is best ascertained by direct experimentation with the water to be purified. Much of the trouble in operating the earlier types of rapid filters has been caused by failure to produce a good "floc" or precipitate because of improper ratios of coagulant and alkalinity. Ferrous sulphate instead of aluminum sulphate is used as a cogulant in some filtration plants; lime must be added with it in order to bring about proper coagulation.

The water, after having been mixed with the coagulant, is allowed to stand three or four hours in the sedimentation basin, where a large proportion of the suspended particles is deposited. It is then passed rapidly through beds of sand to remove the rest of the suspended matter. Many filters now in use are built in cylindrical form 10 to 20 feet in diameter, and some are so designed that filtration can be hastened by pressure. The sand, 30 to 50 inches deep and coarser than that used in slow sand filters, rests on a metallic floor containing perforations large enough to allow ready issue of the water but small enough to prevent passage of sand grains. When the filter has become clogged the flow of water is reversed, filtered water being forced upward through the sand to wash it and to remove the impurities, which pass over the top of the filter with the wasted water. A revolving rake with long prongs projecting downward into the sand mixes it during washing and prevents it from becoming graded into spots of coarse or fine particles. In recently constructed works rectangular filters 300 to 1,300 square feet in area have been built, and compressed air forced through the sand at intervals is used instead of a revolving rake for agitating the sand during washing. Larger orifices in the strainers are also being used, and the introduction of sand is prevented by fine gravel over the strainer pipes. The rate of filtration is from 100,000,000 to 120,000,000 gallons per acre per day. The time between washings is 6 to 12 hours, depending principally on the turbidity of the water applied to the filter.

Mechanical filtration removes practically all suspended matter, reduces the color to an amount that is unobjectionable, and under some conditions removes part of the dissolved iron. The permanent hardness of the water is increased in proportion to the amount of sulphate added by the coagulant, and if only enough lime to decompose the coagulant is added the total hardness is slightly increased. If larger amounts of lime are added, however, the total hardness is reduced. If soda ash is used in place of lime, the foaming constituents of water are slightly increased. The chemicals are always added in solution.

COLD-WATER SOFTENING.

The principal objects of water softening are to remove the substances that cause incrustations in boilers, particularly calcium and magnesium, and to neutralize those that cause corrosion. Chemicals of known strength dissolved in water are added to the raw supply in such proportion as to precipitate all the dissolved constituents that can be economically removed by such treatment. The water is then allowed to stand long enough to permit the precipitate to settle, after which the clear effluent is drawn off or the partly clarified effluent may be filtered very rapidly through thin beds of coke, sponge, excelsior, bagging, or similar material in order to remove particles that have not subsided in the tanks. The water softeners on the market differ from each other principally in the precipitant, in the filtering medium, if one is used, and in the mechanism regulating the mixing of the chemicals with the water. Installations may be of any size to suit consumption, and the process can be combined with rapid sand filtration for purifying municipal supplies. Among the substances that have been proposed as precipitants are sodium carbonate (soda ash), silicate, hydrate (caustic), fluoride, and phosphate, barium carbonate, oxide, and hydrate, and calcium oxide (quicklime), but of these substances lime and soda ash are almost exclusively used on account of their excellent action and comparative cheapness.

When soda ash (Na_2CO_3) and lime dissolved in water to form a solution of calcium hydrate [$Ca(OH)_2$] are added to a water in proper proportion free acids are neutralized, free carbon dioxide is removed, bicarbonates are decomposed, and iron, aluminum, and magnesium hydrates and calcium carbonate are precipitated. The precipitate in settling takes down with it a large proportion of the suspended matter. Such treatment with lime and soda ash removes the incrusting constituents practically to the limit of their solubility; the calcium added as lime also is precipitated. Sodium, potassium, sulphate, and chloride are left in solution, and the alkalies are increased in proportion to the quantity of soda ash added; that is, the foaming constituents are increased and this fixes the maximum amount of incrustants that can be treated. The maximum amount of incrustants left in a treated water is determined by the solubility of the precipitated substances and by the completeness of the reaction between the added chemicals and the dissolved matter. It has been brought below 90 parts per million in some well-treated waters. The sulphate radicle can be removed by using barium compounds, which precipitate barium sulphate, but the poisonous effect of even small amounts of barium and the relatively high cost of its salts are great objections to their use. The chlorides are not changed in amount by water softening. The chemicals should be very thoroughly mixed with the raw water and sufficient time should be allowed for complete reaction, which proceeds rather slowly, for otherwise precipitation will occur later in pipe lines or in boilers.

FEED-WATER HEATING.

Water heaters are designed primarily to utilize waste heat in stationary boiler plants by raising the temperature of the feed water and thereby lessening the work of the boilers themselves, but they also effect some purification, and many heaters have been specially designed with that end in view.

"Open" heaters, which utilize exhaust steam, are operated at atmospheric pressure. In most forms the steam enters at the bottom and the water at the top, and intimate contact between the two is obtained by spraying the water or by allowing it to trickle over or to splash against plates. In this manner the water is quickly heated nearly to boiling temperature. Dissolved gases are expelled, bicarbonates are decomposed, and iron, aluminum, part of the magnesium, and calcium equivalent to the carbonates after decomposition of the bicarbonates are precipitated as hydrates, oxides, and carbonates under varying conditions of temperature, pressure, and time. The precipitate agglomerates the particles of suspended matter and makes them more readily removable by sedimentation and filtration. The slowness with which the reactions take place and the presence of acid radicles other than carbonate to hold the bases in solution prevent complete removal of calcium and magnesium. The addition of soda ash in proper proportion, however, effects fairly complete precipitation of the alkaline earths, and apparatus for constant introduction of this chemical in solution may be provided. After the precipitate has been formed the water passes through filters of burlap, excelsior, straw, hay, wool, coke, or similar materials, arranged in units that can readily be cleaned. Open heaters operated without a chemical precipitant remove substances that are soft and bulky and leave in the water constituents that form hard scale; scale from water treated without chemicals in such heaters is, therefore, not so great in amount but is harder than that formed by the raw water.

"Closed" heaters are heated usually by exhaust steam but are operated at or near boiler temperature and pressure. In them the water is passed through tubes surrounded by steam or around steam pipes, and manholes or other openings are provided for cleaning the scale from the tubes. As the water is heated under pressure, some precipitation takes place, but closed heaters are not so efficient in this respect as open heaters, because they do not permit escape of the gases liberated from the water. This objection does not hold if treatment in a closed heater follows treatment in an open heater, from which the gases escape, and several systems accomplish very good purification by using a unit of each type in series.

Economizers consist essentially of water tubes set in the furnace flues in such manner as to utilize the waste heat of the flue gases. Facilities are provided for cleaning scale from the inside and soot from the outside of the tubes. The water in the tubes can be heated under pressure to much higher temperature than in open or closed heaters, and conditions of ordinary boiler operation are approximated. The precipitation of incrustants varies greatly with the normally fluctuating temperature of flue gases.

SURFACE WATERS.

Series of analyses indicate the composition of the waters of Arkansas River at Little Rock and Mississippi River at Memphis, Tenn., but neither set correctly represents the general quality of surface waters in the lowlands of Arkansas, because both streams drain immense basins above the lowlands and receive relatively little of their discharge from them. Unfortunately, no analyses of water from the smaller rivers are available, and consequently little can be said regarding their quality. The waters of White River and practically all the smaller streams of eastern and northeastern Arkansas are undoubtedly lower in mineral content, softer, and therefore better for general use than that of either the Mississippi or the Arkansas. It is probable that none of the surface water contains as much mineral matter as that from the wells of the area and that none is too poor in quality to be adaptable to general use. As surface waters in such a low, flat country, especially in the thickly settled districts, where irrigation is extensively practiced, are likely to be subject to contamination and to carry fine silt, they should not be used for drinking without first being properly filtered.

Samples of water were collected daily from Arkansas River at the waterworks intake, Little Rock, through the courtesy of Mr. W. J. Riley, superintendent of waterworks, and tested at laboratories maintained by the United States Geological Survey from November 1, 1906, to October 24, 1907. The daily samples were united in sets of 10, and the analyses of the composites thus obtained are given in the following table. The water is highly mineralized and frequently very muddy; its average content of scale-forming ingredients is about 210 parts per million, or slightly more than 12 grains per gallon, and its average hardness is about 190 parts per million. Though it is practicable to remove the suspended matter and a large proportion of the hardening constituents by filtration and use of chemicals, the water even then is likely to foam in boilers and at times to taste brackish because of the salt in it. The striking differences from time to time in the composition of the water are caused by fluctuations in the relative discharge of the several tributaries of the river, the composition of which has been discussed by Parker[1] in connection with his studies of Kansas waters.

[1] Parker, H. N., Quality of the water supplies of Kansas: U. S. Geol. Survey Water-Supply Paper 273, 1911.

Mineral analyses of water from Arkansas River near Little Rock, Ark.[a]

[Parts per million.]

Date, 1906-7. From—	To—	Turbidity.	Suspended matter.	Coefficient of fineness.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total dissolved solids.	Mean gage height (feet).
Nov. 1	Nov. 10	270	172	0.64	31	0.30	84	18	351	0.0	230	136	1.8	535	1,285	3.5
Nov. 11	Nov. 20	140	96	.69	20	.30	86	22	381	.0	221	149	Tr.	568	1,339	3.6
Nov. 21	Dec. 2	140	135	.96	24	.9	39	11	123	.0	115	72	.5	186	519	5.2
Dec. 3	Dec. 19	1,000	894	.89	47	2.4	53	14	180	.0	142	95	.4	276	752	8.0
Dec. 20	Jan. 11	320	294	.92	31	1.2	25	8.9	60	.0	76	57	1.5	80	304	10.4
Jan. 14	Jan. 31	1,320	1,567	1.19	.....	.....	40	13	62	.0	106	.....	2.4	87	451	15.2
Feb. 2	Feb. 20	275	206	.75	20	.40	57	12	83	.0	155	63	3.8	107	433	8.6
Feb. 21	Mar. 7	220	228	1.04	16	.25	54	13	.....	.0	144	74	3.4	.....	460	8.1
Mar. 8	Mar. 28	450	413	.92	25	1.8	42	9.5	67	.0	131	61	1.2	82	366	9.5
Mar. 29	Apr. 12	235	233	.99	19	.8	45	11	80	.0	140	67	1.5	103	412	6.8
Apr. 13	Apr. 22	290	227	.78	20	.9	32	8.7	49	.0	106	42	1.2	65	287	7.3
Apr. 23	May 2	285	192	.67	22	1.2	42	11	74	.0	102	56	2.0	102	377	7.0
May 3	May 13	1,500	1,073	.72	54	1.8	27	6.9	33	.0	86	32	3.6	37	279	18.0
May 14	May 23	860	961	1.12	56	2.2	32	5.6	41	.0	92	43	6.3	40	305	17.4
May 24	June 2	450	460	1.02	40	1.0	31	2.7	31	.0	100	34	1.8	34	271	11.4
June 20	July 18	2,800	2,730	.97	20	.30	49	13	80	.0	181	72	2.8	87	414	10.6
July 19	Aug. 5	270	165	.61	18	.10	66	17	157	.0	196	103	1.1	213	695	5.3
Aug. 8	Aug. 17	1,000	834	.83	29	.15	96	20	415	.0	181	211	1.5	610	1,500	5.3
Aug. 18	Aug. 29	600	480	.80	13	.06	95	23	261	.0	195	212	4.4	347	1,093	4.0
Aug. 30	Sept. 8	3,000	4,119	1.37	36	.12	71	20	155	.0	189	153	1.3	181	736	5.0
Sept. 9	Oct. 6	280	162	.58	26	.33	72	17	179	[b]8.4	184	117	.3	265	806	2.8
Oct. 7	Oct. 24	900	811	.90	26	.8	72	16	155	[b]Tr.	157	98	.2	262	774	3.3
Mean..........		755	748	.88	28	.82	55	13	144	.0	148	93	2.0	203	630	.....
Percentage of anhydrous residue..		......	......	.....	4.6	[c].2	9.0	2.1	23.5	11.9	.....	15.2	.3	33.2	......	.....

[a] Analyses November 1, 1906, to January 31, 1907, by W. M. Barr; February 2 to 20, 1907, by Henry S. Spaulding; February 21 to September 8, 1907, by Walton Van Winkle; September 9 to October 24, 1907, by R. B. Dole, Chase Palmer, and W. D. Collins. Gage heights from records of Weather Bureau gage at Little Rock.

[b] Abnormal; computed as HCO_3 in the average.

[c] Fe_2O_3.

Above Little Rock, Arkansas River drains 158,000 square miles in Arkansas, Oklahoma, Missouri, Kansas, New Mexico, and Colorado, and its various branches are widely diverse in quality as is indicated in the accompanying table. At Arkansas City, Kans., the river carries more mineral matter than at Little Rock. Cimarron River and Salt Fork traverse great areas of gypsum-bearing rocks and salt marshes before they enter the Arkansas between Arkansas City and Little Rock, and the heavy loads of salt and silt occasionally carried by the main stream come chiefly from those tributaries. On the other hand, northeastern branches like the Verdigris and the Neosho contribute calcium carbonate waters of moderate mineral content. The diverse character of the tributaries explains why the main stream at Little Rock exhibits so great variation in composition without apparent relation to discharge; a flood on Salt Fork or the Cimarron sends down salty gypsiferous water, but a flood on a tributary like the Neosho sends down water of relatively low mineral content. This continual fluctuation in composition makes treatment of the water very difficult.

Average chemical composition of the water of certain branches of Arkansas River above Little Rock.[a]

[Parts per million.]

Constituents.	Arkansas River at Arkansas City, Kans.	Cimarron River at Englewood, Kans.	Verdigris River at Coffeyville, Kans.	Neosho River at Oswego, Kans.
Turbidity	2,227	811	388	225
Suspended matter	1,596	606	405	194
Coefficient of fineness	1.19	1.03	1.06	.84
Silica (SiO_2)	31	38	24	20
Iron (Fe)	1.6	1.4	1.4	1.6
Calcium (Ca)	95	85	71	71
Magnesium (Mg)	24	34	11	15
Sodium and potassium (Na+K)	243	356	33	27
Carbonate radicle (CO_3)	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	253	308	261	223
Sulphate radicle (SO_4)	193	157	31	65
Nitrate radicle (NO_3)	1.8	1.7	3.2	2.9
Chlorine (Cl)	292	498	23	9.7
Total dissolved solids	990	1,324	302	304

[a] Analyses performed by F. W. Bushong and A. J. Weith in the chemical laboratory of the University of Kansas, E. H. S. Bailey, director. Each set represents the average quality from December, 1906, to December, 1907. Quoted from U. S. Geol. Survey Water-Supply Paper 273.

The following table gives the results of analyses of composite samples of water from Mississippi River at Memphis, Tenn., a few miles southeast of Marion, Ark. The water averages 150 parts per million, or slightly less than 9 grains per gallon, in its content of scale-forming matter and about 140 parts per million in hardness expressed as $CaCO_3$. It frequently carries heavy loads of silt that is contributed chiefly by Missouri River. After the mud has been removed from the water it constitutes a very fair supply for boilers, though it may be somewhat improved for that purpose by being softened. Treatment similar to that applied at the filtration plant in New Orleans would render the river water anywhere between Memphis and New Orleans thoroughly satisfactory for domestic and industrial use. Though the stream receives several tributaries between those two points, its composition is not essentially changed, for the greater portion of its discharge comes from above Memphis.

Mineral analyses of water from Mississippi River at Memphis, Tenn.[a]

[Parts per million.]

Date, 1907-8. From—	Date, 1907-8. To—	Turbidity.	Suspended matter.	Coefficient of fineness.	Total iron (Fe).	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total dissolved solids.	Mean gage height (feet).
Jan. 10	Jan. 20	420	353	0.84	......	40	0.7	.....	14	....	0.0	146	....	0.3	6.0	198	32.8
Jan. 21	Jan. 30	350	239	.68	......	39	.7	32	17	....	.0	129	....	.5	7.0	209	34.9
Jan. 31	Feb. 9	340	264	.78	......	34	.20	.....	......	....	.0	82	....	.4	7.0	168	39.5
Feb. 10	Feb. 19	270	216	.80	......	37	.7	29	9.0	....	.0	90	....	.5	5.5	165	28.7
Feb. 20	Mar. 1	420	324	.77	......	36	1.2	32	18	....	.0	112	....	.6	7.0	186	18.0
Mar. 2	Mar. 11	425	355	.84	......	34	.8	43	17	....	.0	112	....	.5	10	205	25.8
Mar. 12	Mar. 21	680	615	.90	......	43	.7	.....	12	....	.0	102	....	.3	9.5	172	29.7
Mar. 22	Mar. 31	550	505	.92	......	40	.7	.....	10	....	.0	90	....	.9	9.5	162	34.2
Apr. 1	Apr. 10	960	740	.77	......	34	1.3	37	12	....	.0	115	....	.2	12	188	32.9
Apr. 11	Apr. 20	680	485	.71	......	22	1.3	27	11	....	.0	115	....	1.6	6.5	156	23.6
Apr. 21	Apr. 30	550	415	.76	......	24	1.4	29	8.4	....	.0	104	....	1.8	8.0	161	21.5
May 1	May 10	1,150	816	.71	......	31	2.8	24	15	....	.0	95	....	1.1	9.0	174	24.7
May 11	May 20	375	386	1.03	......	31	1.6	26	9.7	13	.0	95	36	2.9	5.0	188	30.8
May 21	May 30	485	484	1.00	......	19	1.1	30	7.7	13	.0	93	36	5.5	5.1	169	25.8
May 31	June 9	420	332	.79	......	10	.12	.....	12	13	.0	122	46	5.3	6.3	188	19.2
June 11	June 20	1,600	1,421	.89	......	19	.05	42	12	....	.0	153	63	4.9	5.9	247	27.3
June 21	June 30	1,300	1,161	.89	......	12	1.6	36	14	....	.0	....	53	4.9	5.5	231	28.2
July 1	July 10	1,400	1,244	.89	......	16	.18	46	11	28	.0	156	56	5.3	8.7	245	21.9
July 11	July 20	1,000	1,185	1.18	......	13	.30	49	15	21	.0	....	67	2.2	6.0	246	17.8
July 21	July 30	425	1,389	3.26	......	14	.11	41	12	28	.0	172	67	2.4	12	250	22.9
July 31	Aug. 9	900	797	.89	......	16	.08	37	9.3	24	.0	143	41	1.8	9.0	205	22.9
Aug. 10	Aug. 19	950	888	.93	......	21	.20	39	12	21	.0	144	52	4.0	6.8	220	17.0
Aug. 20	Aug. 29	600	......	......	......	22	.13	41	13	21	.0	149	47	4.6	8.0	236	14.8
Aug. 30	Sept. 8	600	451	.75	......	17	.17	36	12	22	.0	144	40	1.7	8.5	207	14.1
Sept. 9	Sept. 18	280	307	1.10	10	22	.16	38	12	17	[b] 8.4	130	33	1.2	8.4	204	11.8
Sept. 19	Sept. 28	270	316	1.17	10	24	.14	39	12	13	[b] 7.2	146	34	Tr.	11	218	10.1
Sept. 29	Oct. 8	220	203	.92	7.4	23	.22	39	10	20	[b] 7.2	145	37	Tr.	9.8	219	10.0
Oct. 9	Oct. 18	240	221	.92	8.8	14	.5	35	10	16	[b] Tr.	142	34	Tr.	9.4	198	10.9
Oct. 19	Oct. 28	270	198	.73	11	21	.37	36	13	17	[b] 7.2	134	34	.20	9.6	208	9.9
Oct. 29	Nov. 9	240	316	1.32	8.8	20	.12	43	13	18	[b] 3.6	159	40	Tr.	11	235	7.0
Nov. 10	Nov. 19	230	203	.88	7.9	21	.52	42	13	28	[b] 7.2	159	39	Tr.	14	257	9.0
Nov. 20	Dec. 1	230	215	.93	13	10	.42	36	11	18	[b] Tr.	127	43	Tr.	16	200	12.0
Dec. 2	Dec. 12	180	187	1.04	8.0	5.6	.07	33	10	14	[b] 8.4	106	29	Tr.	9.0	162	11.6
Dec. 13	Dec. 22	170	160	.94	3.5	24	.24	36	12	17	[b] 13	115	32	1.7	9.6	201	8.4
Dec. 23	Jan. 1	265	265	1.00	7.9	26	.56	33	10	16	[b] Tr.	124	35	1.5	9.6	195	13.5
Mean......		556	519	.97	......	24	.61	36	12	19	.0	129	43	1.7	8.6	202	.....
Percentage of anhydrous residue.		......	......	......	......	11.5	[c] .4	17.3	5.7	9.1	30.5	....	20.6	.8	4.1	....	.....

[a] Analyses January 10 to May 10, 1907, by Jas. R. Evans; May 11 to September 8, 1907, by Walton Van Winkle; September 9, 1907, to January 1, 1908, by R. B. Dole, Chase Palmer, and W. D. Collins. Samples collected in main current by T. D. Shroyer. Gage heights from records of gages at Memphis maintained by Weather Bureau and Corps of Engineers, U. S. Army.

[b] Abnormal; computed as HCO_3 in the average.

[c] Fe_2O_3.

GROUND WATERS.

CHEMICAL ANALYSES.

Forty-seven mineral analyses of water were made especially for this report by Dr. J. R. Bailey, of the University of Texas, in general accordance with the methods outlined[1] in Water-Supply Paper 236, except that somewhat smaller portions of the sample were taken for certain determinations; also the content of the alkalies (Na+K) was calculated from the reacting values of the acid and the other basic radicles in all analyses except those in which silica was determined. Where silica was determined the alkalies were weighed as the mixed chlorides (NaCl+KCl). Besides those by Dr. Bailey, 21 analyses were procured from various sources. Most of these analyses were originally expressed in grains per United States gallon in hypothetical combinations, but they have been recomputed to ionic form in parts per million in order that they may be compared with other data. Expression of the results of water analyses in parts per million has been generally adopted by sanitary and research chemists and by many technical chemists in place of expression in grains per gallon, and the exclusive use of the former unit is delayed only by disinclination to adjust mental standards to the decimal system.

For convenience of those who may desire to transfer the results to other forms of expression it may be stated that multiplying the number of parts per million by 0.058 gives the equivalent in grains per United States gallon of 231 cubic inches; multiplying it by 0.07 gives the equivalent in grains per imperial gallon; and multiplying it by 0.00833 gives the equivalent in pounds per thousand gallons.

The analytical methods commonly employed in examining water permit the estimation of the elements and radicles present, the determination of the total amount of mineral matter in solution, and the more or less approximate separation of the incrusting from the nonincrusting constituents. Further than this, however, ordinary chemical tests give little knowledge regarding the chemical composition of mineral waters and consequently the exact amounts of the different salts in solution are largely conjectural. Though such salts as sodium chloride, potassium carbonate, and magnesium sulphate, for example, are probably present they are not determined as such and their exact amounts can not be computed from the analytical data. Because of that the ionic form of stating the analyses—that is, stating the radicles present—has been used in this report. The figures thus give facts and not opinions and present actual laboratory

[1] Dole, R. B., The quality of surface waters in the United States: U. S. Geol. Survey Water-Supply Paper 236, pp. 9–39, 1909.

Chemical composition of water from wells in eastern and northeastern Arkansas.

[Parts per million.]

No.	Location: Town.	Location: Section.	Location: Township.	Location: Range.	Owner.	Analyst.	Date of collection.	Depth of well.	Depth of principal water-bearing stratum.	Name of principal water-bearing stratum.
	Arkansas County:							Feet.	Feet.	
1	Almyra, 2 miles northwest of	SE. ¼ sec. 21	3 S.	4 W.	H. V. Clutter	J. R. Bailey	July 12, 1912	150	90–150	Pleistocene alluvium
2	Almyra, 5 miles southeast of	NE. ¼ sec. 5	4 S.	3 W.	G. W. Chambers	do	Aug. 30, 1912	174	95–131	do
3	Bayou Meto, 1½ miles southeast of	SE. ¼ sec. 36	5 S.	5 W.	John Rodgers	do	do	100	80–100	do
4	Booty, 2½ miles west of	NE. ¼ sec. 36	7 S.	3 W.	Morgan & Whiting	do	do	137		do
5	Dewitt, 6½ miles east of	SW. ¼ sec. 29	4 S.	2 W.	George Lacotts	do	Sept. 3, 1912	145		do
6	St. Charles, 3½ miles northwest of				W. H. Norsworthy & Co.	do	Aug. 20, 1912	180		do
7	Tichnor, 2½ miles southeast of	SE. ¼ sec. 4	7 S.	2 W.	August Paulman	do	Sept. 3, 1912	162	56–162	do
8	Ulm, 1¾ miles southwest of	NE. ¼ sec. 6	2 S.	4 W.	Casper G. Scheiderer	do	June 24, 1912	110	80–110	do
	Clay County:									
9	Knobel				St. Louis, Iron Mountain & Southern Ry. Co.	J. McFarland	Apr. 18, 1905	97		do
	Craighead County:									
10	Bono, 1 mile north of	NE. ¼ sec. 19	15 N.	3 E.	J. E. Bobbitt	J. R. Bailey	June 24, 1912	78	70–78	do
11	Gilkeson, 2½ miles southeast of	SE. ¼ sec. 8	13 N.	3 E.	Burk & Cole	do	do	103	63–103	do
12	Nettleton, ¼ mile east of	Sec. 26	14 N.	4 E.	F. Kiech Manufacturing Co.	do	Aug. 20, 1912	143	75–143	do
13	Obear, ¼ mile northwest of				J. L. Burns	do	do	148	90–100	do
14	Obear, 3½ miles northwest of	NE. ¼ sec. 18	13 N.	3 E.	Gregg & Houghton Land Co.	do	do	102	33–102	do
15	Earl				Town	Wm. Krauss	1905 (?)	474	414–474	Wilcox formation (?)
	Cross County:									
16	Cherry Valley				St. Louis, Iron Mountain & Southern Ry. Co.	J. McFarland	Dec. 4, 1905	140		Pleistocene alluvium
17	Fairoaks, 2½ miles east of				T. A. Norviel	J. R. Bailey	Sept. 3, 1912	65	18–651	do
18	Hickory Ridge, 3½ miles southeast of	NW. ¼ sec. 36	9 N.	1 E.	Love Banks	do	July 5, 1912	121	82–12	do
19	Tilton, 3½ miles southeast of	SE. ¼ sec. 22	8 N.	1 E.	B. V. Rogers	do	Aug. 20, 1912	96	31.5–96	do
20	Vanndale, 2 miles southwest of				York Lumber Co.	do	July 12, 1912	167		do
21	Vanndale, 7 miles west of	SW. ¼ sec. 2	8 N.	2 E.	J. W. Blue	do	Aug. 30, 1912	102	80–102	do
22	Wynne				St. Louis, Iron Mountain & Southern Ry. Co.	J. McFarland	Mar. 16, 1908	186		Wilcox formation (?)
	Jefferson County:									
23	Wabbaseka, 1½ miles southeast of	Sec. 21	4 S.	7 W.	Shelby Bros.	J. R. Bailey	July 5, 1912	90	65–90	Quaternary alluvium
24	Wabbaseka, 5 miles east of	NW. ¼ sec. 13	4 S.	7 W.	John Ingram, sr.	do	Sept. 3, 1912	66	61–66	do
	Lawrence County:									
25	Alicia				St. Louis, Iron Mountain & Southern Ry. Co.	J. McFarland	May 31, 1905	77	63–77	Pleistocene alluvium
26	Hoxie				do	do	July 24, 1905	65		do
27	Walnut Ridge, 1 mile northeast of	NE. ¼ sec. 1	16 N.	1 E.	S. C. Dowell	J. R. Bailey	Aug. 20, 1912	177	65–177	do
	Lee County:									
28	Marianna				Town	P. H. Walker		619		Eocene
29	Moro, 2 miles north of	NW. ¼ sec. 4	2 N.	1 E.	Johnston Stock Co.	J. R. Bailey	July 5, 1912	145	129–145	Pleistocene alluvium
30	Moro, 2¾ miles northwest of	SW. ¼ sec. 32	3 N.	1 E.	S. D. Johnston	do	July 12, 1912	195	178–195	do
	Lonoke County:									
31	Carlisle, 1½ miles north of	SW. ¼ sec. 10	2 N.	7 W.	Robert Medendorp	do	do	158	125–156	do
32	England	Sec. 10	2 S.	9 W.	Arkansas Cotton Oil Co.	do	June 27, 1912	80		do
33	England, ½ mile southeast of				R. J. Lanford	do	June 24, 1912	70	50–70	do
34	Lonoke, 1½ miles southwest of	NW. ¼ sec. 24	2 N.	9 W.	W. H. Fuller	do	July 3, 1912	148	26–148	do
35	Lonoke, 3 miles north of				Rowena Rice Co.	do	Aug. 20, 1912	160	90–160	do
36	Lonoke, 4 miles north of				do	do	do	142		do
37	Lonoke, 6 miles southeast of	NE. ¼ sec. 11	1 N.	8 W.	W. H. Hicks	do	Sept. 3, 1912	175	75–175	do
	Mississippi County:									
38	Boynton	NE. ¼ sec. 29	16 N.	8 E.	Mill Shoals Cooperage Co.	Arrow Boiler Compound Co.		41	24–41	Quaternary alluvium
39	Burdette	SW. ¼ sec. 20	14 N.	11 E.	Three States Lumber Co.			1,495.5	1,420–1,495	Cretaceous
40	Manila, 3 miles southeast of	Sec. 9	14 N.	9 E.	Chicago Mill & Lumber Co.	(d)		30		Quaternary alluvium
41	Do	do	14 N.	9 E.	do	(d)		40		do
	Monroe County:									
42	Brinkley				Farrell Light, Heat & Water Co.	C. W. Jones	Sept., 1904	565	497–565	Eocene
43	Do	S. ½ sec. 4	3 N.	2 W.	J. D. Edmunds	J. R. Bailey	Aug. 20, 1912	149.75	14–138	Pleistocene alluvium
44	Brinkley, 1½ miles northwest of		3 N.	2 W.	H. G. Adams	do	do	147.5		do
	Phillips County:									
45	Helena				Helena Water Co.	Regis Chauvenet & Bro.		487	480	Claiborne formation
46	Lexa				St. Louis, Iron Mountain & Southern Ry. Co.	J. McFarland	Mar. 26, 1908	175		Pleistocene alluvium.
47	Wabash, ½ mile west of	NW. ¼ sec. 31	3 S.	3 E.	Howe Lumber Co.	Mo. Pacific Ry. Co.	July 1911 (?)	50	40	Quaternary alluvium.
	Poinsett County:									
48	Marked Tree	NE. ¼ sec. 34	11 N.	6 E.	Chapman & Dewey Lumber Co.	Wm. Krauss	1903 (?)	398	366–398	Wilcox formation
49	Waldenburg, 2 miles northeast of	NW. ¼ sec. 18	11 N.	2 E.	Scruggs & Swearengin	J. R. Bailey	Aug. 20, 1912	108.5	28.5–108.5	Pleistocene alluvium.
50	Waldenburg, 2½ miles southwest of	SE. ¼ sec. 35	11 N.	1 E.	Ellis L. Jackson	do	do	101	60–101	do
51	Whitehall, 1½ miles west of	Sec. 22	10 N.	3 E.	B. A. McKinney	do	do	120	40–120	do
	Prairie County:									
52	Devall Bluff, 3½ miles west of		2 N.	5 W.	Thomas Bros.	do	do	179	130–179	do
53	Hazen				Hazen Power & Light Co.			80		do
54	Hazen, 2½ miles west of	NW. ¼ sec. 23	2 N.	6 W.	E. W. Crouch	J. R. Bailey	July 12, 1912	127	80–127	do
55	Hazen, 8 miles southwest of	SW. ¼ sec. 18	1 N.	6 W.	C. H. Chapman	do	Aug. 20, 1912	158		do
	Pulaski County:									
56	Argenta				St. Louis, Iron Mountain & Southern Ry. Co.	O. F. Reynolds	Oct. 21, 1910	80±	40–80±	Quaternary alluvium.
	Randolph County:									
57	O'Kean				do	J. McFarland	May 31, 1912	(f)		Pleistocene alluvium.
	St. Francis County:									
58	Forrest City				do	do	Mar. 3, 1906	170		Eocene
59	Goodwin, 1½ miles west of		4 N.	1 E.	Riley-Harrison Co.	J. R. Bailey	July 5, 1912	160	85–160	Pleistocene alluvium.
60	Wheetley, near				Wm. Fisher	do	Aug. 30, 1912	139	30–139	do
61	Wheetley		4 N.	1 W.	A. Boysen & Sons	do	Aug. 20, 1912	145	80–145	do
62	Zent, east of	SW. ¼ sec. 8	4 N.	1 W.	Norton Bros.	do	June 24, 1912	180.8	33–180	do
63	Zent, 1¼ miles east of	Sec. 6	4 N.	1 W.	The Luhallis Co.	do	July 5, 1912	180	70–180	do
	White County:									
64	Bald Knob				St. Louis, Iron Mountain & Southern Ry. Co.	O. F. Reynolds	June 22, 1912	225	193	Carboniferous
65	Higginson				do	J. McFarland	June 5, 1905	62.5	50–62.5	Pleistocene alluvium.
	Woodruff County:									
66	Hunter, southeast of	Sec. 34	5 N.	1 W.	Hunter Land & Rice Co.	J. R. Bailey	July 5, 1912	156	50–105	do
67	Do	do	5 N.	1 W.	do	do	July 12, 1912	127	40–127	do
68	Penrose, near	SE. ¼ sec. 25	7 N.	1 W.	McCleery & Son	do	Aug. 30, 1912	124	60–124	do

No.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Volatile and organic matter.	Total dissolved solids.	Total hardness as $CaCO_3$.[a]	Probable scale-forming ingredients.[a]	Probable foaming ingredients.[a]	Probability of corrosion.[a b]	Mineral content.	Chemical character.	Quality for boiler use.	Quality for domestic use.	Quality for irrigation.
1		0.4	59	22	46	0.0	352	2.4	33		369	238	250	120	N. C.	Moderate.	Ca-CO_3	Poor	Fair	Good.
2		.7	79	25	42	.0	391	4.0	47		407	290	310	110	N. C.	do	do	do	do	Do.
3		9.1	144	33	72	.0	374	52	205		830	495	510	190	(?)	High	Ca-Cl	Bad	Poor	Fair.
4		6.9	106	39	73	.0	580	8.0	70		614	425	410	200	N. C.	do	Ca-CO_3	Poor	do	Do.
5		.8	101	29	48	.0	435	21	68		512	371	380	130	(?)	do	do	do	Fair	Good.
6		.2	75	25	16	.0	373	6.0	8.0		350	290	300	40	N. C.	Moderate.	do	do	do	Do.
7		1.7	156	51	53	.0	587	16	153		793	599	600	140	(?)	High	do	Bad	Poor	Fair.
8		1.0	58	19	39	.0	331	23	8.2		315	223	240	110	N. C.	Moderate.	do	Poor	Fair	Good.
9	36	c 4.4	36	12	13		164	23	4.7	3	213	139	160	40	(?)	do	do	Fair	Good	Do.
10		1.4	26	16	18	.0	159	37	2.0		180	131	140	50	(?)	do	do	do	do	Do.
11		.1	31	20	1	.0	146	32	6.0		170	159	160	5	(?)	do	do	do	do	Do.
12		.2	22	10	1	.0	102	5.0	7.0		118	96	120	5	(?)	Low	do	do	do	Do.
13		3.1	73	20	32	.0	346	2.0	34		366	265	280	90	N. C.	Moderate.	do	Poor	Fair	Do.
14		.6	52	21	5	.0	241	13	12		244	216	220	15	(?)	do	do	do	do	Do.
15									9		186	44				do	do	Fair	Good	Do.
16	40	c 2.7	66	21	5.5		288	14	8.5	19	318	251	230	15	(?)	do	do	Poor	Fair	Do.
17		.28	96	31	21	.0	429	4.0	39		424	367	370	60	(?)	do	do	do	do	Do.
18		.9	79	26	29	.0	407	7.0	18		385	304	310	80	N. C.	do	do	do	do	Do.
19		2.6	85	25	25	.0	382	4.0	37		411	315	330	70	(?)	do	do	do	do	Do.
20		.24	87	42	36	.0	431	86	17		520	390	360	100	(?)	High	do	do	do	Do.
21		.05	95	32	26	.0	483	5.0	16		415	369	370	70	N. C.	Moderate.	do	do	do	Do.
22	35	c 1.0	79	22	11		341	4.8	14	34	368	288	300	30	(?)	do	do	do	do	Do.
23		6.6	85	21	15	.0	352	20	15		362	299	320	40	(?)	do	do	do	Poor	Do.
24		1.0	89	24	1	.0	338	15	20		332	321	340	5	(?)	do	do	do	Fair	Do.
25	49	c 2.6	62	16	8.7		233	39	5.9	8	306	221	260	25	(?)	do	do	do	do	Do.
26	44	c 2.0	62	14	7		244	20	6.0	5	279	212	250	20	(?)	do	do	do	do	Do.
27		1.0	67	19	2	.0	260	23	8.0		272	245	260	5	(?)	do	do	do	do	Do.
28			83		125		380	131	12		552	207		340		High	do	do	do	Fair.
29		.3	89	36	25	.0	472	17	14		425	370	360	70	N. C.	Moderate.	do	do	do	Good.
30		.7	78	36	23	.0	436	12	16		398	343	320	60	N. C.	do	do	do	do	Do.
31		.6	32	14	6	.0	169	4.1	6.1		175	137	150	15	N. C.	do	do	Fair	Good	Do.
32		17.0	98	26	43	.0	330	51	86		527	352	370	120	(?)	High	do	Poor	Poor	Do.
33		4.0	97	17	20	.0	340	36	27		347	312	350	50	(?)	Moderate.	do	do	Fair	Do.
34		.22	49	15	1	.0	198	4.0	13		195	184	200	5	(?)	do	do	Fair	Good	Do.
35		4.8	24	7.0	16	.0	116	5.0	16		159	89	120	40	N. C.	do	do	do	Fair	Do.
36		.9	32	14	4	.0	158	2.0	10		166	137	150	10	(?)	do	do	do	Good	Do.
37		.6	64	17	1	.0	247	7.0	14		242	230	250	5	(?)	do	do	Poor	Fair	Do.
38	19	c 96	106	72			355	143			641	560	450		C.	High		Bad	Bad	
39		1.4	Trace.	2.4	11		4	8.8	17	63	106	10	40	30	C.	Low	Na-Cl	Poor	Good	Do.
40	40	c 1.5	12	3.4	8.2		34	24	7.3	1	114	44	80	20	(?)	do	Ca-SO_4	Good	do	Do.
41	38	c 4.8	22	5.8	9		82	21	7.3	2	150	79	120	25	(?)	do	Ca-CO_3	Fair	do	Do.
42	19	e .9	25	6.2	649		246	2.3	916	84	1,938	88	100	1,800	N. C.	High	Na-Cl	Very bad	Bad	Poor.
43		1.0	64	31	61	.0	418	9.0	47		437	287	280	160	N. C.	Moderate.	Ca-CO_3	Poor	Fair	Good.
44		.9	64	31	54	.0	440	3.0	29		420	287	280	150	N. C.	do	do	do	do	Do.
45								Low.	100	53	426					do				
46	24	c 2.7	89	43	21		508	.8	18	97	546	399	360	60	N. C.	High	Ca-CO_3	Poor	Fair	Good.
47	24	c 2.1	54	22	2		276		2.7	24	267	225	220	5	N. C.	Moderate.	do	Fair	do	Do.
48									.3		180	104				do			Good	Do.
49		.9	69	27	15	.0	354	2.0	17		330	283	280	40	N. C.	do	Ca-CO_3	Poor	Fair	Do.
50		1.7	78	24	9	.0	337	1.0	25		344	293	300	25	N. C.	do	do	do	do	Do.
51		.27	94	38	1	.0	431	14	17		420	391	380	5	(?)	do	do	do	do	Do.
52		.9	87	27	24	.0	404	13	25		395	328	340	60	N. C.	do	do	do	do	Do.
53								.0	12	108	472	226				do			do	Do.
54		1.1	66	15	22	.0	311	5.3	10		307	226	250	60	N. C.	do	Ca-CO_3	Poor	do	Do.
55		.9	64	16	13	.0	281	2.0	15		284	226	250	40	N. C.	do	do	do	do	Do.
56	33	c 6.7	50	17	29		148	77	13	22	321	195	210	80	(?)	do	do	Fair	do	Do.
57	43	c 3.4	70	18	13		302	11	10	2	319	249	280	40	(?)	do	do	Poor	do	Do.
58	43	c 3.8	55	27	3		292	18	6.1	48	348	248	250	10	(?)	do	do	do	do	Do.
59		1.1	115	35	36	.0	519	19	45		519	431	430	100	(?)	High	do	Bad	do	Do.
60		.6	103	38	60	.0	525	38	52		587	413	400	160	N. C.	do	do	do	do	Do.
61		2.2	119	38	45	.0	529	11	39		517	453	450	120	(?)	do	do	do	do	Do.
62		.26	91	7	61		415	19	20		399	256	320	160	N. C.	Moderate.	do	Poor	do	Fair.
63		.7	76	21	21	.0	360	7.0	14		343	276	290	60	N. C.	do	do	do	do	Good.
64	33		43	8	101		106	54	156	28	475	140	170	270	(?)	do	Na-Cl	do	do	Fair.
65	33	c 1.9	7.2	2.1	6		28	8.0	6.0	6	84	27	60	15	(?)	Low	Ca-CO_3	Good	Good	Good.
66		1.2	92	27	26	.0	417	8.0	33		420	341	350	70	N. C.	Moderate.	do	Poor	Fair	Do.
67		.9	85	28	29	.0	409	4.5	36		410	327	330	80	N. C.	do	do	do	do	Do.
68		.6	78	21	13	.0	316	7.0	30		339	281	300	40	(?)	do	do	do	do	Do.

a Computed.

b C.=corrosive; N. C.=noncorrosive; (?)=uncertain or doubtful.

c $Fe_2O_3+Al_2O_3$.

d Quoted from U. S. Geol. Survey Water-Supply Paper 195, pp. 185–86, 1907.

e Aluminum (Al,) 0.2 part; phosphate radicle (PO_4), 1.5 parts.

f Mixed water from two wells respectively 50 and 97 feet deep.

results for consideration and criticism by others than those who made the tests.

The available chemical analyses of water from wells in eastern and northeastern Arkansas are given in the accompanying table, which is arranged alphabetically by counties. The position of the wells from which samples were taken is indicated in Plate XI. The table gives the water-bearing stratum from which the supply of each well chiefly comes, as determined by Messrs. Stephenson and Crider. The total hardness, the probable content of scale-forming and of foaming ingredients, and the probability of corrosion of each water have been computed from the data of the analyses and entered in the table. Each water has also been classified in respect to its availability for boiler and domestic use and for irrigation. These computations and ratings have been made in accordance with the formulas and standards already discussed (pp. 281–291). It should be thoroughly recognized that the ratings refer only to the effect of the mineral ingredients of the waters and not to other conditions. The statement that a water is good for irrigation implies that it does not contain enough alkali to cause trouble under the conditions of irrigation commonly practiced in this country, but the statement does not take into account soil or crop conditions. The statement that a water is good for domestic use implies likewise that it does not contain harmful or otherwise objectionable mineral substances in solution, but the water may or may not be exposed to harmful pollution.

FIELD ASSAYS.

The field assays by Messrs. Stephenson and Crider in the following table were made according to the methods described by Leighton.[1] The results are necessarily less accurate than those obtained by analysis in a laboratory, because of the approximate nature of the tests and because of the conditions under which the examinations were made. Iron, carbonate, bicarbonate, sulphate, and chlorine were estimated, but as total hardness was not estimated it is impracticable to interpret except in a general way the results of the tests. The figures serve, however, to amplify the data in the table of analyses (p. 302), as they furnish some information regarding the water of wells not otherwise examined. The total mineral content of the waters has been calculated from the estimates of the acid radicles. The relatively high color reported for many of the samples is rather surprising as most deep ground waters are only slightly colored. If these figures represent true color and not the apparent color caused by a slight precipitate of iron or other substance they indicate the presence of more or less vegetable matter, not necessarily harmful, however, in the alluvial deposits.

[1] Leighton, M. O., Field assay of water: U. S. Geol. Survey Water-Supply Paper 151, 1905. See also Dole, R. B., The rapid examination of water in geologic surveys of water resources: Econ. Geology, vol. 6, pp. 340–362, 1911.

Field assays of ground waters in eastern and northeastern Arkansas.

[Parts per million.]

No.	Location.	Source.	Date of collection, 1905.	Depth of well.	Name of principal water-bearing stratum.	Color.	Iron (Fe).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total dissolved solids.[a]
	ARKANSAS COUNTY.			*Feet.*								
1[b]	Dewitt	Driven well at Young's livery stable	May 5	90	Pleistocene alluvium	49	3.5	0	433	0	35	460
2[b]	....do	Driven well of H. Sprague	...do	95	....do	31	1.5	0	273	0	15	290
3[b]	....do	Bored well	...do	40	....do	31	1	0	371	Trace.	95	500
	CRAIGHEAD COUNTY.											
4[b]	Brookland	Bored well	May 29	25	Pleistocene alluvium (?)	[c]75	0	0	572	0	85	660
5[b]	....do	Town well	...do	154	Wilcox formation	18	0	0	84	0	10	120
6[b]	Culberhouse	Well of F. J. Borgman	May 25	18	Quaternary alluvium	4	0	0	334	65	100	570
7[d]	Dee	Well of J. F. McCarty	May —	65	Wilcox formation (?)	....	0	0	334	100	10	490
8[b]	Greenboro	Well of J. W. Johnson	May 29	[e]186	Wilcox formation	18	22	0	48	0	15	100
9[b]	Gubertown, 2 miles northwest of.	Still House spring	...do	....	....do (?)	57	0	0	36	0	15	90
10[b]	Jonesboro	Well at municipal waterworks	June 26	1,214 or 1,265	Cretaceous	45	0	6	1,145	0	270	1,500
11[b]	....do	Well at Warner Hotel	June 23	172	Wilcox formation	18	0	0	143	0	25	180
12[b]	Nettleton	Driven well of Henry Kiech	May 27	30	Pleistocene alluvium	0	0	0	215	Trace.	30	260
13[b]	....do	Driven well of Frank Kiech	...do	25±	....do	102	Trace.	0	429	60	105	660
14[b]	....do	Well of St. Louis, Iron Mountain & Southern Railway Co	...do	[f]147	....do. (?)	0	0	0	95	0	10	130
15[b]	O'Bear	Driven well of Barger Bros	May 30	65	....do	75	3	0	382	0	25	400
16[b]	....do	Driven well of F. L. Rice	...do	30	....do	4	0	0	359	0	25	380
	CRITTENDEN COUNTY.											
17[d]	Ivoton	Driven well of M. L. Woodson	May 24	18	Quaternary alluvium	102	3.5	0	311	Trace.	25	340
18[d]	Marion	Driven well of L. D. Bland	...do	78	....do	133	26	0	383	0	10	380
19[d]	....do	Dug well of L. D. Bland	...do	21	....do	0	0	0	227	100	95	540
20[d]	....do	Lake Marion [g]	...do	....	....	95	2	12	96	0	10	150
21[b]	Turrell	Well of Baker Lumber Co	...do	[h]864	Wilcox formation (?)	18	18	0	526	0	25	520
	GREEN COUNTY.											
22[b]	Lorado	Town dug well	May 31	65	Quaternary alluvium (?)	31	0	0	335	0	15	340
	LONOKE COUNTY.											
23[d]	Baucum	Driven well of J. R. Walter	May 8	32	Quaternary alluvium	0	11	0	430	0	15	420
24[d]	Blakemore	Dug well of Wm. Bradley	May 5	45	....do	30	.2	0	239	35(?)	65	390
25[d]	England	Town well	...do	....	....do. (?)	31	3	0	359	45	25	450
26[d]	Jebb	Driven well near post office	...do	45	....do	0	40	0	239	0	15	260
27[d]	Jebb, 3 miles west of	Driven well of J. A. Collins	...do	42	....do	0	11	0	239	140	15	460
28[d]	"Old River"	Dug well near a bayou	May 8	25	....do	31	0	0	419	40	30	500
29[d]	Toltec	Well of Mr. Laughlin	...do	30	....do	23	11	0	227	60	10	330
30[d]	Tomberlins	Dug well	May 5	45	....do	31	1	0	107	0	20	150
	MISSISSIPPI COUNTY.											
31[d]	Blytheville	Dug well of Mrs. Misho	May 26	21	....do	0	0	0	96	0	40	180
32[d]	....do	Driven well of Mr. Oglesby	...do	60	....do	0	10	0	442	....	25	450
33[d]	....do	Driven well of W. T. Overst	...do	40	....do	0	3	0	196	110	35	420
34[d]	Manila	Driven well of Manila Supply Co	May 27	20	....do	0	Trace.	0	48	Trace.	15	95
35[d]	....do	Driven well of James Ashabramer	...do	28	....do	0	0	0	36	Trace.	40	130
36[d]	Osceola	Driven well of L. A. Morris	May 25	33	....do	45	14	0	627	0	15	590
37[d]	....do	Well at Beal's Hotel	...do	440	Wilcox formation (?)	0	6	0	143	0	20	180
38[d]	....do	Cistern of L. A. Morris [i]	...do	....	....	45	0	31	63	0	10	150
	PHILLIPS COUNTY.											
39[b]	Trenton	Driven well	May 11	75	Pleistocene alluvium	478	2	0	382	40	10	430
	POINSETT COUNTY.											
40[b]	Tyronza	Well near railroad station	May 24	16	Quaternary alluvium	22	0	0	119	Trace.	25	170
41[b]	Weiner	Driven well of Mrs. V. C. Head	May 30	40	Pleistocene alluvium	0	0	0	310	0	15	320
42[b]	....do	Well of St. Louis Southwestern Railway Co	...do	101.5	....do	31	....	0	359	0	15	360
	PRAIRIE COUNTY.											
43[d]	Biscoe	Driven well of G. W. Walker	May 8	35	Quaternary alluvium	0	([j])	0	48	0	50	150
44[d]	Devall Bluff	Well of F. Gates	...do	95	Pleistocene alluvium	122	3.5	0	454	Trace.	20	450
45[d]	....do	Driven well of E. L. Sanders	...do	75	....do	122	3	0	454	([k])	25	470
46[d]	Devall Bluff, ½ mile south of.	Bored well of Jacob Frohlich	...do	75	....do	63	2.5	0	84	380	300	1,200
47[d]	Devall Bluff	Well of W. B. Coyle	...do	85	....do	57	4	0	382	([k])	25	400
48[d]	Hazen	Town well	...do	108	....do	18	.2	0	359	0	15	360
49[d]	....do	Bored well of B. F. Russell	...do	78	....do	18	Trace.	0	431	50	120	670
50[d]	Tollville	Well of R. H. Toll	...do	82	....do	133	4.5	0	454	Trace.	20	450
51[d]	Tollville, ¾ mile west of	Well of C. V. Overman	...do	40	....do	4	0	0	358	Trace.	105	510
	PULASKI COUNTY.											
52[d]	Scott	Well of C. F. Chaer	May 8	42	Quaternary alluvium	0	([l])	0	670	85	25	770

[a] Computed by the formula, total dissolved solids$=35+1.73\ CO_3+0.86\ HCO_3+1.48\ SO_4+1.62$ Cl.
[b] Assay by L. W. Stephenson.
[c] Turbidity, 80 parts.
[d] Assay by A. F. Crider.
[e] Depth of principal water-bearing stratum 175 (?)–186 feet.
[f] Depth of principal water-bearing stratum 87–147 feet.
[g] Surface water.
[h] Depth of principal water-bearing stratum 840–864 feet.
[i] Rain water evidently mixed with ground water.
[j] Less than 1 part.
[k] Less than 5 parts.
[l] More than 11 parts.

QUALITY IN RELATION TO WATER-BEARING STRATUM.

QUATERNARY ALLUVIUM.

More than five-sixths of the wells whose waters have been analyzed draw chiefly from the alluvium, and most of these are situated west of Crowleys Ridge (see Pl. XI) in the Advance lowlands. Indeed, the economic value of ground waters in this area is practically a question of the value of waters from the alluvium, which almost everywhere yields large supplies at moderate depths. According to Mr. Stephenson, the alluvium consists of loams, clays, sands, and gravels; in the Pleistocene deposits there is a general downward gradation from fine surface silts or loams through compact clays and fine sands to coarse sands and gravels at the base. Dark carbonaceous clays, logs, limbs of trees, and peaty accumulations representing buried swamp deposits are occasionally encountered in boring wells.

The following table gives a résumé of the analyses of water from the alluvium and shows the approximate average composition of the supplies and the general range of their constituents. The figures have been rounded off to avoid appearance of undue accuracy. There is a wide range in mineralization, as may be expected in water from any irregularly bedded deposit, and a few waters exceed the limits noted in the table. More than three-fourths of the supplies, however, range in mineral content from 200 to 520 parts and in hardness from 150 to 400 parts per million. In other words, they are calcium carbonate waters of moderate mineral content, rather hard, but containing relatively little alkali. Sulphate (SO_4) exceeds 40 parts per million in only five analyses of water from the alluvium and is generally less than 20 parts. Chlorine exceeds 40 parts in nine, but is as low as 10 parts in a large proportion.

Approximate chemical composition of waters from the alluvium in eastern and northeastern Arkansas.

Constituents.	Approximate average.		Approximate range (parts per million).	
	Parts per million.	Percentage of anhydrous residue.	Highest.	Lowest.
Silica (SiO_2)	40	11	....	....
Calcium (Ca)	75	20	120	25
Magnesium (Mg)	25	7	40	10
Sodium and potassium (Na+K)	25	7	70	5
Carbonate radicle (CO_3)	0	44	0	0
Bicarbonate radicle (HCO_3)	340	....	550	120
Sulphate radicle (SO_4)	15	4	80	1
Chlorine (Cl)	25	7	85	5
Total dissolved solids	370	....	800	160
Total hardness as $CaCO_3$	280	....	500	120

The hardness of the waters indicates the presence of a rather large proportion of calcareous material in the alluvium, and that condition indeed might be expected in view of the great abundance of limestone in the upper basin of Mississippi River and its great tributaries, from which the alluvium is largely derived. Compact crystalline limestones and dolomites comprise much of the older sedimentary formations there, and later deposits are also strongly calcareous. Contrary to common belief the débris carried from limestone regions is not completely robbed of its calcareous material by the water that removes it and later deposits it as alluvial material; limestone even when finely divided is dissolved in appreciable quantity only in so far as the carbon dioxide in the contiguous water renders it soluble; consequently alluvium derived from limestone retains much of its calareous material and wherever waters containing free carbon dioxide percolate through such alluvium they may become as hard as those traversing limestone itself.

It is interesting to note the similarity in composition of water from the alluvium of Arkansas and that from calcareous deposits in Indiana and Ohio. (See table, p. 307.) The unconsolidated deposits of the latter States are mostly glacial drift and yield waters of similar quality; the limestones of the same region also yield similar supplies. The alluvium of Arkansas yields water containing practically as much bicarbonate, only slightly less calcium and magnesium, but much less sulphate. The alluvial water contains about three-fourths as much mineral matter, which in comparison with the waters of Indiana and Ohio is lower in its percentage of sulphate and slightly higher in its percentage of carbonate. The ratios of magnesium to calcium in lines A to E, inclusive, are, respectively, 1:2.6, 1:2.9, 1:2.0, 1:2.6, and 1:3.0—that is, with the exception of water from the "Niagara" limestone, which is highly dolomitic, these waters contain 33 to 39 per cent as much magnesium as calcium. These comparisons show that this alluvium yields water almost as hard as that from old compact limestones, and they also show that even thoroughly washed material may strongly impregnate with mineral matter the waters percolating through it.

The water from the limestone of the Vicksburg formation of Georgia, whose average composition is indicated in lines F and L of the following table, is more or less typical of supplies from the calcareous Tertiary sediments of Georgia and it is inserted for comparison. The water is very much softer and lower in mineral content than that of the alluvium in Arkansas, and the relative proportions of calcium and magnesium are entirely different.

Comparison of the quality of water from the Quaternary alluvium of eastern Arkansas with that of ground waters in Indiana, Ohio, and Georgia.

Mineral content in parts per million.

	Number of analyses averaged.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Dissolved solids.
A	120	20	0.8	90	35	30	0	390	90	50	500
B	169	18	.8	91	31	18	0	306	76	47	467
C	20	20	.5	80	40	20	0	360	80	25	440
D	80	18	1.8	82	31	27	0	341	70	19	466
E	54	40	....	75	25	25	0	340	15	25	370
F	28	20	1	40	5	10	0	140	20	5	190

Percentage composition of the anhydrous residues.

G	....	4	0	18	7	5	38	....	18	10	....
H	....	4	0	21	7	4	35	....	18	11	....
I	....	4	0	18	9	5	40	....	18	6	....
J	....	4	0	20	7	7	40	....	17	5	....
K	....	11	0	20	7	7	44	....	4	7	....
L	....	12	1	24	3	5	40	....	12	3	....

A, G. Unconsolidated deposits of southwestern Ohio.
B, H. Unconsolidated deposits of north-central Indiana.
C, I. "Niagara" limestone of southwestern Ohio.
D, J. Limestones yielding fresh water in north-central Indiana.
E, K. Quaternary alluvium of eastern Arkansas.
F, L. Limestone of Vicksburg formation of Georgia.
(A, G, C, and I from U. S. Geol. Survey Water-Supply Paper 259, p. 212, 1912; B, H, D, and J from U. S. Geol. Survey Water-Supply Paper 254, pp. 260-261, 1910; and F and L from U. S. Geol. Survey Water-Supply Paper 341, pp. 522-523, 1915.)

The iron content of waters from the alluvium of Arkansas differs greatly from place to place, and some of the supplies carry enough to render them distasteful and capable of staining fabrics washed in them. Mr. Stephenson mentions the appearance in the surface materials of iron in the form of small limonite concretions, whose irregular distribution probably explains the difference in iron content of the waters.

The waters of the alluvium are generally potable, but they are so hard that most of them have been rated as only fair for domestic use. Fortunately, the greater proportion of the hardness, being temporary, can be removed by boiling the waters and allowing the sediment thus produced to settle. The waters are, almost without exception, good for irrigation and can be used without fear of their causing accumulations of alkali in the soil. Few would be likely to foam in or corrode boilers, but all carry considerable soft scale forming matter and for boiler use could be greatly improved in preheaters or cold water softening plants. The classification of them as fair to poor for boiler use is rather more severe than the classification adopted by some railroads traversing Arkansas, but it corresponds to the ratings outlined on pages 284–287.

CRETACEOUS AND TERTIARY FORMATIONS.

The analyses of water from Tertiary and Cretaceous formations in eastern Arkansas are so few that little can be deduced regarding their general quality. Analyses 15, 22, and 48 in the table opposite page 302 represent calcium carbonate waters of moderate mineral content from the Wilcox formation, which comprises strata of sands, clays, quartzites, and lignites. No. 45 in the same table is a partial analysis of water from the Claiborne formation in Phillips County. A well 1,495.5 feet deep in Mississippi County is believed to draw its supply chiefly from Cretaceous sands (see analysis No. 39), and a shallower well in White County (analysis No. 64) enters Carboniferous strata. Three other wells in St. Francis, Lee, and Monroe counties (see analyses Nos. 58, 28, and 42) enter undifferentiated formations of the Eocene series. The latter of these yields a salt water of high mineral content.

QUALITY IN RELATION TO GEOGRAPHIC POSITION.

Waters containing moderately large amounts of sulphate or chloride have been occasionally encountered in eastern and northeastern Arkansas but with little apparent regularity, and they probably are derived from local gypsiferous or saline beds that may owe their origin to influxes of highly mineralized silts from the area now included in Oklahoma and southwestern Kansas. Though the waters from the alluvium of the lowlands range in mineral content approximately from 160 to 800 parts per million, the available analyses do not indicate any definite geographic distribution of waters of high or low mineral content. Most of the ground waters are potable, acceptable for irrigation, and capable of being purified for industrial use. Consequently the occasional occurrence of waters relatively high in mineral content is not especially serious.

Of the 68 waters whose analyses are given in the table (p. 302) only 10 exceed 50 parts per million in content of sulphate or 100 in content of chlorine. Six of these are from wells in the area between Arkansas and White rivers. The data of the field assays (p. 304) indicate that waters rather high in sulphate and chlorine come from some but not by any means all wells in the same area. The owners of a few wells in Arkansas and Prairie counties have reported saline waters (pp. 150, 251). All these facts together lead to the conclusion that local deposits of gypsiferous and saline material may be more numerous in the alluvium between Arkansas and White rivers than elsewhere in northeastern Arkansas. The water of Arkansas River contains a large proportion of sulphate and chlorine, and past meandering of this stream may explain the presence of the mineralized alluvial spots. Mr. Stephenson states (p. 271) that the ground waters have a distinct brackish taste in a considerable area in the eastern part of White County, particularly in the vicinity of West Point and Worden and east of Russell. Greater development of ground waters in the lowlands will doubtless result in the discovery of similar areas.

QUALITY IN RELATION TO DEPTH OF WELL.

The averages in the following table indicate that wells less than 100 feet deep in the alluvium are likely to yield waters of somewhat lower mineral content than deeper ones, but this apparent difference may be a fortuitous coincidence of figures, though the number of analyses that have been averaged is fairly great. Aside from this difference the comparative quality of waters from various depths in the alluvium, as indicated by the results in the table opposite page 302, appears to depend entirely on the locality. This condition may be expected because the alluvium is irregularly bedded.

Mineral content of water from the alluvium of eastern and northeastern Arkansas in relation to depth of well.

Depth of wells.	Number of analyses averaged.	Average total dissolved solids.	Average total hardness as $CaCO_3$.
Feet.		*Parts per million.*	*Parts per million.*
60-100	12	366	254
101-149	22	375	296
150-200	16	378	295

ECONOMIC VALUE.

The probable value of the waters that have been analyzed is indicated in the last three columns of the table opposite page 304. So few analyses of supplies from Cretaceous and Tertiary strata are available that no general statements regarding their usefulness can be made.

The waters of the alluvium in general are calcium carbonate waters of moderate mineral content. They are rather hard, but as most of the hardness is carbonate or temporary, they can be softened by being boiled. Some carry enough iron to taste unpleasant, but most are potable. Practically all are suitable for irrigation. Few are likely to cause foaming or corrosion in boilers, but all carry considerable scale-forming matter and for boiler use could be greatly improved in preheaters of cold water softening plants. For these reasons they have been rated as fair or poor for boiler use in their natural state, but capable of being made satisfactory at relatively little expense.

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