UNITED STATES DEPARTMENT OF THE INTERIOR

GROUND WATER IN SOUTH-CENTRAL TENNESSEE

Prepared in cooperation with the
TENNESSEE DIVISION OF GEOLOGY

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BY

CHARLES V. THEIS

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CONTENTS

ILLUSTRATIONS

GROUND WATER IN SOUTH-CENTRAL TENNESSEE

By Charles V. Theis

ABSTRACT

This paper describes the characteristics of the ground water in an area lying in the south half of Tennessee, extending from the west front of the Cumberland Plateau westward to the lower course of the Tennessee River and embracing 12 counties. The geology of the region is sketched as a background for the ground-water data.

This area includes a small portion of the Cumberland Plateau, the south half of the Highland Rim plateau in Tennessee, and the south half of the Nashville Basin. The Cumberland Plateau in this area is a well-preserved uplifted peneplain at an altitude of about 2,000 feet; the Highland Rim plateau is another uplifted peneplain at an altitude of about 1,000 feet, very well preserved and scarcely broken by dissection except on its inner edge and near the Tennessee River; the Nashville Basin, a third somewhat uplifted peneplain at an altitude of about 700 feet, is more rolling in this area than the other two.

The exposed strata range in age from Lower Ordovician to Quaternary. The Paleozoic strata are predominantly limestone and are the surface rocks over most of the area. Cretaceous gravel and sand overlap from the west and south and cover a small portion of the southwestern part of the area. Terrace and flood-plain deposits of later age occur along the streams. The Paleozoic strata are well exposed and express a long period of greatly interrupted sedimentation. A thick mantle of residual cherty clay covers most of the Highland Rim plateau in this area.

In the extreme western and eastern portions of the area ground water occurs in primary openings in gravel and sandstone. Elsewhere in the area it is largely confined to secondary solution openings in limestone. As a consequence its occurrence is somewhat erratic, but fortunately household and stock supplies are usually obtained without difficulty from springs or from wells generally less than 100 feet deep. No large supplies of potable water are obtained from wells, and exploration to this end has been generally disappointing. Municipal supplies are obtained from impounded surface streams or, more commonly, from springs. Water supplies for domestic and stock use in the Highland Rim are usually obtained from dug wells, usually less than 100 feet deep, in the residual clay mantle.

The ground-water resources of the region are best shown by the almost omnipresent springs. Springs flowing several hundred gallons a minute are found in every county along the escarpment of the Highland Rim plateau and along the Tennessee River. Springs capable of yielding adequate supplies for small communities are almost innumerable.

The water obtained from the limestone areas is a moderately hard, calcium-bicarbonate water. Some wells, especially in the Nashville Basin, have struck impotable sodium-chloride or calcium-sulphate water. The water from the

Pennsylvanian rocks of the Cumberland Plateau is soft but likely to carry iron in solution. The water from the Cretaceous gravel in Wayne County is also very soft.

In connection with the textual descriptions the pertinent data on over 500 individual wells and springs in this area are tabulated.

INTRODUCTION

The present paper describes the ground-water resources of an area covering 12 counties in south-central Tennessee. It is expected that the description of typical ground-water supplies throughout the area, together with the generalization drawn from these data, concerning the occurrence of ground water, will aid in the future rural and industrial development of the region. Inasmuch as the area is predominantly agricultural and has abundant shallow supplies of water for this purpose, information concerning supplies from wells for other than domestic and stock purposes is scarce. However, the large springs scattered along the Highland Rim escarpment bear potent promise of adequate ground-water supplies for industries which may develop in the future.

This paper is the third in a series dealing with the ground-water supplies of Tennessee. Piper[1] has discussed the ground water of north-central Tennessee, and Wells[2] that of western Tennessee. A report on the ground water of northern Alabama by Johnston[3] and one on the ground water of Mississippi by Stephenson[4] have also been published. Plates 3 and 4 show the relation of the area discussed herein to the areas in Tennessee covered by these previous ground-water papers and to the geomorphic and drainage boundaries in Tennessee.

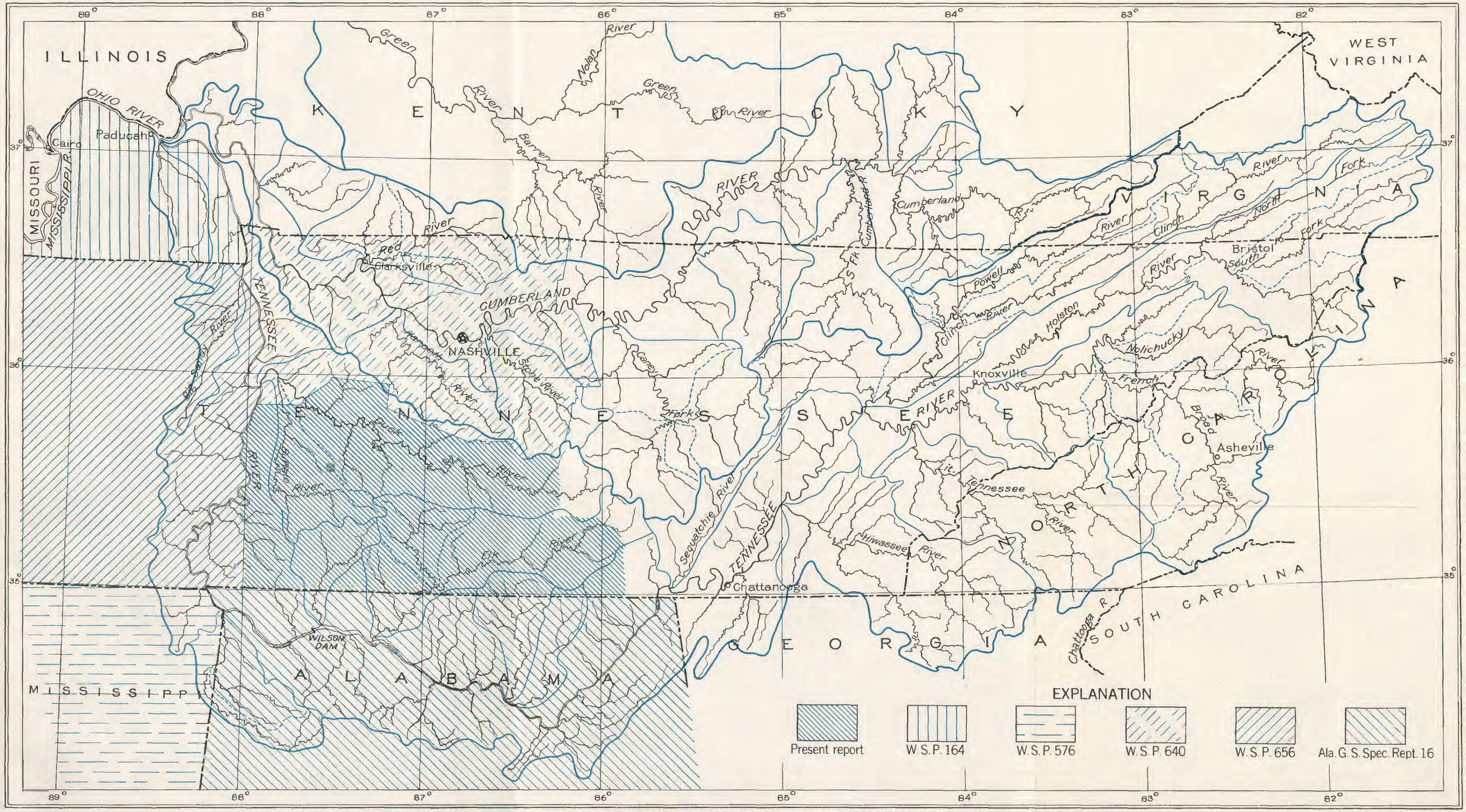
The investigation on which the present report is based, as well as those preceding the other two reports on the ground water of Tennessee, was made by the United States Geological Survey in cooperation with the Tennessee Division of Geology. The writer is indebted to O. E. Meinzer, geologist in charge of the division of ground water, under whom the investigation was made, for helpful criticism and advice, and to W. F. Pond, State geologist of Tennessee, for cooperation and help in the field. Margaret D. Foster, of the United States Geological Survey, and D. F. Farrar, of the Tennessee Geological Survey, made the analyses of water. D. G. Thompson, of the United States Geological Survey, introduced the writer to the field and greatly aided him in the initial field work and later. To officials of

[1] Piper, A. M., Ground water in north-central Tennessee: U. S. Geol. Survey Water-Supply Paper 640, 1932.

[2] Wells, F. G., Ground-water resources of western Tennessee: U. S. Geol. Survey Water-Supply Paper 656, 1923.

[3] Johnston, W. D., Jr., Ground water in the Paleozoic rocks of northern Alabama: Alabama Geol. Survey Special Rept. 16, 1933.

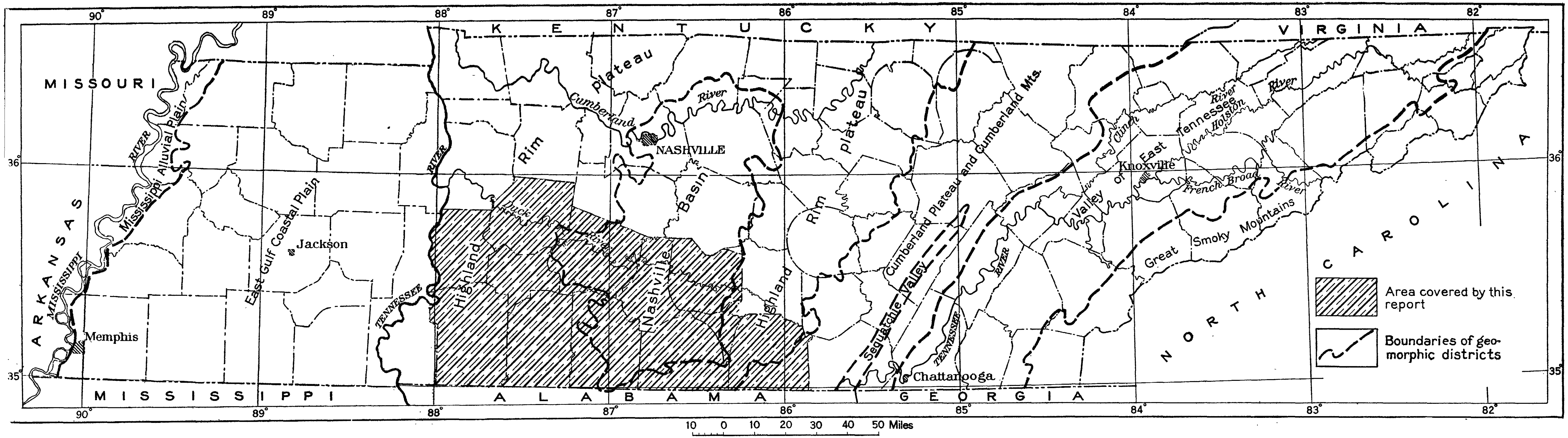
[4] Stephenson, L. W., The ground-water resources of Mississippi: U. S. Geol. Survey Water-Supply Paper 576, 1918.



MAP SHOWING AREA COVERED BY THIS REPORT (SHADED PORTION) IN RELATION TO DRAINAGE BASINS OF THE TENNESSEE, CUMBERLAND, AND GREEN RIVERS

Scale

10 0 10 50 100 Miles



MAP OF TENNESSEE SHOWING GEOMORPHIC DISTRICTS.

water companies in the area, to local geologists, and to the inhabitants in general, the writer is indebted for courteous and intelligent cooperation.

The published work of many other geologists has been used in preparing this report. Although the papers used are cited in the text, it is not out of place to note here that the section on stratigraphy is based largely on the work of Bassler,[5] Butts,[6] Miser,[7] Wade,[8] and Dunbar.[9]

The region under discussion has an area of 6,108 square miles and includes the counties of Bedford, Franklin, Giles, Hickman, Lawrence, Lewis, Lincoln, Marshall, Maury, Moore, Perry, and Wayne. It lies almost entirely within the basin of the Tennessee River and extends from that river, on the west, to the Cumberland Plateau, on the east. It is bounded on the south by the Alabama State line and extends north about to the middle latitude of the State. It is served by numerous highways and by the Louisville & Nashville Railroad and the Nashville, Chattanooga & St. Louis Railway. It is predominantly agricultural in interest, although Maury County and to a less extent Lewis County produce phosphate rock, and Wayne, Lewis, and Hickman Counties have produced brown iron ore up to the last few years and still have large reserves.

CLIMATE

GENERAL FEATURES

South-central Tennessee lies between two of the main storm tracks crossing the eastern United States but not directly upon any.[10] Hence there are many comparatively gentle changes in the weather but relatively few severe ones. Its position with reference to the storm tracks conduces to a generally favorable distribution of rainfall throughout the year and a minimum of destructive storms. Isopluvial charts show that the greatest storms in this general area are less in intensity than in any other area in the same latitude in the eastern United States.[11]

[5] Bassler, R. S., The stratigraphy of the Central Basin of Tennessee: Tennessee Div. Geology Bull. 38, 1932.

[6] Butts, Charles, Geology of Alabama; the Paleozoic rocks: Alabama Geol. Survey Special Rept. 14, 1926.

[7] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, 1921.

[8] Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, Tennessee Geol. Survey, 1914.

[9] Dunbar, C. O., Stratigraphy and correlation of the Devonian of western Tennessee: Tennessee Geol. Survey Bull. 21, 1919.

[10] Summary of the climatological data for the United States, Section 77, Middle and west Tennessee, U. S. Weather Bureau.

[11] Storm rainfall of eastern United States: Miami Conservancy District Tech. Repts., pt. 5, Dayton, Ohio, 1917.

TEMPERATURE

The mean annual temperature of central Tennessee, as well as for stations within the area of this report, is 58.7° Fahrenheit. For individual stations it ranges from 59.7° at Coldwater, Lincoln County, to 58.4° at Franklin, Williamson County, just north of the Maury County line, and 57.2° at Sewanee, Franklin County. These figures indicate a general decrease toward the north and also with increasing altitude above sea level. Maximum temperatures of 110° were reached in the summer of 1930, but as a rule the temperature does not exceed 95° more than about 15 days a year. Minimum temperatures as low as 25° below zero have occurred, but on the average temperatures below zero occur only once a year. July is the hottest month and January the coldest. The average date of the last killing frost in spring is April 6, and of the first in autumn October 24.

Mean monthly temperatures for central Tennessee, as computed from records up to and including 1930, are shown in the following table:

Mean monthly temperatures (°F.) for central Tennessee

January	39.2	May	66.7	September	71.4
February	40.7	June	74.7	October	59.8
March	49.9	July	77.4	November	48.6
April	58.6	August	76.6	December	40.6

PRECIPITATION

The mean annual precipitation for all of Tennessee is about 50 inches and that for central Tennessee is about 51 inches. The figure for the stations in and adjacent to the south-central Tennessee area is about 52.5 inches. The highest mean, as computed from records up to and including 1930, is found at Sewanee, Franklin County, with 54.76 inches, and the lowest at Franklin, Williamson County, with 48.54 inches. The rainfall diminishes slightly northward and increases slightly with altitude.

The rainfall is well distributed throughout the year, reaching a minimum in October with 3.01 inches, and a maximum in March with 5.65 inches. A quantity sufficient for crop needs generally falls during the growing season, and a copious supply is also available during the winter, when recharge of ground water is most favored. The following table gives the mean monthly precipitation in central Tennessee.

Mean monthly precipitation (inches) for central Tennessee

January	5.00	May	4.26	September	3.18
February	4.21	June	4.31	October	3.01
March	5.65	July	4.58	November	3.47
April	4.68	August	4.18	December	4.65

GROUND-WATER SUPPLY IN 1930 COMPARED WITH THAT OF OTHER DROUGHT YEARS

The flow of springs and the depths to the water levels in wells, as well as other ground-water features, vary with the current and preceding climatic phenomena. The current precipitation affects the flow of springs that are connected by relatively large underground passages with open intakes, such as sink holes. The precipitation during many preceding months has also an effect on the flow of other springs, as well as on the height of water in wells, because part of the rainfall moves very slowly downward through the soil to the ground-water level, below which it is stored in the ground-water body until it is discharged. The ground-water level, or water table, usually fluctuates seasonally to some extent, rising during the winter, when more water is contributed to it by precipitation than is discharged by springs and otherwise, and falling during the summer, when the reverse is true. As the water table falls, the flow of springs diminishes. Under conditions of drought it falls much more than normally and consequently the springs discharge much less than their normal flows for the season. Temperature has also both immediate and delayed effects, for it controls in part the rate of transpiration of plants and the rate of evaporation, so that in hot, dry weather much of the ground water is removed by these agencies. Furthermore, when soils have been drying for a long time, much of any rainfall that comes is absorbed by the soil near the surface and never descends to the zone of saturation.

The summer of 1930, in which the field work for this report was done, was characterized by a severe drought throughout the area studied, as well as generally in the central and eastern United States. Although streams in the Tennessee Valley in general did not decline as much in this year as they had in 1925,[12] or in 1931, the flows were reduced in general to much less than normal. The ground-water flow probably did not decrease in as great a ratio as the flow of the surface streams, yet undoubtedly the flows given in this report for many springs are less than normal, and the water levels in wells are probably also lower than their average position.

The exact effect of the climatic conditions upon the ground-water phenomena observed during the summer and fall of 1930 cannot be evaluated from the data collected during one field season. To do so would require an intensive study, during at least several years, of the relations between climatic factors, ground-water levels, and the flow of springs. However, the accompanying tables are given to indicate qualitatively rather than to define exactly the relation of the data acquired during 1930 to data that might have been

[12] King, W. R., Surface waters of Tennessee: Tennessee Div. Geology Bull. 40, p. 50, 1931.

collected in a normal year or in a year when ground-water conditions were even more adversely affected by drought.

The following table gives data concerning the precipitation in middle Tennessee, in an area lying between the Cumberland Plateau and the lower course of the Tennessee River for several "water years" when drought prevailed in this area. A "water year" extends from October of one calendar year through September of the next and is more significant than a calendar year in discussing water conditions, because it includes the period of recharge, which largely furnishes the ground-water flow during the dry season of the year. The years ending in September 1925, 1930, and 1931, have been chosen for comparison because these are the years of greatest drought for which adequate data are available.

Characteristics of the precipitation in recent drought years in middle Tennessee

Month	Precipitation (inches)			Departure from normal (inches)			Accumulated departure from normal (inches)		
	1924–25	1929–30	1930–31	1924–25	1929–30	1930–31	1924–25	1929–30	1930–31
October	0.08	4.23	2.81	−2.84	+1.15	−0.20	−2.84	+1.15	−0.20
November	1.44	5.73	3.20	−2.08	+1.99	−.27	−4.92	+3.14	−.47
December	6.94	3.23	2.89	+2.37	−1.51	−1.76	−2.55	+1.63	−2.23
January	3.39	4.20	1.90	−1.78	−.80	−3.10	−4.33	+.83	−5.33
February	5.07	4.86	4.47	+.94	+.65	+.37	−3.39	+1.48	−4.96
March	2.66	5.04	4.30	−2.84	−.61	−1.27	−6.23	+.87	−6.23
April	4.12	1.47	3.00	−.56	−3.21	−1.66	−6.79	−2.34	−7.89
May	2.24	5.72	2.32	−2.00	+1.46	−1.98	−8.79	−.88	−9.87
June	3.28	1.07	1.89	−1.14	−3.24	−2.46	−9.93	−4.12	−12.33
July	3.32	2.26	4.11	−1.26	−2.32	−.42	−11.19	−6.44	−12.75
August	1.26	2.57	3.46	−2.88	−1.61	−.67	−14.07	−8.05	−13.42
September	2.44	3.31	1.57	−.78	+.13	−1.62	−14.85	−7.92	−15.04

This table shows that although the drought of 1930, beginning and being most intense in the growing season, affected crops more adversely than either of the other droughts, yet the other periods had a much greater total deficiency in rainfall. The accumulated departure from the normal was nearly twice as great in 1925 and 1931 as in 1930. It is therefore concluded that although the ground-water discharge was probably lower than normal in 1930, it by no means represents the minimum that has occurred.

The temperature data are shown in the following table in the same way. The figures for accumulated departures show that the total excess temperature in 1930 was only about half as great as that in 1925, although in the period April to August, when evaporation and transpiration are most active, both years were about equally hot. The water year 1930–31 was cooler than normal. These data, although less significant than the precipitation data, confirm the main inference drawn from the latter—namely, that the ground-water deficiency in 1930 was probably not so great as in other years of drought.

Characteristics of temperature in recent drought years in middle Tennessee

Month	Temperature (° F.)			Departure from normal (° F.)			Accumulated departure from normal (° F.)		
	1924–25	1929–30	1930–31	1924–25	1929–30	1930–31	1924–25	1929–30	1930–31
October	61.9	58.2	57.4	+2.0	−1.5	−2.4	+2.0	−1.5	−2.4
November	50.9	47.6	48.6	+1.5	−1.6	.0	+3.5	−3.1	−2.4
December	39.4	41.6	37.4	−.7	+1.0	−3.2	+2.8	−2.1	−5.6
January	40.1	38.4	39.3	+1.0	−.8	−.1	+3.8	−2.9	−5.5
February	47.5	48.9	44.0	+7.3	+8.2	+2.8	+11.1	+5.3	−2.7
March	52.2	47.1	43.7	+2.5	−2.8	−6.1	+13.6	+2.5	−8.8
April	63.5	61.2	56.9	+5.1	+2.6	−1.8	+18.7	+5.1	−10.6
May	63.9	67.8	63.7	+3.2	+1.1	−3.0	+15.5	+6.2	−13.6
June	78.3	74.0	76.5	+3.9	−.7	+2.0	+19.4	+5.5	−11.6
July	77.5	82.0	80.2	+1.6	+4.6	+2.7	+21.0	+10.1	−8.9
August	80.1	77.4	75.3	+.9	+.8	−1.3	+21.9	+10.9	−10.2
September	57.0	73.9	76.6	+9.0	+2.5	+5.1	+30.9	+13.4	−5.1

Another line of attack on the problem of the relation between ground-water conditions in 1930 and those of normal years is furnished by stream-flow records. During most months of the summer low-water season the streams fall at least once to a stage sustained almost entirely by ground-water discharge. Especially is this true in periods of unusual drought. Accordingly a comparison of the low-water flows of streams for these months gives a general relation between the ground-water discharges. In the following table the low-water flows of streams in south-central Tennessee during the period from May through October in the 3 drought years previously chosen are compared. The data are given in terms of percentage of the average low-water flow for the same months in the period 1921–30.

Minimum flows of several streams in or near south-central Tennessee in summer of recent drought years, in percentage of average minimum flow for months indicated in period 1921–30

Mouth	Duck River at Normandy (drainage area 214 square miles)			Duck River at Centerville (drainage area 2,070 square miles)			Elk River at Elkmont, Ala. (drainage area 1,700 square miles)			Buffalo River at Flatwoods (drainage area 439 square miles)		
	1925	1930	1931	1925	1930	1931	1925	1930	1931	1925	1930	1931
May	58.8	73.5	44.7	51.8	59.3	38.8	37.7	57.3	33.9	62.3	81.5	44.1
June	50.3	73.2	45.8	50.1	46.4	34.6	34.8	53.5	32.2	59.3	69.2	61.7
July	53.8	83.8	59.9	58.2	68.1	55.2	47.4	58.2	39.4	74.2	82.9	85.9
August	58.9	78.3	60.1	22.2	71.8	55.2	26.1	51.3	45.9	50.4	86.6	92.3
September	72.7	97.0	64.8	34.4	81.5	47.8	29.6	81.0	29.6	47.7	91.7	68.2
October	75.5	97.2	-------	64.0	85.5	-------	52.1	76.7	-------	77.0	77.0	------

The data in this table confirm the conclusions previously drawn. Although the low-water flows during the dry season of 1930 were below normal, even in the streams having the smaller drainage basins, yet for all the streams tabulated, in nearly every month, the low flow in 1930 was greater than the low flows of either 1925 or 1931.

A direct approach to the problem is to compare measurements of the discharge of springs during various drought and normal years. Fortunately, although no such measurements are available in the area covered by this report, the record of the daily discharge of Huntsville Spring, in Alabama, about 15 miles south of Lincoln County, from November 1928 to March 1932, is available.[13] The record of this spring during the field season in which the data of this report were collected, the succeeding year, also a drought year, and the preceding more normal year is given graphically in plate 5. The minimum discharge during the dry season of 1929 was 12 second-feet, occurring in August and September; in 1930 it was 5.4 second-feet, occurring in November; and in 1931 it was only 3.2 second-feet and occurred in November. The greater ground-water deficiency in 1931 is again demonstrated. The relationship between the fluctuations in discharge and the precipitation should be noted; it is evident that the amount of low-water flow in the dry summer season is largely dependent on the amount of precipitation during the preceding winter period, that during the winter the discharge in general immediately increases after a heavy rain, and that in summer even heavy rains have little effect upon the discharge.

These data seem to the writer to give a basis for forming a tentative opinion that ground-water discharge was smaller in 1930 than normal, perhaps about 80 percent of normal, but it was perhaps 25 percent greater than the minimum ground-water flow that may be expected.

GEOMORPHOLOGY

SUBDIVISIONS

The area discussed in this report lies almost wholly within the Highland Rim or Interior Low Plateau geomorphic province as defined by Fenneman, [14] being divided about equally between the Highland Rim section and the Nashville Basin section of this province. However, it also embraces a small part of the Cumberland section of the Appalachian Plateau province, which lies to the east and enters the area in the southeastern part of Franklin County. These geomorphic divisions are shown on plate 4.

The Cumberland Plateau is a submaturely dissected peneplain, whose surface is about 2,000 feet above sea level in this area. It is bounded on its northwestern margin by a bold scarp that separates it from the Highland Rim, about 1,000 feet below. This scarp runs southwestward approximately along a line joining the southwest and northeast corners of Franklin County. This plateau section coincides with the area of outcrop of Pennsylvanian rocks, shown on plate 1.

[13] U. S. Geol. Survey Water-Supply Papers 683, 698, 713, 728.

[14] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 6, pl. 1, 1917.

The Highland Rim section is a plateau of little local relief, except near major drainage courses, forming a "rim" completely encircling the lower land of the Nashville Basin. Technically it is a peneplain in a stage of dissection ranging from youthful to mature. Its altitude ranges from about 1,100 feet at its eastern edge to about 700 feet in southern Lawrence County. It abuts against the Nashville Basin in a very distinct though ragged scarp about 300 feet high. Its area approximately coincides with the area in which Mississippian rocks crop out (pl. 1) and includes Perry, Hickman, Wayne, and Lawrence Counties, the western part of Giles County, the southern part of Lincoln County, and the northern part of Franklin County.

The Nashville Basin comprises the lower land enclosed within the Highland Rim escarpment. It has a gently rolling surface at a general altitude of about 700 feet. Its surface represents a third peneplain, which, however, is not as perfect as the other two in this area. In the area covered by the present report this section includes Bedford and Marshall Counties and most of Maury, Giles, and Lincoln Counties.

NASHVILLE BASIN

BOUNDARIES

The predominant characteristic that makes the Nashville Basin a natural unit is its topographic position: It is a very apparent basin with a surface about 600 to 700 feet above sea level surrounded by the higher land of the Highland Rim at an altitude of about 1,000 feet. This difference in altitude causes Ordovician rocks to be exposed in the basin, whereas Mississippian rocks cap the Highland Rim. This difference in the stratigraphy, in turn, causes great differences in the human activities in the two sections.

Although the boundary between the two sections is, on the whole, very sharp, it is also, like most topographic features dependent mostly on erosion, very ragged. The edge of the Highland Rim is greatly frayed, so that jutting ridges project outward into the basin and are continued by rows of outlying knobs. Especially is this true in the southern part of the area studied. The divide between the Duck and Elk Rivers is capped in many places by Mississippian rocks and presents extensive areas of typical flat, Highland Rim surface.

Although the relationship of these mesalike ridges and hills to the Highland Rim must be recognized, they are herein considered a part of the Nashville Basin, and the southern boundary of the basin is drawn south of the Elk River in Lincoln and Giles Counties. This procedure follows the general practice of the various geological surveys of Tennessee and the original definition of the Nashville Basin by Fenneman and others [15] but is at variance with the revised map of the physical divisions of the United States.[16]

The determination of a generalized line separating two geomorphic regions which are separated in nature by an erosional feature, such as separates the Highland Rim plateau and the Nashville Basin, is often difficult and admissive of many viewpoints. Any such generalized line must include on either side areas that partake of the characteristics of the area which is typically developed on the other side. The criteria used in separating the two areas may be of geomorphologic, geomorphogenic, or geographic nature. In localities where the geomorphologic boundaries are not clearly defined the outcrops of stratigraphic contacts are frequently used as boundaries.

Judged by any of these criteria it seems better to the present writer to include much of Lincoln and Giles Counties in the Nashville Basin. The Highland Rim in this vicinity has a remarkably flat, even surface, whereas the Nashville Basin is much more rolling and includes monadnocks in the divide between the Tennessee and Cumberland Rivers. As a consequence the hilly country carrying the monadnock remnants of the Highland Rim on the divide between the Elk and Duck Rivers seems to the traveler in the country much more a part of the Nashville Basin than of the Highland Rim, and the distinct break in the physical character of the region occurs at the scarp south of the Elk River. North of this scarp is a rolling country at a much lower average altitude; south of it is a practically flat plain. Furthermore the lowland level in the Elk River Valley is probably slightly lower than that in the Duck River Valley. The altitude at the courthouse in Fayetteville is 721 feet, whereas Shelbyville is at an altitude of 771 feet and Lewisburg at 735 feet. Howell and Petersburg, in Lincoln County which are respectively 6 and 12 miles from Elk River, have altitudes of less than 750 feet. This region therefore seems to the writer to be a part of the Nashville Basin on the basis of topographic character.

Considered genetically, it is also a part of the Nashville Basin, in that it is an approximately baseleveled region which was reduced in the same geologic period as that in which the part of the Nashville Basin tributary to the Duck and Cumberland Rivers was reduced. The reduction to baselevel was not so complete here as farther north, apparently because the Highland Rim peneplain was uplifted along the Elk River-Duck River divide and consequently a greater overburden of rocks had to be removed by the Elk River. During this period of erosion the Highland Rim south of the Elk River was scarcely touched by dissection.

[15] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 6, pl. 1, 1917.

[16] Fenneman, N. M., Physical divisions of the United States, scale 1:7,000,000, U. S. Geol. Survey, 1930.

Finally, judged by geographic criteria, the area in question should certainly be placed in the Nashville Basin. The geographic character of the country is given by the broad rolling valleys founded upon Ordovician rocks. These were the first settled portions of the region, here are found the most prosperous farms and the densest settlement, and here also is located, near Pulaski, the only mineral development of the region, the mining of Ordovician phosphate rock. It seems, therefore, that the lower part of the Elk River drainage basin should be considered a part of the Nashville Basin on the basis of any criterion selected for drawing the geomorphic boundaries in this region.

As noted above, this interpretation is that previously made by apparently all local workers in Tennessee. Safford [17] and Nelson [18] both followed this interpretation in publishing maps showing the geomorphic divisions of the State.

STRATIGRAPHY

The rocks of the Nashville Basin are predominantly Ordovician, consisting of formations ranging from the upper part of the Stones River group, exposed in Bedford and Marshall Counties, to the Fernvale formation, of the Richmond group. Above this is a varying thickness of variable Silurian formations, exposed only as collars around remnants of the Highland Rim or in the main scarp of the rim itself. The Chattanooga shale (Upper Devonian or Mississippian) succeeds the Silurian in almost every locality in this area, but in a few places in Wayne and Perry Counties Middle and Lower Devonian rocks are present. The Chattanooga is in turn covered by Mississippian rocks of Kinderhook and Osage age. Finally, scattered remnants of the Warsaw formation and St. Louis limestone (both of the Meramec group, Mississippian) are found in the rim outliers.

GENERAL PHYSICAL FEATURES

The general floor level of the Nashville Basin ranges from about 550 feet to 650 feet above sea level, but the lower altitudes are found near the Cumberland River, outside the area here considered. The major streams have cut their beds to levels of about 500 feet (Duck River where it leaves the basin) and 550 feet (Elk River at the State line). The largest of the remnants of the Highland Rim rise to levels equal to those of adjacent parts of the rim proper, reaching altitudes of over 1,200 feet, as, for instance, near the junction of Bedford, Lincoln, and Moore Counties. The total relief within the basin in this area is therefore about 700 feet.

[17] Safford, J. M., and Killebrew, J. B., The elements of the geology of Tennessee, p. 8, Nashville, Tenn., 1900.

[18] Nelson, W. A., Administrative report of the State geologist, 1920: Tennessee Geol. Survey Bull. 25, p. 50, 1921.

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Most of this relief, however, occurs at the plateau remnants, so that in districts containing no remnants the relief is much less, and within the inner basin the relief is about 250 to 300 feet. The local relief in the typical basin areas may be as much as 150 feet, as found in the city of Columbia, in Maury County, on the banks of the Duck River, or as little as 50 feet, as shown over many square miles of territory in the central part of the basin, notably north of Shelbyville, in Bedford County.

The degree of dissection within the basin is that characteristic of old-age topography, upon which the streams have had time to extend and adjust themselves until they drain all portions of the area in the most efficient manner. The topography is rolling in all portions of the basin, although the local relief is greater in the outer areas than in the central portion. In no section are distinct drainage lines farther apart than about a quarter of a mile.

The profiles of the Highland Rim remnants in the basin reflect their stratigraphy. They are generally bounded by a rough and rather steep slope, developed on the cherty shale and limestone of the Ridgetop shale and Fort Payne chert. Their tops, however, are generally much more rolling and the topography more gentle, owing to the erosion, largely by solution and largely in a previous erosion cycle, of the underlying more calcareous Warsaw formation and St. Louis limestone. This is true also of the ascent to the rim proper on the boundaries of the basin.

STREAMS

The drainage of this part of the Nashville Basin all goes by way of the Duck and Elk Rivers, tributaries of the Tennessee. These main streams follow entrenched meandering courses throughout the basin. The meanders are most pronounced on the Duck River, which at the eastern line of Maury County follows a tortuous course of about 17 miles between points only 3 miles apart. Again where it leaves the same county its course along its loops amounts to 10½ miles between points 1 mile apart. These meanders are all of large amplitude and are meanders of the valley itself; there is very little meandering of the stream upon its flood plain.

The total entrenchment beneath the basin floor is about 150 feet at its maximum, where the Duck River passes the western boundary of the basin. The slope from the basin level to this river is broken by at least one terrace level, and careful topographic studies might perhaps show more. This terrace level slopes downstream in the Columbia quadrangle, with a gradient about half that of the present stream. The terrace is about 600 feet above sea level in the vicinity of Columbia and 550 feet at Centerville,[19] whereas in the same interval the present stream falls from nearly 550 feet above sea level to about 450 feet.

[19] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 1, 1903.

ADJUSTMENT OF DRAINAGE TO STRUCTURE

A noteworthy correlation between the geologic structure and the courses of the streams is found in the Nashville Basin, as well as in the Highland Rim, to be discussed later. The tributaries of the rivers commonly run in synclinal troughs. Complete data that would show that this condition is characteristic of the entire southern part of the basin are not available. However, it is notably true in the Columbia quadrangle, the only one mapped in the area, of which it is said:

> In a great majority of cases in ascending one of the larger tributaries of Duck River the strata are found to rise from the mouth of the stream toward its head, a particular bed thus retaining a practical parallelism with the bottom of the valley. Further, the same relation is often observed upon the side tributaries of the main creeks, which thus appear to be located in many cases in gentle synclines.[20]

The same condition is shown in the Franklin quadrangle,[21] which touches the area here considered in northern Maury County, and also in the Woodbury quadrangle,[22] northeast of Bedford County. Within the entire area considered the same condition prevails, although it is impossible to state, on the basis of the data available and the observations made, that the same degree of correlation between structure and drainage is everywhere present.

GEOMORPHIC DIVISIONS OF NASHVILLE BASIN

Two types of country, quite distinct geomorphically and geographically, are included in the Nashville Basin. These two distinct areas may be designated the "inner basin" and the "outer basin."

The distinction between these two types rests on both lithologic and topographic grounds. Topographically the inner basin represents the country whose peneplanation was most highly perfected; the relief is small. On the other hand the outer basin, as its name implies, lies on the outskirts of the peneplaned area; its topography is more rolling than that of the inner basin, and its relief is greater. It is in this area that the large Highland Rim remnants lie.

The distinction of highest geographic and economic importance is the difference in lithology of the two sections. The inner basin is underlain by the Lower Ordovician Stones River group and the Middle Ordovician Lowville limestone; the outer basin is founded upon the Ordovician formations lying above these. These higher Ordovician rocks have a considerable phosphatic content, all except the Cannon limestone yielding in places commercial phosphate. They are also somewhat clastic, so that their weathering generally yields a soil of

[20] Idem, p. 4.

[21] Bassler, R. L., Geologic map of the Franklin quadrangle, Tennessee, scale 1:62,500, Tennessee Geol. Survey.

[22] Ulrich, E. O., and Bassler, R. S., Geologic map of the Woodbury quadrangle, Tennessee, scale 1:62,500, Tennessee Geol. Survey.

workable thickness. That part of the country founded upon the Bigby and Hermitage formations is probably the richest agricultural land in Tennessee aside from the Mississippi River bottom lands. On the other hand, the rocks underlying the inner basin are dense limestones, in large part thin and platy. It is these rocks that form the "glades" of central Tennessee. The formation of widest outcrop in the inner basin is the Lebanon limestone, which received from Safford the name †"Glade limestone" [23] because of the great area of cedar glades formed upon it. The glades are areas of bare rock or very thin soils mixed with small platy slabs of the underlying rocks. They have a low agricultural value, and the land is best adapted to its original growth of cedars.

It is impossible at present to draw a sharp boundary between these two areas because detailed geologic maps of the region have not been made. Although, as is frequently the case in drawing geomorphic boundaries, there is a zone of transition in which the outer basin changes to the inner basin, the most convenient and usable boundary would probably be the base of the Hermitage formation. Therefore, in the absence of complete data the boundary may be taken as very roughly a curving line running from the vicinity of Bellbuckle somewhat south of Shelbyville and Lewisburg, about 5 miles east of Columbia and southeast of Springhill. North of the line lies the inner basin; south of it, the outer basin.

COMPARISON WITH LEXINGTON PLAIN

An association of the Nashville Basin and the Lexington Plain, in Kentucky, is almost inevitable from a geologist's viewpoint. The comparable features in the two areas are so obvious that it may be advantageous to point out the features wherein these two areas differ, as well as those in which they are similar.

The two areas are very much alike in their broad geologic relationships. Structurally each represents a dome upon the Cincinnati geanticline. Each exposes a large area of Ordovician rocks within a boundary of higher strata. The topography of the two areas is in a large measure similar.

The differences between these two areas are probably as great as the resemblances but not as obvious. In the first place, the two areas are not of the same age. The Nashville Basin is younger than the Lexington Plain, inasmuch as the Lexington Plain is continuous with the Highland Rim level, beneath which the Nashville Basin is cut.[24] The Nashville Basin is at an altitude of about 600 feet above sea level, whereas the Lexington Plain has an altitude of about 1,000

[23] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey. Quotation marks, formerly used to indicate abandoned or rejected names, are now used only in the ordinary sense.

[24] Campbell, M. R., U. S. Geol. Survey Atlas, Richmond folio (no. 46), p. 1, 1898.

feet, the same as the Highland Rim in the eastern part of south-central Tennessee.

In the second place, the Nashville Basin is lower than the Lexington Plain stratigraphically as well as topographically. The Lexington Plain represents a central outcrop of Middle Ordovician strata surrounded by a broad ring of Upper Ordovician, the Lower Ordovician being present only in the Kentucky River gorge. On the other hand, the Nashville Basin is made up of a central portion underlain by Lower Ordovician rocks surrounded by a peripheral portion of Middle Ordovician, the Upper Ordovician being largely absent in Tennessee. The effect of this condition is very important geographically, for it is the Middle Ordovician rocks that give rise to the most fertile soils. Hence in Kentucky a very fertile area is surrounded by one of less agricultural value, whereas in Tennessee the very fertile area surrounds the less fertile.

A further difference is found in the valleys of the main streams in the two areas. In the Lexington Plain the entrenchment is much greater than that in the Nashville Basin, being of the order of 500 feet, as contrasted with 200 feet in the Nashville Basin.

HIGHLAND RIM REMNANTS

The remnants of the Highland Rim lying within the Nashville Basin as defined above are present throughout its extent in south-central Tennessee. Every county has representatives of this type of topography. They occur throughout the drainage basin of the Elk River, which flows along the south edge of the basin, and are most numerous and best preserved on the divide between the Elk and Duck Rivers. They are also present within the Duck River Basin in the vicinity of Columbia and on the divide between this river and the Cumberland.

These higher islands within the generally flat basin represent all topographic ages. The largest have rather flat surfaces and attain altitudes of 1,200 feet, as, for instance, the one near the corner of Bedford, Lincoln, and Moore Counties. Others represent all stages of reduction to the Nashville Basin level.

HIGHLAND RIM PLATEAU

BOUNDARIES

The Highland Rim plateau section stands about 1,000 feet above sea level through most of this area, although it descends to about 700 feet along its southwestern and western borders. Its most distinctive feature is its plateau character.

The Highland Rim is bounded toward the center of Tennessee by the escarpment descending to the Nashville Basin, a few hundred feet below. This scarp is practically collinear on a map with the contact of the Mississippian and lower formations. On the east the rim is bounded by the scarp ascending to the Cumberland Plateau, nearly 1,000 feet above the rim. This scarp approximately coincides on the map with the contact of the upper Mississippian and lower Mississippian strata—that is, with the top of the St. Louis limestone. The boundaries of the Highland Rim on the south and west are not so sharp as those in other directions, for in these directions it joins the Coastal Plain province without a topographic break. The boundary between the Highland Rim plateau and the Coastal Plain is taken arbitrarily as the Tennessee River,[25] throughout Tennessee. In south-central Tennessee, however, the Coastal Plain Cretaceous sediments extend far north and east of the Tennessee River over the depressed surface of the typical Highland Rim plateau and reach thicknesses of 150 to 200 feet.[26] In this area, therefore, the topography is greatly different from that in other portions of the rim.

STRATIGRAPHY

The strata that are of importance in determining the geomorphic character of the Highland Rim plateau are those belonging to the St. Louis limestone, Warsaw formation, Fort Payne chert, and Ridgetop shale. These form the cap of the plateau. All are more or less calcareous and siliceous formations, but they differ enough among themselves to cause considerable differences in the topographic expression. The St. Louis limestone and Warsaw formation are limestones with some chert, which weather to a very productive soil. The Fort Payne chert and Ridgetop shale are much more cherty, and the derived soil is generally unproductive. The Ridgetop shale in particular, being more argillaceous than calcareous, commonly weathers to steep slopes that make agriculture practically impossible.

In southwestern Wayne County the Tuscaloosa and Eutaw formations, of Upper Cretaceous age, overlap the Mississippian limestones.

GENERAL PHYSICAL FEATURES

The Highland Rim plateau in southern Tennessee is a peneplaned surface arched over the southern edge of the Nashville dome. On the eastern edge of the area, in the Decherd quadrangle, the general level of the Highland Rim plateau is about 1,000 feet near its contact with the Cumberland Plateau. West of this and somewhat farther north, near the corner of Lincoln, Bedford, and Moore Counties, a remnant has an altitude of more than 1,200 feet as shown by highway profiles. The surface declines westward from an axis somewhere in this vicinity, and where next seen in the Columbia and Waynesboro

[25] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 6, p. 60, 1917.

[26] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 25, 1921.

quadrangles it has descended to about 1,000 feet. This altitude is apparently continued westward to the vicinity of Hohenwald, in Lewis County, and southwestward several miles past Collinwood, in Wayne County, where it transgresses the Cretaceous deposits. West of Hohenwald the land surface gradually descends on long linear ridges between westward-flowing streams and is only about 600 feet above sea level on the east side of the Tennessee River. The general surface level descends also on both sides of an axis running southwestward through Collinwood and approximately bisecting the angle made by the Tennessee River in its change of course in northwestern Alabama and falls to altitudes of 850 and 900 feet on the western and southern edges of Wayne County and about 850 feet in southern Lawrence County. This surface is probably composite in origin, as more thoroughly discussed on pages 20–24.

The Tennessee River flows along the western border of the area at about 340 feet above sea level. The total relief of the whole area is therefore about 650 feet. The Elk River leaves the eastern Highland Rim at an altitude of 780 feet, about 200 feet lower than the plateau in this area. In this eastern part of the area the plateau is in a very youthful stage of dissection in the present cycle: the streams tributary to the Elk and Duck Rivers are sunk in bold trenches in the plateau. Away from these streams, however, the topography is practically that of the old peneplain. The streams draining southward flow in broad, shallow depressions, and the local relief is small. Sink-hole topography characterizes much of this area. In the western part of the area, on the other hand, the dissection is mature, and the local relief within a mile is 300 feet or more.

STREAMS

The Tennessee River surrounds the Highland Rim plateau in southern Tennessee and intercepts all its drainage. The Elk River and Duck River are its major tributaries in this section. The Tennessee River is here characterized by a rather straight course, although a few pronounced meanders exist, but its tributaries are marked by the same intricate meandering in the Highland Rim plateau as in the Nashville Basin.

In the eastern part of the Highland Rim the youthful streams flow in entrenched meanders, marked by slip-off slopes and complementary undercut banks. No prominent terraces exist, and the erosion process seems to have been one of continuous down-cutting by streams that are now approaching grade and developing flood plains between steep hill slopes.

In the western part of the plateau the stream valleys are marked by terraces. Especially is this true on the Duck and Buffalo Rivers. The most prominent of the terrace areas is that at Flatwoods, in

Perry County, where a long flat spur at an altitude of about 675 feet, covered with alluvial material, projects into a meander of the Buffalo River. The surface of this terrace is 130 feet above the river. Farther down the Buffalo River terrace remnants are found at Linden and at Lobelville. Both these remnants are about 90 feet above the river and are capped with alluvial materials. Whether they are parts of the Flatwoods terrace or represent younger terrace stages is problematic. Abandoned meanders surround some of the terrace remnants, notably at Lobelville, where the present divide in the old meander stands about 80 feet above the river of today.

Similar features marking periods of relative quiescence in the erosion process are found on the Duck River also. Hayes and Ulrich [27] note that the old broad valley of the Duck River descends from an altitude of 600 feet at Columbia to 550 feet at Centerville. Another terrace level appears to be present here some 100 feet higher. The meandering of the river during the period of valley widening at the lower level is recorded in an abandoned meander at Littlelot, in Hickman County, where the divide in the meander now stands at an altitude of 547 feet, or about 50 feet above the river. A similar abandoned meander is found farther downstream, at Coble, where the divide in the meander is now at an altitude of 450 feet, or 50 feet above the present river. The recency of the down-cutting below this level is attested by the fact that at the divide in this meander the land is very poorly drained; the drainage has not had time to extend itself backward to the divide.

ADJUSTMENT OF DRAINAGE TO STRUCTURE

On the Highland Rim, as in the Nashville Basin, the streams flow as a rule in synclinal troughs. This has been pointed out in regard to the Waynesboro area by Miser.[28] The same condition is found also in the adjacent counties, although the data in these areas are not complete. The sharp right-angled bend of the Buffalo River where it forsakes its almost due west course only 7 miles from the Tennessee River to flow almost due north for nearly 50 miles before finally entering the Tennessee is to be correlated in some way with the structure. A rather sharp anticline with a height of about 150 feet lies between the two rivers at the bend. Beech Creek of the Tennessee River system is now striving to capture the Buffalo River through a sag in this anticline.

GEOMORPHIC TYPES

The varying amount of dissection of the Highland Rim gives rise to two geomorphic types in the portion of the rim lying in south-

[27] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 1, 1903.

[28] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 41, 1921

central Tennessee. These two types are separated by a broad transitional zone.

The frayed outer edge of the Highland Rim is typified in Perry County, where the erosion cycle is at high maturity. Although practically no upland areas remain here, the crests of the ridges are still very nearly level. Roads follow these ridges in some places and indicate the topographic character of the region by their sinuous courses. Practically no cut or fill is necessary on these roads, but any attempt to straighten them would result in very large fills where the steep-sided hollows must be crossed. Despite the narrowness of the divide between the contending streams, it is nearly level. The optimum conditions for rapid erosion exist: every part of the region has been reached by the drainage lines, and this drainage has now its greatest possible average gradient.

The result of the mature dissection is that this region has a valley culture, in contrast to much of the remainder of the plateau. The cultivated soils are those resulting from the decomposition of the Devonian and Silurian rocks and, to a slight extent, of the Ordovician rocks, greatly modified by the debris which has come down from the cherty Ridgetop shale and Fort Payne chert of the valley walls. The intensive dissection has resulted in a great accumulation of rather angular chert fragments in wide stream beds, to such an extent that in places the surface streams disappear in summer beneath the gravelly alluvium.

This type of topography is best exemplified in Perry County but is also characteristic of Wayne County and parts of adjacent counties. The interstream remnants of the plateau become larger with increasing distance from the Tennessee River, and Lewis County and northern Lawrence County are characterized by an upland culture.

In these upland areas on the western part of the plateau the soils are those derived from the Warsaw and St. Louis limestones. Communication is easier, and two lines of railroad cross the region. These upland areas have been the last parts of the south-central Tennessee area to be put under cultivation, and even now clearing is still going on and many portions are only sparsely inhabited. As a result of this late settlement large Swiss and German elements are found in the population of this portion of the Highland Rim, in distinction to the almost purely early American settlement of the Nashville Basin or the Tennessee Valley.

The eastern part of the rim, in Franklin and Lincoln Counties, is much like the less dissected part of the western rim just described. The topography, except in the immediate vicinity of the Elk River, is gently rolling. This part of the rim lies farther from the Tennessee River and as a result is less dissected than any of the western part. Sink holes of small and large dimensions are found throughout the area, especially in Franklin County. The soils are on the whole more fertile than those on the western rim, probably as a result of the greater thickness of St. Louis limestone remaining in this area.

CUMBERLAND PLATEAU

Only a small part of the Cumberland Plateau is represented in this area. This part lies entirely in Franklin County, southeast of a line joining the northeast and southwest corners of the county.

The distinguishing characteristic of the Cumberland Plateau is implied in its name. The plateau is at an altitude of about 2,000 feet at Sewanee, near the eastern edge of Franklin County, and declines somewhat toward the south. It stands about 1,000 feet above the neighboring part of the Highland Rim. Its position is indicated on the geologic map by the outcrop of Pennsylvanian rocks.

In the neighborhood of Sewanee this plateau possesses a gently rolling surface with no greater local relief than that of the Highland Rim or the Nashville Basin. In the southern part of Franklin County, however, it is greatly frayed, the dissection is mature, and the local relief within a mile may be over 800 feet.

The stratigraphic section of the Cumberland Plateau in this area consists of a cap of Pennsylvanian shales and conglomeratic sandstones overlying limestones of Chester (late Mississippian) age. Where the Pennsylvanian cap is removed great sinks are formed in the underlying soluble limestones. Owing to the sandy and comparatively poor soils of the Cumberland Plateau, this region is sparsely inhabited. The coves heading the limestone valleys in the plateau are fertile, but communication between individual coves and between the coves and the outside is so difficult that they, too, are only sparsely settled.

GEOMORPHIC HISTORY

The present surface of south-central Tennessee is the result of a long-continued process divisible into several periods. The history of the development of this surface must be read from the surface itself. In some places and for some stages in this development the history seems clearly written; in other places and for other stages the record is only vaguely indicated.

The pioneer work on the genesis of the surface of this area, as well as a much larger contiguous area, was that of Hayes and Campbell.[29] This work pointed out the existence of two peneplains in the area here considered—one, called the "Cretaceous peneplain", represented by the hilltop surface of the Cumberland Mountains in this region, and the other, called "Tertiary", represented by the surface of the Highland Rim. Both peneplains were shown to be warped. A map

[29] Hayes, C. W., and Campbell, M. R., Geomorphology of the southern Appalachians: Nat. Geog. Mag., vol. 6, pp. 63–126, 1894.

accompanying the text showed the Cretaceous peneplain to descend from about 2,000 feet above sea level in the vicinity of Sewanee, Franklin County, to about 1,800 feet in the southern part of Franklin County and to about 1,000 feet in the vicinity of Hohenwald, Lewis County, and the southeast corner of the Waynesboro quadrangle.[30] These peneplains were correlated with the Upper Cretaceous and Tertiary sediments, respectively, of the Coastal Plain. Hayes [31] later dropped the nomenclature implying the age of formation of these peneplains and described essentially his Cretaceous peneplain as the "Cumberland peneplain" and his Tertiary peneplain as the "Highland Rim peneplain." A third peneplain, the Coosa, was also described, with which the Nashville Basin was correlated.

The slopes as given by Hayes and Campbell for the peneplains in the central part of the south-central Tennessee area were corrected after a study of the Columbia quadrangle.[32] The 1,000-foot level in this quadrangle was recognized to be continuous with the eastern Highland Rim, and hence part of the Highland Rim peneplain rather than a part of the so-called "Cretaceous peneplain", as the earlier work implied.

Galloway,[33] without adducing evidence, dated the completion of the Highland Rim peneplain at the end of Eocene time, and the Nashville Basin peneplain as middle Pleistocene.

Shaw,[34] in a study of the geomorphology of an area southwest of the area here considered, developed hypotheses profoundly modifying the conclusions drawn from the other work applying to south-central Tennessee. From observations extending from central Mississippi into Wayne County, Tenn., he was led to believe that the Highland Rim peneplain remains much higher than indicated by the work of Hayes and Campbell and, sloping seaward at a very flat angle, probably passes under the Pliocene and perhaps the Miocene deposits of the Gulf coast,[35] so that it is probably not older than the beginning of Pliocene time, although perhaps as old as early Miocene.[36] A second point of importance is the fact that the upland levels in the Mississippi-Tennessee region cannot be correlated with a single erosion surface or peneplain, but that along "a line 25 miles northeast of Iuka, Miss., or, in other words, a line traversing the southwestern portion of Wayne County", the Highland Rim peneplain intersects

[30] Hayes, C. W., and Campbell, M. R., op. cit., pl. 6.

[31] Hayes, C. W., Physiography of the Chattanooga district: U. S. Geol. Survey 19th Ann. Rept., pt. 2, pp. 1–58, 1899.

[32] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), 1903.

[33] Galloway, J. J., Geology and natural resources of Rutherford County, Tenn.: Tennessee Geol. Survey Bull. 22, pp. 17–24, 1919.

[34] Shaw, E. W., The Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108, pp. 125–163, 1918.

[35] Idem, p. 153.

[36] Idem, p. 162.

a more steeply sloping and older planed surface, which dips under Cretaceous deposits.[37]

This "pre-Cretaceous peneplain is apparently represented by hilltops in and near the northeast corner of Mississippi." There is also indication that a peneplain emerges from between the Cretaceous and Tertiary systems in Mississippi and passes upward toward the northeast but slopes less steeply than the pre-Cretaceous peneplain, with the result that the two intersect. Plains younger and lower than the Highland Rim or Miocene (?) peneplain are noted.

This work of Shaw furnishes the keynote to the erosional history of the extreme western and southwestern portion of the area considered in this report. The Highland Rim plateau, as defined, does not coincide in its southwestern part with the Highland Rim peneplain. It is evident that the topography of Perry County and much of Wayne County preserves in its upland levels essentially the exhumed pre-Tuscaloosa (or pre-Upper Cretaceous) peneplain found by Shaw. This interpretation of the Highland Rim in this area has previously been made by Drake [38] and Wade.[39]

It is a priori evident that such peneplains as exist in the Appalachian area must at least approach coincidence in the western part of south-central Tennessee, and their planes must intersect in or near this area, for in the inland, highland area the older peneplains must be above the younger peneplains, while at their seaward edges the sediments in the Mississippi embayment derived from the erosion of the older plains must lie beneath the sediments from the younger plains. The area here considered is therefore a critical area where the different baselevel planes must be close together and any one may be above or below any other.

The fact that the high ridges of Perry County and much of Wayne County represent essentially the pre-Tuscaloosa surface is manifest from the fact that gravel of Tuscaloosa age thinly caps them in places. Thus, in and near Hohenwald there is a Tuscaloosa outlier 20 or 30 feet thick. Westward from Hohenwald gravel forms thin cappings on the high ridges east of the Tennessee River.[40] If a general profile is drawn along a line from Hohenwald westward across the Tennessee River, it will be found that a gentle arch with slight upward convexity connecting the base of the Cretaceous deposits (Eutaw) west of the Tennessee River with the base of the Cretaceous (Tuscaloosa) at Hohenwald will touch the intervening high points of the surface. The Buffalo and Tennessee Rivers have apparently side-slipped in

[37] Shaw, E. W., op. cit., p. 162.

[38] Drake, N. F., Economic geology of the Waynesboro quadrangle: Resources of Tennessee, vol. 4, no. 3, p. 99, Tennessee Geol. Survey, 1914.

[39] Wade, Bruce, The gravels of West Tennessee Valley: Resources of Tennessee, vol. 7, no. 2, p. 57, Tennessee Geol. Survey, 1917.

[40] Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 173, Tennessee Geol. Survey, 1914.

their erosion down the slope of this surface, which is also the direction of dip of the strata.

The same situation holds for much of Wayne County, as can be seen from the numerous small outliers of Tuscaloosa scattered over the Waynesboro quadrangle. Miser [41] states:

> The Tuscaloosa gravel and Eutaw sand, of Upper Cretaceous age, cap the ridges in the southwest part of the [Waynesboro] quadrangle and the Tuscaloosa is present on most of the ridges in the other parts of the quadrangle. It is therefore reasonably evident that the Tuscaloosa and perhaps the Eutaw at one time extended as continuous beds over the quadrangle.

It follows that many of the ridges here represent essentially this exhumed pre-Tuscaloosa surface. This seems especially evident in the northern part of the Waynesboro quadrangle. The highland areas slope away rather abruptly from the 1,000-foot level in the southeastern part of the quadrangle and continue an even slope down to an altitude of about 550 feet in the Tennessee River valley 15 miles south of the quadrangle. The origin of this slope is somewhat obscure. The portion of it in the Waynesboro quadrangle may represent essentially the pre-Tuscaloosa surface. It corresponds in a rough way with the base of the Tuscaloosa a few miles farther west. However, the entire slope southward in Alabama does not represent the pre-Tuscaloosa surface, for, as cited above, the upland slope descends gradually to the Tennessee River, whereas the base of the Tuscaloosa is much higher in the hills south of the Tennessee River. It does not represent either the so-called "Cretaceous peneplain" or the Highland Rim peneplain, for the upland levels south of the Tennessee River rise abruptly to 900 and 1,000 feet above sea level in Little Mountain, which was first considered a part of the Cumberland Plateau by Johnston [42] and later included in the Highland Rim.[43] The higher peneplains therefore extend over the Tennessee Valley. The slope is apparently analogous to the slopes of the spurs east of the Tennessee and Buffalo Rivers in Perry County. It appears to represent lateral planation of the Tennessee River during its down-cutting while it was side-slipping to the south. The line of intersection between the old pre-Tuscaloosa surface and the younger slope of the Tennessee River cannot be located at present, owing to the lack of data concerning the topography and concerning any surficial deposits that may be present in the valley.

The history of the surface of south-central Tennessee as so far considered begins, then, in pre-Cretaceous time, probably with the production of a peneplain as represented in Perry County and much

[41] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 62, pl. 1, 1921.

[42] Johnston, W. D., Jr., Physical divisions of northern Alabama: Alabama Geol. Survey Bull. 38, p. 10, 1930.

[43] Johnston, W. D., Jr., A revision of physical divisions of northern Alabama: Washington Acad. Sci. Jour., vol. 22, no. 8, p. 221, 1932.

of Wayne County, and possibly in parts of adjacent counties. As this surface approached baselevel, a thick residual mantle of cherty clay probably accumulated upon it. The western and southwestern part of the area here considered next sank beneath sea level in early Upper Cretaceous (Tuscaloosa) time, and the sea encroached upon it. It is probable that the depression of the west end of the area was accompanied by an uplift of the eastern part and the Appalachian region. As the sea encroached over the western part of the area it may have planed off irregularities left on the surface, but the action seems to have been of small amount, and the residual mantle seems to be undisturbed except in its upper portion.

While the Tuscaloosa gravels and Eutaw sands were being deposited and, according to Hayes and Campbell, during the remainder of Cretaceous time the land to the east was being worn down. Near the end of the Cretaceous period, according to the same authorities, the area had been planed down by erosion to a gently rolling surface such as that seen on the Cumberland Plateau near Sewanee today, though much nearer sea level. This surface extended westward beyond the limits of the area considered in this report. Apparently no part of this surface is represented in this area today except that in eastern and southern Franklin County. The remainder has been eroded.

The area was then warped upward. On the east side of the area the uplift amounted to about 1,000 feet; on the west side it was much less, but the amount cannot be determined.

During and after this uplift the streams were again engaged in cutting down the land. The erosion continued until almost the whole area was cut down nearly to sea level, and the second or Highland Rim peneplain (the so-called "Tertiary peneplain") was developed. This process continued until the end of Vicksburg (Oligocene) time, according to Hayes and Campbell,[44] until the beginning of Miocene or more probably Pliocene time, according to Shaw;[45] or until the end of the Eocene, according to Galloway.[46]

At the end of this period of erosion the divides between the streams were very low, and the surface exhibited little relief. This plain of slight relief extended over the entire area of this report with the exception of the part of Franklin County containing the Cumberland Mountains. It was cut about 1,000 feet below the older, Cumberland peneplain in the eastern part of the area and a much less distance below it in the western part of the area.

Later the area was again uplifted, and the streams were rejuvenated. A third peneplain was produced and is represented in Tennessee by

[44] Hayes, C. W., and Campbell, M. R., Geomorphology of the southern Appalachians: Nat. Geog. Mag., vol. 6, p. 125, 1894.

[45] Shaw, E. W., The Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108, p. 162, 1918.

[46] Galloway, J. J., Geology and natural resources of Rutherford County: Tennessee Geol. Survey Bull. 22, p. 17, 1919.

the Nashville Basin. This erosion surface has been correlated with one in Georgia by Hayes and Campbell and called the "Coosa peneplain."

It is necessary to consider the nature of the rocks and the way in which the strata were bowed at the time in order to explain the origin of the Nashville Basin. For here we have a peneplain almost entirely surrounded by higher land, which has been so little affected by the erosion that brought the basin down to a plainlike surface that broad portions of an older peneplain are still preserved. All other conditions being the same during a process of erosion, the seaward portions of the land must be worn away first, for here the streams have been at work longer than they have in the inland portion. As the central area rather than the seaward portion of the surface was first reduced here, it is evident that other conditions have modified the process of erosion.

The strata of central Tennessee have been bowed up over the central basin throughout most of the decipherable geologic history of the State. They seem to dip away in all directions from the vicinity of Murfreesboro, Rutherford County, and throughout geologic time since the origin of the rocks now exposed the highest structural point has apparently been somewhere in this vicinity. As a result, when the streams produced the Cumberland peneplain and again when the Highland Rim peneplain was established they cut down in central Tennessee into rocks that lay several hundred feet below the surface rocks in the circumferential area. It is evident, then, that when the Highland Rim peneplain was uplifted and streams began anew the process of dissection of the land, they had different rocks to erode in the central area from those in the area around it.

The cap rocks over the whole area were the siliceous limestones and shales of the Mississippian epoch. Over the central area, however, these rocks were thin. Consequently in a comparatively short time the streams in the central area cut through them and began to wear away the underlying calcareous shales and limestones, which evidently were much easier to erode. The fine debris furnished by the weathering of the shaly rocks could be more easily handled by the streams than the large amount of chert resulting from the weathering of the cherty Mississippian rocks. Erosion in the central area proceeded much more rapidly than in the surrounding area, with the result that the central area was reduced to a fairly level surface, while the streams to which the erosion was due were not able to widen their valleys very greatly in the thicker Mississippian rocks downstream.

The Nashville Basin level or perhaps group of levels is probably continued downstream in the terrace remnants preserved along the stream valleys. Detailed data that would make it possible to correlate some of the terraces observed with topographic features in the basin are not available. However, Hayes and Ulrich[47] have traced a terrace representing a former broad valley of the Duck River at Columbia into terrace remnants at Centerville. These remnants are 600 feet above sea level at Columbia and about 550 feet at Centerville. Some distance above Centerville, at Littlelot, an abandoned meander of the Duck River has an altitude of 547 feet and lies about 50 feet above the river. A similar abandoned meander is found about 20 miles below Centerville at an altitude of about 450 feet, also about 50 feet above the river. These remnants probably indicate the slope of the 600-foot terrace at Columbia. Above this terrace in the vicinity of Centerville there appears to be at least one other terrace, about 100 feet higher. Similar terrace remnants and high-level abandoned meanders also exist on the Buffalo River. Some of these are probably to be correlated with the Nashville Basin level.

The time at which the basin level was perfected is not known. Galloway [48] states, without giving evidence, that it was middle Pleistocene. Miser [49] regards the terrace deposits on the Buffalo River as Quaternary but gives no evidence for this conclusion. Wade [50] accepts this interpretation for Perry County but notes that no fossils have been found in the terrace deposits and that there is no direct evidence for the view.

Apparently there is no reason why this conclusion may not be tentatively accepted. However, before the geologic age of these features can be considered established, their relations to the broad terraces on the Ohio and Mississippi Rivers, which were largely cut in Pliocene time,[51] must be determined.

STRATIGRAPHIC SYNOPSIS AND COLUMNAR SECTION

The rocks of south-central Tennessee are all of sedimentary origin and range in age from Lower Ordovician to Recent. Those younger than Paleozoic are in general unconsolidated and consist of gravel, sand, and clay. Such deposits cap some of the ridge tops and highlands in the western part of the area and are also represented in the alluvium of the streams throughout the area. The consolidated rocks, which are all of Paleozoic age, consist almost entirely of lime-

[47] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 1, 1903.

[48] Galloway, J. J., Geology and natural resources of Rutherford County: Tennessee Geol. Survey Bull. 22, p. 17, 1919.

[49] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 25, 1921.

[50] Wade, Bruce, Geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 174, Tennessee Geol. Survey, 1914.

[51] Shaw, E. W., Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108, pp. 126, 139, 1917.

stone and shale. The strata are on the whole very fossiliferous, and the fossils represent the ultimate and in places the only means of differentiating the formations. Lithologic differences are generally not conspicuous, and many of them are not consistent over a large area. A thick mantle of residual chert makes the determination of contacts in the western part of the area difficult.

The strata are not consistent in their relations with one another, partly because of nondeposition of some of the beds and partly because of interformational erosion, which has removed earlier beds in many places. The Nashville dome has been an island throughout most of its sedimentary history, with the result that many of the formations change facies within rather short distances, that the sequences are somewhat different on opposite sides of the dome, and that many of the formations, from Ordovician to Mississippian, were deposited only in elongated embayments. In the Nashville Basin and Highland Rim sections 22 unconformities have been recognized. In one place as many as 21 recognized formations are missing, partly through nondeposition and partly through interformational erosion.

The rocks exposed in the area are described in detail on pages 52–81, and a columnar section is presented below. In this section an attempt is made to express the variation of the sequence in different localities in the area by indicating the magnitude of the many unconformities in it in terms of the formations locally absent. Where an unconformity is noted without mention of its stratigraphic extent (as between the Pennsylvanian and Mississippian series), the interpretation is that the two contiguous formations are in unconformable contact throughout the area in which they occur. Where the extent of the unconformity is noted the interpretation is that all formations below the unconformity and above the named formation are absent in places. Thus the notation "Unconformity extending to Wayne formation" at the base of the Pegram limestone (Devonian) indicates that the Pegram limestone rests on the Wayne formation wherever the Pegram is known; and the notation "Unconformity extending locally to Decatur limestone" at the base of the Harriman chert indicates that the Harriman may be expected to rest on any of the formations below it down to the Decatur limestone except where the intervening formations may have been removed in intervening periods of erosion or where they may not have been deposited.

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Stratigraphic section for south-central Tennessee

System	Series	Formation	Description	Thickness (feet)	Locality	Water-bearing properties
Quaternary and Tertiary (?).		Alluvium.	Unconsolidated gravel, sand, and silt.	(?)	On flood plains and terraces and in abandoned meanders throughout area.	Furnishes water for domestic purposes and stock. Where present in terraces may be well drained and contain little water.
		—Unconformity extending throughout exposed section—				
Cretaceous.	Upper Cretaceous.	Eutaw formation.	Unconsolidated red and gray sand with thin clay layers.	0–50	Southwestern Wayne County.	Generally barren, water being drained into the underlying Tuscaloosa formation.
		Tuscaloosa formation.	Unconsolidated cherty gravel with subordinate sand and clay.	0–150	Principally in southwestern Wayne County but also as outliers in adjacent counties.	Yields water of low mineral content to many springs in southwestern Wayne County. Wells obtain water principally from its base but also from perched water bodies above clayey layers higher in the formation.
		—Unconformity extending to St. Louis limestone—				
Carboniferous.	Pennsylvanian.	Whitwell shale.	Clayey and sandy shale with some coal.	0–80	Eastern Franklin County.	Not known.
		Sewanee conglomerate.	Soft massive cross-bedded sandstone with scattered vein-quartz pebbles.	0–70	Eastern Franklin County.	Yields water to small springs near Sewanee.
		Gizzard formation.	Shale and sandstone.	0–100	Eastern Franklin County.	The Warren Point sandstone member near the middle of the formation yields water, generally high in iron, to wells near Sewanee.
		—Unconformity—				
	Mississippian.	Pennington shale.	Red and varicolored shale with thin limestone beds.	0–100±	Eastern Franklin County.	Not known.
		Bangor limestone (restricted).	Blue coarsely crystalline or oolitic, highly fossiliferous medium to thick-bedded limestone.	0–375	Eastern Franklin County.	Yields water to small springs.
		Hartselle sandstone (restricted).	Calcareous sandstone.	0–10±	Eastern Franklin County.	Not known.
		Golconda (?) shale.	Marly shale and limestone.	0–40	Eastern Franklin County.	
		Gasper formation.	Thick-bedded light-gray oolitic limestone.	0–125±	Eastern Franklin County.	
		Ste. Genevieve limestone.	Lithologically similar to the Gasper.	0–100±	Eastern Franklin County.	

Carboniferous.	Mississippian.	St. Louis limestone.	Fine-grained to compact, generally thick-bedded gray limestone with a few crinoid plates, fenestellid Bryozoa, and colonial corals. Weathers to cherty clay.	80–150	Throughout Highland Rim of this area but generally not seen in unweathered state in western part of the area.	Yield abundant water to tubular springs and wells in eastern part of area. The clayey residual mantle furnishes meager supplies of water to dug wells in western and southern portions of Highland Rim.
		-Unconformity in eastern part of area				
		Warsaw formation.	Grayish thick-bedded, in places cross-bedded limestone resembling St. Louis limestone. Somewhat sandy in Franklin County.	75±	Throughout Highland Rim.	
		-Local unconformity extending to Bigby limestone				
		Fort Payne chert.	Siliceous limestone and shale, weathering to a cherty sandy soil.	0–100±	Throughout Highland Rim.	
		-Local (?) nnconformity				
		Ridgetop shale (including ? at top a representative of New Providence formation).	Gray and green siliceous and calcareous shale, with minor amounts of coarsely crystalline crinoidal limestone that may represent overlying New Providence formation. Includes Maury glauconitic member at its base.	0–120	Wayne, Perry, and Hickman Counties and in embayments on west side of Nashville Basin.	Calcareous portions yield water to many springs.
		-Unconformity				
Carboniferous or Devonian.	Mississippian or Upper Devonian	Chattanooga shale.	Fissile black bituminous shale with the Hardin sandstone member, commonly phosphatic, at its base.	0–35	Throughout area.	Joint cracks yield hydrogen sulphide waters to springs around its outcrop. Serves as basal impermeable member to support perched water table in many areas.
		-Unconformity extending locally to Bigby limestone				
Devonian.	Middle Devonian.	Pegram limestone.	Gray coarsely crystalline crinoidal limestone.	0–6	Known only in this area near mouth of Fortyeight Creek, in Wayne County.	Not known.
		-Unconformity extending to Wayne formation				
		Camden chert.	White novaculite, weathering buff.		Probably not present in this area but is known to occur just west of the Tennessee River.	
		-Unconformity extending locally to Decatur limestone				
	Lower Devonian.	Harriman chert.	White novaculite, weathering buff.	0–60	Western Perry County.	Highly fractured condition probably renders this formation very permeable to water.
		-Unconformity extending locally to Decatur limestone				
		Quall limestone.	Fine-grained siliceous limestone.	0–3	Only known exposure is at Town Spring, at Linden, Perry County.	Not known.
		-Unconformity				

Stratigraphic section for south-central Tennessee—Continued

System	Series	Formation	Description	Thickness (feet)	Locality	Water-bearing properties
Devonian.	Lower Devonian.	Decaturville chert.	Gray to yellowish chert.		Not known in this area; present west of the Tennessee River.	
		Unconformity extending locally to Olive Hill formation				
		Birdsong shale.	Argillaceous limestone and calcareous shale.	0–22	Northern Perry County.	Gives rise to large tubular springs.
		Unconformity extending locally to Decatur limestone				
		Olive Hill formation.	Massive, coarsely crystalline gray siliceous limestone (Ross limestone member).	0–55	Known in this area only near Clifton, in Wayne County, where the Ross limestone member is exposed.	Not known.
		Unconformity				
Silurian.		Decatur limestone.	Massive light-gray coarse to fine-grained limestone.	0–60	Western parts of Wayne and Perry Counties.	Give rise to tubular springs and will doubtless yield water to wells.
		Unconformity				
		Brownsport formation.	Varicolored shale and gray shaly limestone (Lobelville shaly limestone member); massive, coarsely crystalline gray limestone, in places cherty (Bob crystalline limestone member); and shaly fossiliferous limestone and green and purple shale (Beech River shaly limestone member).	0–100	Wayne, Perry, and Hickman Counties, successively lower members being cut out by truncation eastward.	
		Wayne formation.	Red to gray earthy limestone and shale (Dixon earthy limestone member); argillaceous or crystalline, pink to blue-gray limestone (Lego limestone member); gray fossiliferous clay (Waldron clay member); crystalline pink to gray limestone (Laurel limestone member); thin-bedded earthy limestone (Osgood earthy limestone member).	0–120	Western and southern parts of area.	
		Unconformity extending locally to Catheys limestone				
		Brassfield limestone.	Fine- to coarse-grained light-gray, locally glauconitic limestone.	0–30	Western and southern parts of area.	
		Unconformity extending locally to Catheys limestone				
Ordovician.	Upper Ordovician.	Fernvale formation.	Coarsely granular limestone and chocolate-brown and green shale.	0–40	In embayments throughout area.	
		Unconformity extending locally to Hermitage formation				

Ordovician.	Upper Ordovician.		Arnheim limestone.	Cherty gray fossiliferous limestone.	0-3	Known in this area only at Clifton in Wayne County.	Not known.
			-Unconformity extending locally to Hermitage formation-				
			Leipers limestone.	Fossiliferous calcareous shale and shaly rubbly limestone with some granular laminated phosphatic limestone.	0-100	Present generally throughout area.	Yield water to tubular springs Wells furnish household supplies.
	Middle Ordovician.		-Unconformity-				
			Catheys limestone.	Fossiliferous knotty earthy limestone and shale.	0-100	Present generally throughout area.	
			-Unconformity extending to Bigby limestone on western side of Nashville Basin-				
			Cannon limestone.	Massive to thin-bedded crystalline or argillaceous limestone, with a little shale and dense semilithographic ("dove") limestone beds, especially near base.	0-300	East side of Nashville Basin.	
			-Unconformity extending to Hermitage formation on eastern side of Nashville Basin-				
			Bigby limestone.	Gray phosphatic semioolitic granular and crystalline laminated or cross-bedded limestone.	0-100	West side of Nashville Basin.	
			-Unconformity-				
			Hermitage formation.	Thin-bedded, somewhat phosphatic shaly limestone, with intercalated shale and sandy shale. Generally contains *Dalmonella fertilis* in abundance.	0-100	Throughout area.	Calcareous portions furnish water to tubular springs; yields water in household quantities to wells.
			-Unconformity-				
			Lowville limestone.	Thin-bedded white to gray limestone underlain by thick-bedded white magnesian limestone (Carters limestone member).	0-100	Upper limestone present generally throughout Nashville Basin; Carters limestone restricted to west side.	Furnishes water to tubular springs and wells.
	Lower Ordovician.		-Unconformity-				
		Stones River group.	Lebanon limestone.	Thin-bedded compact dense blue to dove-colored limestone with intercalated shale laminae. Weathers to bare rock glades.	0-120	Maury, Bedford, and Marshall Counties.	Yield water to wells and small springs.
			Ridley limestone.	Massive dense dove-colored limestone, weathering to red soil.	80-125	Northern Marshall and Bedford Counties.	
			Pierce limestone.	Thin-bedded argillaceous fine-grained to coarsely crystalline limestone.	25	Not exposed in this area.	Yield water to wells.
			Murfreesboro limestone.	Generally massive dove-colored limestone.	70±	Not exposed in this area.	

GROUND WATER

SOURCE

All the potable ground water of south-central Tennessee probably has its origin in rain and snow that fall upon the surface of the ground and percolate down to the ground-water level. This source is evident in an area such as this, where many of the water supplies are drawn from springs: the discharge of most of the springs increases after a long rainy season and decreases after a long drought. This response of the discharge of a typical spring to the precipitation is shown by the behavior of Huntsville Spring (p. 8 and pl. 5).

The highly mineralized water found at many places in the area, especially in the Nashville Basin, may have had in part another origin, although some of it without doubt, perhaps a considerable part of it, is water that differs from the normal water only in having passed, perhaps more slowly, through rocks capable of yielding to it greater quantities of various soluble salts. An inspection of the analyses from the wells and springs numbered 12, 17a, 18, and 19, in Bedford County (p. 88), 60, in Franklin County (p. 96), 139, 150, and 167, Hickman County (p. 114), 239, in Lewis County (p. 128), 279, in Lincoln County (p. 134), 374 and 383, in Maury County (p. 153), and 427, in Perry County (p. 164), will show that this water ranges in character between two types—calcium-sulphate water, represented by the water from Primm Springs (167), Hickman County, and that from well 374, Maury County, and sodium-chloride water, represented by the water from well 18, near Haley, Bedford County. The water from the other wells is intermediate in character between these two types. All this water except that from Primm Springs comes from shallow wells, and the rocks that yielded the samples range in age from Ordovician to Mississippian.

The origin of the Primm Springs water indicates the possible origin of the other calcium sulphate water of the area. This water is discharged from two weak springs close together in joint cracks in the Chattanooga shale. This formation contains considerable iron sulphide, which probably oxidizes and hydrolyzes to sulphuric acid and iron hydroxide in the presence of water carrying oxygen in solution. The sulphuric acid probably then reacts with the adjacent limestone to form calcium sulphate. This explanation seems obvious for these particular springs and similar "sulphur" and chalybeate springs in the Chattanooga shale. The source of the sulphate in the remainder of the water highly charged with sulphate cannot be pointed out, although the common occurrence of hydrogen sulphide in the water of the region shows the presence of sulphur-bearing compounds.

The sodium chloride water and, in part, the calcium sulphate water may have obtained their mineral constituents by passage through lenses containing gypsum or salt in the limestone, or they may be fossil water. The facts that water of this type is distinctly different from the normal ground water in the area and that there is no clear gradation between the normal water and the highly mineralized water seem to indicate that there is little or no physical connection between the two types. Some of this water may have been trapped in the rocks in past geologic time. It is probably not truly connate water, or water in which the sediments were laid down, for the evidence in the area seems to show that most of the original porosity of the limestone containing this water has been lost. More probably the limestone was rendered porous and cavernous during some Paleozoic epoch of erosion, and the contained water was trapped in the pores by the deposition of the overlying sediments after the land again sank below sea level. Evidence of such Paleozoic interformational solution is found in sink holes which have been filled by the Chattanooga shale [52] and in the many other unconformities in the area. Although all the wells producing the samples of this water that have been analyzed are shallow, most of them are slightly deeper than the average in their respective vicinities. It may therefore be that this water is fossil water trapped in openings which the underground erosion of the present cycle has not yet been able to reach and flush effectively. It should be noted, however, that this water in general is not merely diluted sea water or water that could be produced by the simple evaporation of sea water.

TYPES OF OPENINGS IN WHICH WATER IS FOUND

The openings in which ground water is found in south-central Tennessee may be classified as to origin into primary and secondary types, or those formed at the time the containing rock itself was formed and those which had a later origin. The primary openings in this area are represented by those in the Cretaceous and later formations. These openings are simply the interstices between the individual grains of gravel or sand and have, of course, existed there since the gravel and sand were laid down. Openings of primary origin are practically nonexistent in the Paleozoic rocks of this area. The bedding planes that slowly seep water—as, for instance, on the face of a quarry—are, to be sure, primary openings, but the relative amount of water passing through such openings is negligible in comparison with the amount passing through openings of other types in the Paleozoic formations.

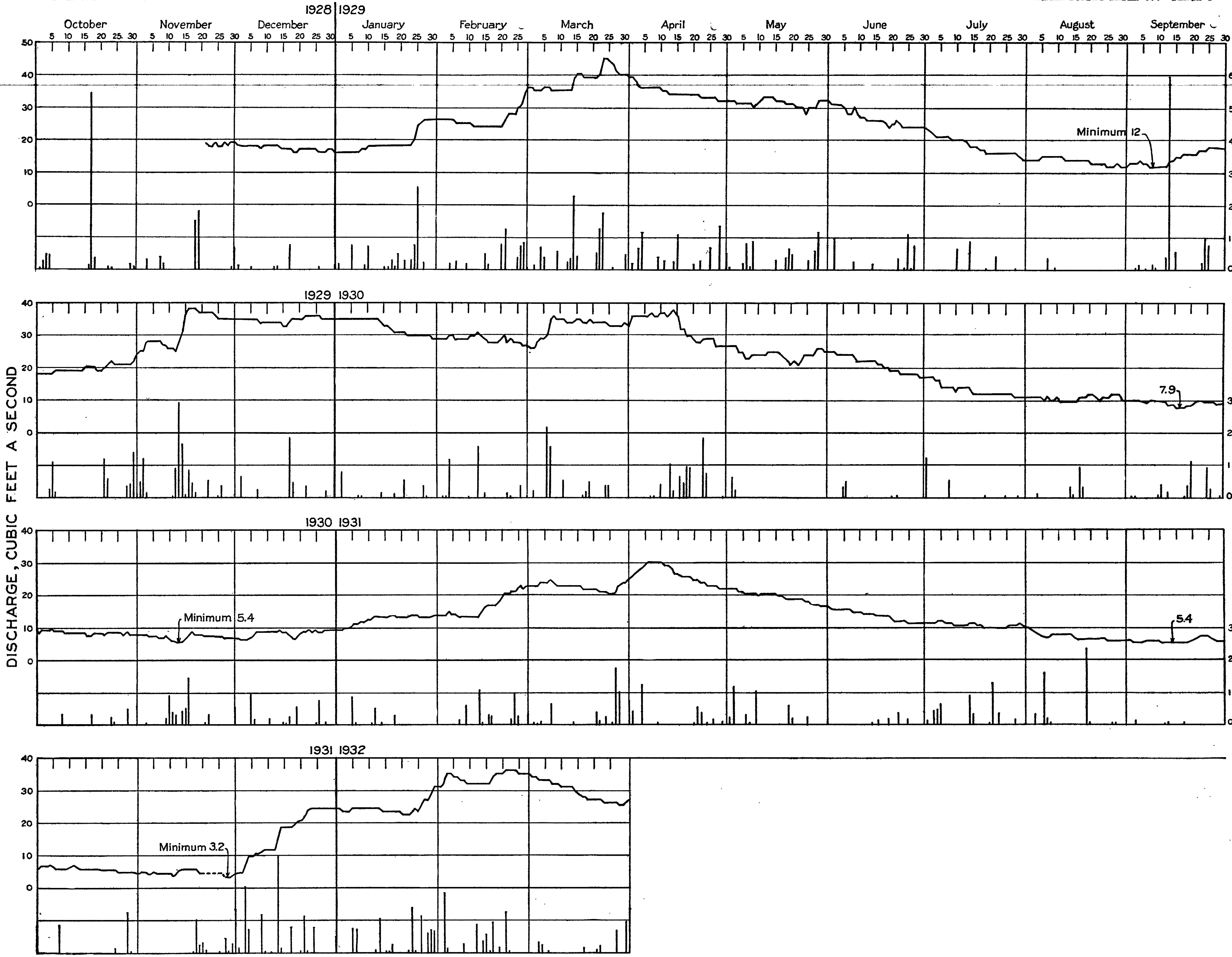
The secondary openings, comprising practically all those in the Paleozoic rocks, may in turn be classified as structural openings and solution openings. The types of structural openings important as containers of ground water in south-central Tennessee are the fractures resulting from the stresses set up in the rock during its deformation.

[52] Lusk, R. G., A pre-Chattanooga sink hole: Science, vol. 65, pp. 579-580, 1927.

The greatest of such fractures are the faults in which one portion of the rock is displaced vertically or horizontally with respect to neighboring portions. In many regions the openings along fault planes have an important bearing on the movement of ground water, but in south-central Tennessee their influence seems to be practically negligible. Of much greater effect are the joint cracks that divide an individual bed of rock into small or large blocks. As water producers, joint cracks are especially effective in south-central Tennessee in the Chattanooga shale. Many of the so-called "medicinal springs" scattered throughout the area along the outcrop of this formation derive their water from joint cracks in it. Joint cracks are probably also of special importance as water-bearers in the Harriman chert of Perry County. This dense and otherwise impervious formation is so intensely jointed that a tap of the hammer upon an outcrop may break the rock into innumerable very small fragments. No wells or springs are known to derive water from this chert within the area covered by this report—chiefly, probably, because of its small area of outcrop and the fact that it lies upon generally uninhabited and agriculturally poor hill slopes, but its intensely fractured condition must greatly facilitate the movement of water through it to the underlying formations.

Solution openings, which are of greatest importance in connection with ground water in the Paleozoic rocks of south-central Tennessee, are those which have been formed by the ground water itself by solution of the walls of the passageways through which it moves. Solution openings may be of any size from hardly visible pores to caverns many feet or many scores of feet in height or diameter. The most outstanding example of a rock with solution openings of very small size is the tripolite, locally called "chalk", at certain localities in Wayne County near the contact of the Fort Payne chert and the Warsaw (?) limestone. This material, which probably was originally a very fine grained calcareous chert or siliceous limestone, has suffered progressive leaching of the calcareous constituent until a fairly uniformly porous siliceous rock is left. In certain localities of the Nashville Basin the Hermitage formation, which was originally at these localities a calcareous sandstone, has also suffered progressive and uniform leaching of the calcareous cement until a porous sandstone is left, at least at the outcrop. Small openings such as these will not deliver water rapidly to a well, and hence a well that taps them may be weak, but because they occur uniformly throughout the rock any well reaching their horizon is almost certain to find water.

A second kind of opening which occurs uniformly throughout the rock is found in the basal part of the Fort Payne chert immediately above the Chattanooga shale in certain localities. Openings of this type can best be seen in the road cut on the Shelbyville-Fayetteville highway where it crosses the remnant of the Highland Rim near the



DISCHARGE OF HUNTSVILLE SPRING, ALA., AND PRECIPITATON AT MADISON, ABOUT 9 MILES WEST.

corner of Moore, Bedford, and Lincoln Counties. The basal Fort Payne at this locality is rather uniformly permeated by pores a quarter or half an inch in diameter. The openings are actually intertwining tubes, so that a hand specimen of the rock looks rather like a mass of loosely intertwined large worms, and a cast of the pores themselves would have about the same appearance. This rock is the main water-bearing stratum of this remnant, and nearly all the wells upon it derive their water from it. Material of practically the same kind was taken from a well at the Waynesboro Hotel, in Wayne County, and came from a horizon close to the base of the Fort Payne chert.

Most of the water derived from the Paleozoic rocks of this area, however, is drawn from the much larger and more irregularly spaced solution openings. Many of these openings are joint cracks or bedding planes enlarged by solution, but in some of them all traces of the parent opening have been lost. The diameter of openings of this tubular type ranges from a fraction of an inch to several feet. The cross section of such an opening may be of almost any shape.

These tubular openings, especially those of large size, are likely to make very intricate patterns in three dimensions in the rock. They may exemplify almost any type of hydraulic conduit. They may be interconnected among themselves and may even divide and form distributaries. In some places the passageways may be of such shape and have such relations to one another that freakish hydrologic phenomena may result. The reported behavior of Bigby Spring (392), in Maury County, yields such an example and is more fully discussed on page 40.

The irregular spacing of these tubular openings gives rise to many difficulties in obtaining ground-water supplies in the limestone of the Nashville Basin. Where the tubular passageways are distantly spaced it becomes more or less a matter of chance whether the drill will encounter one. For instance, near Fall Creek, in Bedford County, 6 dry holes were drilled within a radius of about 200 feet, and only a seventh well yielded water. Similar examples could be found in the other counties of the Nashville Basin. However, in most areas the tubular passageways are spaced closely enough for most wells to obtain water at some shallow depth.

Inasmuch as solution openings are formed by moving water, it may be expected that they will be more numerous in portions of rocks in which the ground-water circulation is vigorous—that is, above drainage level. The most common exceptions to this generalization occur where the ground-water level has risen either because of depression of the area or because of the emplacement upon it of additional sediments, as in glaciated regions.[53] In south-central Tennessee neither

[53] Meinzer, O. E., The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, p. 132, 1923.

of these has occurred in recent geologic time, and the solution channels seem to be generally confined to shallow depths—that is, to a zone which does not extend more than, say, 100 feet below the general drainage level, although there are some exceptions.

The outstanding examples of failure to obtain potable water at depth are given by the attempts to obtain municipal supplies for the cities of Pulaski and Lewisburg. Well 93, at Pulaski, reached a reported depth of 1,700 feet and is said to have obtained no water except a seep near the surface. Well 338, near Lewisburg, reached a depth of 1,860 (?) feet with similar negative results. Among the other wells that are reported to have been dry below shallow depths are wells 11 (1,200 feet), 49 (850 feet), 55 (950 feet), and 57 (1,907 feet). However, a few exceptional wells in the region have apparently found solution openings filled with water at depth. These openings were probably produced by ground-water circulation in past geologic ages. Much of the water obtained at depth is salty and unpotable and therefore indicates that these deeper openings are at least not freely connected with the more or less vigorous ground-water circulation at shallow depths. Among such salty deeper wells are wells 13, 47, 62, 102, 283, 335, and 336. A few deep wells have obtained potable water, among them well 192, near Lawrenceburg, which is reported to have yielded potable sulphur water from a depth of 2,105 feet; well 146, near Centerville, which is reported to have yielded water of the same type from a depth of 1,300 feet; and wells 137, near Lyle, and 360, near Mount Pleasant, which yielded apparently potable water from depths of about 700 feet. In part the deeper waters may come from sandstone beds rather than solution openings in limestone, the water-bearing bed in the Centerville well (146) being, for instance, apparently at about the horizon of the St. Peter sandstone. Well 481, near Waynesboro, logged "water sands" at depths of 1,390 and 1,738 feet.

Many dug wells in the cherty clay mantle derived by weathering from the Mississippian rocks of the western Highland Rim obtain water from sand stringers in the clay, which are apparently fossil tubular openings. These apparently represent large solution passages that once existed in the limestone and were partly filled with sand or gravel by the streams that flowed through them. Later, with continued weathering, the limestone dissolved away, leaving its clayey residue encasing the gravel and sand that once filled the channel.

CIRCULATION OF GROUND WATER

Water derived from rainfall descends beneath the surface under the action of gravity through any available openings in the soil and underlying rock. It may percolate slowly downward through the interstices between the grains of sand and gravel, as in the Tuscaloosa formation, or through joint cracks in limestone, as in many areas in south-central Tennessee. In limestone areas it may also descend more rapidly through openings that have been enlarged by solution. The larger of such passageways may reach the surface as sinks, which are small or large surface depressions with more or less centripetal drainage to a swallow hole, in which the water descends beneath the surface. Sinks are a common feature of the landscape in the eastern Highland Rim in Franklin County and adjacent areas. They are also numerous in the cove areas along the frayed margin of the Cumberland Plateau in the same general area. In the western part of the Highland Rim the most outstanding example of a sink is found near Pleasantville, Hickman County, where Sinking Creek disappears into such a swallow hole, the water coming to the surface again in several springs along Cane Creek a few miles above Pleasantville.[54]

In a more or less uniformly porous rock, such as the Tuscaloosa formation, water descends vertically until it reaches the level below which the pores of the rock are completely saturated with water. This level is called the water table and is essentially the level at which water stands in wells. Usually the water table is not horizontal but has a gentle slope at all points, its shape as a rule conforming to that of the land surface above it, because the water below the water table is in motion laterally in the direction of slope of the water table, which must therefore slope from the hills, where the water is replenished, to the valleys, where it is discharged in springs. The rapidity of its movement depends upon the amount of slope of the water table, called the "hydraulic gradient", and the innate capacity of the containing rock to transmit water, called its "hydraulic permeability." The permeability of a rock depends upon the size and continuity of the openings in it. Units for measuring it have been proposed[55] and accepted. The water table usually slopes down to and intersects the perennial streams at their water level, so that the ground water below the water table usually discharges into these streams through springs along its banks. This condition is clearly exemplified in the series of large springs in the Tuscaloosa formation lining the banks of Cypress Creek in its lower course.

In places where the downward movement of the water is temporarily arrested by an impervious bed the water will accumulate above such a bed, forming what is termed a perched water table. Such perched water tables probably occur over small areas in the Tuscaloosa formation and would explain those wells which get water considerably above the base of the formation, such as well 483, in Wayne County. Similarly well 241, in Hohenwald, derives its water from a

[54] Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 166, Tennessee Geol. Survey, 1914.

[55] Meinzer, O. E., Outline of ground-water hydrology: U. S. Geol. Survey Water-Supply Paper 494, p. 44, 1923.

water body of very local extent in an outlier of the Tuscaloosa formation, probably perched upon the rather impervious clay residue of the Mississippian limestone.

The most extensive perched water table in south-central Tennessee is the regional one perched above the Chattanooga shale. This formation probably deflects most of the water that percolates to it; its upper surface is the outstanding horizon of springs throughout the area, and many wells draw their supplies from the beds just above it. In certain areas, such as the remnant of the Highland Rim at the northwest corner at Moore County, wells that do not obtain water above the Chattanooga shale generally remain dry or at least must be drilled much deeper before water is found.

In the limestone regions of south-central Tennessee and elsewhere, the water table is not as plainly marked as it is in uniformly porous material such as that of the Tuscaloosa formation. Neighboring wells do not in general strike water at about the same level, but commonly their depths vary somewhat widely, depending upon the levels at which openings filled with water are found. In many and perhaps most areas,[56] however, the water will rise in shallow wells to about the same level. In such areas a surface connecting these levels may be considered a water table, the inference being that the maze of solution channels, open joints, and open bedding planes are all filled with water to this level. When the hydrologic conditions in limestone are compared with those in uniformly porous material, the limestone may be considered a greatly magnified portion of the uniformly porous deposit, the limestone blocks between bedding planes and joints being compared to the grains of sand or pebbles or boulders in the porous deposit, and the joint planes and solution openings being analogous to the open interstices of the porous deposit. However, owing to the fact that the water-bearing openings in a limestone region may be of greatly different sizes, the hydrologic conditions may be so variable in the region as to render the concept of a water table valueless or even to invalidate its application entirely. Martel [57] has denied its existence in limestone regions and proposes instead to substitute for it the conception of a system of underground channels, vertical and horizontal, which carry the water much like the system of pipes in an artificial water-supply system. He cites many examples from the calcareous regions of Europe showing that the concept of the water table does not apply.

The general question as to the extension of the term "water table" to limestone conditions seems academic. The concepts of hydrology merge into one another, and the answer to the question where to

[56] Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, p. 133, 1923.

[57] Martel, E. A., Nouveau traité des eaux souterraines, p. 222, Paris, 1921.

bound one and begin another is largely subjective. As stated above, in areas where the water in normal wells stands at interrelated levels the concept may be applied, with the realization that it is an extension from the areas where it is more obvious. In areas where this condition does not exist the concept is clearly out of place. The more practical aspect of the problem is to examine the ways in which the circulation of ground water in limestone differs from that in porous materials.

An obvious difference is indicated by the rapid increase in flow of some springs after heavy rains. It is evident that when this occurs, especially when the water is muddy or carries debris, there is a direct connection between the spring and the ground surface at some other point, allowing storm water to be immediately discharged. Spring 236, near Iron City, is reported to follow the fluctuations of Holly Creek, 2 miles distant, and to become muddy when the creek does. Similarly spring 131, near Coble, indicates by its high summer temperature that it is discharging water which has spent only a relatively short time underground. For this spring the inlet of the surface water is known. Examples of this sort could be multiplied in this as well as other limestone regions. In such regions there may or may not be a local water table, but where there is one it is evident that there is also a direct surface connection superimposed upon a maze of smaller interstices, filled to approximately the same levels, which feed water to the main opening more slowly during dry periods.

Furthermore, although the maze of joint planes and smaller solution openings may be filled with water to a certain level, thus forming a water table in the sense in which the term could be used in soluble rocks, there may still be a larger tubular passage beneath such a water table, draining the smaller passageways and yet only partly filled with water. Where water drops continually from the walls or roofs of caverns, or where stalactites and other tufaceous deposits indicate that it has done so in the past, it is evident that saturation has been reached somewhere in the interstices above. The interstices may be of such a nature that saturation in the overlying rock has proceeded uniformly enough to establish a water table above the cavern, or the openings may differ so much in size that the water level is variable and the concept becomes useless.

If several systems of passageways are present, interconnected with various degrees of freeness by openings of different sizes, the conditions give rise to various heads in the several systems. Such conditions may be considered somewhat analogous to a system of perched water tables. In an area characterized by such conditions neighboring wells are likely to vary not only in depth to water but also in static water level and seasonal variation.

Finally, owing to the irregular character of the solution openings freakish hydrologic phenomena may occur. Solution openings may be expanded in some parts and constricted in others. In many places they have the shape of siphons. One of the better-known freakish phenomena associated with limestone regions is exemplified by ebbing and flowing springs,[58] which, regardless of meteorologic conditions, vary widely in their flow, usually at more or less regular intervals. Such phenomena are probably usually associated with siphons in the conduits.

Bigby Spring (392), according to report, has a regimen that ranks it as one of the most freakish springs. This spring, which had a flow of a few gallons a minute when visited, furnishes water to several hydraulic rams to supply the needs of inhabitants in the community of Bigbyville. According to reports, after each of several heavy rains in a recent wet year the spring ceased flowing and another normally dry opening about 100 yards up the creek and at nearly the same altitude began to flow. This continued so long after each of the heavy rains that the rams were moved to the new spring several times. Unfortunately, however, the new spring would soon cease to flow and Bigby Spring would begin again, necessitating the return of the rams. The solution openings that feed this spring are not large enough to enter for investigation, but such behavior can be explained on the basis of a hydraulic system involving siphons whereby one channel is put in operation when the water table is high and the other when it is low.

Figure 1 shows one hypothetical system by which this effect could be produced. The system shown is supposed to be in connection at the right of the diagram with the regional system of passages in which the hydraulic head varies between the levels marked 1 and 2. Ordinarily the head is supposed to be at the height 1, and water flows through the passages drawn with full lines—that is, through *a*, then through the pseudosiphon *b*, which is connected with the surface and the atmosphere by the fracture or solution opening *c*, and then through the constricted passage *d*, emerging at the spring, S_1. Under this condition, the hydraulic gradient will be represented by the broken line marked 1, the gradient being steeper along the constricted passage *d* than elsewhere because of its small size. If the water level at the right of the diagram rises over the small passage *f*, a part of a second system of passages shown by dotted lines, water will flow through it but will drain through the connecting passage *g* into the first system of passages and will emerge at S_1. However, if the water rises in the regional system to the level marked 2, the hydraulic gradient will follow the line marked 2, and the hydro-

[58] Bridge, Josiah, Ebb and flow springs in the Ozarks: Missouri Univ. School of Mines and Metallurgy Bull., vol. 7, no. 1, pp. 17-26, 1923. Meinzer, O. E., unpublished manuscript.

static pressure will be sufficient to fill the true siphon formed by g and h and their connection. When this occurs the water will begin flowing up g and down h, and will emerge at S_2. Inasmuch as the passage connected to S_2 is of about the same size as a, the hydraulic gradient will now be a straight line, marked by line 3; the hydrostatic pressure on b will be reduced below the level of its top, water will cease flowing through d, and, consequently, spring S_2 will discharge the entire flow. It will continue to do so until the regional water level falls below f, the hydraulic gradient at that time being approximately along the line 4, upon which air will enter through f, and the siphoning action through g and h will be stopped. The

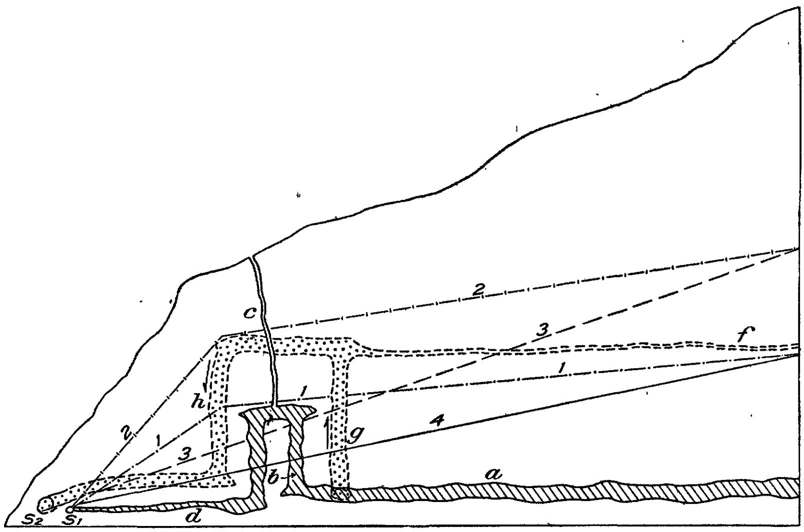


FIGURE 1.—Hypothetical system of underground channels to account for the behavior of Bigby Spring. See text for explanation.

second system being no longer operative, the hydraulic gradient will again take the form 1, and the system will operate as originally.

Many variations of this hydraulic system, giving identical effects, are possible, and the system diagrammed should be regarded not necessarily as a representation of the conditions believed to exist at Bigby Spring but as a possible type of system to explain what is apparently a very unusual and, at first sight, rather mysterious behavior of ground water.

DEVELOPMENT OF UNDERGROUND DRAINAGE IN LIMESTONE

The ground-water circulation in limestone progressively modifies itself, making the passage of water through the rock more easy and rapid.

Limestones, when first deposited as sediment, are, like all other sediments, somewhat porous. Some, such as coquina, may remain very porous even after solidification. However, nearly all the limestones of south-central Tennessee, through the diagenetic processes of compaction by the weight of overlying sediments, solution, and recementation by calcite, have become practically impervious to water in the process of solidification. The impervious nature of some of these rocks at the present time is shown by certain wells, notably wells 111 and 375, which did not obtain any water and are used as cisterns.

The processes that made some of the rocks permeable to water, reversing the action of the processes previously effective, probably originated at the time the area was first uplifted from the sea. The stresses set up at this time found partial relief in the formation of joint planes. Through these openings, and through original minute openings which must have been present in some rocks, such as the parent rock of the "chalk" of Wayne County, fresh water began to circulate. With the initiation of a circulation through the rock, very slow and difficult at first, the openings began to enlarge by solution.

Calcium carbonate ($CaCO_3$), the essential constituent of limestone, although nearly insoluble in pure water, is in a geologic sense very soluble in water carrying dissolved carbon dioxide, with which it combines to form calcium bicarbonate, $Ca(HCO_3)_2$. The chief source of carbon dioxide is probably found in decaying vegetation in the soil zone, where it enters the ground water either directly as carbon dioxide or as organic compounds which later oxidize to carbon dioxide. One evidence of the higher concentration of carbon dioxide at depth in the zone of aeration than at the surface is its presence in dangerous quantities in moderately deep dug wells. Some of the well diggers in the western Highland Rim have added small blowers to their equipment as a safeguard against the carbon dioxide encountered.

The factors affecting the amount of solution that will take place in a given bed of limestone may be divided into two groups, one having to do with the rock itself and the other dealing with the solvent water. In the first group are the solubility of the rock and its physical condition. Limestone beds vary in purity, the constituents other than calcium carbonate including in different beds various amounts of magnesium carbonate, calcium phosphate, silica, and clayey or sandy detritus. These impurities change the solubility of the rock because they are themselves of different solubilities and also because they change the conditions of equilibrium in the solution in which they dissolve. The physical condition of the rock affects its solubility by impeding or facilitating the movement of the solvent water through it. If there are primary openings in the rock, the ease of movement through it will be controlled by the size and continuity of the openings. If the rock is brittle it is generally much more fractured than a more plastic rock, and consequently the movement of water is facilitated.

In the second place, the condition of the ground water affects the amount of solution that takes place. All physical and chemical characteristics affect the solvent power of the water to some extent, but the amount of dissolved carbon dioxide available is the preponderant factor. Carbon dioxide is absorbed both from the atmosphere and, in larger quantities, from the soil zone. Possibly, at least in some localities, it may be absorbed throughout the zone of aeration above the water table, inasmuch as it is fairly abundant at moderate depths in the wells of the western Highland Rim. Apparently, however, there is no important source of carbon dioxide below the water table. It appears, therefore, that the solvent power of water falling upon the surface and destined to join the ground-water body increases as it passes through the soil zone and possibly as it passes through the remainder of the zone of aeration. However, after the water reaches the water table its ability to dissolve more of the limestone of its surroundings progressively diminishes as it becomes more and more nearly saturated with calcium bicarbonate, and the available free carbon dioxide conversely diminishes.

If the water below the water table flows without turbulence, as it undoubtedly does in at least the initial stages of solution, the newest accretions of water from above must be near the water table; each particle of water added is at the water table at the instant it joins but progressively descends farther beneath the water table as it flows down gradient beneath newer and newer accretions.[59] As the newest accretions are near the water table and are also the most potent in their ability to dissolve the limestone of their environment, it follows that the greatest amount of solution below the water table, if the beds are innately uniformly soluble, must take place near this level. Other conditions being the same, therefore, the large solution passages should be formed near the water table.

THE SOLUTION CYCLE

In the initial stage of ground-water circulation in limestone the water must move through the openings already available—that is, either the primary openings provided during sedimentation or the fractures produced during uplift. This stage may be compared to the sheet flow of surface drainage. In it the circulation of water

[59] Compare Slichter, C. S., The motions of underground waters: U. S. Geol. Survey Water-Supply Paper 67, figs, 13, 14, pp. 36, 37, 1902.

occurs in the least efficient manner. However, even in this first stage more water will flow through certain portions of the rock that are either more porous or more openly fractured.

Solution, beginning at once, immediately tends to increase the size of the openings through which the water moves. The openings that were originally somewhat larger tend to become much larger in proportion than the smaller ones, because of the more rapid circulation of water through them. As they increase in size the passage of water through them becomes more easy, so that they tend by diversion to reduce the flow of water through the smaller openings. In this manner a sort of piracy takes place undergound. There is a distinct tendency for the larger passages to develop in the more soluble or more fractured rocks and, other factors being equal, above or near the water table.

By the process of piracy thus set up, the underground drainage is integrated into large trunk streams with branches, which in turn have smaller tributaries, as in a surface drainage system. Larger vertical channels as well as horizontal channels develop and give rise to sink holes at the surface. As the movement of water is made more easy and more rapid the underground streams obtain velocities high enough to enable them to move debris and thus enlarge their channels in part by mechanical erosion. Martel [60] and others have invoked hydraulic pressure to explain the disruption of constricting partitions in caverns.

In the late stages the passageways have become so large, or the surface erosion has worn the roofs of the caverns so thin that they may collapse, and sink holes are formed. Well 429, the "natural well" in Perry County (see p. 162), is forming today in this way. With progressive foundering of the roof, the drainage returns to the surface, so that the final stage of the solution cycle finds all the streams flowing at the surface over a peneplain.

Before or after this final stage is reached the region may be uplifted, and a new cycle of underground erosion will be started. The uplifts that terminated the periods of erosion represented by the Cumberland and Highland Rim peneplains were undoubtedly accompanied by such rejuvenation of underground erosion, and smaller, later uplifts are recorded in the present river terraces and dry caverns above the present drainage level (pl. 6, *A*).

The Highland Rim, at least in the western part of Tennessee, probably reached the final stage of the solution cycle.[61] This is indicated by the thick mantle of residual material left upon it, apparently reaching about 200 feet in well 257 in Lewis County, and by the

[60] Martel, E. A., Nouveau traité des eaux souterraines, p. 542, Paris, 1922.

[61] Piper, A. M., Ground water in north-central Tennessee: U. S. Geol. Survey Water-Supply Paper 640, p. 81, 1932.

included stringers of gravel and sand in this residuum, which probably represent fillings of solution channels, whose walls and roof were later completely decomposed by solution.

INTERRELATION WITH SURFACE DRAINAGE

While solution and other forms of erosion are going on below the surface, normal erosion by running water is taking place on the surface. The relative rate of surface and underground erosion depends on many factors, which may favor one or the other process. Among the factors that tend to promote surface erosion as against underground erosion are steep surface slopes, readily erodible surface rocks such as clays and shales, poor cover of vegetation, and, in newly uplifted areas, the inheritance of a drainage system from a previous cycle of erosion. Underground erosion is favored by high solubility of the rocks; a permeable surface cap such as sand and gravel and their consolidated equivalents, which tend to absorb the rainfall before it can flow off in streams; extensive and intensive jointing and other fracturing; and probably heavy vegetable cover, yielding more organic substances that can be oxidized to carbonic acid gas. The lack of any of the factors listed for either type of erosion tends to increase the relative efficacy of the other type.

Throughout the erosion cycle there is usually a continual struggle between the two forms of erosion. In the western part of the Highland Rim, which has reached the stage of maturity, the struggle is still taking place in detail, although as shown by the fact that all areas of any size are served by surface streams and the underground drainage is tributary to them through springs at stream level, surface erosion is the master type at present. For instance, a creek in Perry County has breached an underground channel at spring 467, where the ground water, which has normal ground-water temperature, appears in the opening shown in plate 7, *A*, and disappears again about 75 feet farther downstream in the opening shown in plate 7, *B*. The same action has occurred on Beaver Dam Creek near Coble and at many places elsewhere. On the other hand, near Pleasantville a subsurface system has captured upper Sinking Creek. The topography at this locality is shown in figure 2.

In other parts of south-central Tennessee the underground drainage has so far been able to master the surface drainage. The most outstanding example of this is found in the cove area at the edge of the Cumberland Plateau in Franklin County. The coves are large valley sinks or series of sinks, which are completely surrounded by higher land and therefore have interior drainage. Some of the coves are several miles long and several hundred feet deep. Factors which tend to give the underground drainage the mastery here are the great mass of Mississippian limestones underlying the plateau, its permeable cap of sandstone of Pottsville age, which is also resistant to surface erosion, and its topographic youth.

QUALITY OF WATER

GENERAL FEATURES

The analyses of water given in the tables in connection with the county reports list the important substances in solution in the water. The quantities of these substances in solution are given in terms of parts per million by weight. These figures can be changed to grains

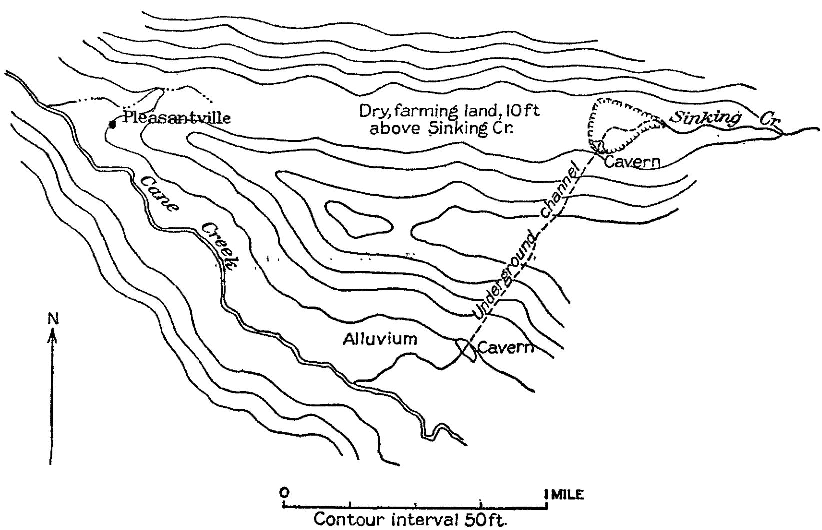


FIGURE 2.—Topography near Pleasantville, Hickman County, showing the capture of Sinking Creek by underground drainage. After Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 166, Tennessee Geol. Survey, 1914.

per gallon, the other system of expressing water analyses commonly used, by multiplying by the factor 0.05842.

The effects and nature of the common dissolved constituents in natural waters are as follows. Silica may be precipitated as scale in boilers but has otherwise no significance. Iron when occurring in quantities greater than 0.1 part per million may separate out from the water as a reddish sediment discoloring containers or clothing laundered in it. It may be removed by aeration. It is especially prominent in the samples of water from the Pennsylvanian and Cretaceous formations of south-central Tennessee. Calcium is generally the most abundant basic constituent of the water in this area. It causes most of the hardness in the water. Magnesium also contributes to the hardness of the water. In a few of the samples of impotable water from the area magnesium exceeds calcium and suggests contamination by sea water in past geologic time. Calcium and magnesium are also scale formers in boilers. Sodium and potassium are generally low in the waters of the area. Where they amount to over 100 parts per million they are likely to cause foaming in boilers. Carbonate is absent in practically all the water in the area, but bicarbonate is the most prominent acid radicle. Waters high in calcium bicarbonate will form scale in vessels in which the water is heated, because the substance is decomposed by the heat, carbon dioxide is liberated, and insoluble calcium carbonate is formed. Sulphate generally occurs in only small amounts in the water of south-central Tennessee, but where it is present with large quantities of sodium or magnesium the water may have a bitter taste. Chloride is likewise not abundant in the potable waters of the area. In some of the impotable waters it is the chief acid constituent, and its presence with accompanying sodium suggests also contamination by ancient sea water. Nitrate is usually of small amount and has no chemical significance, but as it is often formed by the oxidation of organic compounds, its presence in excess may point to possible pollution of the well or spring from which the water came. The item "total dissolved solids" expresses the residue left on evaporation of the water. In the water of this area it is usually approximately the sum of the constituents mentioned above minus about half of the bicarbonate, the deduction representing approximately the weight of the carbon dioxide driven off in the evaporation.

The hardness is the most important quality of most of the water of this area. The amount of soap necessary to use in laundering or washing in the water is approximately proportional to the hardness. In the analyses the hardness is computed by multiplying the calcium by 2.5 and the magnesium by 4.1. The hardness of the water from many wells and springs in the Nashville Basin for which no analyses are available was determined in the field by agitation with a standard soap solution. The figures so obtained are probably within 10 percent of the hardness that would be calculated from an analysis.

The water of the Cumberland Plateau, in Franklin County, and of the Tuscaloosa formation, in Wayne County, is low in all dissolved substances. Most of the potable water of the rest of the area is calcium-bicarbonate water—that is, calcium is the most abundant basic radicle and bicarbonate is the most abundant acid radicle. However, one exceptional type of water occurs in the Nashville Basin. It is a sodium-bicarbonate water represented by the analyses of wells 17a (Bedford County), 98 (Giles County), and 329 (Marshall County). Water of this type is greatly prized in the Nashville Basin because of its softness. Most of this water differs from the normal calcium-bicarbonate water of the area only in that sodium takes the place of the calcium and magnesium. Apparently it has resulted from natural zeolitic softening, a process in which certain clay minerals (zeolites and their mineralogic relatives) in the rocks abstract the calcium and magnesium from water percolating past them, yielding to the water in turn the sodium which they originally contained.

The impotable waters of the area range in chemical character between two types—calcium-sulphate water and sodium-chloride water. The probable origin of these waters is discussed on page 32.

RELATION BETWEEN QUALITY OF WATER AND STRATIGRAPHY AND GEOMORPHOLOGY

In a limestone region the ground water is usually a calcium-bicarbonate water. Deviations from this standard type in the limestone areas of south-central Tennessee are represented by the addition to or substitution in them of the alkaline bases and the chloride and sulphate constituents.

The following table shows the characteristics of the water samples that have been analyzed from each formation or group of formations. It gives the average quality of the water from each formation, as indicated by the analyses available, in terms of hardness, total quantity of solids in solution, sum of sodium and potassium, and sum of chloride and sulphate. The table gives also figures for wells that have been excluded from the average because of their exceptional character. Some of the samples included in the averages have been referred to the given formations with some doubt, but correction of any errors due to faulty correlation would probably not change the general character of the table, as it is believed that such errors amount at most only to a shift from the proper formation to one that is stratigraphically adjacent.

Average quantities of certain chemical constituents of waters from various geologic formations in south-central Tennessee

[Parts per million]

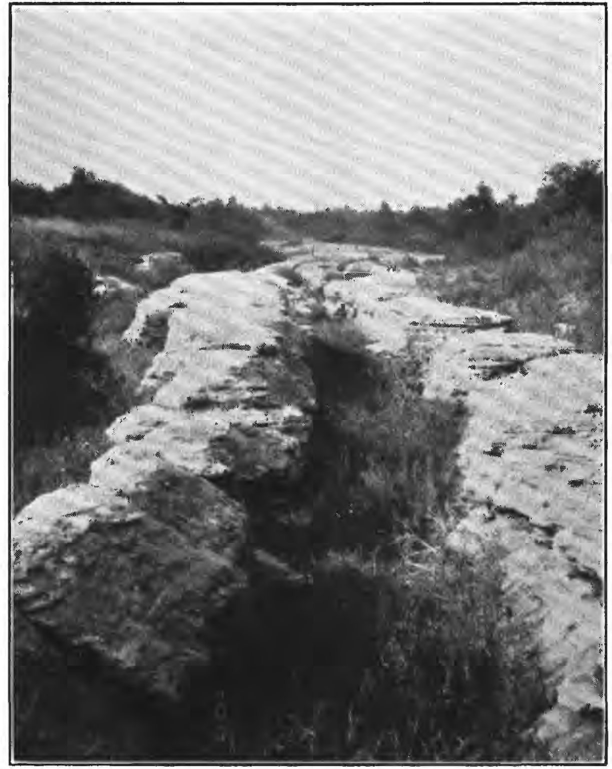
Stratigraphic unit	Number of analyses	Source	Average results: Hardness as $CaCO_3$	Average results: Total dissolved solids	Average results: Sodium and potassium (Na+K)	Average results: Chloride and sulphate ($Cl+SO_4$)	Wells excluded from averages: No. of well	Wells excluded from averages: Hardness as $CaCO_3$	Wells excluded from averages: Total dissolved solids	Wells excluded from averages: Sodium and potassium (Na+K)	Wells excluded from averages: Chloride and sulphate ($Cl+SO_4$)
Tuscaloosa formation	1	Spring	10	22	0	6					
	2	Wells	52	82	3	20					
Pennsylvanian series	1	Spring	26	62	6	27					
	3	Total	43	76	4	23					
St. Louis limestone and Warsaw formation	12	Springs	155	196	2	58	60	888	1,212	19	642
	4	Wells	108	137	4	25					
Fort Payne chert	4	Springs	89	106	2	7					
	8	Total	98	121	3	16					
Ridgetop shale	7	Springs	81	102	2	26					
Birdsong shale	2	do	81	98	2	7					
Brownsport formation and Decatur limestone	4	do	101	117	1	9	427	367	3,121	918	1,940
Fernvale formation	3	do	101	124	3	16					
	1	Well	213	257	4	59					
Leipers limestone	1	Spring	41	56	1	5	139	1,126	1,614	21	977
	2	Total	127	157	3	32					
Catheys limestone	1	Spring	131	152	1	4	239	3,340	19,160	5,490	11,030
Cannon limestone	2	do	102	122	2	5					
Bigby limestone	2	do	142	183	5	23					
	2	Wells	221	255	3	13					
Hermitage formation	2	Springs	131	155	2	12	279	4,015	7,724	955	4,952
	4	Total	176	205	3	13					
	4	Wells	218	453	83	95					
Lowville limestone	2	Springs	223	254	5	12	12	7,256	10,813	313	7,141
	6	Total	220	387	57	67					
Lebanon limestone	6	Wells	414	833	125	320	374 18	2,324 4,868	3,283 30,830	39 9,894	1,941 19,670
Ridley limestone	3	do	281	374	7	41					

The hardness and total mineral content of the waters in the predominantly sandy Tuscaloosa formation and Pennsylvanian rocks are low, owing to the low calcium content of these rocks. The hardness and mineral content of the waters from the strata below the Fort Payne chert increase downward in general to a maximum in the Lebanon limestone, the Ridley showing somewhat lower figures for all the characteristics listed. The total abnormal constituents increase in the same order. Although this is probably, at least in part, a stratigraphic correlation, it represents also a progression from the greatly dissected Highland Rim to the rolling Nashville Basin, where there is little local relief. The difference in character may therefore be correlated in part with the character of the ground-water circulation, which in the sections with great relief is presumably relatively vigorous, hence giving comparatively little time for the solution of the containing rock, and in the Nashville Basin is relatively sluggish.

In line with the latter explanation, which is perhaps only partial, of this change in character of the water, the water from springs is invariably lower in mineral content than that from wells in the same formation. Similarly the total alkalies and chlorides and sulphates are higher in wells than in springs, generally conspicuously so. The same holds true for the hardness except in the waters from the Lowville limestone, in which the hardness is slightly less in wells than in springs. This exception, however, only supports the same generalization, for the samples from the Lowville limestone include a sodium-bicarbonate water, which without doubt has undergone natural zeolitic softening, whereby the calcium and magnesium have been exchanged for sodium, thus pointing again to a sluggish circulation. The generalization that the mineral content of the water from springs is lower than that from wells in this limestone country may be explained as a corollary to the fact that the springs represent the outlets of naturally developed and in general extensively developed circulation systems in limestone. As a consequence much of the water moves rapidly through these well-developed passageways and so dissolves little limestone. On the other hand, wells may derive water from small fractures and solution passages in limestone, in which the movement of the water is sluggish and in which as a result much of the rock material is dissolved in the water.

If this conclusion is true it may be expected that large springs will discharge softer and less mineralized water than small springs, inasmuch as the greater the flow of a spring the more certain it is that the spring is connected with a well-developed drainage system. The data available for testing this possibility in this area are unsatisfactory because of their paucity, for as the type of water discharged by a spring is obviously dependent upon lithologic and other factors as well as size, the correlation between size and quality could be demon-

A. DRY SOLUTION PASSAGE IN RIDGETOP SHALE.
Cave Creek, about half a mile below Ashtons Branch, Lewis County.



B. HORSES OF UNALTERED BIGBY LIMESTONE AND CUTTERS FROM WHICH THE RESIDUAL PHOSPHATE ROCK HAS BEEN TAKEN.

The cutters represent solution of the original limestone along joint cracks. Abandoned phosphate pit 2 miles east of Mount Pleasant.

A. OUTLET OF UNDERGROUND STREAM BREACHED BY SURFACE EROSION.
Lost Creek 3 miles northeast of Lobelville, Perry County. Brownsport formation.

B. INLET OF UNDERGROUND STREAM BREACHED BY SURFACE EROSION.
About 75 feet downstream from outlet shown in *A*.

strated only by statistical methods. However, the data available have been made to bear what evidence they can on the question and are presented in the following table.

In this table the springs from the various formations are listed in the order of their size, and the total solids contained in the water are also given. If there is an inverse relation between the size of a spring and the quantity of mineral matter dissolved in its water, there should be a tendency for the total solids to increase as the size of the springs decreases. It will be observed that this tendency is shown for 8 of the 10 formations listed, the Fort Payne chert showing little or no relation between the two quantities and the Hermitage formation showing a contrary relation.

Variation in mineral content of springs from several formations in south-central Tennessee

Spring no.	Discharge (gallons a minute)	Total dissolved solids (parts per million)
ST. LOUIS LIMESTONE OR WARSAW FORMATION		
221	600	57
262	500	65
260	300	55
263	150	85
152	50	149
234	40	80
314	8	189
150	4	841
385	3	74
WARSAW FORMATION IN FRANKLIN COUNTY		
74a	750	245
79	150	214
76	25	296
FORT PAYNE CHERT		
71b	1,200	156
224	1,100	70
519	100	43
156	100	156
RIDGETOP SHALE		
270	300	81
450	200	58
235	15	75
513	3	104
134a	1	43
177c	½	198
177d	⅛	148
BIRDSONG SHALE		
464	1,000	79
458	150	118
BROWNSPORT FORMATION		
160	100	97
447	75	108
518	5	170
FERNVALE FORMATION		
119	200	70
302a	3	110
298	½	93
CANNON LIMESTONE		
300	125	106
405	75	138
BIGBY LIMESTONE		
132	10	117
398	Small	249
HERMITAGE FORMATION		
126	12	190
342	5	121

THE STRATA AND THEIR WATER-BEARING PROPERTIES

An introduction to the stratigraphy of south-central Tennessee and a columnar section with a synoptic description of the rocks of the area and their water-bearing properties are given on pages 28–31. Detailed descriptions of the stratigraphic, lithologic, and water-bearing properties of the rocks are given in the following pages.

QUATERNARY SYSTEM

FLOOD-PLAIN ALLUVIUM

The youngest and topmost geologic material is the alluvium of the flood plains of the streams. This material consists of unconsolidated debris from the drainage basins of the streams along which it lies. Its constituent particles range in character from silty clay along the larger streams to coarse gravel on some of the rapidly eroding creeks of the Tennessee Valley. The larger particles found in it are generally chert, derived from the weathering of the nearby siliceous limestones of the Mississippian series, although in the eastern part of the area the Pennsylvanian sandstones have furnished some quartz sand.

Wells sunk into this alluvium are generally dug and obtain water at about stream level. There is generally a considerable underflow in the thick deposits of chert gravel found in the streams tributary to the Tennessee and Buffalo Rivers in the western part of the area, the streams in this part being generally dry in summer near their mouths, although springs are flowing freely in the headwater portions of the streams. "Springs" are found in this gravel where a hole has been dug into the alluvium by natural erosion or by artificial methods. Bubbling or upwelling springs rise from the alluvium in the headwater portions of some of the streams, apparently in some places as a result of the water from a spring that emerges from the bedrock hills nearby, beneath the alluvium, being forced to the surface by a subsurface dam. In other places toward the mouths of the streams weak springs emerge from above cemented layers in the alluvium.

QUATERNARY (?) SYSTEM

TERRACE DEPOSITS

An alluvial mantle generally caps the terrace remnants throughout the area. This older alluvium varies in composition from silt to gravel and is in general poorly assorted. The individual pieces of gravel may be thoroughly water-worn, but in most places they are still subangular.

These terrace materials are found at various heights above the rivers throughout the area. They have been observed 65 feet above the Tennessee River at Clifton, 100 feet above the Buffalo River at Flatwoods, and 50 feet above the Buffalo at Linden and Lobelville. In the vicinity of Centerville they lie from 50 to over 200 feet above the Duck River. Similar deposits are also present on the Elk River at Baugh, in Giles County. The thickness of the deposits may reach 30 feet.

The terrace materials on the Buffalo, Duck, and Tennessee Rivers have been referred to the Quaternary system by Miser [62] and Wade.[63] Apparently similar deposits in Rutherford County have been regarded as Pliocene by Galloway.[64] No evidence is given by any of these authors for these conclusions. It seems probable from a consideration of the Pliocene terraces covered with gravel (Citronelle) along the Mississippi River [65] that at least some of the terrace deposits on the streams of south-central Tennessee will be found to be Pliocene. Wade [66] has referred to the Pliocene series gravel found above an altitude of 620 feet on the Tennessee River—some 50 feet lower than the gravel on the Buffalo River at Flatwoods. However, final dating of these deposits must await their tracing into terrace deposits of the Ohio River.

These alluvial deposits are used in many places as sources of water. In general they yield satisfactory domestic supplies. The town of Littlelot, in Hickman County, uses this material as the general source of supply for its wells, and many homes in Flatwoods and Clifton also draw upon this material for their water supplies. The material is in general poorly assorted, is thin, and, as it lies upon the hilltops near the river, is well drained. As a consequence it cannot be expected to yield large supplies of water.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

Representatives of only the lower formations of the Upper Cretaceous series of the Coastal Plain are found in south-central Tennessee. These formations enter from the southwest corner of Wayne County, where they have a thickness of about 150 feet, and, overlapping the Paleozoic consolidated rocks, thin out to a featheredge in a northeastern direction. Small outliers are found as far northeast as Hohenwald, where they have a thickness of about 30 feet.

EUTAW FORMATION

The highest formation of the Upper Cretaceous series in this area is the Eutaw formation, which caps the ridges in the southwest

[62] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 25, 1921.

[63] Wade, Bruce, Geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 173, Tennessee Geol. Survey, 1914.

[64] Galloway, J. J., Geology and natural resources of Rutherford County: Tennessee Geol. Survey Bull. 22, p. 21, 1919.

[65] Shaw, E. W., Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108, pp. 132–139, 1918.

[66] Wade, Bruce, The gravels of West Tennessee Valley: Resources of Tennessee, vol. 7, no. 2, p. 70, Tennessee Geol. Survey, 1917.

corner of the Waynesboro quadrangle. It consists mostly of red sand, weathering gray at the surface, but it contains in places many horizontal layers of gray clay less than an inch thick.[67] It probably rests conformably on the underlying Tuscaloosa formation. It ranges from a featheredge to 50 feet in thickness in this area.

Few data concerning the water-bearing properties of this formation are available. In its small area of outcrop in south-central Tennessee it caps ridges that are only sparsely inhabited, and most wells go through it into the underlying Tuscaloosa formation. In Alabama, where the Eutaw is below drainage level, it is one of the important artesian aquifers. In Tennessee it apparently has the requisite physical characters of a good aquifer, but owing to its high topographic position it is well drained and hence will probably supply only small quantities of water.

TUSCALOOSA FORMATION

The Tuscaloosa formation, immediately underlying the Eutaw formation in this area, consists of cherty gravel with a very small amount of sand and clay. The constituent pieces reach a maximum diameter of about 4 inches. It is exposed principally in the southwest corner of Wayne County and in the high divide between the streams flowing south and those flowing west to the Tennessee River. It extends as a continuous outcrop as far north as Waynesboro and occurs as isolated outlying patches capping high points near the 1,000-foot level eastward into Lawrence County and northeastward to Hohenwald, in Lewis County. Isolated patches are found north of this area in Tennessee and also in Kentucky, capping the divide between the Tennessee and Cumberland Rivers.[68] In the southwestern part of Wayne County the Tuscaloosa formation reaches a thickness of 150 feet, but it rapidly diminishes in thickness northeastward. Its maximum thickness in northern Wayne County is given by Miser [69] as about 50 feet.

The unconformable contact of the Tuscaloosa with the underlying Mississippian limestones is very indistinct. "Water-worn gravel occurs in some places in cuts as much as 40 feet below large angular pieces of St. Louis chert. * * * A zone a number of feet thick along the contact * * * consists of a heterogeneous mixture of angular chert, water-worn gravel, and red and yellow clay." [70] A thick layer of cherty clay, residual from the underlying limestone, generally lies below the gravel.

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[67] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 25, 1921.

[68] Wade, Bruce, The occurrence of the Tuscaloosa formation as far north as Kentucky: Johns Hopkins Univ. Circ., new ser., no. 3, pp. 104–105, 1917.

[69] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 25, 1921.

[70] Wade, Bruce, Geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 173, Tennessee Geol. Survey, 1914.

The Tuscaloosa gravel has the porosity, permeability, and chemical character of an exceptionally good aquifer. However, this very excellence of structure makes it difficult to obtain well water from the gravel in many places. Inasmuch as it caps the ridges, the water that sinks into it is comparatively quickly discharged into the neighboring streams. It furnishes copious supplies of spring water to the valleys cut below it, but wells on it generally pass almost or entirely through it before enough water for even domestic supplies is obtained. However, in places the gravel is cemented with ferruginous materials, especially in the lower portions, and it seems probable that some exceptional wells draw their water from water bodies perched above such impervious cemented layers. The water obtained from the Tuscaloosa is soft and low in mineral content, as a result of the insoluble character of the formation.

CARBONIFEROUS SYSTEM

PENNSYLVANIAN SERIES

The Pennsylvanian series is represented in south-central Tennessee by the Whitwell shale, Sewanee conglomerate, and Gizzard formation. These belong to the Lee group, of lower Pottsville age. They enter the area only in the southeastern part of Franklin County.

WHITWELL SHALE

The Whitwell shale, the topmost formation of the Pennsylvanian series exposed in the area, has little significance in connection with this report. It is found in only one small area 2 miles east of Sewanee, where it is about 80 feet thick. It consists of clayey and sandy shales and some coal.[71]

No data concerning the water-bearing properties of this formation are available; probably no wells in Franklin County draw water from it. Some sandy lenses in the formation might yield water, but the existence of such lenses is problematic.

SEWANEE CONGLOMERATE

The Sewanee conglomerate received its name from the type locality at Sewanee, in Franklin County. It caps the Cumberland Plateau throughout the extent of that plateau in Franklin County, except on the projecting ridges, where it has been removed by erosion. The formation consists of a soft, massive cross-bedded dirty-yellow sandstone, in which are scattered numerous pebbles of milky-white vein quartz, from one-sixteenth to 1½ inches in diameter. The formation is as much as 70 feet thick in Franklin County.[72]

[71] Nelson, W. A., The southern Tennessee coal field: Tennessee Geol. Survey Bull. 33-A, pp. 48, 103, 1925.
[72] Idem, pp. 45, 103.

The Sewanee conglomerate furnishes water supplies of domestic magnitude around Sewanee. The University of the South, which furnishes water to the city of Sewanee as well as for its own use, obtains its water in part from 7 springs in this formation, which in the fall of 1930 yielded a total of only 30 gallons a minute, the largest spring flowing only about 5 gallons a minute. This small yield seems to be typical for the entire area underlain by the conglomerate in Franklin County and is probably to be ascribed to the high topographic position of the formation rather than to any innate properties of the formation itself.

GIZZARD FORMATION

The Gizzard formation is the basal formation of the Pennsylvanian series in this region. It consists of a series of shales and sandstones. The following section [73] exemplifies its character in this area:

Stratigraphic section at old Shake Rag mines, about 2 miles east of Sewanee

	Ft.	in.
Sewanee conglomerate: Sandstone	70	
Gizzard formation:		
Covered	35	
Warren Point sandstone member	30	
Coal		6
Shale, very sandy in middle	35	
Coal, mined	1	8
Shale.		

The topmost member of the formation is generally a shale which separates the Sewanee conglomerate from the Warren Point sandstone member. This separating shale ranges in thickness from a few feet to 20 feet. The Warren Point sandstone member forms cliffs around the edge of the plateau.

The base of the Gizzard formation is marked by the unconformity between the Mississippian and Pennsylvanian series. An intraformational angular unconformity has been noted at the base of the Warren Point sandstone.[74]

The Warren Point sandstone member is apparently the important aquifer in this formation. The water supply for St. Andrew's and St. Mary's Schools and much of that for the University of the South and Sewanee seems to be drawn from this sandstone. The well at St. Mary's furnishes about 5,000 gallons a day constantly and is reported to have been bailed when first drilled at the rate of 20 gallons a minute without reducing the water level. The two wells at the University of the South furnish a total of about 20,000 gallons a day. The wells at St. Andrew's are much weaker.

[73] Nelson, W. A., op. cit., p. 102.
[74] Idem, p. 103.

The water derived from this formation contains considerable iron in solution and therefore gives considerable difficulty when used for laundering.

MISSISSIPPIAN SERIES

The rocks of the Mississippian series everywhere cap the Highland Rim and extend up the scarp of the Cumberland Plateau almost to its top. These rocks as a mass consist largely of limestone, in part very cherty, with subordinate amounts of shale and sandstone.

For the purposes of this report they may be divided very conveniently into two parts—an upper part made up of the formations of Chester age, and a lower part consisting of those of Meramec, Osage, and Kinderhook age. The upper rocks are of only subordinate importance in south-central Tennessee, for they crop out only in the small area of the escarpment of the Cumberland Plateau. Those of the lower groups form the principal strata of the Highland Rim.

FORMATIONS OF THE CUMBERLAND ESCARPMENT

GENERAL SECTION

Because formations of Chester age crop out in this area only in the escarpment of the Cumberland Plateau and in some of the coves within this plateau, they are restricted to rather narrow areas in eastern and southeastern Franklin County. Habitations upon them are found only in the small areas of the coves. Hence they have comparatively little importance in a regional study of ground water in south-central Tennessee.

The following section,[75] compiled from highway and railroad sections, typifies the lithology of these formations as found in this area:

Section from Sewanee to Cowan

	Feet
Pennsylvanian series:	
Gizzard formation:	
Sandstone.	
Black shale with plant fossils	10
Thin-bedded gray-brown sandstone	10
Covered	15
Thin-bedded grayish-yellow sandstone	5
Mississippian series:	
Pennington shale:	
Covered	10
Gray crystalline limestone with *Archimedes* and *Pentremites*	10
Covered	5
Red shale	5
Covered	10
Red shale	10
Dove-colored birdseye limestone	1

[75] Nelson, W. A., op. cit., pp. 26, 27.

Section from Sewanee to Cowan—Continued

	Feet
Mississippian series—Continued.	
Pennington shale—Continued.	
Yellow limestone	5
Red shale	9
Covered	25
[Bangor limestone (restricted):]	
Gray crystalline limestone full of crinoid fragments; contains *Agassizocrinus*	15
Hard grayish-brown crystalline limestone	5
Covered	30
Yellowish-gray shaly limestone	15
Unconformity.	
Gray shale	15
Yellowish shaly limestone	5
Covered	10
Yellowish-gray earthy limestone	5
Covered	10
Yellow limestone containing 2-inch band of glassy quartz	5
Yellow shale	5
Hard porous gray-brown limestone with oily smell	5
Yellow shaly limestone	20
Gray oolitic limestone	15
Covered	5
Gray limestone	10
Yellow shaly limestone	5
Shaly limestone	20
Gray birdseye limestone and gray semilithographic limestone	10
Gray granular limestone with gypsum geodes	5
Covered	40
Gray sandy limestone weathering slabby	5
Covered	30
Sandy limestone	5
Covered	4
Bentonitic greenish clay	1
Yellow and dove-colored limestone	30
Yellow semilithographic limestone containing fossil mud cracks	14
Coarse crystalline gray limestone	5
Yellow semilithographic limestone	10
Gray limestone	10
Hardinsburg sandstone [Hartselle sandstone restricted]:	
Calcareous sandstone	12
Golconda formation:	
Gray limestone	5
Gray shale	4
Covered	26
Gray limestone with small yellow pellets	3
Red and green mottled shale	2

Section from Sewanee to Cowan—Continued

	Feet
Mississippian series—Continued.	
Gasper formation:	
Gray oolitic limestone	5
Massive limestone	10
Covered	5
Massive gray limestone	5
Covered	45
Massive limestone with chert nodules	10
Covered	5
Dove-colored limestone	5
[Ste. Genevieve limestone:]	
Gray oolitic limestone containing *Platycrinus huntsvillae*	10
Generally limestone, with locally a foot or two of limy shale	95
St. Louis limestone:	
Gray cherty limestone, containing *Lithostrotion*	10

PENNINGTON SHALE

The Pennington shale is composed of sandstone, shale, and limestone. In many places in Tennessee the upper member is a 20-foot to 40-foot fossiliferous limestone. The sandstones are generally soft, fine-grained, and yellowish red and are in many places ripple-marked. The most outstanding characteristic of the Pennington formation consists of the red and green colors of its shales. These shales are generally fissile.[76]

The upper surface of the Pennington formation is very irregular, for it marks the unconformity between the Mississippian and Pennsylvanian series. The thickness of the formation is accordingly variable, ranging from 100 to 300 feet in eastern Tennessee.[77] The unconformity at its top is equivalent to at least 2,000 feet of sediments making up the Parkwood formation of the Cahaba Valley of Alabama.[78]

BANGOR LIMESTONE (RESTRICTED)

The Bangor limestone (restricted) is defined as lying between the Hartselle sandstone (restricted) below and the Pennington shale above. It includes only a part of the strata formerly called "Bangor limestone," which comprised all the strata from the Warsaw limestone to the Hartselle sandstone. The lower part of the Bangor limestone (restricted) is correlated with the Glen Dean limestone of Kentucky; the upper part represents higher formational units of the Illinois and western Kentucky section.[79]

[76] Nelson, W. A., op. cit., p. 36.
[77] Idem, p. 36.
[78] Butts, Charles, Geology of Alabama: Alabama Geol. Survey Special Rept. 14, pp. 204-206, 1926.
[79] Idem, p. 199.

The Bangor limestone as thus restricted consists largely of blue, coarsely crystalline or oolitic and highly fossiliferous medium to thick bedded limestone. The upper quarter, however, partakes more of the nature of the overlying Pennington shale; it is thin-bedded, gray, clayey, and nonfossiliferous.[80]

Several fossils are common and of diagnostic value. *Archimedes* is common in the Bangor and is only rarely found in lower formations. This bryozoan is recognized by the screw-shaped axis, which is usually the only part of the colony preserved. *Prismopora serrulata* is found in the lower part of the formation. This bryozoan is a diagnostic fossil of the Glen Dean limestone of western Kentucky and southern Illinois and is distinguished by the cross section of the colonies, which is in the shape of a small three-rayed star.[81]

This formation reaches a thickness of 375 feet in Franklin County.[82]

The water-bearing properties of the Bangor are those of other limestones: water is found in it generally in solution cavities. A small spring from this formation, high on the hillside, furnishes water for the town of Sherwood.

HARTSELLE SANDSTONE (RESTRICTED)

The Hartselle is a calcareous sandstone from 8 to 10 feet thick where observed in this area. It has been recognized near Cowan and Sherwood.

GOLCONDA (?) SHALE

A thin representative of the Golconda formation of southern Illinois has been identified by Butts [83] in Franklin County. It is about 40 feet thick in this section and consists of marly shale with subordinate limestone.

GASPER FORMATION

The strata in Franklin County identified as Gasper formation by Butts are composed largely of thick-bedded light-gray, generally oolitic limestone although some beds with a compact lithographic texture are also present. The formation is from 100 to 160 feet thick in other parts of Tennessee. It is lithologically indistinguishable from the underlying Ste. Genevieve limestone. Its guide fossils include *Campophyllum gasperense*, a compound coral differing from *Lithostrotion* in that the septa of the corallites do not meet; *Talarocrinus*, a crinoid that is almost entirely restricted to this formation; and several species of *Pentremites* with concave ambulacral areas.

STE. GENEVIEVE LIMESTONE

The Ste. Genevieve limestone has the same lithologic characteristics as overlying strata that are correlated with the Gasper formation.

[80] Butts, Charles, op. cit., pp. 195-199. Nelson, W. A., op. cit., pp. 30, 36.
[81] Butts, Charles, op. cit., p. 197.
[82] Nelson, W. A., op. cit., p. 35.
[83] Butts, Charles, Geology of Alabama: Alabama Geol. Survey Special Rept. 14, p. 191, 1926.

Its thickness in Tennessee is from 80 to 130 feet. Its chief guide fossil is *Platycrinus huntsvillae* (*penicillus*). This species is characterized by spiny stem plates and a base with three sharp keels. It is fairly common throughout the Ste. Genevieve in this region.

FORMATIONS OF THE HIGHLAND RIM

The formations of the Highland Rim are correlated with the Meramec, Osage, and Kinderhook groups of the Mississippian series. They consist in most part of cherty limestone, with subordinate cherty shale. On the east side of the rim the capping rocks belong almost entirely to the St. Louis and Warsaw formations; on the west side the lower formations are more prominent.

ST. LOUIS LIMESTONE

The St. Louis limestone is the uppermost formation capping the Highland Rim. It is best shown in the portion of the rim east of the Nashville Basin but extends over the western part of the Highland Rim almost to the Tennessee River, where, however, it is so thoroughly weathered that exposures of it are rarely seen. This formation consists generally of a fine-grained to compact gray, generally thick-bedded limestone carrying crinoid plates and some fenestellid Bryozoa. It is characterized by the compound corals *Lithostrotion canadense* and *L. proliferum*. These species are easily recognized. In both of them the corallites have septa which meet in the center in a raised protuberance, a characteristic which distinguishes *Lithostrotion* from the *Campophyllum* of the Gasper. In *L. canadense*, the more common species, the corallites are closely crowded, and their cross sections are polygonal; in *L. proliferum* the corallites may or may not touch, and their cross sections are circular. These diagnostic fossils, however, are not abundant enough to make it possible to distinguish between the St. Louis and the underlying Warsaw in a rapid survey of the territory.

The St. Louis limestone is 80 to 140 feet thick under the Cumberland Plateau in Tennessee.[84] At Sherwood, Tenn., and at Huntsville, Ala. (about 20 miles south of Lincoln County, Tenn.), it is 160 to 175 feet thick.[85] In the western part of the Highland Rim plateau its exposed thickness has not been determined because the contact with the underlying Warsaw is rarely if ever seen, being obscured by the mantle of chert debris that covers it. In Wayne County the exposed thickness of the St. Louis and Warsaw formations together is given as 150 feet.[86] The St. Louis is generally absent in Alabama south of Wayne and Lawrence Counties,[87] where the

[84] Nelson, W. A., op. cit., p. 32.

[85] Butts, Charles, op. cit., p. 177.

[86] Wade, Bruce, Geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 172, Tennessee Geol. Survey, 1914.

[87] Butts, Charles, op. cit., p. 175.

overlying formations are exposed. It is probably absent also in places in the southern parts of these counties.

The term "St. Louis limestone" has in earlier reports been used in Tennessee to include both the St. Louis limestone proper and the Warsaw formation.

The St. Louis limestone in unweathered outcrop is rarely seen in most of the area of this report. As a result of the long-continued weathering to which it has been exposed and of the solubility of the rock, it is generally covered by a thick mantle of residual clay and chert. The mantle derived from it and underlying formations has locally a thickness of 100 feet and probably in a few places reaches 200 feet. The depth of weathering increases westward. Where the St. Louis is thick it has well-developed underground drainage. Sink-hole topography seems to be much more common on it than on the other formations of the Highland Rim. Many examples are shown on the map of the Decherd quadrangle. The chert derived from the St. Louis is typically porous and in large pieces and is likely to contain the molds of many stem plates of crinoids. These characteristics of the chert serve to differentiate it from the chert derived from the Fort Payne and Ridgetop formations but not from that of the Warsaw formation, immediately underlying the St. Louis.

The water-bearing characteristics of the St. Louis limestone are, so far as observed, the same as those of the Warsaw formation and are set forth in connection with that formation.

WARSAW FORMATION

The Warsaw formation in this area is generally a grayish thick-bedded, in places cross-bedded limestone very much resembling the St. Louis. In the northern part of the State, along the western part of the Cumberland Mountains, it is a very sandy limestone about 100 feet thick.[88] Southward it loses its sandy characteristic, and in Alabama it appears to be a high calcium-carbonate rock with little insoluble impurity.[89] Here it suggests an original coquina composed largely of fossil fragments. Large and abundant fenestellid Bryozoa characterize many horizons in this formation in south-central Tennessee and elsewhere.

The Warsaw formation has never been mapped in south-central Tennessee. In all published reports on this area it has been included in the St. Louis limestone. Hayes and Ulrich [90] note the presence of several beds of heavy blocky chert carrying Warsaw fossils at the base of their St. Louis in the Columbia quadrangle. Miser,[91] in a

[88] Nelson, W. A., op. cit., p. 31.
[89] Butts, Charles, op. cit., p. 171.
[90] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 3, 1903.
[91] Miser, H. D., in Drake, N. F., Economic geology of the Waynesboro quadrangle: Resources of Tennessee, vol. 4, no. 3, p. 100, Tennessee Geol. Survey, 1914.

tentative correlation of the formations of the Waynesboro quadrangle, notes that the St. Louis of that quadrangle may include some Spergen limestone at the base. The Spergen has not been definitely recognized in southern Tennessee or Alabama. The lower part of the beds formerly called "St. Louis" in Wayne County probably belongs to the Warsaw formation, for 18 miles south of Wayne County, in Colbert County, Ala., the Warsaw is 200 feet thick and the St. Louis is absent.[92]

The St. Louis and Warsaw formations are both very soluble, and as a consequence both have well-developed underground drainage systems. In the eastern Highland Rim and in the deep valleys of the Cumberland Plateau many springs issue from these formations. They range in yield from about 2 gallons a minute or less to over 1,500 gallons a minute in those from which Winchester gets its water. On the west side of the Highland Rim springs from these formations are less prominent, because the formations are less well developed and commonly high in the hills. However, springs 260 and 152, used for the public supplies of Hohenwald and Wrigley respectively, derive their water from these formations. Adequate supplies of water for domestic and minor industrial uses are obtained from these formations by wells in parts of Franklin County.

In the western part of the Highland Rim no wells, so far as known, derive water from the unweathered St. Louis and Warsaw formations. These formations are here covered with a mantle of residual material, and in many places they have been entirely decomposed into clay and chert. Dug wells sunk into this residue usually find enough water for domestic uses. The average depth of such wells is about 75 feet, but some of the wells are considerably more than 100 feet deep, and one drilled well in western Lewis County is nearly 200 feet deep.

This thoroughly weathered residual material in many places preserves the traces of the solution channels that once existed in its parent limestone. Sand and gravel lenses and ribbons permeate it in various localities and in all probability represent deposits made in solution cavities in the limestone long ago. With the progressive decay of the limestone they were left in their present state, embedded in the chert and clay residue. These gravel and sand deposits probably act as galleries that collect the water from the less permeable clay in which they lie. Definite data proving that many wells obtain water from these deposits could not be obtained, but it is probable that to these sand pockets is to be ascribed in part the fact that the water level in wells in this residual cover is so variable.

[92] Butts, Charles, op. cit., pp. 169, 171.

FORT PAYNE CHERT

The Fort Payne chert varies in its lithology in this area from a siliceous limestone to a calcareous chert or a cherty shale. Bassler [93] describes the Fort Payne of the central basin as massive argillaceous limestone, weathering into a solid, brittle blocky chert and siliceous shale. In the western part of this area it is exposed as a calcareous chert, locally interbedded with shale. The chert is usually dull and of strong texture, but in many places layers of glassy solid chert can be seen. Near the top of this formation and extending into the overlying Warsaw (?) limestone in Wayne County are beds of tripolite, a soft, porous siliceous rock, derived by the leaching of the calcareous constituents from the original siliceous limestone. These beds attain a thickness exceeding 25 feet.[94] The thickness of the Fort Payne in Wayne County is from 100 to 200 feet.[95]

On the west side of the Highland Rim the Fort Payne rests on the Ridgetop shale. On the east side that formation is missing and the Fort Payne rests on the Chattanooga shale.

The Fort Payne chert furnishes water to many springs. Among the largest of these are those near Flintville and Kelso, in Lincoln County, from which Fayetteville derives its municipal water supply. On the west side of the Highland Rim the most outstanding springs from this horizon are those at Waynesboro and Lawrenceburg.

RIDGETOP SHALE

The strata lying below the Fort Payne chert and above the Chattanooga shale in Tennessee belong to two formations, the New Providence formation, of Burlington and Fern Glen age, and the Ridgetop shale, of Kinderhook age. In the area of this report the New Providence formation has never been identified, all the strata between the Chattanooga and the Fort Payne having been ascribed to the Ridgetop shale or its earlier-named partial equivalent the †Tullahoma formation. Without much doubt some of these strata will be placed in the New Providence formation when detailed stratigraphic work is done, but owing to the general lithologic similarity of the two formations and to the lack of opportunity for stratigraphic studies in the field season in which the data were collected for the present report, all these strata are here referred to the Ridgetop shale, as they were by Miser.[96] Those beds which are more calcareous than the typical Ridgetop shale and contain the large crinoid plates commonly associated with the New Providence formation are indicated by the explanatory term "crinoidal phase."

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[93] Bassler, R. S., The stratigraphy of the central basin of Tennessee: Tennessee Div. Geology Bull. 38, p. 155, 1932.

[94] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 129, 1921.

[95] Idem, p. 24.

[96] Idem, pp. 23, 24.

The stratigraphically higher of the two formations is the New Providence. This formation, whose type area is in Indiana, was first described in Tennessee by Bassler,[97] who identified it at Whites Creek Springs, about 12 miles north of Nashville. This description was later amended, and the section at this locality, where it is 35 feet thick, is now given as "coarsely crystalline white to gray crinoidal limestone layers 12 to 18 inches thick, formed by lenses of organic remains, separated by thin green to blue shale bands and overlain by gray-green to blue shales." Bassler [98] also points out that this formation is present only in embayments upon the Nashville dome.

In other parts of the Highland Rim escarpment the proportion of shale increases, and the description given by Bassler [98] for the formation in central Tennessee is "bluish clay shale with occasional crinoidal limestone layers." Its thickness ranges from 200 feet to the vanishing point, and it is confined to about the same geographic limits as the Ridgetop formation—that is, to the west and north sides of the Nashville dome.

Hayes and Ulrich [99] noted that occasional layers in the †Tullahoma formation of the Columbia quadrangle carried Burlington fossils. Hence it is probable that thin representatives of the New Providence occur in this region. In the southeastern part of the Waynesboro quadrangle "beds of apparently * * * [Ridgetop] age are present * * *; they are green siliceous shale and thin and thick beds of gray coarse-grained crinoidal limestone, in which there is generally some chert. Fossils are numerous in the limestone." [1] These beds are also well exposed in many places in the south half of Lawrence County and in southwestern Giles County. Some of the individual layers are composed of dense chert full of the molds of large crinoid plates and stems.

In Alabama, south of Wayne and Lawrence Counties, Butts [2] found lenses of green clay and shale and limestone containing Burlington fossils immediately above the Chattanooga shale. He concluded that some of the Ridgetop shale of the Waynesboro quadrangle is therefore of an age later than Kinderhook.

The name "Ridgetop shale" was proposed by Bassler [3] in describing a section near Ridgetop, Tenn., about 18 miles north of Nashville. Later the same author [4] amended his description somewhat and

[97] Bassler, R. S., The Waverlyan period of Tennessee: U. S. Nat. Mus. Proc., vol. 41, p. 218, 1911.

[98] Bassler, R. S., The stratigraphy of the central basin of Tennessee: Tennessee Div. Geology Bull. 38, p. 147, 1932.

[99] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 3, 1903.

[1] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 24, 1921.

[2] Butts, Charles, Geology of Alabama: Alabama Geol. Survey Special Rept. 14, p. 164, 1926.

[3] Bassler, R. S., The Waverlyan period of Tennessee: U. S. Nat. Mus. Proc., vol. 41, p. 216, 1911.

[4] Bassler, R. S., The stratigraphy of the central basin of Tennessee: Tennessee Div. Geology Bull. 38, p. 144, 1932.

described as the typical Ridgetop about 50 feet of light-blue to green shale with a little argillaceous limestone and chert. The predominant fossils are ostracodes.

This formation has been assigned to a Kinderhook age largely on the basis of one ostracode, *Ctenobolbina loculata* Ulrich, contained in it.[5] Hayes and Ulrich[6] recognized at the base of their †Tullahoma formation a group of siliceous and calcareous shales carrying an ostracode fauna, indicating that the shale is of very early Mississippian age. Bassler[7] later assigned these shales in the type section of the †Tullahoma formation to the Ridgetop shale.

In the Waynesboro quadrangle the Ridgetop shale is from a featheredge to 90 feet thick, increasing in thickness southward and southeastward. It is a gray and platy shale with few fossils, which becomes more calcareous and siliceous as it thickens.[8] In the Perry County region a maximum thickness of 120 feet of green, gray, and black fissile shale carrying fossils is correlated, at least in part, with the Ridgetop.[9] This shale is best developed on Coon and Cane Creeks and pinches out west of the Buffalo River. On the east side of the Highland Rim this formation is apparently everywhere absent.[10]

A bed of greenish glauconitic shale or, less commonly, sandstone, usually containing nodules of calcium phosphate, generally lies immediately above the Chattanooga shale in central and western Tennessee and is locally present in its proper stratigraphic position even where the Chattanooga is absent. This shale, from a few inches to 7 feet thick, has been named the "Maury shale." In the present usage of the United States Geological Survey it is called "Maury glauconitic member" and is considered the basal member of the Ridgetop shale. However, according to Bassler[11] it occurs at the base of so many formations that he considers it the introductory phase of whatever formation overlies it, and Swartz[12] presents faunal evidence indicating it to be much younger in western than in central Tennessee, reporting, for instance, basal Fort Payne species in this shale at Linden, Perry County.

The Ridgetop shale in some places where it has the more shaly facies serves as a deflecting member to bring the ground water in the overlying formations to the surface. Where it is more calcareous it is characterized by enlarged joint cracks, carrying water, and tubular springs.

[5] Bassler, R. S., op. cit. (Tennessee Div. Geology Bull. 38), p. 146.

[6] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 3, 1903.

[7] Bassler, R. S., op. cit., p. 144.

[8] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 24, 1921.

[9] Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 171, Tennessee Geol. Survey, 1914.

[10] Bassler, R. S., op. cit., p. 145.

[11] Idem, p. 143.

[12] Swartz, J. H., The age of the Chattanooga shale of Tennessee: Am. Jour. Sci., 5th ser., vol. 7, p. 29, 1924.

CARBONIFEROUS OR DEVONIAN SYSTEM

CHATTANOOGA SHALE

The Chattanooga shale is a fissile black bituminous shale that usually includes the Hardin sandstone as its basal member. The black shale is 22 feet in maximum thickness and the sandstone member 15 feet. In general both members thicken westward in this area. On the east side of the Highland Rim the Hardin sandstone was not seen, and in a few places, as near the Moore-Franklin County line, the typical Chattanooga shale is absent. In the valley of east Tennessee, east of this area, however, the Chattanooga thickens again.

The Hardin sandstone member ranges from a fine-grained to a coarse sandstone. In some places it is brown; in others black. It is generally somewhat phosphatic, and in eastern Lewis and Hickman Counties it is a commercial source of blue phosphate. Here the Hardin is gray to blue-black, generally fine-grained, in places granular.

The black shale is locally full of *Lingula* and conodonts. The Hardin sandstone also in many places contains these fossils and the bones of large fishes.

The Chattanooga shale is separated from both overlying and underlying beds by pronounced unconformities.

The age of the Chattanooga is a moot question. Evidence from fossils is inconclusive. In this area it was first ascribed to the late Devonian. Later areal stratigraphic work showed that the black shale of this region is probably, at least in part, of lower Mississippian age.

The Chattanooga shale is chiefly interesting in ground-water studies because of its imperviousness. It restrains the downward-moving ground water and deflects it laterally. As a consequence many of the large springs of the region issue from rocks close above this formation. The best example of a water table perched above the Chattanooga shale is shown in the plateau remnant in the vicinity of Hawthorne, Bedford County, where the Fort Payne immediately overlies the Chattanooga. The basal few feet of the Fort Payne is chert which has been honeycombed by ramifying and anastomosing solution channels, as well shown in the road cut on the Shelbyville-Fayetteville highway near Hawthorne. Practically all drilled wells in the plateau remnant above derive their water from this zone just above the Chattanooga.

Small springs issue from bedding planes and joint cracks in the Chattanooga at practically every exposure. These springs generally yield chalybeate or "sulphur" waters. Much pyrite (iron sulphide) is present in this shale. This compound, by interaction with the percolating water and the gases dissolved in it, yields, under various conditions, the "black sulphur" (iron sulphide) waters, "white sulphur" (hydrogen sulphide) waters, and "red sulphur" (iron hydroxide or chalybeate) waters. Small watering places and summer resorts are scattered along the outcrop of the Chattanooga.

DEVONIAN SYSTEM

Rocks of undoubted Devonian age have been recognized in south-central Tennessee only in Perry and Wayne Counties. The sea in which they were laid down evidently did not extend very far east of the present location of the Tennessee River. Furthermore, the shore line of the sea frequently shifted back and forth across the Perry-Wayne County area, with the result that erosional unconformities separate all of the eight formations ascribed to the Devonian in this area. As a result the stratigraphy is very complex, many different groupings of the strata have been made, and various ages have been ascribed to these strata by different students of the area. The subjoined discussion follows that of Dunbar,[13] who has made the latest and most thorough study of these formations.

PEGRAM LIMESTONE

The uppermost formation of unquestioned Devonian age in western Tennessee is the Pegram limestone. Although probably it once covered much of this area, it has been largely removed by pre-Chattanooga erosion, so that it is seen at only a few places in the valley of the Tennessee. It is exposed in only one locality in south-central Tennessee—in Wayne County near the mouth of Fortyeight Creek. It is a gray, coarsely crystalline crinoidal and pebbly limestone, about 6 feet thick at this exposure. It is of Onondaga age.[14]

CAMDEN CHERT

The Camden chert, also of Onondaga age, is probably not represented in this area. It occurs just west of Perry County but has not been identified in that county. Wade[15] ascribed 60 feet of chert in western Perry County to the Camden chert, but Dunbar[16] later correlated this same chert with the older Harriman chert. The two formations are lithologically similar, and a discussion of the chert of Perry County is given in the section on the Harriman chert, below.

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[13] Dunbar, C. O., Stratigraphy and correlation of the Devonian of western Tennessee: Tennessee Geol. Survey Bull. 21, 1919.

[14] Idem, p. 90. Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 23, 1921.

[15] Wade, Bruce, Geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 168, Tennessee Geol. Survey, 1914.

[16] Dunbar, C. O., op. cit., fig. 1, pp. 9, 79–91.

HARRIMAN CHERT

The Harriman chert, of Oriskany age, is a white novaculite weathering buff and brown. It is in general greatly fractured and crumbles, where exposed, into small fragments. It is exposed in the northwestern part of Perry County, along Lick and Toms Creeks, and also on Marsh Creek over a small area about 4 miles above its mouth. The maximum thickness of the chert in Perry County noted by Wade [17] is about 60 feet. This chert, although called "Camden" by Wade, is mapped by Dunbar as Harriman.

The influence of the Harriman chert upon the ground-water features of Perry County appears to be slight. It is generally found on steep hillsides, and the water used by inhabitants in the vicinity of its outcrop generally comes from springs in the underlying limestone. Its fractured condition probably renders it quite permeable to ground water.

QUALL LIMESTONE

The Quall limestone is typically a rather fine-grained, highly siliceous limestone about 10 feet thick. Its type locality is in Hardin County, and it is of Oriskany age. It is present at only a few places in the Tennessee Valley, and its only recognized representative in the area covered by this report is at the Town Spring, at Linden. Here, underlying the Hardin sandstone, there is a 30-inch layer of muddy and cherty gray limestone which has been doubtfully referred to this formation by Dunbar.[18]

DECATURVILLE CHERT

The Decaturville chert, the uppermost formation of the Linden group, of Helderberg age, occurs in western Tennessee but appears to be absent throughout the area considered in this report. On the west side of the Tennessee Valley it is a gray to yellowish chert about 5 or 6 feet thick.

BIRDSONG SHALE

The Birdsong shale consists of limestone and calcareous shale, with limestone predominating in this area. The formation was named from Birdsong Creek, in Benton County, where the upper, shaly portion of the formation is exposed. Through most of Perry County only the basal, more calcareous portion is present. In this region the Birdsong is generally represented by 11 to 22 feet of massive or thick-bedded crystalline fossiliferous limestone, although in a few places some of the fossiliferous shaly higher members of the Birdsong are present. The Birdsong includes the outcrops near Linden which gave the name "Linden group" to the strata of Helderberg age in western Tennessee.

[17] Wade, Bruce, op. cit., p. 168.
[18] Dunbar, C. O., op. cit., p. 69.

The Birdsong shale is exposed in this area only in Perry County north of the latitude of Linden, and even in this small region of outcrop it is absent at many places. About 5 feet is exposed at the Town Spring at Linden, 13 feet 1 mile north of the Buffalo River, 20 feet at Hinsons Mill, about 3 miles east of Beardstown, and comparable thicknesses along the Tennessee River. The water-bearing properties of the limestone member of the Birdsong shale in this area are similar to those of the other limestones. Large and small solution channels are developed in it, and these supply many tubular springs that issue from it. The best example of such springs is probably that at Hinsons Mill, on Cane Creek about 3 miles east of Beardstown. The flow of this spring is about 1,000 gallons a minute.

OLIVE HILL FORMATION

The Olive Hill formation lies stratigraphically below the Birdsong shale but is confined to the southern part of the valley of the Tennessee River in Tennessee, whereas the Birdsong is confined to the northern part, so that the two formations have never been found together. Only one member of the Olive Hill formation, the Ross limestone, is exposed in the area covered by this report, and that only in a small area around Clifton, in Wayne County. In an exposure 2¾ miles north of Glenkirk 9 feet of massive, coarsely crystalline gray siliceous limestone is exposed. Near Hughes Hollow, 2 miles south of Clifton, the thickness of the member is apparently 55 feet.[19]

SILURIAN SYSTEM

The Silurian rocks in south-central Tennessee consist of limestone and shale. They are more constant in their occurrence than the overlying Devonian and much more widely developed. However, they, too, were laid down in small embayments and suffered extensive erosion during Silurian and later time. Four formations are recognized. Unconformities separate these from the overlying and underlying rocks and from one another, with the single exception that the Brownsport formation is conformable upon the Wayne formation.

This report follows the present usage of the United States Geological Survey in that the underlying Richmond strata are placed in the Ordovician system, rather than in the Silurian. The Tennessee Geological Survey considers the Richmond to be of Silurian age.

DECATUR LIMESTONE

The uppermost formation of the Silurian in this area is the Decatur limestone, of late Cayuga age. This is a massive light-gray coarse- to fine-grained limestone, generally lacking fossils. It is separated from the overlying Devonian formations by a pronounced erosional

[19] Miser, H. D., op. cit., p. 23.

unconformity, which is, however, generally not distinguishable in single outcrops. The unconformity at its base is much more distinctly shown. The bulbous crinoid root *Camarocrinus* is somewhat common in this limestone but is also common in the overlying Birdsong shale.

This formation is exposed in places in the western part of Wayne County, where it attains a maximum thickness of 60 feet, and also along the Tennessee Valley in Perry County, where it attains about the same thickness.

The Decatur limestone presents the usual water-bearing features of limestones in this area. Many tubular springs issue from it.

BROWNSPORT FORMATION

The Brownsport formation is a stratigraphic unit consisting of shale, shaly limestone, and crystalline limestone. It and the underlying Wayne formation, on which it rests conformably, are of Niagaran age. It is separated from the overlying Decatur by an unconformity, as noted above. The formation attains a thickness of about 100 feet in Perry County and is somewhat thicker in Wayne County. Most of the exposures are in the western parts of these counties. It thins to the east and finally disappears, owing to truncation by post-Silurian erosion, the higher beds thus disappearing first. It is divided into three members, which are, in descending order, the Lobelville shaly limestone, the Bob crystalline limestone, and the Beech River shaly limestone.

The Lobelville shaly limestone member is composed of gray shaly limestone and yellow, blue, red, or purple shale. It has been divided into two zones—an upper coral zone, 45 feet thick, in which many species of coral are abundant, and a lower bryozoan zone, 31 feet thick, full of Bryozoa as well as corals.[20] Lithologically the Lobelville merges into the underlying Bob member, so that the contact is seldom clear.

The Bob crystalline limestone member is characterized by a massive, coarsely crystalline light-gray limestone, locally with some thin-bedded cherty limestone, reaching a thickness of 35 feet in places.[21] As defined by Pate and Bassler[22] the member is about two-thirds shale and is divided into three faunal zones on the basis of the brachiopods contained in it. It merges lithologically with the underlying Beech River member.

The Beech River shaly limestone member, the lowest member of the Brownsport formation, consists of shaly fossiliferous limestone and green and purplish shale. It attains a thickness of about 100 feet

[20] Pate, W. F., and Bassler, R. S., The late Niagaran strata of west Tennessee: U. S. Nat. Mus. Proc., vol. 34, no. 1621, pp. 422–423, 427, 1908.

[21] Miser, H. D., op. cit., p. 21.

[22] Pate, W. F., and Bassler, R. S., op. cit., p. 428.

in Wayne County. The sponge *Astreospongia meniscus* is common in it. It has been divided into three faunal zones by Pate and Bassler,[23] on the basis of the crinoids it contains.

The shales and limestones making up the Brownsport formation give rise to many tubular springs. The solution of the limestone layers allows the collapse of the intervening shaly strata. Springs of this nature are found in many places in the western counties of this area.

WAYNE FORMATION

The Wayne formation underlies the Brownsport conformably and is separated from the underlying formations by an unconformity. It is a series of shaly limestones and crystalline limestones. It has been divided into five members, described in descending order below.

The Dixon limestone member, the uppermost member of the Wayne formation, is an earthy limestone with shale layers. It is from 10 to 45 feet thick in Wayne County. Around Clifton and to some extent on the Buffalo River its color is red, but elsewhere it is blue to gray. The bryozoan *Fistulipora hemispherica* is abundant. At the top is a layer of indurated clay, 4 to 15 feet thick, which spalls off on an exposed surface, giving a distinctive rounded outcrop.[24]

The Lego limestone member is a resistant argillaceous and crystalline pink to blue-gray limestone, in layers from a few inches to 2 feet thick. It reaches a thickness of about 35 feet. Fossils are few, but small crinoid plates are locally present. The upper part of the member is more shaly and merges with the overlying Dixon.

The Waldron clay member is a thin indurated pink to gray fossiliferous clay, from 2½ to 5 feet thick, that lies below the Lego limestone. It generally contains a thin limestone layer near its center. Despite its thinness, it occurs over a wide area.

The Laurel limestone member is lithologically very similar to the Lego limestone, and generally only the position of the Waldron clay will determine to which of these two members a limestone outcrop belongs. Its thickness ranges from 15 to about 30 feet. The lower part of the member is shaly, and it grades thus into the underlying Osgood member.

The Osgood earthy limestone member is a thin-bedded earthy limestone from 10 to 17 feet thick. Near Clifton and Iron City it is red, but elsewhere it is bluish gray. It is somewhat fossiliferous.

Like all other limestone formations of this area, the Wayne formation is permeated with underground channels, and consequently its springs are numerous. The variation of the lithology within the formation does not seem to have any noticeable effect on its water-

[23] Pate, W. F., and Bassler, R. S., op. cit., pp. 418–419, 428.

[24] Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, no. 4, p. 165, Tennessee Geol. Survey, 1914.

bearing properties. The large spring resulting from the rise of Sinking Creek near Pleasantville, Hickman County, is in the shaly limestone of the Dixon, and Bunch Spring, on Cedar Creek, which is of comparable though somewhat smaller size, is in the massive Laurel limestone.

BRASSFIELD LIMESTONE

The Brassfield limestone is a fine to coarse crystalline light-gray limestone in many places glauconitic. Its maximum thickness is about 25 or 35 feet. It is bounded both above and below by unconformities and in places has been entirely removed. In some places a conglomerate and in others a sandy limestone forms its base. Near Iron City the Brassfield contains about 17 percent of metallic iron.[25] This formation is typically developed throughout the western part of the Highland Rim in this area. The sandy base and glauconitic limestone appear on the western edge of the eastern part of the rim, in southern Giles County. East of this it may be represented in some of the siliceous Silurian limestones, but, if so, it is different in its lithology.

The Brassfield limestone is characterized by solution passages similar to those of other limestones in this section.

ORDOVICIAN SYSTEM

FERNVALE FORMATION

The Fernvale formation, of Richmond age, consists of coarse-grained limestone and chocolate-brown and green shale. The proportion of limestone to shale varies locally, but in general about the lower half of the formation consists of limestone and the upper half of shale. In Wayne County the limestone is generally light gray, cross-bedded, and somewhat phosphatic. In the Columbia quadrangle the limestone locally assumes a flesh to red color and contains green specks. In some places the lower layers are conglomeratic. In eastern Giles County the formation is red and coarsely crystalline. Its thickness ranges usually in this area from 20 to 40 feet. It is bounded above and below by unconformities.

ARNHEIM LIMESTONE

The Arnheim limestone, also of Richmond age, has been recognized in only one place in this area—at Clifton, in Wayne County.[26] Here it is a bed of cherty gray fossiliferous limestone about 3 feet thick. Elsewhere in central Tennessee it includes some light-colored shale and attains a thickness of 60 feet.[27] Unconformities exist above and below it.

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[25] Miser, H. D., op. cit., p. 19.
[26] Idem, p. 18.
[27] Bassler, R. S., op. cit. (Bull. 38), pp. 121–124.

The reference of the Richmond formations of this area to the Ordovician system follows the usage of the United States Geological Survey. By the Tennessee Geological Survey and some other investigators this group is referred to the Silurian system and regarded, with the Brassfield formation, as of Medina age.

LEIPERS LIMESTONE

The highest Ordovician formation that is nearly continuous over the whole of south-central Tennessee is the Leipers limestone, the only representative of the Maysville group in the area. The type locality is along Leipers Creek, in northwestern Maury County.

The Leipers limestone is absent along the Tennessee River, where the Hermitage formation underlies the Arnheim limestone or the Fernvale formation. In southeastern Wayne County it consists of dark-blue fossiliferous phosphatic limestone and some shale and is over 75 feet thick. It is exposed around Centerville, in Hickman County, where it yields commercial phosphate rock. In this locality it is generally a granular oolitic and granular crystalline laminated phosphatic limestone and is 60 to 90 feet thick. Eastward to the vicinity of Columbia the character of the formation changes and new beds appear at the top. The whole formation becomes more shaly: the limestones become argillaceous, and shale beds are intercalated. At the top appear the distinctive large brachiopod forms, chief of which is the large, fat *Platystrophia ponderosa.* These beds are usually rubbly and knotty. The total formation is about 100 feet thick in this locality, and it maintains this thickness across to the east side of the Nashville Basin. Some of the lower beds were not deposited in certain places, and the erosion recorded in the unconformity at the top has planed off the higher beds. A pronounced unconformity exists at the base, the Eden group being missing throughout the area.

CATHEYS LIMESTONE

The Catheys limestone, of Trenton age, is lithologically very much like the Leipers. It is a highly fossiliferous knotty earthy limestone and shale. Its original thickness in the Columbia quadrangle was from about 50 to about 100 feet, but erosion has locally thinned the formation and even removed it entirely in places. Large masses of *Stromatocerium pustulosum* are locally abundant, and the evolute snail *Cyclonema varicosum* is characteristic of the formation. Beds of impure fine-grained limestone in the upper beds of the formation carry large ostracodes of the genera *Leperditia* and *Isochilina.*

CANNON LIMESTONE

The Cannon limestone, of Trenton age, consists predominantly of limestone but contains some shale. The limestone layers vary greatly in character, being at various levels argillaceous, crystalline, or semilithographic and thin-bedded or massive. The most distinctive lithologic feature of the formation, wherein it differs from the immediately underlying and overlying formations, is the large number of "dove" or semilithographic limestones. These "dove" members are compact, subcrystalline pale-green or blue to light-gray limestones which usually weather to white, smoothly rounded surfaces. The fracture is shallowly conchoidal, and fragments broken off are generally thin and keen-edged. The more argillaceous and crystalline layers resemble those of the Catheys formation, and the contact cannot be located without much more detailed work than could be done in the present investigation.

The entire formation is profusely fossiliferous, and the fauna is exceedingly varied. Near its base pelecypods of the genus *Cyrtodonta,* including the large species *C. grandis,* are abundant. Many of the "dove" layers are full of the ostracodes *Leperditia* and *Isochilina* and of the calcite-filled tubes of the alga *Scolithus columbina.* Large gastropods, particularly of convolute species, the colonial coral *Tetradium,* sponges, bryozoans, and brachiopods abound throughout.[28]

This formation has a maximum thickness of 300 feet in the eastern part of the Highland Rim. It decreases in thickness westward and is absent in the Columbia quadrangle. Formerly the lower portion was apparently considered an eastern, lithologically and faunally different facies of the typical Bigby of the Columbia quadrangle.[29] Later, however, Bassler [30] adduced evidence to show that it is a distinct formation with its greatest development on the east side of the Cincinnati arch but overlapping on the Bigby formation, deposited mainly on the southwest side of the Nashville dome. According to the usage of Bassler,[31] followed in this report, the †Dove and †Ward limestones of the section at Nashville are ascribed to the Cannon formation rather than to the Bigby formation, as formerly. The Cannon formation as defined for Rutherford County by Galloway,[32] following some of the earlier work of Ulrich,[33] included the Catheys and Bigby and hence is not the same as the Cannon limestone as the name is now used.

BIGBY LIMESTONE

The Bigby limestone near its type locality on Bigby Creek, in the Columbia quadrangle, is a nearly uniform series of gray phosphatic, semi-oolitic or granular, crystalline, laminated and locally cross-bedded limestone. At its base and at its top there may be a few

[28] Bassler, R. S., The stratigraphy of the central basin of Tennessee: Tennessee Geol. Survey Bull. 38, p. 106, 1932.

[29] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95) p. 2, 1903.

[30] Bassler, R. S., op. cit., pp. 85–105.

[31] Idem, p. 86.

[32] Galloway, J. J., Geology and natural resources of Rutherford County: Tennessee Geol. Survey Bull. 22, pp. 52–53, 1919.

[33] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 417, 1911.

feet of shaly layers, those at the top being generally arenaceous. It is here 30 to 100 feet in thickness. It is absent in many places on the east side of the Nashville Basin. The main mass of the formation is as a rule nearly devoid of fossils other than the minute gastropod *Cyclora* and related genera. The upper shaly beds, however, are in many places rich in Bryozoa, and shalier lenses throughout the formation locally contain *Hebertella, Dalmonella, Rhynchotrema,* and other brachiopods as well as gastropods. It is 45 to 90 feet thick in a well at Iron City, in southwestern Lawrence County.[34] It is absent in many places in the eastern part of the Highland Rim.

The Bigby limestone is equivalent to the †Capitol limestone and †Mount Pleasant phosphate and was formerly considered equivalent in part to the †Dove and †Ward limestones of Safford.[35] Bassler,[36] however, has correlated the †Dove and †Ward with the Cannon limestone. The Bigby rests unconformably on the underlying Hermitage formation.

The Bigby limestone is the most important source of phosphate in Tennessee. The limestone itself, although somewhat phosphatic, is not of commercial grade, and the phosphate deposits are the result of surficial enrichment of the beds. These deposits furnish an outstanding example of the work of ground water in this section. The unweathered rock was chemically a mixture of calcium carbonate and calcium phosphate and other materials. Calcium phosphate is much less soluble than calcium carbonate in ordinary ground water, which is charged with carbonic acid gas. During the long periods of weathering contemporaneous with the formation of the central basin the ground water slowly dissolved the surficial part of the rock, carrying away the calcium carbonate and leaving behind, in large part, the calcium phosphate. The result is that the soil and partly decomposed rock remaining are much higher in calcium phosphate than the original rock.

The mode of occurrence of workings in the phosphate demonstrates the action of ground water in seeking passages already partly opened for it by previously existing, generally minute fractures. The phosphate is found in parallel trenches or "cutters", between ridges or "horses" of unaltered phosphatic limestone. These cutters are enlarged joint cracks, which the percolating ground water has slowly enlarged from their originally minute dimensions to trenches many feet wide. Plate 6, *B*, shows some of these horses and cutters developed in old phosphate workings about 2 miles east of Mount Pleasant.

[34] Miser, H. D., op. cit., p. 17.

[35] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), correlation table, 1903.

[36] Bassler, R. S., The stratigraphy of the central basin of Tennessee: Tennessee Div. Geology Bull. 38, fig. 4, 1932.

HERMITAGE FORMATION

The Hermitage formation is a slightly phosphatic shaly and sandy limestone or calcareous sandy shale. When weathered it frequently has the appearance of a sandstone. In the Columbia quadrangle and near Andrew Jackson's old homestead, "The Hermitage", from which it takes its name, the basal 12 to 20 feet is generally composed of thin, even-bedded argillaceous and siliceous blue limestone layers separated by shale. Above this, for the remainder of its thickness of 40 to 70 feet, it is composed of thicker-bedded siliceous subgranular limestone with a little shale. Elsewhere in the area the limestone becomes less prominent, and in Giles, Marshall, and Lincoln Counties most outcrops are predominantly sandy shale. Where exposed in the banks of the Tennessee River at Clifton and nearby it consists of 70 to 80 feet of alternating layers of blue argillaceous limestone and shale. A well at Iron City, in southwestern Lawrence County, showed its thickness to be 126 feet.[37] Throughout the central basin the formation can generally be recognized by its lithology alone, as its sandy and shaly character is distinct from that of contiguous formations.

In most exposures this formation is distinguished by the multitude of shells of the small brachiopod *Dalmanella fertilis* (closely related to and formerly considered *D. testudinaria*), contained in it. These shells are generally silicified and may be found thickly speckling the soil derived from the Hermitage or thickly covering slabs of limestone from it. The abundance of these shells led Safford [38] to call this formation the "*Orthis* bed", these fossils being at that time referred to the genus *Orthis*. Locally, however, the *Dalmanella*-bearing beds are absent. Other prominent genera represented in its fauna are the corals *Tetradium* and *Columnaria*, the gastropod *Bucania*, the pelecypods *Ctenodonta* and *Modiolodon*, the brachiopods *Platystrophia*, *Rafinesquina*, and *Dinorthis*, and the bryozoan *Amplexopora*.[39] The Hermitage rests unconformably upon the Lowville limestone.

LOWVILLE LIMESTONE

The Lowville limestone, of lower Black River age, is a light-blue compact semilithographic limestone. In the Columbia quadrangle it is almost entirely thick-bedded and weathers out in white boulder-like masses in a red soil. In other portions of the central basin it shows the same character in part, but the upper beds are in many places medium-bedded and in some places—for instance, in Lincoln County—very thin-bedded and shaly, resembling the Lebanon limestone (described below) both lithologically and paleontologically.

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[37] Miser, H. D., op. cit., p. 15.

[38] Safford, J. M., Geology of Tennessee, p. 269, Nashville, 1869

[39] Bassler, R. S., op. cit., pp. 73-80.

The thick beds so typically represented on Carters Creek, in the Columbia quadrangle, were designated the "Carters limestone" by Hayes and Ulrich [40] and assigned an average thickness of 50 to 60 feet. The same name has generally been applied throughout the Nashville Basin to all strata between the Lebanon limestone below and the Hermitage formation above. Bassler,[41] however, has presented evidence that the Lowville limestone, or, as it has been generally called, the Carters limestone, is composed of two members. The lower, the Carters limestone member, is the typical Carters limestone of the Columbia quadrangle and is present only on the west side of the central basin. The upper member, with a maximum thickness of 100 feet, is, according to Bassler, equivalent to the Tyrone limestone of Miller in Kentucky and is developed throughout the Nashville Basin, except in the Columbia quadrangle.

This Lowville limestone is not very fossiliferous. *Stromatocerium rugosum*, *Columnaria halli*, and *Tetradium* are fairly common. Ribbonlike Bryozoa (*Escharopora* and *Rhinidictya*) mark some of the thinner layers. Very many species of evolute gastropods are locally present. Small ostracodes (*Primitella* and *Eurychilina*) are abundant in many places. In the thin shaly beds present here and there at the top of the Carters limestone, *Plectambonites* and other typically Lebanon forms occur.

The Lowville limestone rests unconformably on the Lebanon limestone.

At or near the top of the Lowville in the eastern part of the basin there are one or two beds of bentonite, or altered volcanic ash.[42] The bentonite of this section is usually a green unctuous clay, in which numerous flakes of black mica and locally feldspar grains occur. Bands of granular calcium carbonate are common in the upper part of the deposit. The unusual mineral leverrierite, resulting from the alteration of the original rhyolitic material, gives the bentonite its characteristic soapy feel and its property of swelling in water. The bentonite of this area extends at least to Birmingham, Ala., on the south and to Frankfort, Ky., and probably beyond, on the north. Good exposures of the bentonite are found near Singleton, in southeastern Bedford County (the discovery locality); about 1 mile south of Bellbuckle, in the northeastern part of Bedford County; and near Belfast, in Marshall County. When the bentonite is encountered in drilling, it commonly caves off in long pencil-like forms. The green caving formation is readily recognized by the drillers and has been named by them the †"Pencil Cave." In drilling operations this is the most valuable horizon marker in the Ordovician system.

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40 Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 1, 1903.

41 Bassler, R. S., op. cit., pp. 61–70.

42 Nelson, W. A., Volcanic ash bed in the Ordovician of Tennessee, Kentucky, and Alabama: Geol. Soc. America Bull., vol. 33, pp. 605–615, 1922.

LEBANON LIMESTONE

The Lebanon limestone is a very thin-bedded formation composed of bluish compact argillaceous limestone, as a rule extremely fossiliferous. It weathers to bare surfaces, the "cedar glades" of the central basin, and although other formations give rise to some of these glades, the Lebanon limestone so commonly underlies them that Safford gave it the name "Glade limestone." In the Columbia quadrangle it is over 125 feet thick, the base being nowhere exposed. It averages over 100 feet in thickness.

The Lebanon limestone is in general abundantly fossiliferous, although in some beds and in some localities fossils are rare. The most common fossils are the brachiopods *Plectambonites*, *Zygospira*, *Scenidium*, and *Orthis tricenaria*, many gastropods, including large forms of *Trochonema*, the rather large ostracode *Leperditia fabulites*, and the bryozoan with alined rhombic apertures, *Escharopora*.

The Lebanon limestone crops out in a circular band entirely surrounding the Nashville dome. It underlies the towns of Shelbyville and Lewisburg and the eastern part of Maury County. The Lebanon rests conformably on the Ridley limestone.

RIDLEY LIMESTONE

The Ridley limestone has little surface exposure in this area, being confined to northwestern Bedford County and northern Marshall County. It is a massive, dense drab limestone, and its massiveness contrasts with the thin-bedded structure of the Lebanon limestone above. It is only sparingly fossiliferous. Its characteristic fossils as given by Galloway [43] for Rutherford County, where it is best developed, are *Stromatocerium rugosum*, *Camarella volborthi*, *Hebertella bellarugosa*, *Gonioceras anceps*, *Orbignyella sublamellosa*, *Liospira convexa*, *Rafinesquina minnesotensis*, and *Protorhyncha ridleyana*. Its thickness in the same locality is given as 100 to 120 feet.

ROCKS NOT EXPOSED

Conformably underlying the Ridley limestone is the Pierce limestone, which in turn overlies the Murfreesboro limestone. These are the lower formations in the Stones River group. The Pierce is a thin-bedded, somewhat shaly limestone about 25 feet thick; the Murfreesboro is a massive limestone more than 70 feet thick. Under these in the central basin are other limestones and dolomites of Lower Ordovician age, of which only one formation is outstanding in the well logs that furnish all available data concerning these formations in the basin. This is a sandy limestone, in places perhaps a real sandstone, lying about 1,500 feet below the Chattanooga shale at Nashville and apparently about 600 feet below the top of the Murfreesboro lime-

[43] Galloway, J. J., Geology and natural resources of Rutherford County: Tennessee Geol. Survey Bull. 22, p. 42, 1919.

stone at Murfreesboro. This formation has been doubtfully correlated with the St. Peter sandstone.[44] A similar formation lies at an approximately equal depth below the Murfreesboro limestone in the Gower well, in Marshall County. It is important because it yields water and oil in various parts of the basin.

WATER-BEARING PROPERTIES OF THE ORDOVICIAN ROCKS

All the Ordovician formations as exhibited in this area have much the same water-bearing properties. All are calcareous, and as a result underground drainage is well developed throughout. In the purer limestones the openings are likely to have somewhat regular cross sections; in the more shaly members, where the channels are probably due to caving of the shaly beds accompanying the solution of the more calcareous beds, their cross sections are more varied. The channels emerge in the form of tubular springs throughout the stratigraphic section and in all parts of the area. As a rule, the springs emerging from the Ordovician rocks are smaller than those from the Mississippian beds, but this difference is probably a result of the low relief of the country in which the Ordovician rocks crop out rather than of lithologic differences. This conclusion is borne out by the exception to the rule found in a few large springs in the Ordovician in regions where the relief is greater than usual. For instance, one spring north of Campbellsville, in Giles County, which had a flow of about 1,700 gallons a minute when visited, issues from the Catheys limestone but lies at the base of a steep hill capped by the Mississippian. Similarly a spring just north of Smithport, in southern Maury County, flowing 400 gallons a minute from the Hermitage formation, is at the base of the dividing ridge between the Duck and Elk Rivers.

In general wells for domestic use are drilled successfully in all parts of the Ordovician outcrop area. They range in depth from 20 to about 200 feet. In a few places no water has been obtained, the rock for considerable depths having been found tight and dry. East of Match a well 300 feet deep was drilled through the Lebanon and Ridley limestone and probably through the Pierce into the Murfreesboro limestone without finding water. The hole was so tight that it was used for a cistern. Two other dry holes within 300 feet were also drilled. Another well at Baugh, in southeastern Giles County, over 350 feet deep, was also dry and was used for a cistern. This well started in Catheys (?) limestone and probably went into the Lowville limestone or possibly farther. Such localities probably represent areas in which the jointing of the rock is not well developed, and the failure to get water probably cannot be correlated even indirectly with the stratigraphy.

[44] Piper, A. M., Ground water in north-central Tennessee: U. S. Geol. Survey Water-Supply Paper 640, p. 61, 1932.

Many wells penetrating the Stones River group find water that is highly mineralized and impotable. Other wells are highly charged with hydrogen sulphide. Some shallow wells are reported to strike pockets of natural gas and petroleum. These wells all derive water from below the general drainage level of the region. It is believed that these abnormal waters are largely fossil waters, included in cavities in the rocks in some past geologic period, and hence have no relation to the stratigraphy. The high sodium chloride content of most of the mineralized waters strongly suggests this origin.

COUNTY DESCRIPTIONS

SCOPE

In the following pages the ground-water supplies and the general geologic characteristics of the individual counties in the area are discussed. For each county a table of wells and springs studied individually and a table of chemical analyses is included. These tables present the data on which the general description of water supplies in the county is largely based.

The altitude given in these tables is of course the altitude of the ground surface at a well and of the orifice at a spring. Most of these altitudes were determined by aneroid barometer. A curve showing the variation in air pressure was plotted for each day from readings at known altitudes, and from data on the rate of variation given by readings on the same point passed twice or oftener during the same day. The barometric readings at the wells and springs were corrected according to the curve thus obtained. For many of the shallow wells the depth to the water-bearing beds was unrecorded and unknown. As drilling is generally stopped when an adequate supply of water is reached, which does not need to be large for most household wells, the aquifer has been assumed in most shallow wells to be at or near the bottom of the hole. The depths of most wells less than 200 feet deep were measured by steel tape if less than 100 feet, or by heavy cord if between 100 and 200 feet. If the well was not actually measured and the depth given is a reported depth, no date is given under "Date of measurement." This last statement also applies to the data on water level in the wells; if a date is given, the depth to water level was measured; if no date is given, the depth was reported. The total hardness of the water from most of the wells and springs as given in the well and spring tables was determined in the field by shaking a measured volume of the water with enough of a standard soap solution to cause a thick semipermanent layer of suds to form, hardness being indicated by the amount of the soap solution needed. The results so obtained should in the main be comparable to the total hardness determined in the laboratory, and a comparison with the figures for total hardness shown in the tables of chemical analyses will show that they are generally reliable within 10 percent.

If the date of measurement is given beside the figure for approximate yield in the spring table, the yield was measured; if not, it was reported. The measurements of yield are rough and were made by the float method. The best available stretch of channel was selected, and the time taken for floating material to travel a given distance, both in the main current and near the sides of the channel, was determined. The average cross section of the channel was determined, and the rate of flow was then calculated. The rate so obtained was then generally reduced by 20 percent, to take account of the fact that the surface velocity is usually somewhat greater than the average velocity of the stream.

The figures given for population are those of the census of 1930.

BEDFORD COUNTY

[Area 514 square miles, population 21,077]

Bedford County is a roughly square area on the east side of the Nashville Basin. It is bounded on the north by Rutherford County, on the east by Coffee County, on the south by Moore and Lincoln Counties, and on the west by Marshall County. Shelbyville is the chief city and county seat and has a population of 5,010.

The Duck River flows approximately through the middle of the county in a westerly direction. The northern boundary of the county is roughly the divide between the Duck River and the Stones River, a tributary of the Cumberland, and the southern boundary in general separates the waters of the Duck and Elk Rivers.

Transportation in the county is furnished by one railroad and several highways. The Nashville, Chattanooga & St. Louis Railway crosses the eastern part of the county from north to south, and a branch line connects Shelbyville with the main line. Two fair-sized towns, Bellbuckle and Wartrace, lie on the main line. Hard-surfaced State and Federal highways connect Shelbyville with Murfreesboro, Tullahoma, Lynchburg, Fayetteville, and Lewisburg, giving trunk roads to the north, southeast, south, and west. The county is entirely rural in character.

GEOLOGY

Bedford County lies almost entirely in the Nashville Basin. A few promontories and remnants of the Highland Rim fringe its southern, eastern, and northeastern boundaries, but these are minor topographic features. The Highland Rim remnant at the corner of Moore and Bedford Counties represents the highest point of the rim in the entire south-central Tennessee area, so far as observed. It attains an altitude of over 1,200 feet, to judge from highway levels run over it. The Duck River is at an altitude of about 600 feet in the eastern part of the county, and therefore the total relief in the county is about 600 feet. Most of this relief is concentrated near the dividing ridges. The northeastern three-quarters of the county varies in its topography from plainlike to gently rolling. The entire county is well drained by tributaries of creeks flowing into the centrally located Duck River. The underground drainage is expressed at the surface by numerous small sink holes.

Bedford County exhibits a long stratigraphic column ranging from the Warsaw formation of the Mississippian series down to the Ridley limestone of the Ordovician system. The Warsaw formation is represented by weathered chert beds on the eastern border of the county and near Hawthorne, on the southern border. Only a thin remnant of the formation now remains. The Fort Payne chert, the next formation below the Warsaw, is well developed. Its thickness in the southern part of the county is about 100 feet. The Fort Payne is underlain by about 1 foot of green clay shale that apparently represents the Maury glauconitic member of the Ridgetop shale, the only part of the Ridgetop present in this area, which in turn overlies about 5 feet of the black Chattanooga shale (Devonian or Mississippian), containing in places a bed of black sandstone about 2 inches thick, which may represent the Hardin sandstone member. The Silurian system is unrepresented in this county, so far as observed, if the Fernvale formation is considered as not belonging to that system. Underneath the Chattanooga shale lies a thickness of 20 to perhaps 45 feet of strata of Richmond age, the greater part, at least, of the beds seen representing the Fernvale formation. On the Shelbyville-Fayetteville highway near the county line 22 feet of fossiliferous chocolate-brown, green, and blue shale and shaly limestone is exposed in a road cut. This is probably Fernvale. Below this exposure there is a covered interval of 25 feet, below which appears nodular blue argillaceous limestone with the giant fauna of the upper member of the Leipers limestone. The Catheys limestone, with similar lithologic characteristics, lies below this and overlies the Cannon limestone with its dove-colored compact limestone beds. These two formations are of the order of 200 feet thick in the county. The Bigby limestone was not recognized in the county. The general sequence below this is best represented by the following section, largely quoted from Bassler.[45]

[45] Bassler, R. S., The stratigraphy of the central basin of Tennessee: Tennessee Div. Geology Bull. 38, pp. 34-35, 1932.

Section 4½ miles southeast of Shelbyville

	Feet
Cannon limestone:	
Massive impure dove-colored limestone, interbedded with dark blue granular limestone to top of hill. *Tetradium laxum* zone near base and *Cyrtodonta grandis* 10 feet higher.	
Earthy, knotty limestone crowded with *Tetradium fibratum* in lower part and trilobite fragments in upper part	10
Hermitage formation:	
Argillaceous, rather thin-bedded limestone yielding *Lichenaria* on weathering	10
Yellow shale and sandy unfossiliferous strata	20
Lowville limestone (upper part):	
Worm-burrowed dove-colored limestone, sun-cracked and cherty	¼
Dove-colored limestone in layers 1 to 4 inches thick with interbedded thin shaly dove-colored strata. Bryozoa and other fossils in upper part and pelecypods in lower part	8
Bentonite—unctuous green clay with sandy clay bed in middle	2
Thin-bedded dove-colored limestone interbedded with thin layers of gray clayey limestone full of fucoidlike markings. *Rhinidictya* zone in upper part; reef of *Tetradium cellulosum* below; small ostracodes below this; *Leperditia fabulites* at base	20
Lower bentonite bed—green to yellow clay with coarse feldspathic sand grains	0.7
Massive pure dove-colored limestone with a few magnesian layers in 1-foot and 2-foot beds; fossils few; weathers to chert.	

The Lowville limestone is underlain by the Lebanon limestone (of the Stones River group), a thin-bedded limestone that is about 100 feet thick in this county but has a measured thickness of 80 to 120 feet in Rutherford County, just to the north.[46] This formation is the most common surface rock of the county, covering most of the northwestern part. A few outcrops of the underlying massive Ridley limestone occur.

Structurally, Bedford County lies on the southeast side of the Nashville dome. Minor folds occur in the county, and in the southwest corner some faults were observed.

GROUND WATER

The water-carrying properties of the rocks of Bedford County seem to be little influenced by their stratigraphic position. The rocks exposed here are a series of limestones and shales, and the members

[46] Galloway, J. J., Geology and natural resources of Rutherford County: Tennessee Geol. Survey Bull. 22, p. 31, 1919.

differ apparently only in the proportion of shale in them and the character of the bedding of the limestone—that is, whether it is thick-bedded or thin-bedded. Water passes through them through openings which it has largely made itself, by solution of the limestone along original planes of weakness formed by bedding planes or joint cracks. The character of the rocks in Bedford County may influence the development of the underground channels to some extent, but there is not enough variation in lithology to establish any other mode of occurrence of ground water. The intensity of jointing and the present and former positions of the rocks with respect to the water table seem to be the factors largely controlling the number and size of underground channels. In that part of the county lying away from the Highland Rim remnants all the larger springs appear to issue from the more massive limestone beds, indicating that larger channels are developed in these beds than in the thinner-bedded rocks. This seems to be the only effect of the lithology upon the ground-water occurrence in the plainlike portions of the county.

In the high remnants of the Highland Rim in the southern and eastern parts of the county there is one prominent lithologic control of the ground water. The Chattanooga shale forms an impassable membrane which deflects the percolating ground water laterally and gives rise to a perched water table. This is especially well shown in the vicinity of Hawthorne, on the southern border of the county, where a very porous zone in the basal Fort Payne chert may be seen just above the outcrop of the Chattanooga on the Shelbyville-Fayetteville highway. This porous zone forms the aquifer for wells on these outliers. All the wells go down to about the level of this zone, and drillers report that many of the wells are drilled into the black shale. It is further reported that if water is not found at this depth the well is likely to be dry or, at least, must be drilled much deeper to find water in the underlying Ordovician rocks. Well 401, just across the line in Moore County, is representative of these wells deriving water from the basal Fort Payne chert.

Although the number and size of the openings must be affected by the jointing developed by structural movements, this effect is more or less uniform throughout the county. No local ground-water phenomena have been correlated with local structural conditions.

In the plains of the northwestern part of the county apparently only the uppermost rocks are porous enough to yield water to wells. Drilled wells are generally successful at depths averaging about 100 feet. The deepest successful well drilled for water, of which a record was obtained, is only 185 feet deep (well 2), and many deeper holes were reported dry. For instance, a well reported to be 280 feet deep, northeast of Rover, in the extreme northeastern part of the county, is dry. At Unionville water was obtained in a well 114 feet deep (well 5), after six other holes about 200 feet deep had been drilled within a radius of 200 feet of the site of the successful well. At Bellbuckle an oil test, reported to be 1,200 feet deep, is said not to have struck water at any depth in sufficient quantity with which to drill. It would seem, therefore, that the rocks lying much below the general drainage level are likely to furnish very little water.

Many of the deeper wells and some of the shallower ones in this area yield water containing hydrogen sulphide, and a few yield strong chloride and sulphate waters. These impotable waters are probably derived from cavernous or porous zones which apparently are not connected with the present drainage system. Such cavernous zones were probably developed in some Paleozoic erosion period and later filled with sea water or concentrated brines during a succeeding submergence of the area.

Data concerning large supplies of water for other than domestic uses are very scarce. The only well in the county that furnishes a fairly large amount of water, so far as known, is well 20a, at the ice plant of the Tennessee Electric Power Co. in Shelbyville. This well is pumped at the rate of 90 gallons a minute, with, as reported, no weakening of the well. The water level is reported to vary seasonally from 50 to 63 feet below the surface. Unfortunately the aquifer is not known, because an old well reported to be 1,500 feet deep, about 400 feet from the well in use, is apparently connected with it through a large solution channel 110 feet below the surface. The water level in one well is reported to be always the same as that in the other. Therefore, the aquifer furnishing the water may be at any depth ranging from 110 to 1,500 feet. The analysis (see p. 92) shows nothing particularly unusual; the water might be derived from shallow water-bearing beds, and the report that there is a large seasonal variation in the water level indicates that the aquifer is connected with the surface not far distant and suggests that the water is derived from a comparatively shallow depth.

A heavy flow of salty hydrogen sulphide water is reported to have been struck at a depth of 1,800 feet in well 13, an oil test about 2 miles east of Bellbuckle. This reported depth is considerably greater than that of the supposed horizon of the St. Peter sandstone. No other data on this horizon are available. It is possible that the report is in error as to the depth at which water was struck.

No large springs exist in this plainlike part of the county. The best-known spring and the one furnishing the largest flow so far as known is Sims Spring (spring 38), in the west-central part of the county, the flow of which was about 12 gallons a minute when measured. Spring 34b furnishes a milk plant at Bellbuckle. It is reported to satisfy the plant requirement of 2,000 gallons a day, except in a dry summer, such as that of 1930, when water had to be hauled to the plant from Murfreesboro.

Springs issue from above the Chattanooga shale in many places on the side of the hills. The largest in the vicinity are Cascade Springs, in Coffee County, a few miles east of Normandy. These springs were to be the source of a projected public supply for Wartrace. The water issues just above the Chattanooga shale, for a distance of over 100 feet. This spring and another a quarter of a mile distant flow a total of 1,700,000 gallons a day, or 1,180 gallons a minute, according to measurements made by engineers in planning the water supply. The flow is reported to be nearly constant throughout the year.

The quality of water obtained in the county varies widely. The water from the chert beds overlying the Chattanooga shale is soft and has a low mineral content, as shown by the analysis of well 401 given on page 159. That from the Ordovician limestone beds is usually a calcium-bicarbonate water and therefore hard, although the water from well 17a is very soft, probably as a result of natural zeolitic softening. Hydrogen sulphide is a common constituent of these waters. A few, including wells 12 and 18, for which analyses are given, are high in the sulphate and chloride radicles and entirely unfit for ordinary uses.

The city of Shelbyville derives its water from the Duck River. The system has a capacity of 1,000,000 gallons a day.

Records of wells in Bedford County

[No. 32 dug; all others drilled]

No. on plate 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
1	Unionville, 4 miles north	Bedford County	Plain	790	130	6
2	do	Rover Baptist Church	do	770	185	6
3	do	J. W. Brown	do	785	75	5
4	Unionville	G. N. Brown	do	720	150	5
5	Fall Creek	S. J. Osborn	do	750	114	6
6	Longview	W. E. Brown	do	770	81	5
7	do	do	do	780	91	6
[a] 8	Shelbyville, 11 miles north	Preacher Blackman	do	830	700+	9
[a] 9	do	D. B. Spence	do	825	102	6
10	Shelbyville, 5 miles north	T. P. Overcast	do	820	156	6
11	Bellbuckle, 1 mile northwest	D. C. Vance	do	870	1,200	(?)
[a] 12	Bellbuckle, 1½ miles south	Emmet Arnold	Hillside	870	36?	5
13	Bellbuckle, 2 miles east	J. H. Crouch	do	880	2,445	(?)
14	Bellbuckle, 5½ miles northeast	W. T. Jacobs	Valley	885	55	6
15	Bellbuckle, 3½ miles southeast	J. W. Winnette	Hillside	870	157	6
16	Wartrace, 1 mile northwest	T. A. Shriver	do	810	1,900	10
[a] 17a	Wartrace	E. L. Blackman	do	865	185	6
17b	do	do	do	865	40	6
[a] 18	Haley	Nashville, Chattanooga & St. Louis Ry	do	850	155	6
[a] 19	Shelbyville, 2 miles south	J. B. Rogers	Spur	845	116	6
[a] 20a	Shelbyville	Tennessee Electric Power Co	Plain	640	120	10
20b	do	do	do	640	430	10
20c	do	Nashville, Chattanooga & St. Louis Ry	do	640	1,500	(?)
21	Shelbyville, 3½ miles northwest	H. C. Bledsoe	do	760	93	6
22	Bedford, 4 miles west	R. C. Pearman	do	810	50	5
23	Bedford	R. L. Tucker	do	810	42	5
24	do	Ernest Cooper	do	810	60±	5
[a] 25	Bedford, 3 miles west	W. A. Dillard	do	770	75	6
26	Petersburg, 5 miles northeast	W. G. Freeman	Hillside	860	30	5
27	do	C. F. Smith	do	870	56	5
28	Shelbyville, 6 miles south	G. P. Evans	do	875	65	5
29	do	do	do	865	84	6
30	Flat Creek, 3 miles northeast	Joe Harrison	do	810	101	6
31	Flat Creek	John Haithcote	do	780	53	6
32	Flat Creek, 4 miles southeast	George Gowan	Plateau	1,100	41	60
33	Flat Creek, 4 miles east	A. H. Riddle	Plain	860	19	4

[a] Analysis given in table of analyses.

No. on plate 1	Water-bearing beds			Water level		Use of water	Total hardness as $CaCO_3$ (parts per million)[b]	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)			
1	130±	Limestone	Ridley limestone	−39.5	Oct. 25	Domestic	70	
2	185±	do	do	−29.5	do	Domestic; stock	225	
3	75±	do	Lebanon limestone (?)	−23	do	do	275	
4	150±	do	Ridley limestone (?)	−18.5	do	None	80	Water has green color.
5	114±	do	do. (?)	−58	Oct. 27	Domestic	135	Contains H_2S; 6 other holes drilled to a depth of 200 feet within a radius of about 200 feet yielded no water.
6	81±	do	do. (?)	−31.6	Oct. 25	Domestic; stock	290	
7	91±	do	do. (?)	−34.6	do	do	215	Contains H_2S.
8	(?)	(?)	(?)	−4.0	do	do	260	
9	102±	Limestone	Ridley limestone	−20.0	do	Stock	315	
10	156±	do	do	−30		Domestic; stock	305	Contains slight amount of H_2S.
11				(?)				Oil test; reported no water in sufficient quantity with which to drill. Well started in Lowville.
12	36?	Limestone	Lowville limestone	−27	Oct. 20	Medicinal		
13	85	do	do					Oil test. At this depth water, gas, and oil.
	248	do	Stones River group					Oil.
	1,800	(?)	(?)					Heavy flow of "Blue Lick" water.
14	55±	Limestone	Lowville limestone (?)	+3.3	Oct. 21	Stock	185	Contains H_2S.
15	157±	do	Lebanon limestone (?)	−27		Domestic; stock	25	Contains H_2S; oily taste.
16	(?)			(?)		None		Oil test. Struck water but amount and quality unknown. Well started near top of Lowville.
17a	170	Limestone	Lebanon limestone	−170±		Washing	10	Contains much H_2S. Similar "sulphur" wells in town reported to be very responsive to precipitation.
17b	40±	do	Lowville limestone	−34.3	Oct. 20	Drinking and cooking	375	Supplements previous well for domestic use.
18	152	do	Lebanon limestone (?)	−105		None		Salty; odor of natural gas; unfit for domestic use.
19	116±	do	Lebanon limestone	−92	Oct. 24	Domestic; stock		Salty, acid taste; H_2S.
20a				−50 −63		Cooling water	320	Contains H_2S; probably connects through solution channel, 10 inches in height, with 1,500-foot well (20c) 400 feet distant.
20b				−50 −63		None		Well 3 feet from preceding one. Apparently no water struck below the open channel at 110 feet.
20c	(?)	(?)	(?)	−50 −63				Water reported to contain H_2S. Water in this and two preceding wells reported always to be at same level, uninfluenced by pumping but varying with season.

[b] Determined in field with standard soap solution.

Records of wells in Bedford County—Continued

No. on plate 1	Water-bearing beds			Water level		Use of water	Total hardness as $CaCO_3$ (parts per million)	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)			
21	93±	Limestone	Ridley limestone	−64.2	Oct. 27	Domestic	365	
22	50±	do	Lebanon limestone	−38.8	do	Domestic; stock	345	
23	42±	do	do	−23.0	do	Domestic	220	
24	60±	do	do	−19.5	do	Domestic; stock	265	Contains H_2S.
25	75±	do	Ridley limestone (?)	+1	do	do	265	Do.
26	30±	do	Hermitage formation	−14.2	Oct. 28	do	370	
27	56±	do	do	−45.6	do	do	490	
28	65±	do	do. (?)	−50	do	None	485	Reported to have been 96 feet deep and water unfit to drink.
29	84±	do	Lowville limestone	−39.4	do	Domestic; stock	375	
30	42	do	do	−10.5	Oct. 24	Domestic	235	Contains H_2S.
31	53±	do	do	−14.0	do	None	305	Do.
32	60±	Residual chert	Fort Payne chert	−35.4	Nov. 19	Domestic		
33	19±	Limestone	Cannon limestone	−9.5	Oct. 24	do	180	

Records of springs in Bedford County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude above sea level (feet)	Kind of rock	Stratigraphic position
34a	Bellbuckle	Bellbuckle Milling Co	Valley	865	Limestone	Lowville limestone.
35b	do	Carnation Milk Co	do	865	do	Do.
[a] 35	Bellbuckle, 1 mile south	Oscar Lovell	Bluff	845	Bentonite	Do.
36	Wartrace, 4 miles northeast	A. E. Strong	do	810	Limestone	Do.
37	Haley	W. T. Hickson	Head of drain	890	do	Cannon limestone.
38	Shelbyville, 9 miles west	Wm. Darnell estate	Branch	730	do	Ridley limestone (?).
39	Shelbyville, 5 miles southeast	E. C. Swing	Hillside	810	do	Lowville limestone.
40	Normandy, 3 miles northeast	Robt. Marshall, Jr	Bluff	1,000	do	Fort Payne chert.

[a] Analysis given in table of analyses.

No. on pl. 1	Openings		Approximate yield		Use of water	Total hardness as $CaCO_3$ (parts per million) [b]	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)			
34a	1	Enlarged joint crack	½	Oct. 21	Community supply		
34b	2	do			Industrial		Reported to yield about 2,000 gallons a day except in dry summer, when yield is 1,000 gallons a day.
35	1	Bedding plane	1/10	Oct. 21	Domestic	195	Water seeps from base of bentonite member.
36	1	Enlarged joint crack	9	Oct. 20	Domestic; stock	235	Reported to become muddy after rain in vicinity of Bellbuckle, 4 miles northwest.
37	1	Solution channel	6	Oct. 22	do	230	Furnished 15 families in Haley during drought. Potable well water rare at this place.
38	1	Enlarged joint crack	12	Oct. 27	do		Sims Spring, largest and most noted spring in western part of county.
39	1	Bedding plane	1½	Oct. 25	do	175	Issues above bentonite bed. Low hardness and temperature probably due to access of surface water.
40	Many	Porous zone			None	40	Caseade Springs; issue from a porous zone above Chattanooga shale. Springs are in Coffee County.

[b] Determined in field with standard soap solution.

Analyses of ground waters from Bedford County

[D. F. Farrar, Tennessee Geological Survey, analyst. Parts per million. Numbers at heads of columns correspond to numbers in tables of well and spring data]

	8	9	12	17a	18
Silica (SiO_2)	11	11	34	16	12
Iron (Fe)	1.3	1.6	2.8	.75	3.6
Calcium (Ca)	105	113	2,783	3.9	1,724
Magnesium (Mg)	7.0	12	76	1.2	138
Sodium (Na)	1.2	6.1	308	396	9,870
Potassium (K)		1.8	5.2	18	24
Carbonate (CO_3)	0	0	0	26	0
Bicarbonate (HCO_3)	346	357	360	461	240
Sulphate (SO_4)	8.6	38	6,661	5.2	4,420
Chloride (Cl)	1.8	13	480	319	15,250
Nitrate (NO_3)	.55	.64	2.1	1.3	3.2
Total dissolved solids	304	384	10,813	1,103	30,830
Total hardness as $CaCO_3$ (calculated)	291	331	7,256	15	4,868
Date of collection (1930)	Oct. 25	Oct. 25	Oct. 20	Oct. 20	Oct. 22

	19	20a	25	35	Duck River [a]
Silica (SiO_2)	14	11	14	16	8.9
Iron (Fe)	1.3	2.2	1.7	1.1	.85
Calcium (Ca)	156	113	92	67	33
Magnesium (Mg)	19	12	7.6	6.0	2.3
Sodium (Na)	180	33	7.2	5.0	1.0
Potassium (K)	16	6.2			
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	543	310	258	231	101
Sulphate (SO_4)	16	67	47	1.4	8.6
Chloride (Cl)	293	57	11	7.5	1.0
Nitrate (NO_3)	.85	1.3	.75	.66	.34
Total dissolved solids	978	476	318	224	106
Total hardness as $CaCO_3$ (calculated)	467	331	261	192	92
Date of collection (1930)	Oct. 24	Oct. 28	Oct. 27	Oct. 21	Oct. 29

[a] Water from Duck River at Shelbyville; municipal supply, filtered but not chlorinated.

FRANKLIN COUNTY

[Area 575 square miles, population 21,796]

Franklin County is a roughly square area lying in the extreme southwest corner of the area covered by this report. It is bounded by Coffee County on the north, Grundy County on the northeast, Marion County on the east, Jackson County, Ala., on the south, and Lincoln and Moore Counties on the west. The county seat and chief city is Winchester (population 2,210). Other important small cities are Decherd, Cowan, Sewanee, and Sherwood.

The Elk River flows in general southwestward through the northern and central parts of the county. It drains the entire county except the part embraced in the Cumberland Mountains, which drains southward to the main Tennessee River.

The Nashville, Chattanooga & St. Louis Railway serves the county. Hard-surfaced highways at present (1930) connect Winchester with Tullahoma, to the northwest, and with Monteagle, to the east. Others are in course of construction.

The chief industry is agriculture. Tree nurseries have been made a specialty. Most of the county is underlain by the St. Louis limestone, the residual soil from which is fertile. There is a large lime quarry at Sherwood, in the southeastern part of the county, in a deep valley in the Cumberland Plateau. The University of the South and two Episcopalian preparatory schools, St. Andrew's (boys) and St. Mary's (girls), are at Sewanee.

GEOLOGY

About three-fourths of Franklin County lies on the Highland Rim; the southeast quarter is a part of the Cumberland Plateau. The portion on the Highland Rim has an average altitude of about 1,000 feet above sea level. The Cumberland Plateau is at an altitude of about 2,000 feet at Sewanee, but the western part of the plateau in the county has been much reduced by erosion. The Elk River is 780 feet above sea level near the western edge of the county. The total relief is therefore about 1,200 feet.

The Highland Rim portion of the county is a gently rolling plateau except in the neighborhood of the Elk River, where the river and its tributaries flow in rough gorges. The general surface level declines in a southeasterly direction from about 1,100 feet in the northwest corner of the county to about 1,000 feet along the railroad from Winchester to Huntland. Large and small shallow sink holes abound in areas away from the major drainage channels. To judge from maps now available, few of these sinks are more than 20 feet deep.

The Cumberland Plateau in the vicinity of Sewanee presents a gently rolling surface with a local relief of scarcely more than 100 feet, except, of course, in the deep gorges cut into the face of the escarpment. Its level character is striking considering the great escarpment that separates it from the Highland Rim. Elsewhere in the county the Cumberland Plateau is maturely or postmaturely eroded, and although these areas have patches of rolling land on the hilltops they are on the whole very rugged. Deep sinks break the surface of the plateau.

The stratigraphic column shown in Franklin County ranges from the basal Pennsylvanian down to the Upper Ordovician. The various formations exposed in the escarpment of the Cumberland Plateau have been described on pages 55–61. The St. Louis and Warsaw limestones form the surface of the Highland Rim throughout the county. They are massive, somewhat siliceous limestones. The St. Louis weathers to a red clay soil which is conspicuous over most of the county. The black Chattanooga shale crops out in a narrow band on the valley walls of the lower Elk River and its tributaries. A very siliceous, cherty limestone underlies the Chattanooga shale in places and overlies the red crystalline limestone and shale of the Fernvale formation. No examination was made of the underlying Ordovician rocks in the Elk River Valley. Quaternary terrace gravel is present in several places in this valley.

Structurally, Franklin County lies on the southeast flank of the Nashville dome. The regional dip is southwest; the Chattanooga shale is at an altitude of about 950 feet in the northwest corner of the county, but at the southeast corner it is about 400 feet lower. Minor folds are present.

GROUND WATER

All sections of Franklin County have obtained adequate water supplies, so far as known, except the vicinity of Sewanee. A few dug wells on the Highland Rim are reported to have been very low during the summer of 1930, but drilled wells have been generally successful throughout the rim. Well 53, on a stock farm near Huntland, in the southwest corner of the county, is reported to furnish water sufficient for 300 head of stock. The well is only 96 feet deep and derives its water from the Fort Payne chert or, perhaps, the Warsaw formation. The public supply of Decherd is obtained from wells 48a and 48b, draining water from a subterranean channel in the Fort Payne chert. Both wells are 112 feet deep. The main well is equipped with a pump having a rated capacity of 80 gallons a minute and is reported to be pumped continuously 16 hours a day in summer. The second well is used only in emergencies.

The most abundant sources of water are the springs that issue at all stratigraphic horizons in topographically favorable locations. Springs 71a and 71b, in Owl Hollow, about 5 miles west of Winchester, are probably the largest springs in the county. Water from these springs issues from the Fort Payne chert and a limestone of Silurian age, just above and just below the Chattanooga shale, respectively, and is used to drive a gristmill. The combined flow from these springs was about 1,200 gallons a minute when measured in the fall of 1930. It was reported that they were then at their lowest known stage. The fact that the area is broadly synclinal in structure is probably to be correlated with the size of the springs.

Winchester derives its public supply from spring 74a, which taps a large solution channel in the Warsaw (?) formation about 2 miles north of the town. This spring flows about 750 gallons a minute; spring 74b, adjacent to it and fed apparently from the same channel, delivers about 600 gallons. The supply of Cowan is derived from spring 76, in the St. Louis limestone or the Warsaw formation. It furnishes the town needs of about 40,000 gallons a day, or 30 gallons a minute.

The water requirements of the schools on the Cumberland Plateau are barely met by the supplies available. The University of the South, at Sewanee, furnishing water also to a large part of the town, uses about 60,000 gallons a day. The water is derived from seven small springs and two wells of small capacity. The largest of the springs flows less than 5 gallons a minute, and the better of the two wells yields only 15 gallons a minute. The wells tap the Gizzard formation and the springs issue from the Sewanee conglomerate. At St. Andrews, a few miles east of Sewanee, each of two wells yields only about 2,500 gallons a day. At St. Mary's, however, on the brink of the escarpment southeast of Sewanee, a well 150 feet deep derives sufficient water for the needs of the institution from the Gizzard formation. The well is reported to have been bailed immediately after drilling, at the rate of 20 gallons a minute, without lowering the water level, and it is pumped at the rate of 5,000 gallons a day throughout the summer. The local variation in water-bearing capacity of the Gizzard formation may be due to variations in the lithology of this very diverse formation.

Records of wells in Franklin County

No. on pl. 1	Location with reference to nearest map point	Owner or lessee	Topographic situation	Approximate altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)
41	Belvidere, 5 miles northwest	N. A. Majors	Plateau	935	Dug	49	48±
42	do	J. W. Chasteen	do	950	do	62	48±
43	Winchester, 1½ miles west	Joe Shadow	Valley	860	Drilled	2,245	
44	Winchester, 1½ miles northeast	J. W. Shadow	Plateau	925	do	1,500	
45	Winchester, 1¾ miles northwest	A. B. Webb	Spur	895	do	955	
46	do	—— Wilkson	Valley	840	do	600	8
47	Winchester	—— Weinger	Plateau	970	do	1,476	
48a	Decherd	Decherd Mill Co	do	950	do	498	8
[a] 48b	do	do	do	950	do	112	8
49	do	C. E. Murray	do	985	do	850	8
50a	do	J. L. Haynes	do	1,000	do	300	8
50b	do	do	do	1,000	do	300+	8
51	Decherd, 1 mile south	Ben Heikens	do	975	do	1,395	
52	Alto, 3 miles west	P. P. Featherston	do	1,090	Dug	38	24
53	Huntland, 2 miles east	M. B. Reynolds & Sons	do	950	Drilled	96	6
54a	Huntland, 2 miles northeast	Mrs. J. P. Buckner	do	930	do	109	6
54b	do	do	do	930	Dug	30	48±
55	do	T. R. Trigg (No. 2)	do	950	Drilled	950	
56	do	T. R. Trigg (No. 1)	do	945	do	1,115	
57	Belvidere, 4 miles south	J. A. Butler	Valley	975	do	1,907	
58	Belvidere	J. T. Huffman	Plateau	960	do	250	6
[a] 59	do	do	do	960	do	65	6
[a] 60	Belvidere, 1½ miles north	G. W. Sanders	do	1,050	do	118	6
61	Pelvidere, 1½ miles northeast	J. C. Shockley	do	995	do	1,900(?)	16
62	Cowan	Cumberland Portland Cement Co	do	1,000	do	1,752	
63a	Sewanee	University of the South	do	1,980	do	120	6
63b	do	do	do	1,970	do	110	6
63c	do	do	do	1,955	do	210	6
64a	Sewanee, 2 miles northeast	St. Andrews School	do	2,010	do	285	6
[a] 64b	do	do	do	1,970	do	185	6
65	Sewanee, 1½ miles southwest	St. Marys School	do	1,925	do	150	6
66a	Sherwood	Gager Lime Co	Valley	670	do	60	8
66b	do	do	do	670	do	70	8

No. on pl. 1	Water-bearing beds			Water level		Use of water	Remarks
	Depth (feet)	Character of material	Stratigraphic location	Above or below surface (feet)	Date of measurement		
41	49±	Residual chert	Fort Payne chert	−43	Nov. 25	Domestic	
42	62±	do	do	−57	Nov. 25	do	
43	37 1,285 1,638	Limestone	do	(?)		None	Oil test; characteristics of water from various beds not known.
44	(?)					do	Do.
45						do	Do.
46	60	Shaly limestone	Cathys limestone (?)			do	Oil test; water contained H_2S.
47						do	Oil test; salt water.
48a	100	Limestone	Fort Payne chert	−60		Public supply	Water used as public supply for Decherd.
	450					None	Salt water, plugged off.
[a] 48b	100	Limestone	Fort Payne chert	−60		Public supply	Water used as public supply for Decherd.
49						None	Oil test; abundance of water above 220 feet (Chattanooga shale ?).
50a	165	Limestone	Fort Payne chert			do	Oil test.
50b	50	do	St. Louis limestone (?)			do	Oil test; Chattanooga shale at 245 feet; no water below.
51						do	Oil test.
52	38±	Residual chert	St. Louis limestone	−20	Nov. 22	Domestic	
53	96±	Chert	Fort Payne chert (?)			Stock	
54a	109±	do	Fort Payne chert			Domestic; stock	
54b	30±	Residual clay	Warsaw formation (?)			Domestic	
55							Oil test; reported no water was struck.
56							Oil test; reported strong flow of water was struck between depths of 200 and 300 feet (Ordovician system).
57	44	Limestone (?)	St. Louis limestone or Warsaw formation.				Oil test.
58	250±		Upper Ordovician series			None	Water contaminated by petroleum.
[a] 59	65±	Limestone	Fort Payne chert (?)			Cooling	
[a] 60	118±	do	Warsaw formation (?)	−72	Nov. 24	Stock	Water highly mineralized.
61	160	do	Fort Payne chert				Oil test; other aquifers encountered at lower depths.
62	1,600±			−70		None	Water reported somewhat salty.
[a] 63a	120±	Sandstone	Gizzard formation	−40		Public supply	Water used as part of public supply of Sewanee.
63b	110±	do	do			do	Do.
63c	25	do	do	−30		Domestic	
64a	(?)	do	do	(?)		School supply	
[a] 64b	(?)	do	do			do	
65	150±	do	do	−90±		do	
66a	20	Limestone	Warsaw formation	−10		Domestic; industrial	
66b	40	do	do	(?)		do	

[a] Analysis given in table of analyses.

Records of springs in Franklin County

No. on pl. 1	Location with reference to nearest map point	Owner or lessee	Topographic situation	Approximate altitude above sea level (feet)	Kind of rock	Stratigraphic location
67	Maxwell, 1 mile southwest	J. M. Fitzpatrick	Valley	880	Limestone	Warsaw formation (?).
68	Maxwell, 3 miles southeast	J. A. Butler (?)	do	970	do	St. Louis limestone or Warsaw formation.
69a	Eastbrook, 1 mile northwest	Scott Ferris	Branch	875	Shale	Chattanooga shale.
69b	do	do	do	875	Chert	Fort Payne chert.
69c	do	do	Hillside	880	do	Do.
70	Winchester, 5 miles west	W. H. Higginbotham	Sink hole	960	Limestone	St. Louis limestone or Warsaw formation.
[a] 71a	do	Gray Weddington	Valley	820	Chert	Silurian system.
[a] 71b	do	do	do	855	do	Fort Payne chert.
72	do	John Boswell	do	865	do	Do.
73	Winchester, 3 miles west	(?)	do	860	do	Do.
[a] 74a	Winchester, 1½ miles northwest	Tennessee Electric Power Co.	do	875	Limestone	Warsaw formation (?).
74b	do	do	do	875	do	Warsaw formation.
75	Cowan	A. J. Hines	Hillside	995	do	St. Louis limestone.
[a] 76	do	Tennessee Electric Power Co.	Branch	930	do	Warsaw formation (?).
[a] 77a	Sewanee	University of the South	Low bluff	1,910	Sandstone	Sewanee conglomerate.
77b	do	do	do	1,910	do	Do.
78	Sherwood	J. D. Barnes	Mountain side	1,355	Limestone	Bangor limestone (?).
[a] 79	do	Fred Miller	Hillside	640	do	Warsaw formation.
80	do	Martin Marugg	Valley	640	do	Do.

No. on pl. 1	Number	Character	Approximate yield: Gallons a minute	Approximate yield: Date of measurement (1930)	Use of water	Remarks
67	1	Solution channel	25		Railroad	Fitzpatrick Spring.
68	1	do	25	Nov. 22	Domestic	
69a	1	Joint crack	½	do	Medicinal	Winchester Springs.
69b	1	Bedding plane	3	do	do	
69c	2	do. (?)	½	do	do	
70	1	Solution channel	3	Nov. 25	Domestic	Syric Spring.
[a] 71a	1	do	225	do	Power	
[a] 71b	1	do	1,200	do	do	
72	1	do. (?)	5	do		
73	1	do	50	Nov. 27		
[a] 74a	1	do	750	Nov. 29	Public supply	
74b	1	do	600	do	None	
75	1	do	2	Nov. 28	Domestic	Hines Spring.
[a] 76		Concealed	25		Public supply	Public supply of Cowan.
[a] 77a	1	Joint crack	5	Nov. 28	do	Part of public supply of Sewanee.
77b	1	do	5	do	do	Do.
78	2	Enlarged joint crack	2	Nov. 26	do	Small public supply in Sherwood.
[a] 79	1	Solution channel	150	do	Domestic	
80	1	do	200	do	do	

[a] Analysis given in following table.

Analyses of ground waters from Franklin County

[D. F. Farrar, Tennessee Geological Survey, analyst. Parts per million. Numbers at heads of columns correspond to numbers in table of well and spring data]

	48b	59	60	63a	64b	71a
Silica (SiO_2)	11	13	16	12	11	13
Iron (Fe)	.85	.85	2.1	.66	.62	.72
Calcium (Ca)	70	48	305	21	12	41
Magnesium (Mg)	4.7	6.3	31	4.3	1.1	4.6
Sodium (Na)	2.6	9.2	16	3.6	1.0	.4
Potassium (K)			3.4			
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	157	165	302	43	38	143
Sulphate (SO_4)	62	9.2	615	33	1.8	4.2
Chloride (Cl)	3.9	14	27	5.5	1.5	.6
Nitrate (NO_3)	.71	.67	.92	.45	.30	.10
Total dissolved solids	239	182	1,212	114	51	141
Total hardness as $CaCO_3$ (calculated)	194	146	888	70	34	121
Date of collection (1930)	Nov. 22	Nov. 24	Nov. 24	Nov. 28	Nov. 28	Nov. 25

	71b	74a	76	77a	79
Silica (SiO_2)	12	12	13	8.9	14
Iron (Fe)	.55	.85	.88	.65	1.2
Calcium (Ca)	40	72	82	7.3	61
Magnesium (Mg)	7.8	3.6	6.4	1.9	4.7
Sodium (Na)	.6	3.0	5.8	5.3	1.9
Potassium (K)				1.1	
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	145	165	189	8.2	153
Sulphate (SO_4)	12	58	72	18	42
Chloride (Cl)	.9	4.5	8.7	9.3	2.8
Nitrate (NO_3)	.41	.55	.36	.33	.83
Total dissolved solids	156	245	296	62	214
Total hardness as $CaCO_3$ (calculated)	132	194	231	26	172
Date of collection (1930)	Nov. 25	Nov. 29	Nov. 29	Nov. 28	Nov. 26

GILES COUNTY

[Area 628 square miles, population 28,016]

Giles County lies on the southwest side of the Nashville Basin. It is bounded on the north by Maury County, on the northeast by Marshall County, on the east by Lincoln County, on the south by Limestone County, Ala., and on the west by Lawrence County. The county seat and largest city is Pulaski (population 3,367). Lynnville, in the northern part of the county, is the only other city of any size.

The entire county is tributary to the Elk River, which crosses the southeast corner, and all except small areas in the southern part of the county drains to Richland Creek, the chief tributary of the Elk River, which flows southward roughly along the central meridian of the county.

The county is served by two lines of the Louisville & Nashville Railroad, both running southward, one through the central part of the county and the other along the eastern boundary. Hard-surfaced highways radiate from the county seat north to Columbia, south to Athens, Ala., west to Lawrenceburg, and east to Fayetteville. Others under construction go northeast to Lewisburg and southwest toward Florence, Ala.

The chief pursuit is agriculture. A large phosphate plant is operated at Wales, north of Pulaski.

GEOLOGY

Giles County lies mostly in the Nashville Basin but overlaps both the eastern and western sections of the Highland Rim and includes many large remnants of the rim in that portion which technically is classified as basin area. The higher portions of the rim in the northwest corner of the county and the large remnant northeast of Pulaski lie about 1,000 feet above sea level, but in the southern part the level of the rim is about 100 feet lower. The Elk River is about 570 feet above the sea. The total relief in the county is therefore somewhat in excess of 400 feet. The terrane is gently rolling nearly everywhere except at the edges of the rim and its outliers, where the slopes are steep.

Giles County is immediately underlain by strata ranging from the Warsaw formation and perhaps, in local patches, the St. Louis limestone, down to the top member of the Lowville limestone. The Warsaw and St. Louis limestones are present only locally along the western county line and in the extreme southeast corner. The Fort Payne chert is the surface rock through practically the entire area belonging to the Highland Rim or its remnants. A few feet of coarsely crystalline limestone with large crinoid joints and stems, which may represent the New Providence formation, is found locally along the western border of the county just below the Fort Payne chert. The Maury glauconitic member of the Ridgetop shale and the Chattanooga shale are exposed in many places in the escarpments of the Highland Rim and its remnants. In the southeastern quadrant of the county as much as 50 feet of Silurian cherty limestone is present. In the southwestern part of the county, in the vicinity of Minor Hill, a thin conglomeratic limestone probably represents the Brassfield limestone, and the same formation is probably represented by a crystalline limestone with green specks in the southeast corner of the county, at Elkmont Springs. About 20 feet of coarse pinkish and yellowish limestone and yellow-green shale representing the Fernvale formation underlie this limestone.

The following section, adapted from Bassler,[47] describes the strata found on the lower slopes of the hills and in the lowlands of Giles county. The portion of the section from the lower part of the Cannon limestone to the top was measured at the spring north of the square in Pulaski and continued to the top of the hills along the road running north. The lower part of the section was measured in the vicinity of Aspen Hill.

[47] Bassler, R. S., The stratigraphy of the central basin: Tennessee Div. Geology Bull. 38, p. 32, 1932.

Stratigraphic section in Giles County

	Feet
Fernvale formation:	
Brownish-yellow shale with *Platystrophia acutilirata*	8
Gray shale with Bryozoa and *Rhynchotrema capax*	10
Bluish and pink limestone	20
Leipers limestone:	
Nodular irregular blue fossiliferous limestone below with *Strophomena maysvillensis* and other typical Leipers fossils	25
Catheys limestone:	
Dirty-gray to dove-colored argillaceous limestone with *Scolithus*	7
Thick-bedded fine-grained blue cobbly limestone; *Hebertella* abundant	10
Massive subgranular blue-gray limestone; *Tetradium columnare* abundant	4
Massive fine-grained laminated limestone	5½
Cobbly blue limestone	2
Granular blue and shaly limestone full of ramose Bryozoa, particularly *Constellaria emaciata* and *C. fischeri*	4
Cannon limestone:	
Covered	25
Blue shale full of fossils, particularly *Eridotrypa briareus*, sponges, and gastropods	15
Covered	5
Granular blue limestone with *Solenopora compacta*	5
Massive granular semiphosphatic gray-blue speckled limestone	15
Thin-bedded fossil clayey limestone and shale with numerous *Rhynchotrema increbescens* and massive Bryozoa	8
Massive gray-brown speckled granular limestone, laminated and cross-bedded, resembling Bigby	15
Dove-colored limestone filled with *Scolithus* markings	1
Bigby limestone:	
Massive laminated and cross-bedded, coarsely crystalline blue and gray phosphatic limestone	60
Hermitage formation:	
Shale and shaly limestone; upper beds slightly phosphatic, *Dalmonella fertilis* abundant	50
Massive coarsely crystalline gray limestone weathering into rounded boulders, without chert; fossils abundant, including *Columnaria*, *Solenopora*, and *Echinosphaerites*. A few mottled dove-colored limestone beds, 12 to 20 inches thick, in lower part	35
Lowville limestone (top member):	
Thin-bedded dove-colored and blue shaly limestone	10
Thin-bedded dove-colored fucoidal limestone weathering to small fragments full of holes	10

The Hermitage formation becomes much more sandy and is very conspicuous around Brick Church and Diana.

The character of the unexposed strata is given in the following log of the Krapp Spring well (well 88). The individual formations cannot be recognized from the description available. Probably all the strata below the Chattanooga shale belong to the Ordovician system.

The determination of the "Pencil Cave" or bentonite horizon in the interval from 430 to 470 feet seems possible, although the interval from the Chattanooga shale to it is somewhat greater than that given by available surface sections. If the determination is correct this interval represents the approximate top of the Lowville limestone. The entire Stones River group must have been passed through, but the hole was apparently not deep enough to reach the horizon of the St. Peter sandstone (Lower Ordovician).

Log of well at Krapp Spring, Swann Creek, Giles County

[Drilled by J. W. Young, December 1928. Cuttings examined Dec. 21, 1928, by W. F. Bailey, assistant geologist, Tennessee Division of Geology]

	Thickness (feet)	Depth (feet)
Chattanooga "black" shale	48	55
Cuttings consist of large chunks of siliceous and calcareous skeleton masses of crinoid stems and lace like Bryozoa. Material probably has fallen down from Fort Payne formation above black shale	5	60
Blue shaly limestone	35	95
Blue-gray crystalline limestone containing fragments of brachiopod shells	25	120
Same as above but lighter-colored	5	125
Same as above, with dark-blue dense limestone	20	145
Blue shaly limestone	5	150
Dark blue-gray crystalline limestone with considerable pyrite. No fossils	15	165
Dark blue-gray shaly limestone	30	195
Light blue-gray crystalline limestone	5	200
Dark blue-gray crystalline limestone	65	265
Very light gray crystalline limestone	30	295
Very dark (nearly black) dense limestone	70	365
Very light gray dense limestone. Resembles †Dove limestone	10	375
Nearly white dense limestone	35	410
Very light colored brownish-gray dense limestone	10	420
Light blue-gray dense limestone	10	430
Dark blue-gray finely crystalline limestone ("Pencil Cave")	40	470
Dark blue-gray dense limestone	10	480
Light brownish-gray dense limestone	10	490
Dark blue-gray crystalline limestone	25	515
Dark blue-gray dense limestone	10	525
Mixture of light and dark blue-gray dense limestone	70	595
Very light gray dense limestone. Nearly white	15	610
Same as above but slightly darker	10	620
Dark-gray dense limestone	10	630
Same as above but lighter color	55	685
Same as above but darker	15	700
Dark blue-gray dense limestone	10	710
Light blue-gray crystalline and somewhat shaly limestone	5	715
Very light blue-gray dense limestone	10	725
Same as above, with brownish color	5	730
Dark blue-gray dense limestone	30	760
Dark-blue dense limestone and balls of dark clayey material	5	765
Dark blue-gray dense limestone	5	770
Very light gray crystalline limestone	5	775
Dark blue-gray dense limestone	40	815
Very dark, nearly black dense limestone	65	880
Dark blue-gray dense limestone	50	930
Same as above, very dark	5	935
Dark blue-gray dense limestone	35	970
Same as above, a little lighter color	15	985
Dark blue-gray dense limestone	15	1,000

Giles County lies on and just west of the southward extension of the crest of the Cincinnati anticline, on the southwest flank of the Nashville dome.

GROUND WATER

Giles County exhibits the usual ground-water features of counties in Tennessee crossed by the Highland Rim escarpment. Abundant springs, many of large size, furnish good supplies of water to many of the rural dwellings; shallow drilled or dug wells generally yield adequate supplies for domestic and stock use, although in some localities a satisfactory well is hard to obtain; and but few large water supplies are furnished by wells. The largest proved capacity of any well in this county, so far as known, is 11 gallons a minute, yielded by well 85, which furnishes most of the city supply of Lynnville. This well probably taps a channeled zone in the Lowville limestone. Drillers report that strong flows of water are struck at shallow depths throughout this vicinity.

Wells are frequently unsuccessful in certain localities. On two adjoining farms about 3 miles southwest of Lynnville about 12 wells were drilled to depths as great as 150 feet before well 83 was drilled. This well struck a heavy flow of water at a depth of 100 feet, in the Lowville or the Lebanon limestone, under sufficient head, according to report, to raise the water within 20 feet of the surface. At Baugh station, in the southeast corner of the county, a hole 350 feet deep was dry, and the rocks were so impervious that it was used as a cistern. The well extended from the Catheys limestone down to probably the base of the Lowville limestone. A well drilled about 1905 at the ice plant north of the square in Pulaski, seeking a water supply for the town, is reported to have encountered no water in a depth of 1,700 feet. This well starts in the lower part of the Cannon limestone and, if the reports of its depth are true, reached horizons probably considerably below that of the St. Peter sandstone. It illustrates the apparent fact that the probability of striking potable water at depth is very small.

The ground-water resources of the county are more truly represented by the number of strongly flowing springs than by the wells, the capacities of which are practically never ascertained. The largest spring in the county is spring 112, a few miles north of Campbellsville. The flow when measured was roughly 1,700 gallons a minute. The spring issues from the uppermost of the Ordovician rocks at this point, probably the Catheys limestone, but it is reported that there is a fall in the underground stream a short distance under the hill, so that probably the main channel is in the basal part of the Fort Payne chert. The water is used to develop power for a gristmill. Other springs on the western edge of the county derive water from the calcareous beds that may represent the New Providence formation. Spring 121, at the ice plant north of the square in Pulaski, a few yards from the deep hole drilled there, flows about 125 gallons a minute from the basal part of the Cannon limestone.

Practically all the waters of the county contain calcium carbonate, which increases in a rough way with descent in the stratigraphic column. Some waters from the lower beds contain hydrogen sulphide.

The municipal water supply of Pulaski is derived from Highland Creek.

Records of wells in Giles County

[Nos. 99, 100, 105, 110a, 110b dug; all others drilled]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
81	Campbellsville, 6 miles north	Mrs. E. B. Braden	Base of hill	850	17	6
82	Lynnville, 3½ miles southwest	R. H. Owens	Ridge	1,020	38	5
[a] 83	Lynnville, 2½ miles southwest	J. C. Rhea	Low hill	695	103	6
84	Buford	Arthur Baker	Base of hill	705	77	6
[a] 85	Lynnville	City of Lynnville	Valley	735	37	-----
86	Diana	Louisville & Nashville R. R.	Open valley	810	84	6
87	Brick Church	Wiley Griffin	Hill	800	55	5
88	Brick Church, 3 miles southwest	John Spears	Ridge	1,065	1,000	10
89	Pulaski, 5½ miles north	Louisville & Nashville R. R.	Valley	690	80±	(?)
90	Pulaski, 4½ miles northwest	do	do	670	80	(?)
91	Pulaski, 6 miles west	Mrs. L. D. McMasters	Creek terrace	700	40±	5
92	Pulaski, 2 miles west	J. M. Smith	do	670	62	6
93	Pulaski	City of Pulaski	Small valley	670	1,700	10
94	Pulaski, 7 miles east	E. E. Ray	Sharp ridge	985	46	6
95	Diana, 6 miles south	J. R. Reaves	End of spur	765	98	6
96	Diana, 6½ miles south	Louisville & Nashville R. R.	Hillside	720	80±	-----
97	Tarpley	Holt and Bass	do	710	85	5
[a] 98	Aspen Hill	Jerry Hester	Low hill	655	185	6
99	Goodspring, 1 mile west	Jos. Reynolds	Ridge	1,015	30	60±
100	Goodspring, 3 miles west	A. A. Warren	Plateau	985	27	36
101	Minor Hill, 3 miles southwest	Jack Cole	Base of hill	670	630	10
102	Minor Hill, 2½ miles southwest	Dr. W. H. Cole	Hillside	710	625	10
103	Minor Hill, 2 miles southwest	N. B. Harrison	do	675	630	10
104	Minor Hill, 1 mile northwest	Sam Thompson	do	885	430	10
105	Minor Hill	Dr. W. H. Cole	Plateau	885	33	48
106	Minor Hill, 1 mile northeast	Mrs. Waites	Hillside	765	260	8
107	do	do	Spur	795	-----	-----
108	Prospect, 5 miles west	Lotha Jackson	Low hill	660	35	6
109	Prospect	Louisville & Nashville R. R.	Hillside	590	80	6
110a	Elkton, 2½ miles northeast	T. B. Gregory	Valley	660	13	36
110b	do	do	Hilltop	670	31	36
111	Elkton, 3 miles northeast	Louisville & Nashville R. R.	Hillside	680	350	(?)

[a] Analysis given in table of analyses.

Records of wells in Giles County—Continued

No. on pl. 1	Water-bearing beds: Depth (feet)	Water-bearing beds: Lithologic character	Water-bearing beds: Stratigraphic position	Water level: Above or below surface (feet)	Water level: Date of measurement (1930)	Use of water	Total hardness as $CaCO_3$ (parts per million) [b]	Remarks
81	Bottom		Bigby limestone (?)	−10.4	Oct. 17	Domestic; stock	150	
82	do	Chert	Fort Payne chert	−35.4	Oct. 6	do	135	
83	do	Limestone	Lebanon limestone (?)	−40.0		do	390	
84	do	do	Lowville limestone	(?)		Stock	245	
85	do	do	do	(?)		Public supply	295	Pumped continuously; yield, 15,000 gallons a day.
86	do	do. (?)	Hermitage formation (?)	−63		Domestic	590	
87	do	do	Lowville limestone (?)	−44.4	Oct. 7	do	300	
88						None		Oil test.
89	Bottom	(?)	Bigby limestone (?)			Domestic		Well nearly dry.
90	do	Limestone	Lowville limestone (?)	−30		do	365	
91	do	(?)	Catheys limestone (?)	(?)		do	155	
92	do	(?)	Hermitage formation (?)	−45.7	Oct. 29	do	215	
93								No water, except seep near top, according to report.
94	Bottom	Chert	Fort Payne chert	−40.9	Nov. 9	Domestic; stock	70	
95	do		Lowville limestone (?)	−86.2	Nov. 10	do	600	Iron-bearing.
96	do		Lowville limestone	−40		Domestic		Inadequate; cistern used.
97	do		Hermitage formation (?)	−7	Nov. 3		85	Salty hydrogen sulphide water.
98	do		Lebanon limestone (?)	−62.4	do	Domestic	15	Hydrogen sulphide water.
99	do	Residual chert	Fort Payne chert	−29.2	Sept. 30	do		Inadequate for domestic supply.
100	do	do	do	−25.3	do	Domestic; stock	65	
101	300±	(?)	Lowville limestone (?)			None		Oil test, water at 300 feet flowed over top; gas reported.
102	102		Cannon limestone (?)			do		Oil test; well starts in Leipers limestone.
	160		Catheys limestone (?)			do		Black sulphur water.
	340		Lowville limestone (?)			do		Salt water.
	625		Stones River group			do		Do.
103	100±		Catheys limestone (?)			do		
	160±		Bigby limestone (?)			do		"Black sulphur" water.
104	70	Chert	Fort Payne chert			do		
	105					do		Do.
105	Bottom	Residual chert	Fort Payne chert	−29.5	Oct. 1	Domestic	105	
106	106		Catheys limestone (?)			None		Oil test; fresh water at this depth.
	154		Cannon limestone (?)			do		Sulphur water.
107	110		Catheys limestone (?)			do		Oil test.
	140		Cannon limestone (?)			do		
108	Bottom		Bigby limestone (?)	−24.2	Oct. 11	Domestic; stock	210	
109			Lowville limestone	−40±		Domestic	375	
110a		Gravel	Quaternary alluvium	−11.6	Oct. 10	Stock		Inadequate.
110b	Bottom	do	do	−30.5	do	Domestic		Do.
111						do		Passed from Catheys limestone to Lowville limestone (?) without finding water; now used as cistern.

[b] Determined in field with standard soap solution.

Records of springs in Giles County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
[a]112	Campbellsville, 3 miles north	L. D. Knuckles	Base of hill	765	Earthy limestone	Catheys limestone.
113	Campbellsville	Miss Mattie West	Valley	735		Cannon limestone(?).
114	Lynnville, 3 miles southwest	A. L. Johnson	Base of bluff	775	Dense limestone	Lowville limestone(?).
115	Lynnville	City of Lynnville	Shallow valley	735	Limestone	Hermitage formation(?).
116	do	do	do	735	do	Do.(?).
117	Brick Church	Henry Hatfield and others	Head of drain	790	Calcareous sandstone	Hermitage formation.
118	Pulaski, 6 miles northeast	Mrs. Mollie Tennery	Hillside	950	Chert	Fort Payne chert.
[a]119	Bodenham, 4 miles west	Oscar Horne	Base of hill	770	Calcareous shale	Fernvale formation(?).
120	Bodenham	Dr. S. C. Gaines	Creek bottom	680		Catheys limestone(?).
121	Pulaski	Pulaski Ice & Storage Co.	Small valley	665	Limestone	Cannon formation.
122	Pulaski, 4½ miles southeast	J. A. Loyd	Base of hill	670	Cherty limestone	Silurian system.
123a	Pulaski, 6½ miles east	T. G. Campbell	do	800	Shaly limestone	Leipers limestone.
123b	do	do	do	790	do	Do.
124	Frankewing	Frankewing	do	640	do	Hermitage formation.
[a]125	Bunker Hill	Mrs. S. E. Watson	do	660	Limestone	Silurian system.
[a]126	Tarpley, 1 mile east	J. P. Suttle	Valley	640	do	Hermitage formation.
127	Goodspring	Ray Davis	Base of hill	735	do	Bigby limestone.
128	Goodspring, 3½ miles west	G. H. Snead	do	890	do	Ridgetop shale.
129	do	Mrs. Pearl Rhodes	do	900	do	Do.
130	Minor Hill, 3 miles northwest	Widow Hagin	Base of steep hill	765	Earthy limestone	Catheys limestone(?).
131	Minor Hill, 3 miles southwest	W. F. Newton	Hillside	680	Limestone	Ridgetop shale (calcareous phase).
[a]132	Prospect, 4½ miles northwest	Ed. Howard	Base of hill	795	do	Bigby limestone.
133	Elkton	Elkton Water Co.	Valley	605	do	Cannon limestone(?).
[a]134a	Ardmore, 1½ mile northeast	W. A. Kinnibrew	Hillside	785	Chert	Ridgetop shale.
134b	do	do	do	770		Brassfield limestone(?).
134c	do	do	do	800	Chert	Fort Payne chert.
134d	do	do	do	830	do	Do.
134e	do	do	do	775	do	Brassfield limestone.

[a] Analysis given in table of analyses.

Records of springs in Giles County—Continued

No. on pl. 1	Openings		Approximate yield		Use of water	Total hardness as $CaCO_3$ (parts per million) [b]	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)			
112	1	Large cavern	1,700	Oct. 4	Domestic; stock; power	130	
113	1	Concealed	20	do	Domestic; stock	190	Campbellsville Spring.
114	1	Solution channel	30	Oct. 6	do	140	Cave Spring.
115	1	Joint plane	½±	Oct. 7	Public supply	240	This spring furnishes Lynnville during spring and winter.
116	1	Concealed	1±	do	do		Emergency supply for city during drought.
117	1	do	2	do	Domestic	70	
118	1	do	1½	Oct. 10	do	65	
119	1	Solution channel	200	Sept. 22	Domestic; stock	55	Kilpatrick Spring.
120	1	Concealed	5±	Sept. 29	Stock		
121	1	do	125	Oct. 11	Cooling water		
122	1	Enlarged bedding plane	20	Oct. 9	Domestic; stock	115	
123a	1	Concealed	½	do	Domestic	125	
123b	1	do	75	do	Stock		
124	1	Bedding plane	1±	do	Domestic	230	Harwell Spring; rises and gets turbid after rain.
125	(?)		25	Oct. 10	Domestic; stock	75	
126	1	Enlarged joint crack	12	Oct. 3	do	185	
127	1	Collapsed cavern	20	Sept. 30	do	30	
128	1	Concealed	3	do	do		
129	1	Solution channel	150	do	do	65	One of several similar springs.
130	1	Concealed	5	Sept. 30	do		
131	1	Solution channel	5	Oct. 1	Domestic		
132	1	do	10	Oct. 11	Domestic; stock	90	
133	1	Enlarged bedding plane(?)	35		Public supply	245	
134a	Several	Solution channels	1	Oct. 2	Medicinal	75	Elkmont Springs.
134b		Concealed	¾	do	do	135	Elkmont Springs.
134c		do	⅛	do	do		Elkmont Springs.
134d		do	⅛	do	do		Elkmont Springs.
134e	1	Solution channel	5	do	Domestic		

[b] Determined in field with standard soap solution.

Analyses of ground waters from Giles County

[Nos. 98 and 119 analyzed by Margaret D. Foster, U. S. Geological Survey; the rest by D. F. Farrar, Tennessee Geological Survey. Parts per million. Numbers at heads of columns correspond to numbers in table of well and spring data]

	85	98	112	119	125
Silica (SiO_2)	12	10	9.4	11	8.5
Iron (Fe)	.61	.15	.85	.07	.34
Calcium (Ca)	114	8.8	45	18	22
Magnesium (Mg)	11	3.5	4.4	3.5	6.7
Sodium (Na)	6.1	89	1.1	[a] 1.1	1.7
Potassium (K)	2.1	4.0			
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	260	160	153	67	82
Sulphate (SO_4)	110	37	2.6	4.4	12
Chloride (Cl)	12	42	1.5	.9	2.5
Nitrate (NO_3)	.82	4.5	.04	1.2	.30
Total dissolved solids	424	286	152	70	102
Total hardness as $CaCO_3$ (calculated)	331	36	131	59	82
Date of collection (1930)	Oct. 7	([b])	Oct. 4	Sept. 22	Oct. 10

	126	129	132	134-a
Silica (SiO_2)	6.3	8.2	12	8.4
Iron (Fe)	.56	.37	.85	.81
Calcium (Ca)	53	24	27	12
Magnesium (Mg)	8.2	4.3	5.1	2.0
Sodium (Na)	1.2	.4	3.1	1.5
Potassium (K)				
Carbonate (CO_3)	0	0	0	0
Bicarbonate (HCO_3)	188	90	103	39
Sulphate (SO_4)	11	1.4	5.8	1.7
Chloride (Cl)	2.0	.5	4.0	2.5
Nitrate (NO_3)	.10	.12	.31	.04
Total dissolved solids	190	85	117	43
Total hardness as $CaCO_3$ (calculated)	166	78	89	38
Date of collection (1930)	Oct. 3	Sept. 30	Oct. 11	Oct. 2

[a] Calculated.
[b] Sample analyzed July 1931.

HICKMAN COUNTY

[Area 570 square miles, population 13,613]

Hickman County lies on the northern boundary of the western part of the area described in this report. It is bounded on the north by Dickson County, on the east by Williamson and Maury Counties, on the south by Lewis County, and on the west by Perry and Humphreys Counties. Its county seat is Centerville (population 943).

The Duck River flows westward through the middle of the county. All except a very small area in the northeast corner of the county, which is tributary to the Cumberland River, is drained to this stream.

A branch line of the Nashville, Chattanooga & St. Louis Railway runs more or less northward through the middle of the county. The highway system focuses at Centerville; good gravel roads connect that town with Dickson, Columbia, Hohenwald, and Beardstown. The Memphis-Nashville highway, under construction (1930), runs diagonally through the county. The chief industry of the county is agriculture. Iron smelters, utilizing the residual brown ores of the St. Louis limestone, operate at Wrigley and formerly operated at Aetna. Charcoal burning and other wood-products industries are also carried on at Wrigley.

GEOLOGY

Hickman County lies almost entirely on the western part of the Highland Rim Plateau, near its east edge. The general upland level is about 950 feet above the sea in the southeastern half of the county and decreases somewhat to the northwest. Parts of the upland have been reduced in several erosion cycles, so that at present long, flat-crested ridges are found at different altitudes below the general rim level. The Duck River is at an altitude of about 450 feet in this county; the total relief is therefore about 500 feet. Erosion has reached a mature stage over most of the county, so that the local relief is great and there are few broad areas of level upland. Terraces, covered with alluvial gravel, occur up to about 250 feet above the general level of the river.

The stratigraphic column exhibited in Hickman County extends from the St. Louis limestone down to the Hermitage formation. The St. Louis limestone and Warsaw formation immediately underlie all the high parts of the county and have an outcrop area larger than any other formation in the county except perhaps the Fort Payne and Ridgetop. The limestones of St. Louis and Warsaw age are generally covered with a thick mantle of residual chert and clay, so that the unweathered rock is rarely seen. The outcrops are more numerous in the northern part of the county. Under these limestones lie chert and siliceous limestone ranging from about 20 to 250 feet in thickness and belonging to the Fort Payne chert and Ridgetop shale. The basal part of these strata is well exposed along the Piney River. The black Chattanooga shale crops out in a band along the Duck River and its major tributaries. The basal member of the Chattanooga is here a nodular phosphatic zone which was formerly mined on Swan Creek and marketed as "blue rock" phosphate. The Silurian system is represented in the valley of the Duck River from Centerville westward and locally in embayments in the eastern part of the county. The Brownsport formation (Silurian) is exposed in the extreme western part of the county, but these formations drop out eastward, owing to pre-Chattanooga erosion. From the vicinity of Coble eastward the Silurian is made up of the Wayne formation with a few local developments of the Brassfield limestone. The Ordovician strata are exposed in the stream valleys east of Centerville. Throughout most of this area the surface rock is the Leipers limestone, quarried as brown rock phosphate near Centerville. The Catheys limestone, Bigby limestone, and Hermitage formation are found on the Duck River and some of its tributaries in the extreme eastern part of the county.

Hickman County lies on the northwest side of the Nashville uplift. The regional dip is northwest, the Chattanooga shale declining from an altitude of about 650 feet above sea level in the southeast corner of the county to 430 feet near Pinewood, in the northwest corner. Local irregularities and reversals of the dip occur throughout the county.

GROUND WATER

Ground water in Hickman County, as in most of the other counties in this area, occurs principally in solution channels in the calcareous bedrocks. A few wells dug in the residual cherty soils of the uplands furnish water for household purposes, and in the vicinity of Littlelot alluvial materials in an abandoned channel of the Duck River yield household quantities of water to dug wells. However, these modes of occurrence are exceptional.

No wells of large capacity in the county are known. Well 139, on Pineview Farms, north of Graham, in the northeastern part of the county, is reported to have obtained a flow of 10 gallons a minute in the Fort Payne chert and an untested quantity in Leipers (?) limestone just below the Chattanooga shale. It satisfied a continuous demand of about 2,500 gallons a day, according to reports. Well 137, at Wrigley, is 700 feet deep and is used to supplement surface water for condenser uses in the chemical plant. Its capacity is unknown. It is reported that about 10 other holes, put down to the same depth in this vicinity, obtained only very small flows. Well 146, an oil test near the Duck River about 3½ miles west of Centerville, is reported to have obtained potable water containing hydrogen sulphide at a depth of 1,300 feet, which overflowed the top of the well. This depth is apparently lower than the horizon of the sandstone that has been correlated with the St. Peter sandstone. The report is of interest because, if it is true, this is one of the few wells in the entire area described in this report that obtain potable water at considerable depth.

Springs issue from practically all horizons on the hillsides and in the valleys. Spring 174, about 3½ miles southeast of Aetna, on Swan Creek, is one of the largest. This spring issues slightly above the horizon of the Chattanooga shale in the Fort Payne (?) chert. It was flowing about 450 gallons a minute when visited. The water is impounded and used to drive a gristmill.

The municipally owned public supply of Centerville derives its water from spring 165, about 1½ miles southeast of the town, on the Duck River. A subterranean stream in the Leipers limestone, flowing about 140 gallons a minute, is impounded in its cavern a few rods from the mouth. The industrial village of Wrigley obtains water from a spring rising in alluvial gravel in a branch. The water apparently issues from the St. Louis limestone under cover. It flows about 50 gallons a minute.

The underground channels divert surface waters in at least two places in the county. Sinking Creek sinks about a mile east of Pleasantville, and its waters find their way to Cane Creek, about a mile to the south, where they issue as springs. One of the largest of the outlets is spring 179, half a mile east of Pleasantville, in the Dixon limestone member of the Wayne formation, which was flowing about 300 gallons a minute when visited. The water had a temperature of 67° F. (September). Part of the water of Beaverdam Creek sinks a short distance above the highway bridge near Coble. This water reappears in spring 161, about a mile north of Coble, in a short tributary to Beaverdam Creek. This spring was estimated to be flowing 2,500 gallons a minute, and its temperature was 69° F. when visited in August 1930. The ordinary temperature of ground water in this area is about 59° F.

Records of wells in Hickman County

[Nos. 136, 138, 144, 147, 149 dug; all others drilled]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
135	Lyle, ½ mile northeast	J. D. Lyle	Plateau	880	99	5
136	Lyle	Town of Lyle	do	875	17	60±
137	Lyle, 1 mile south	Tennessee Products Co	Valley	730	700	10
138	Lyle, 3 miles southeast	W. J. Tyler	Ridge	840	33	48
[a] 139	Pinewood	Chas. Nelson and A. B. Benedict	Valley	525	100	5
140	do	do	do	525	35	5
141	Graham	Nashville, Chattanooga & St. Louis Ry	Hillside	530	135	8
142a	Nunnelly	Hickman County	Terrace	635	110	5
142b	do	do	do	635	175	5
143	do	Nashville, Chattanooga & St. Louis Ry	Ridge	715	167	8
144	Only, 2 miles southwest	W. A. Brown	Terrace	560	91	36
145	Coble	Hickman County	Valley	450	85	5
146	Centerville, 3½ miles west	S. C. McClanahan	do	475	1,505	10
147	Littlelot	Alonzo Anderson	Abandoned meander	560	24	36
148	Duck River	O. J. Baker	Valley	535	43	5
149	Aetna	Tennessee Products Co	Terrace	715	40	(?)

[a] Analysis given in table of analyses.

Records of wells in Hickman County—Continued

No. on pl. 1	Water-bearing beds			Water level		Use of water	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)		
135	30-97	Residual chert	St. Louis limestone	−30	Aug. 22	Domestic	
136	(?)	do	do	−4.1	do	Domestic; stock	
137	700±	Limestone (?)	Ordovician	−100		Industrial	About 10 other wells to the same depth in this vicinity furnished only negligible amounts of water. Water from this well reported free from H_2S and hard.
138	33±	Residual chert	St. Louis limestone	−22.3	Aug. 27	Domestic; stock	
[a]139	96	Limestone	Leipers limestone (?)	−20		do	Contains much H_2S. Somewhat salty. Well reported to yield continuously about 2,500 gallons a day without noticeable effect. Water also obtained at 45 feet, from Fort Payne chert.
140	35±		Fort Payne chert	−24.5	Aug. 13	do	
141	100	Chert	do. (?)			None	Water contains much H_2S.
142a		do	do	−92		do	Well did not furnish enough water for use of schoolhouse and was abandoned and replaced by well 142b.
142b		do	do. (?)	−112	do	Domestic	
143	160		do. (?)	−60	do	Domestic; stock	
144		Residual (?) chert	do. (?)	−85.1	Aug. 14	do	
145	85±		Leipers limestone (?)	−34.2	Aug. 15	Domestic	
146	1,300		(?)			None	Reported potable water carrying H_2S which flowed over the top. Some water obtained at 180 feet (Leipers limestone (?)). Well now plugged by river alluvium.
147		Fine sand	Quaternary alluvium	−18.5	Aug. 27	Domestic; stock	Furnishes school of 100 children.
148	20?		Hermitage formation	−10±	Aug. 26	Domestic	
149		Residual chert	St. Louis limestone (?)	−35.1	Aug. 28	do	

[a] Analysis given in table of analyses.

Records of springs in Hickman County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
[a]150	Bon Aqua, ½ mile southeast	Harry White	Creek terrace	730	Limestone	St. Louis limestone.
151	Bon Aqua, 1 mile southeast	do	Base of hill	740	do	Do.
[a]152	Lyle, 1 mile south	Tennessee Products Co.	Flood plain	770	do	Do.
153	Lyle, 2 miles southwest	do	Base of hill	680	do	Do.
154	Lyle, 3 miles southwest	Ellis Randolf	do	625	do	Do.
155	Goodrich	Tennessee Products Corp	do	515	Siliceous limestone	Fort Payne chert (?).
[a]156	Nunnelly, 2 miles west	Nunnally Bros	do	490	do	Do.(?)
157	Spot, ½ mile east	J. T. Mayberry	do	605	do	Do.(?)
158	Spot	Colin Pewitt	do	565	Chert	Do.(?)
159	Only	Jake and Harvel Young	do	450	Siliceous limestone	Do.(?)
[a]160	Coble, 2½ miles northwest	Mrs. W. T. Lancaster	do	450	Shaly limestone	Brownsport formation.
161	Coble, 1 mile north	Will McClanahan	do	430	Limestone	Do.
162	Centerville, 3½ miles west	S. C. McClanahan	do	490	do	Do.
163	Centerville	Flynn	do	470	do	Leipers limestone.
164	Centerville, 1 mile south	Tennessee Illinois Phosphate Co.	do	500	do	Do.
[a]165	Centerville, 1½ miles southeast	City of Centerville	do	480	do	Do.
166	Centerville, 4 miles east	Tom Patton	do	560	Cherty limestone	Fort Payne chert.
[a]167	Primm	Primm Spring Co.	Hillside	635	Sandstone	Hardin sandstone member.
168	Duck River	Mrs. J. M. Anderson	Base of hill	590	Shaly limestone	Bigby limestone.
169	Duck River, 3½ miles northwest	W. E. McDonald	do	565	Limestone	Leipers limestone.
170	Duck River, 5 miles west	Joe Lane	do	645	do	St. Louis limestone.
171	Centerville, 5 miles southeast	Mrs. Geo. Hutchinson	do	565	do	Leipers limestone.
172	Aetna, 3½ miles southeast	J. W. Garner	Hillside	615	Cherty shale	Ridgetop shale. (?)
173	do	Mrs. E. J. P. Morris	Base of hill	560	Limestone	Wayne formation. (?)
174	do	Joe Lindsey	do	640	Chert	Fort Payne chert.
175	Aetna	Tennessee Products Co.	Valley	675		Do.(?)
176	Aetna, 2 miles west	J. D. Breece	Branch	710	Siliceous limestone	Do.(?)
177a	Aetna, 6 miles west	Horace Raney	do	655	Cherty shale	Ridgetop shale.(?)
177b	do	do	do	655	do	Do.(?)
[a]177c	do	do	do	655	do	Do.(?)
[a]177d	do	do	do	660	do	Do.(?)
177e	do	do	do	660	do	Do.(?)
177f	do	do	do	660	do	Do.(?)
178	do	do	Base of hill	600	do	Do.(?)
179	Pleasantville, ½ mile east	R. B. Qualls	do	565	Limestone	Wayne formation.

[a] Analysis given in table of analyses.

Records of springs in Hickman County—Continued

No. on pl. 1	Openings		Approximate		Use of water	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)		
150	4	Concealed	4	Aug. 22	Medicinal	Bon Aqua Springs.
151	1	Enlarged bedding plane	3	do	Domestic; stock	
152	(?)	Concealed	50±	do	Public supply	Used as public supply for town of Wrigley.
153	1	Enlarged joint crack	3	do	Domestic; stock	
154		Concealed	10	do	do	
155	1	Solution channel	150	Aug. 13	do	
156	1	do	100	Aug. 14	do	
157	1	Concealed	60	do	do	
158	1	do	5	do	do	One of smaller springs in this section.
159	1	do	125	do	do	Only spring.
160	1	Solution channel	100	Aug. 15	do	Flowers Spring.
161	1	do	2,500±	do	Stock	High temperature indicates access of surface water.
162	1	Concealed	5±	do	Domestic; stock	
163	1	Solution channel	(?)			Privately owned, inadequate municipal supply, largely superseded by municipally owned supply.
164	1	do	5	Aug. 29	Domestic; stock	
165	1	do	140		Public supply	Municipal supply.
166	3	do	15	Aug. 16	Domestic; stock	Fielder Spring.
167	3	Bedding plane	¼	Aug. 27	Medicinal	Primm Springs.
168	3	Solution channels	5±	Aug. 26	Domestic	
169	1	do	10±	Aug. 16	Domestic; stock	
170	(?)	Concealed	110	Aug. 29	do	
171	1	Solution channel	5±	Aug. 28	do	
172	5	Bedding plane	5±	Aug. 29	do	Used also for irrigating garden.
173	1	Large cavern	15±	Aug. 29	Stock	Bat Cave.
174	Several	Concealed	450	Sept. 3	Power	Water is impounded and used in grist mill.
175	1	do	3	Aug. 28	Domestic; stock	
176	1	Solution channel	35	do	do	
177a	1	Bedding plane	⅛	do	Medicinal	Beaverdam Springs, "White Sulphur Spring."
177b	1	do	½	do	do	Beaverdam Springs, "Chalybeate Spring."
177c	1	do	½	do	do	Beaverdam Springs, "Red Sulphur Spring."
177d	1	do	⅛	do	do	Beaverdam Springs, "Black Sulphur Spring."
177e	1	Enlarged bedding plane	20	do	Domestic	
177f	2	do	20	do	do	
178	1	Enlarged joint	225	do	Domestic; stock	
179	1	Solution channel	500±	Sept. 2	Stock	One outlet of the underground stream which diverts Sinking Creek.

Analyses of ground waters from Hickman County

[Margaret D. Foster, U. S. Geological Survey, analyst. Parts per million. Numbers at heads of column correspond to numbers in table of well and spring data]

	139	150	152	156	160
Silica (SiO_2)	20	11	19	17	13
Iron (Fe)	.06	.14	.07	.05	.06
Calcium (Ca)	265	146	43	43	25
Magnesium (Mg)	113	67	4.5	7.2	4.5
Sodium and potassium (Na+K) (calculated)	21	1.1	.9	1.8	1.3
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	182	201	148	163	91
Sulphate (SO_4)	963	456	3.6	3.7	6.5
Chloride (Cl)	14	1.8	1.3	1.6	1.3
Nitrate (NO_3)	.0	.34	1.2	1.4	.62
Total dissolved solids	1,614	841	149	156	97
Total hardness as $CaCO_3$ (calculated)	1,126	640	126	137	81
Date of collection (1930)	Aug. 13	Aug. 26	Aug. 26	Aug. 14	Aug. 15

	165	167 [a]	167 [b]	177c	177d
Silica (SiO_2)	11	16	12	11	10
Iron (Fe)	.07	.17	.17	.13	.26
Calcium (Ca)	13	502	453	42	31
Magnesium (Mg)	2.1	82	76	11	9.3
Sodium and potassium (Na+K) (calculated)	1.1	14	13	2.0	2.4
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	46	210	171	89	77
Sulphate (SO_4)	3.3	1,391	1,274	73	52
Chloride (Cl)	1.5	.3	3.5	3.8	2.5
Nitrate (NO_3)	.33	.0	.0	.19	.19
Total dissolved solids	56	2,206	2,000	198	148
Total hardness as $CaCO_3$ (calculated)	41	1,591	1,444	150	116
Date of collection (1930)	Aug. 26	Aug. 27	Aug. 27	Aug. 28	Aug. 28

[a] "Arsenic spring."
[b] "Calomel spring."

LAWRENCE COUNTY

[Area 611 square miles, population 26,776]

Lawrence County is a very nearly rectangular area adjoining Alabama in the southwestern part of the area considered in this report. The neighboring counties are Lewis, to the north; Maury, to the northeast; Giles, to the east; Lauderdale (Alabama), to the south; and Wayne, to the west. Lawrenceburg, the county seat, with a population of 3,102, is the largest city. Small towns lie along the railroad throughout its course in the county.

The county is situated on the dividing area separating the waters of the Buffalo River, to the north, the Elk River, to the southeast, and Shoal Creek, to the southwest.

Transportation in the county is furnished by the Louisville & Nashville Railroad, which runs about diagonally through the county from the northeast to the southwest corner. Hard-surfaced highways connect Lawrenceburg with Columbia, Pulaski, Florence (Ala.), and Waynesboro.

The county is rural in character, although an iron-smelting industry, more active formerly than now (1930), using chiefly the brown St. Louis residual ores, is operative in the southwest corner.

GEOLOGY

Lawrence County very typically represents the western part of the Highland Rim plateau. Its general surface slopes southward from an altitude of about 1,000 feet along the northern boundary to about 850 feet along the Alabama line. Shoal Creek is at an altitude of about 550 feet in the southeast corner, making the total relief about 450 feet. Except in the neighborhood of Shoal Creek and its tributaries and of Anderson Creek, the local relief is not great. Most of the area has a gently rolling topographic character.

The formations that crop out in Lawrence County range from the St. Louis limestone down to the Leipers limestone, or perhaps slightly lower at the heads of the creeks along the eastern border of the county. The St. Louis and Warsaw limestones are covered by a residual mantle, over 100 feet thick in places, and are therefore rarely seen. Scattered outcrops are found in the vicinity of Summertown, where the mantle seems to be thinner than elsewhere. Below the Warsaw are the Fort Payne and Ridgetop strata, which crop out in large, rather broad areas along the streams. The Fort Payne chert is apparently represented by a less cherty limestone than that shown to the west. Crystalline limestone carrying large crinoid joints, interbedded with blue shale, is commonly present near the base of the Mississippian strata in all parts of the county. These beds are here considered part of the Ridgetop shale, as assigned by Miser,[48] but they may perhaps represent the New Providence formation. These strata are particularly well exposed in the vicinity of Iron Springs. The Chattanooga shale, present in the valley sides, has a thickness of about 5 feet. The Silurian system is represented by the Wayne formation and the Brassfield limestone. The Osgood, Laurel, and Lego members of the Wayne formation crop out in a small area in the Shoal Creek Valley. The Brassfield limestone averages 4 feet in thickness in the vicinity of Shoal Creek. The Fernvale formation (uppermost Ordovician of this region), consisting of light-colored shale above and coarse crystalline limestone below, is present in most localities where its horizon is exposed. The Leipers limestone crops out in small areas in the southern and eastern parts of the county.

GROUND WATER

All large ground-water supplies of Lawrence County are derived from springs. Domestic supplies are obtained from springs and from wells dug into the residual cover of the Mississippian formations.

All the springs are of the tubular variety, issuing from underground channels in the various calcareous formations. Probably the largest in the county is Hope Spring (spring 224), about 1 mile west of the square in Lawrenceburg, from which the municipal supply of the city

[48] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 24, 1921.

is derived. This spring was flowing about 1,100 gallons a minute when visited in September 1930. It issues from the Fort Payne chert, which in this section is a siliceous limestone. A second large spring is spring 225, at the head of Spring Creek. This spring, which was flowing about 1,000 gallons a minute in September 1930, issues from a crystalline crinoidal limestone lens in the Fort Payne chert or the Ridgetop shale. Iron City derives a public supply from a comparatively small spring (spring 235) in crinoidal limestone near the base of the Ridgetop shale. Other good-sized springs issue from practically all exposed formations.

Many of these springs are subject to contamination, a condition common to tubular limestone springs. Local residents report that spring 236, at Wayland Springs, becomes muddy when Holly Creek, 2 miles to the west, becomes muddy.

Wells on the uplands are generally dug into the residual cherty cover overlying the Mississippian formations. Apparently most of them, though not all, obtain their water near the base of the residual cover. The depths of these wells vary widely. Near Summertown they are mostly shallow, wells 20 to 40 feet deep generally obtaining abundant domestic supplies, although this locality is one of the highest in the county and only a few miles from the Highland Rim escarpment. In the central part of the county the wells are generally deeper, reaching a maximum depth of 126 feet (well 203), so far as observed. In the southern part of the county they are usually much shallower. This variation would probably find an explanation in the geomorphic history of the county. In the central part of the county the Highland Rim peneplain probably approached coincidence with a pre-Tuscaloosa peneplain, as indicated by the outliers of Tuscaloosa gravel in the west-central part of the county. This central area was therefore probably exposed to two baseleveling processes rather than one, and a thicker residual mantle was developed as a consequence.

The wells of the plateau are erratic as to depth and the quantity of water yielded. At least one factor in this erratic nature is the fact that the residual chert and clay mantle encloses gravel stringers that represent fillings of old solution channels in the limestone from which the mantle was derived. Such gravel pockets are frequently struck in digging wells on the plateau.

Some deep drilling has been done in the county in search of oil. The deepest of these wells are nos. 192, 193, 194, and 195, west of Lawrenceburg. Water was found at various depths from about 1,500 to 2,100 feet. The water struck at a depth of about 2,100 feet near the bottom of well 192 is reported to have been a potable sulphur water.

Records of wells in Lawrence County

[Nos. 185, 192, 193, 194, 195, 196, 210b, 213 drilled; all others dug]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
180	Summertown, 7 miles west	A. W. Wooten	Low spur	800	37	36
181	Summertown	F. R. Usher	Plateau	1,010	18	36
182	do	S. V. Dunn	do	975	62	36
183	Henryville	W. K. Woodward	do	880	36	40±
184	Henryville, 4½ miles southwest	W. H. Long	do	1,030	73	40±
185	Abner, 4 miles west	Mrs. Ellen C. Mitchell	do	980	65	5
186	do	do	Head of drain	950	10	60±
187	Abner	T. M. Dixon	Plateau	950	36	40±
188	Abner, 1 mile south	S. R. Brewer	do	995	63	40±
189	Westpoint, 9 miles north	Lawrence County	do	965	80	40±
190	Lawrenceburg, 4 miles southwest	A. M. Luna	do	900	73	42
191	Lawrenceburg, 4 miles west	J. H. Stribling	do	895	28	42±
192	do	do	do	920	2,177	
193	Lawrenceburg, 2 miles west	do	Valley	790	2,127	
194	do	do	do	790	2,420	
195	do	do	do	790	2,125	
196	Lawrenceburg, 4 miles northwest	Dr. E. R. Brawley	Plateau	870	40	6
197	Ethridge, 2 miles west	Dr. Warren Short	do	940	61	36±
198	Ethridge	T. A. Barnes	do	930	53	36±
199	do	Louisville & Nashville R. R	do	945	62	48±
200	Leoma, 2 miles north	do	do	925	42	
201	do	Bennie Williams	Spur	910	57	48±
202	Lawrenceburg, 4 miles southeast	Mart Kobeck	Plateau	930	25	48±
203	Fall River, 4 miles northwest	John Smith	do	950	126	36±
204	Fall River, 3 miles west	H. T. Box	do	890	63	36
205	Pleasant Point, 2 miles northeast	J. W. Golden	do	940	79	36
206	do	Southern Methodist Church	do	925	40	36
207	Westpoint, 4 miles northeast	John A. Kelly	Creek terrace	570	24	36
208	Westpoint, 1 mile east	D. T. McMasters	Spur	775	65	42±
209	do	H. M. Dixon	Creek terrace	600	22	36±
210a	Iron City	Abraham Myers	Spur	590	36	30
210b	do	Seavy & Lull	Valley	540		
210c	do	do		550	261	
210d	do	do		540	341	
210e	do	do		560	880	
211	St. Joseph	Lawrence County	Plateau	780	32	
212	do	W. W. Garner	do	785	51	48±
213	Loretto	Mrs. Emma Neidert	do	820	70	6
214	do	John Hollander	do	790	34	48±
215	Pleasant Point, 4 miles southeast	H. C. Chandler	do	935	35	36±
216	Appleton, 2 miles north	H. G. Norwood	Hillside	680	21	36±
217	Appleton, 3 miles west	J. A. Bonner	Plateau	805	20	36±
218	Loretto, 5 miles south	O. W. White	do	795	63	48±
219	Loretto, 3 miles southeast	Mrs. J. R. Foust	do	830	20	36

No. on pl. 1	Water-bearing beds			Water level		Use of water	Total hardness as $CaCO_3$ (parts per million) [a]	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)			
180	35±	Residual chert	Fort Payne chert	−35	Sept. 25	Domestic		
181	14±	do	St. Louis limestone or Warsaw formation.	−14	Sept. 6	do		Most wells in this vicinity are shallow.
182	61±	do	do	−61	do	do		One of the deepest wells in the vicinity.
183	24±	do	Fort Payne chert	−23.9	Sept. 23	do	50	
184	65±	do	St. Louis limestone or Warsaw formation.	−65.4	do	Domestic; stock	25	Furnished water for 20 head of stock during drought.
185	65±	do	do	−64.9	Sept. 20	None		Well originally 82 feet deep and inexhaustible for farm supply. Since partly filled.
186	6±	do	do	−5.5	do	Stock		
187	32±	do	do	−32.2	do	Domestic		Roadside well; estimated to furnish 100 gallons a day.
188	59±	do	do	−58.9	do	Domestic; stock		
189	75±	do	do	−74.8	Sept. 25	Domestic	15	Furnishes 3-room schoolhouse.
190	72±	Limestone		−71.5	Sept. 19	do		
191	23±	Residual chert	Fort Payne chert	−23.1	Sept. 25	Stock		Furnished 225 to 300 gallons a day throughout drought.
192	104		do					Oil test.
	1,520							
	2,105							Reported potable H_2S-bearing water.
193	1,650							
194	1,479							
	2,044							
	2,128							
195	30		Fort Payne chert					
	95		do					
	1,525							
	1,915							
	2,110							
196	40±	Chert	St. Louis limestone or Warsaw formation.	−35.1	Sept. 19	Domestic	265	
197	56±		do	−56.5	Sept. 23	Stock		Could not be bailed dry.
198	46±	Residual chert	do	−45.6	Sept. 20	Domestic	45	
199	55±	do	Fort Payne chert	−54.6	do	do		Well went dry in 1928.
200	34±	do	St. Louis limestone or Warsaw formation.	−34.0		do		
201	54±	do	do	−54.0	Sept. 17	do		
202	23±	do	do	−23.5	Sept. 22	do		
203	122±	do	Fort Payne chert	−122.0	do	Domestic; stock	20	Deepest well seen; almost surrounded by valleys at distances of 500 or 1,000 feet.
204	59±	do	do	−59.1	do	do	20	

[a] Determined in field with standard soap solution.

Records of wells in Lawrence County—Continued

No. on pl. 1	Water-bearing beds			Water level		Use of water	Total hardness as $CaCO_3$ (parts per million)	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)			
205	74±	Residual chert	St. Louis limestone or Warsaw formation.	−74.0	Sept. 17	Wayside garage		
206	35±	do	do	−35.1	do	Domestic		Semipublic well.
207	16±	Limestone	Leipers limestone	−15.9	Sept. 19	Domestic; stock	225	Water struck 18 inches below dug part of well in a drill hole.
208	62±	Residual chert	Fort Payne chert	−61.5	Sept. 16	do		Reported that most wells in neighborhood are shallower.
209	7±		Quaternary alluvium	−6.5	do	do		
210a	34±	Limestone	Ridgetop shale (?)	−34.2	Sept. 24	Domestic		Water reported to come from solution channel opening in railroad cut 150 feet north.
210b								Oil test.
210c	182	Limestone	Bigby limestone (?)					Estimated 500 gallons an hour of saline water containing H_2S.
210d								Water containing H_2S from unknown depth.
210e								Reported that no water was encountered in drilling.
211	31±	Residual chert	Fort Payne chert (?)	−30.9	Sept. 24	Domestic		Inadequate for 10-room school.
212	50±	do	do. (?)	−50.4	do	do	40	
213	68±	do	do. (?)	−68.0	do	do	85	
214	31±	do	Fort Payne chert	−31.3	do	Domestic		
215	29±	do	St. Louis limestone or Warsaw formation.	−28.8	Sept. 18	Domestic; stock		
216	14±			−14.1	do	do		
217	16±	Residual chert	St. Louis limestone or Warsaw formation.	−15.5	do	do		
218	61±	do	Fort Payne chert	−61.3	Sept. 24	do		Well on high point nearly surrounded by valleys.
219	18±	do	St. Louis limestone or Warsaw formation.	−17.9	do	Domestic	20	

Records of springs in Lawrence County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
220	Summertown	Edgar Phelen	Small drain	940	Limestone	St. Louis limestone.
[a] 221	Ethridge, 6 miles northeast	M. P. McIlroy	do	930	do	St. Louis limestone or Warsaw formation.
222	Lawrenceburg, 7 miles northwest	Nashville Trust Co.	Valley bottom	870	do	Do.
223	Lawrenceburg, 3½ miles north	Lawrence County	Base of hill	865	do	Do. (?).
[a] 224	Lawrenceburg, 1 mile west	City of Lawrenceburg	Valley side	785	do	Fort Payne chert.
225	Lawrenceburg, 5 miles west	Grady Kaufman	Creek	820	do	Do. (?).
226	Lawrenceburg, 2 miles southwest	City of Lawrenceburg	Creek bluff	740	Shaly limestone	Do. (?).
227	Fall River, 3 miles northwest	Frank L. Smith	Base of hill	805	Limestone	Ridgetop shale.
228	do	Ed Williams and others	do	760	Siliceous limestone	Fort Payne chert (?).
229	Appleton, ½ mile southwest	N. L. Grisham	do	650	do	Ridgetop shale.
230	Appleton, 5 miles west	J. L. Hammonds & Son	Open valley	825		St. Louis limestone or Warsaw formation.
231	Appleton, 6 miles west	Second Creek Baptist Church	Branch	735	Limestone	Ridgetop shale.
232	do	John H. Ezell	Head of branch	715	do	Do.
233	Appleton, 4 miles northwest	W. A. Lindsey and others	Youthful branch	745	Cherty limestone	Fort Payne chert (?).
[a] 234	Pleasant Point	Walter Brown and others	Head of open valley	840		St. Louis limestone or Warsaw formation.
[a] 235	Iron City	Iron City Water Co.	Valley side	580	Limestone	Ridgetop shale.
236	Iron City, 2½ miles north	W. R. J. Hardwick	Valley bluff	575	do	Do.
237	do	Mineral Right Co.	Creek flood plain	550		Quaternary alluvium.
238	West Point, 6 miles north	Mrs. G. W. Lopp	Branch	785		Fort Payne chert (?).

[a] Analysis given in table of analyses.

Records of springs in Lawrence County—Continued

No. on pl. 1	Openings: Number	Openings: Character	Approximate yield: Gallons a minute	Approximate yield: Date of measurement (1930)	Use of water	Total hardness as $CaCO_3$ (parts per million)[b]	Remarks
220	1	Solution channel	30	Sept. 6	Domestic; stock	1	
221	Several	(?)	600	Sept. 23	do	70	Marcella Falls Spring.
222	Several	Concealed	200	Sept. 20	do	70	Big Spring.
223	1	Solution channel	200	do	Domestic		
224	1	do	1,100	Sept. 15	Public supply	75	Hope Spring. Public supply of Lawrenceburg.
225	Several	Concealed	1,000	Sept. 19	Domestic; stock	90	
226	1	Joint crack	5	Sept. 17	do		
227	1	Solution channel	600	Sept. 22	do	70	
228	1	do	150	do	do		Fall River Spring. Gets somewhat turbid after rain.
229	1	do	7	Sept. 18	do	90	
230	1	Concealed	5	do	Boiler water		
231	1	do	20	do	Domestic; stock		
232	1	do	60	do	do	70	
233	1	Solution channel		do	do		
234	1	Concealed	40	Sept. 17	do		
235	Several	do	15	Sept. 16	Public supply	90	Big Spring. Reported to pump at rate of 1,000 gallons an hour.
236	1	Collapsed cavern	75	do	Domestic; stock	80	One of 5 large springs within 100 yards. All outlets of same collapsed cavern. Reported that turbidity of this spring follows that in Holly Creek, 2 miles west.
237	1		3	do	Medicinal	125	Precipitates iron hydroxide.
238	3	Concealed	45	Sept. 25	Domestic; stock	80	

[b] Determined in field with standard soap solution.

Analyses of ground waters from Lawrence County

[No. 221 analyzed by D. F. Farrar, Tennessee Geological Survey; the rest by Margaret D. Foster, U. S Geological Survey. Parts per million. Numbers at heads of columns correspond to numbers in table of well and spring data]

	221	224	234	235 [a]	Iron City [a] [b]
Silica (SiO_2)	8.0	9.1	7.9	9.2	12
Iron (Fe)	.65	.06	.07	.03	.33
Calcium (Ca)	14	18	22	18	104
Magnesium (Mg)	2.1	3.7	3.6	2.9	44
Sodium (Na)	1.0	[c] 1.5	[c] 1.5	2.0	1,245
Potassium (K)				1.8	26
Carbonate (CO_3)	0	0	0	.0	.0
Bicarbonate (HCO_3)	50	69	81	69	593
Sulphate (SO_4)	1.3	4.4	4.1	3.0	324
Chloride (Cl)	1.5	1.0	1.0	1.8	1,764
Nitrate (NO_3)	.03	1.0	1.2	.91	1.0
Total dissolved solids	57	70	80	75	[d] 3,857
Total hardness as $CaCO_3$ (calculated)	44	60	70	57	440
Date of collection	Sept. 23, 1930	Sept. 15, 1930	Sept. 17, 1930	Apr. 9, 1921	Apr. 9, 1921

[a] Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tenn.: Tennessee Geol. Survey Bull. 26, p. 156, 1921.
[b] "8-inch drilled well, 315 feet deep, of Seavy & Lull, Iron City. Water for analysis obtained from a depth of 200 feet." Probably one of the wells numbered 210 in the well tables.
[c] Calculated.
[d] Hydrogen sulphide (H_2S) 104 parts per million.

LEWIS COUNTY

[Area 286 square miles, population 5,258]

Lewis County is situated on the eastern edge of the western section of the Highland Rim. Its neighboring counties are: Hickman, on the north; Maury, on the east; Lawrence and Wayne, on the south; and Perry, on the west. Its county seat and chief town is Hohenwald (population 980). A phosphate plant at Gordonsburg has localized a town at that point.

The county is a divide area between the waters of the Buffalo River to the south and west and more direct Duck River drainage to the north and east.

A branch line of the Nashville, Chattanooga & St. Louis Railway runs northward through Hohenwald and the west-central part of the county. Hard-surfaced highways connect Hohenwald with Linden and with Columbia. Excellent gravel roads run from Hohenwald to Centerville and to Waynesboro.

The chief industry is farming. Blue rock phosphate is mined and treated at Gordonsburg.

GEOLOGY

Lewis County exhibits the plateau characteristics of the western Highland Rim probably better than any other county in the area described in this report. Continuous stretches of the county maintain an altitude close to 1,000 feet. The streams have cut down to about 600 feet at the boundaries of the county, making the total relief about 400 feet. The streams are closely spaced in the northeast corner, and the resulting complex of ridges and valleys has a local relief approaching the total relief of the county. An area stretching from the southeast corner of the county to Hohenwald represents a fairly broad divide on which the local relief is small and which is level enough for cultivation.

Except for a few thin deposits of Tuscaloosa gravel in the western part of Lewis County, the strata capping the plateau are part of the St. Louis limestone. This and the underlying Warsaw formation are represented in outcrop in general only by weathered chert and clay. Below these beds, outcropping on the upper hill slopes, lies the Fort Payne chert. The black or gray calcareous Ridgetop shale is exposed on the lower slopes of the hillsides in the southwestern part of the county. The black fissile Chattanooga shale crops out on the valley sides. At Gordonsburg, in the northeastern part of the county, the basal member of the formation is highly phosphatic and is mined on a commercial scale as blue rock phosphate.

The Silurian system is represented by earthy and shaly limestone of the Wayne formation at or just above creek level in the corners of the county. The Fernvale formation, the uppermost Ordovician of this area, crops out in the southwest corner in the Buffalo River Valley, and the Leipers formation crops out in the stream valleys in the northeast corner.

GROUND WATER

Wells are of greater importance as a source of domestic water in Lewis County than in most of the surrounding counties, because the highlands of Lewis County are more thickly settled. The wells on the plateau are erratic as to depth and quantity of water. One dug well in Hohenwald (well 241) gets a copious domestic supply at a depth of 33 feet. It is on one of the Tuscaloosa outliers and probably draws its water from a perched water body at the base of the gravel deposit. Other wells in Hohenwald are reported to be from 25 to 45 feet deep and to fail in dry weather. At such times the wells here, as in most other parts of the county, are used as cisterns. The fact that this practice has been developed points out clearly the relative imperviousness of the residual clay from the Mississippian formations and indicates the scant supply of water that it may be expected to yield. The depth of this residual cover apparently reaches a maximum of about 200 feet. One drilled well on the Linden road near the western county line (well 257) is 195 feet deep and, according to report, is cased the entire depth, indicating that solid rock was never struck. This inference is confirmed by the character of the dump pile, which showed no solid rock fragments.

The erratic nature of the wells is illustrated by wells 246 to 250, which are spaced about half a mile apart. The depth of these wells is from 43 to 64 feet. The only one that furnished an adequate domestic supply was the shallowest one, at the highest altitude. It seems very probable that these apparent anomalies are to be explained largely by the fact that the clayey residue from the Mississippian limestones contains old underground channel fillings of chert and quartz gravel and sand, which serve as the main carriers of the ground water. These gravel deposits are found at various depths in many of the wells on the plateau.

Springs of medium size issue from several formations exposed in the valleys. The city supply of Hohenwald is obtained from Downey Spring (no. 260), about 2 miles northwest of the city. This spring, which flows about 300 gallons a minute, issues from a solution channel near the contact of the Warsaw formation and Fort Payne chert. Springs 262 and 263, in the extreme southeast corner of Lewis County, having a combined flow of about 650 gallons a minute, issue from the St. Louis limestone and furnish the municipal water supply of Mount Pleasant (Maury County).

An oil test hole (no. 255) was drilled at Riverside to a reported depth of 1,300 feet. The well started in the basal Fort Payne chert and probably went below the horizon of the St. Peter sandstone. The only water found, according to report, was at depths of about 200 feet and 400 feet.

Records of wells in Lewis County

[Nos. 239, 240, 255, 257 drilled; all others dug]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
[a] 239	Gordonsburg, 5½ miles northeast	Robert Peary	Valley	610	84	5
[a] 240	Gordonsburg, 6½ miles northeast	J. J. Savage	do	610	50	5
241	Hohenwald	John Brown	Plateau	970	33	48±
242	Hohenwald, 2 miles southeast	—— Tanner	do	940	32	60±
243	do	M. V. Chandler	do	945	23	48±
244	Hohenwald, 4 miles southeast	Karl Wolf	do	940	34	60±
245	Hohenwald, 6 miles southeast	J. W. Floyd	do	920	17	48
246	Summertown, 7½ miles northwest	—— Vest	do	965	58	48
247	Summertown, 7 miles northwest	Henry Heinz	do	975	64	42
248	Summertown, 6½ miles northwest	do	do	975	54	48
249	Summertown, 5½ miles northwest	Marion Stagg	do	1,015	43	42
250	Summertown, 5 miles northwest	Henry Heinz	do	1,000		36
251	Napier	Napier Iron Works	Terrace	810	30	60
252	Napier, 1½ miles west	J. M. Scott	do	815	28	48±
253	Riverside, 2 miles east	Mrs. F. E. Voorhies	Edge of valley	685	31	60±
254	do	E. M. Adcox	Terrace	715	38	48
255	do	H. M. Mann	do	695	1,300	7
256	Hohenwald, 6 miles west	G. H. Turnbow	Head of creek	775	50	36
257	Hohenwald, 7 miles west	C. C. Hinson	Ridge	970	195	5

No.	Water-bearing beds			Water level		Use of water	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)		
239	84±		Catheys limestone	0	Sept. 3	None	Salt water carrying H_2S; well flows about 1/10 gallon a minute.
240	50±		Leipers limestone	+2.5	do	Domestic; stock	Well flows 3 gallons a minute.
241	26±	Gravel	Tuscaloosa formation	−26.3	Sept. 1	Domestic	
242	29±	Residual chert and clay.	St. Louis limestone	−29.1	do	Domestic; stock	
243	20±		do	−20.3	do	do	
244	31±	do	do	−31.3	do	Domestic	
245	16±	do	do	−15.7	do	do	

246		do	do		Sept. 6		Reported to have been dug 80 feet. No water.
247	62±	do	do	−62.0	do	Domestic	Inadequate.
248	54±	do	do	−53.7	do	do	Do.
249	36±	do	do	−35.5	do	Domestic; stock	Furnishes several families in neighborhood.
250	57±	do	do	−57.0	do		Dug to depth of 57½ feet when visited. Digging continuing.
251	28±	do	Fort Payne chert (?)	−27.8	Sept. 4	Domestic; stock	
252	21±	do	Fort Payne chert	−21.4	do	do	
253	29±	do	Quaternary alluvium	−29.0	do	do	
254	34±		Brownsport formation (?)	−33.9	do	Domestic	
255	200		(?)			None	Oil test. Depths to aquifers are reported depths.
	400		(?)			do	
256	39±	Residual cherty clay.	Fort Payne chert	−38.7	Sept. 5		
257	195±	do	do. (?)	−185.0	do		

[a] Analysis given in table of analyses.

Records of springs in Lewis County

No. on pl. 1	Location with reference to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic location
258	Hohenwald, 6 miles northeast	John Peary	Base of hill	695		Fort Payne chert (?).
259	Gordonsburg	City of Gordonsburg	Hillside	730	Chert	Fort Payne chert.
[a] 260	Hohenwald, 2 miles north	City of Hohenwald	Valley	765	Cherty limestone	St. Louis limestone (?).
261	Hohenwald, 2½ miles southeast	Commodore Lovelace	do	800	Siliceous limestone	Do. (?).
[a] 262	Summertown, 2 miles north	Mount Pleasant	do	890	Limestone	St. Louis limestone.
[a] 263	Summertown, 1 mile north	do	do	980	do	Do.
264	Napier	Elias Napier	Foot of low hill	770	Chert	Fort Payne chert.
265	Riverside, 1 mile south	Tennessee Products Corporation	Foot of bluff	660	Limestone	Brownsport formation (?).
266	Riverside, ½ mile west	Roscoe Robinett	do	645	Shaly limestone	Do. (?).
267	Hohenwald, 7 miles southwest	Carl Hinson	Base of hillside	730	Chert	Fort Payne chert.
268	Hohenwald, 6½ miles southwest	J. L. Wilson	do	710	do	Do.
269	Hohenwald, 6 miles southwest	D. J. Sham	do	705	do	Do.
[a] 270	Hohenwald, 5 miles northwest	John Fain	do	680	Calcareous shale	Ridgetop shale.

No. on pl. 1	Number	Character	Approximate yield: Gallons a minute	Approximate yield: Date of measurement (1930)	Use of water	Remarks
258	1		20±	Sept. 3	Domestic; stock	
259	1	Joint crack	1½	do	Town supply	
260	1	Solution channel	300	Sept. 1	Public supply	Downey Spring; public supply for Hohenwald.
261	1	do	150	do	Domestic; stock	
262	1	Enlarged bedding plane	500		Public supply	Kidd Spring. Part of public supply of Mount Pleasant.
263	1	do	150		do	Carpenter Spring. Part of public supply of Mount Pleasant.
264		Concealed	10	Sept. 4	Domestic; stock	
265	1	Collapsed cavern	100	do	do	Blowing Spring.
266	1	Bedding plane	¼	do	Domestic	
267	1	do	10	Sept. 5	Domestic; stock	
268	1	Concealed	55	do	do	
269	1	Bedding plane	2	do	do	
270	2	Greatly enlarged joint crack	300	do	do	Another spring from same horizon 15 feet distant flows 175 gallons a minute.

[a] Analysis given in following table.

Analyses of ground waters from Lewis County

[Margaret D. Foster, U. S. Geological Survey, analyst. Parts per million. Numbers at heads of columns correspond to numbers in table of well and spring data]

	239	240	260	262	263	270
Silica (SiO_2)	11	13	8.8	9.8	8.7	14
Iron (Fe)	2.0	.13	.08	.16	.13	.07
Calcium (Ca)	669	67	13	15	21	20
Magnesium (Mg)	407	11	2.3	3.7	4.9	3.8
Sodium (Na)	[a] 5,490	[a] 3.9	[a] 1.7	1.2	1.4	[a] 1.8
Potassium (K)				.6	1.0	
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	279	193	48	59	80	74
Sulphate (SO_4)	5,200	56	4.9	3.8	4.5	5.7
Chloride (Cl)	6,830	3.1	.8	1.0	1.6	1.1
Nitrate (NO_3)	5.3	.10	.05	.64	1.9	.25
Total dissolved solids	19,160	257	55	65	85	81
Total hardness as $CaCO_3$ (calculated)	3,340	213	42	53	73	66
Date of collection (1930)	Sept. 3	Sept. 3	Sept. 1	July 11	July 11	Sept. 5

[a] Calculated.

LINCOLN COUNTY

[Area 587 square miles, population 25,422]

Lincoln County lies in the southeastern part of the area and adjoins Alabama. It is bounded by Bedford County on the north, Moore County on the northeast, Franklin County on the east, Madison and Limestone Counties, Ala., on the south, Giles County on the west, and Marshall County on the northwest. Fayetteville, the county seat, with a population of 3,822, is the chief city. Several other towns are located around the outskirts of the county.

The main drainage line of the county is the Elk River, which flows in a general westerly direction more or less through the middle of the county. The country north of the river is drained by fair-sized tributaries of the Elk, but the southern tributaries are negligible. Most of the southern part of the county is drained by the headwaters of the Flint River, another tributary of the Tennessee.

The Nashville, Chattanooga & St. Louis Railway runs from the north-central to the southeastern part of the county. Hard-surfaced highways connect Fayetteville with Shelbyville and Huntsville, Ala., and similar highways are under construction (1930) to Pulaski, Winchester, and Lynchburg.

GEOLOGY

Lincoln County lies across the Highland Rim escarpment, which is just south of the Elk River. The part of the county to the north is in the Nashville Basin, although many large and high remnants of the rim are scattered through it. The remainder of the county is a part of the Highland Rim plateau.

The Highland Rim is about 1,000 feet above sea level at its north edge in this county and decreases southward to about 900 feet or less along the Alabama line. This suggested northerly rise of the plateau surface may be projected across the basin section of the county to the remnants along the Bedford County line, which are about 1,200 feet above the sea. The rate of rise is about 10 feet to the mile. In the typical Highland Rim area south of the escarpment the relief is very small, and the topography very gentle. The valleys are open, and the streams flow southward down the slope of the plateau.

The general altitude of the central basin in this section is about 700 feet above the sea, some 300 feet below the edge of the Highland Rim. The Elk River is at an altitude of slightly less than 600 feet, so the total relief of the county is about 400 feet. The basin section has much more local relief than the Highland Rim, owing to the presence of Highland Rim remnants in it.

The uppermost formation exposed in Lincoln County is the St. Louis limestone, except in the extreme southeast corner, where higher strata ranging up to the Bangor limestone are present in a spur of the Cumberland Plateau. The St. Louis limestone is gray and weathers into a red soil. Underlying it is the very similar limestone of the Warsaw formation, generally somewhat more sandy than the St. Louis. These formations cap the Highland Rim in the southern part of the county and are present in very small patches in the outliers in the northern part of the county. The residual soil from them in this region contains much less chert than that developed on the western part of the Highland Rim, and the soil is much thinner. As a result these formations are here seen in their original lithologic character much more frequently than they are on the west side of the rim.

Underlying the Warsaw formation is the Fort Payne chert, generally exhibited in a more calcareous phase than that seen in the western rim. The Ridgetop shale is apparently thin or absent throughout the county. The black Chattanooga shale is generally present in the escarpments and hillsides and is from 1 to perhaps 10 feet thick. In the western and perhaps the southern portions of the county the Silurian system is represented by hard siliceous limestone, reaching a thickness of apparently about 50 feet in the western part of the county. The Fernvale formation (uppermost Ordovician), consisting of coarsely crystalline limestone and light-colored shale, is present in most of the county. The Leipers rubbly shaly limestone is generally found below this. Some 200 feet of shale, argillaceous limestone, crystalline limestone, and semilithographic limestone, outcropping on the hillsides over the entire county, represent the Catheys and Cannon limestones. The basal members of the Cannon formation are a dark argillaceous limestone about 20 feet thick (called "Ward limestone" in early reports), underlain by a gray semilithographic limestone about 5 feet thick (locally known as the "True Dove"). Succeeding this downward is the Bigby limestone, a coarse to fine granular, in places cross-bedded or laminated, somewhat sandy limestone about 40 feet thick. Below this is the Hermitage formation, varying in the county from a hard siliceous limestone, weathering sandy, to a sandy shale. It is about 50 feet thick. In the northwestern part of the county the top of the Lowville is exposed. Near Boons Hill it has the misleading appearance of the Lebanon limestone.

It is at this point a thin-bedded dove-colored limestone with *Plectambonites*. This facies is more common north of the area described in this report.[49]

Lincoln County lies in the southeast sector of the Nashville dome. Near the Bedford County line the Chattanooga shale is about 1,100 feet above sea level, and in the southwest corner it dips to about 800 feet. There has been considerable local folding and minor faulting in the neighborhood of Howell.

GROUND WATER

Ground water in Lincoln County occurs almost entirely in solution channels in the various limestone strata and, on the Highland Rim, in the weathered residue of the Mississippian formations. Wells on the Highland Rim are usually dug wells about 30 feet deep. These wells in Lincoln County are much shallower than the corresponding wells on the western Highland Rim.

In the basin area water for domestic purposes is generally obtainable at shallow depths, irrespective of stratigraphic position. The city of Petersburg obtains water from a well 40 feet deep drilled into a solution channel in the Lowville limestone. It is reported to have been pumped at 22 gallons a minute for a period of 20 hours without any effect on the water level.

Generally the water obtained carries calcium bicarbonate, varying widely in amount. A few shallow wells, among them well 279, obtain impotable water.

Large springs occur around the edge of the Highland Rim in the county. The largest lie in the basal part of the Fort Payne chert, just above the Chattanooga shale. The municipal supply of Fayetteville, amounting to 600,000 gallons a day, originates in 26 small springs on Wells Hill, about 3 miles south of the town, and one spring (no. 309) near Kelso, about 6 miles southeast of Fayetteville. All these are in the basal part of the Fort Payne chert. In addition spring 300, at Wells Hill, in the Cannon formation, flowing about 125 gallons a minute, may be used in emergency. The water from it is much harder than that from the Fort Payne chert. The largest group of springs is at Vinsons Mill, near Flintville, where about 900 gallons a minute issues from several springs in the Fort Payne chert just above the Chattanooga shale. The water is used to run a gristmill—a common use for large springs in the Highland Rim part of the area considered in this report.

Cottrell Spring (no. 306) is somewhat unusual because of its topographic position. It lies in a shallow valley in the Highland Rim. The flow is about 300 gallons a minute. The stratigraphic horizon is the Fort Payne chert, probably about 25 feet above the Chattanooga shale.

[49] Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 1, 1903.

Records of wells in Lincoln County

[Nos. 272, 284–289, 291, 293–296 dug; all others drilled]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
271	Belleville, 3½ miles north	J. H. Dunn	Valley head	940	63	5
272	do	do	do	930	35	48±
[a] 273	Petersburg	City of Petersburg	Valley flat	730	40	6
274	Petersburg, 6 miles southwest	C. H. Sullivan	Hillside	780	36	5
275	Boons Hill, 1 mile southwest	W. R. Trentham	Valley	665	15	5
276	Boons Hill, 3 miles east	Mrs. N. T. Tucker	Hillside	725	51	5
277	do	R. P. McWhorter	do	720	38	5
278	Belleville	H. R. Brown	do	770	45	5
[a] 279	do	Dr. W. F. Cannon	do	790	66	5
280	do	R. V. More	Valley	810	23	5
281	Belleville, 3 miles southeast	—— Groce	Spur	820		
282	Mulberry, 3 miles north	C. A. Ashby	Hillside	730	44	5
283	do	H. B. Parks	Valley	715	572?	9
284	Mulberry	Mrs. T. M. Elmore	Hillside	765	18	100±
285	Taft, 1½ miles southeast	—— Dedman	Plateau	900	26	40±
286	Taft, 2 miles east	Jim Rogers	do	895	22	40±
287	do	Bud Ables	do	900	27	40±
288	Taft, 2½ miles east	J. W. Yarbrough	do	910	35	40±
289	Taft, 3 miles east	Mrs. Pinnie Turner	do	920	26	40±
290	Fayetteville, 6 miles southwest	W. M. Templeton	Hillside	680	35	5
291	Fayetteville, 6 miles south	John Davis	Plateau	965	15	42
292	Flintville, 7 miles southwest		do	925		
293	Flintville, 6 miles southwest	Mrs. Minnie Mitchel	do	830	33	60
294	Flintville, 4 miles south	Lee Vance	do	925	41	40±
295	Elora, 3½ miles west	Mrs. Shelton	do	890	24	60±
296	Elora	W. H. Smith	do	915	26	

[a] Analysis given in table of analyses.

No. on pl. 1	Water-bearing beds			Water level		Use of water	Total hardness as $CaCO_3$ (parts per million)[b]	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)			
271	63±	Limestone	Cannon limestone (?)	−56	Nov. 12	Domestic; stock	235	Furnishes abundant water for all farm purposes.
272	35±	do	do. (?)	−35	do	Domestic	290	Failed about Nov. 1, 1930.
273	40±	do	Lowville limestone	−22		Public supply		Public supply for Petersburg. Reported to have been tested at the rate of 22 gallons a minute for 20 hours.
274	36±		Hermitage formation	−15	Nov. 3	Domestic	120	
275	15±		do	−5	Nov. 14	Stock	245	
276	51±	Limestone	Lowville limestone	−29	Nov. 13	Domestic	120	H_2S odor; slightly salty.
277	38±	do	do	−24.5	do	do	310	
278	45±	do	Hermitage formation	−20.5	Nov. 12	Domestic; stock	580	
279	66±	do	do. (?)	−25.0	do	Stock		Very salty; carries H_2S.
280	23±	do	do	0	do	Domestic	300	Flowing well; water carries H_2S.
281								Oil test.
282	44±	Limestone	Bigby limestone (?)	−35	Nov. 18	Domestic		
283	42	do	Cannon limestone			None		H_2S water at 42 feet; dry nearly to bottom, where petroleum and salt water were struck.
284	12±	Shaly limestone	do	−11.7	Nov. 18	Domestic		Never known to lower.
285	20±	Residual chert	Fort Payne chert	−20.2	Nov. 17	do		
286	19±	do	do	−19.0	do	Domestic; stock	30	
287	23±	do	do	−22.5	do	Domestic	25	
288	33±	do	do	−32.7	do	do	15	
289	22±	do	do	−21.9	do	Domestic; stock	15	
290	35±	Limestone	Bigby limestone (?)	0	Nov. 15	do	250	Flowing well; water carries H_2S.
291	11±	Chert	Fort Payne chert	−10.9	Nov. 8	do	45	
292					do			Oil test.
293	27±	Residual chert	Fort Payne chert	−26.6	do	Domestic	60	
294	38±	do	do	−37.8	do	Domestic; stock	20	
295	20±	do	do	−20.4	do	Domestic	25	
296	19±	Limestone	Warsaw limestone (?)	−18.6	do	Domestic; stock	85	

[b] Determined in field with standard soap solution.

Records of springs in Lincoln County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
297	Boons Hill	W. E. Whitehead	Valley	655	Limestone	Bigby limestone.
[a] 298	Howell	Mary Belle Conoway	Branch	890	do	Fernvale formation.
299	do	—— Moore	Plain	790	do	Bigby limestone.
[a] 300	Fayetteville, 4 miles south	City of Fayetteville	Branch	760	do	Cannon limestone.
301	Kelso, 5 miles east	Walter Crawford	Hillside	830	do	Do. (?).
[a] 302a	Delrose, ½ mile northeast	Mrs. Mattie Oliver	do	755	do	Fernvale formation.
302b	do	W. F. Mitchell	do	790	do	Silurian system.
303	Coldwater	E. E. Mitchell and Mattie Dunlap	Creek bottom	615	do	Cannon limestone (?).
304	Taft, ½ mile north	G. W. Sulser	Head of branch	820	Chert (?)	Fort Payne chert (?).
305	Blanche, 3 miles northwest	L. O. Reynolds	do	860	do. (?)	Do. (?).
306	Flintville, 6 miles southwest		Plateau	885	do. (?)	Fort Payne chert.
307	Flintville, 7 miles southwest	Olley Hill	Branch	830	Limestone	Fernvale formation.
308	Kelso, 1 mile south		Hillside	740	do	Leipers limestone (?).
309	Kelso, 2½ miles south	City of Fayetteville	Branch	870	Chert	Fort Payne chert.
310	Kelso, 3½ miles south		Valley	905	Shale	Chattanooga shale.
311	Flintville	Curry Gin Co. and others	Creek level	900	Chert	Fort Payne chert.
312	Flintville, ½ mile north	J. W. Bruce	do	905	do	Do.
313	Flintville, 2½ miles northeast	Ridge Realty Co.	Branch	915	do	Do.
[a] 314	Elora, ½ mile south	J. B. Scivally	Base of hill	915	Limestone	St. Louis limestone.

[a] Analysis given in following table.

No. on pl. 1	Openings		Approximate yield		Use of water	Total hardness as $CaCO_3$ (parts per million[b])	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)			
297	1	Solution channel	35	Nov. 14	Domestic; stock	200	
298	1	Enlarged bedding plane	½	Nov. 13	Community supply	175	Furnishes several families in Howell.
299	1	Enlarged joint crack	35	do	Domestic; stock	295	
300	1	Concealed	125	Nov. 18	Public supply		Part of public supply of Fayetteville. Used only when other springs fail to supply city.
301	1	Bedding plane	3±	Nov. 20	Domestic; stock		No turbidity at any time.
302a	1	Enlarged bedding plane	3	Nov. 15	Domestic	95	Furnishes several families in Delrose.
302b	1	Solution channel		do	do		Do.
303		Concealed			Domestic; stock	195	Cold water spring. Stream rises in middle of creek, and the water is carried to a spring box at the bank through clay tile; spring seen when creek was up and muddy; water was only slightly turbid.
304	Several	do	50	Nov. 17	Stock		Spring issues from talus 5 feet above Chattanooga shale.
305	1	do	50±	do	Domestic; stock		Water pumped to schoolhouse by ram.
306	Several	Porous chert bed (?)	300±	Nov. 8	Domestic; stock, power		Cottrell Spring.
307	1	Bedding plane	1	do	Domestic; stock	85	Springs issuing above Chattanooga shale, 20 feet higher, have hardness of only 10 parts per million.
308	1	Solution channel	225	Nov. 20	Stock		Roadside spring.
309	1	Concealed			Public supply		Kelso Spring; largest source of public water supply of Fayetteville.
310	1	Bedding plane	3	do	Medicinal		
311	1	Porous chert bed (?)	80	do	Domestic; stock		
312	1	do. (?)	150	do	do		This and other springs in area of ½ square mile of marsh here flow total of about 1 cubic foot per second.
313	Several	Solution channels	900±	do	Domestic; stock; power		Vinsons Mill Springs. Water carried through mill race ¼ mile to overshot wheel; springs in adjacent hollow reported to flow as much as these.
314	1	Solution channel	8	Nov. 8	Domestic; stock	185	Water pumped from artificial pool in small cave; this stream not known to reach surface in vicinity.

[b] Determined in field with standard soap solution.

Analyses of ground waters from Lincoln County

[D. F. Farrar, Tennessee Geological Survey, analyst. Parts per million. Numbers at heads of columns correspond to numbers in table of well and spring data]

	273	279	298	300	302a	314	Fayetteville [a]
Silica (SiO_2)	14	18	14	9.8	8.8	9.8	11
Iron (Fe)	1.2	2.7	.88	.84	1.3	.74	.63
Calcium (Ca)	119	1,438	54	27	28	58	15
Magnesium (Mg)	10	104	5.2	4.3	4.2	5.0	3.3
Sodium (Na)	18	935	4.3	2.5	3.6	2.1	.9
Potassium (K)	4.0	20					
Carbonate (CO_3)	0	0	0	0	0	0	0
Bicarbonate (HCO_3)	350	361	162	100	91	193	52
Sulphate (SO_4)	47	3,492	21	1.2	9.4	4.9	8.2
Chloride (Cl)	31	1,460	6.5	3.8	5.5	3.5	1.4
Nitrate (NO_3)	.68	2.3	.45	.35	.72	.65	.42
Total dissolved solids	434	7,724	193	106	110	189	72
Total hardness as $CaCO_3$ (calculated)	338	4,015	156	85	87	165	51
Date of collection (1930)	Nov. 6	Nov. 12	Nov. 13	Nov. 18	Nov. 15	Nov. 8	Nov. 21

[a] Municipal water supply of Fayetteville; sample taken from private tap.

MARSHALL COUNTY

[Area 378 square miles, population 15,574]

Marshall County, which is elongated in a north-south direction, lies in the northeastern part of the area described in this report. Its neighboring counties are Williamson and Rutherford to the north, Bedford to the east, Lincoln to the southeast, Giles to the southwest, and Maury to the northwest. Lewisburg, the county seat and chief city, has a population of 3,112.

The Duck River flows westward across the northern part of the county and drains all except the extreme southern part, which is tributary to the Elk River.

The Louisville & Nashville Railroad runs southward through the middle of the county. The Nashville Chattanooga & St. Louis Railway runs southeastward in the southern part of the county, intersecting with the other railroad at Lewisburg. Hard-surfaced highways connect Lewisburg with Nashville, Columbia, and Shelbyville.

Agriculture is the basic industry of the county.

GEOLOGY

Marshall County lies entirely within the Nashville Basin. The northern part represents the flat, more or less glady character of the inner basin; the topography in the southern part is diversified by remnants of the Highland Rim on the Duck River-Elk River divide. The Duck River is about 600 feet above sea level, and the remnants probably reach a little more than 1,000 feet; the total relief is thus about 400 feet, most of it concentrated in the southern part of the county.

Sink-hole topography is shown in the vicinity of the Duck River. Interrupted streams are present in the northern part of the county.

The Highland Rim remnants in the southern part of the county are capped by the Fort Payne chert. The Ridgetop shale is thin or absent in this county. Below the Fort Payne lies the Chattanooga shale, apparently succeeded immediately below by the Leipers limestone or Catheys limestone, of Ordovician age. These formations, exposed only in the remnants in the southern part of the county, are relatively unimportant as aquifers in this county, as comparatively few people live on these higher portions. Below the Catheys limestone lies the Cannon. The following section, adapted from Bassler,[50] illustrates the character of the remainder of the exposed rocks in the southern part of the county:

Stratigraphic section along the old Belfast-Petersburg road 1 to 3½ miles south of Petersburg

	Feet
Catheys limestone: Shale and nodular limestone, with branching Bryozoa (*Eridotrypa briareus*, *Constellaria emaciata*, and *Homotrypella* sp.)	6½
Cannon limestone:	
Granular and crystalline limestone with *Columnaria alveolata*, *Tetradium columnare*, and *Stromatocerium pustulosum*	5½
Blue-gray limestone, with few fossils	6
Unfossiliferous shale, with 3-foot laminated limestone at base	16
Very cherty fine-grained limestone weathering into a red soil containing silicified *Columnaria* and *Stromatocerium*	9
Dove-colored limestone	2
Clay bed with *Tetradium fibratum*	1
Dove-colored limestone with numerous *Leperditia*	2
Dove-colored limestone separated by clay layers. *Scolithus columbina* at base	15
Limestone with abundant gastropods, including *Lophospira*, *Bucania*, and *Hormotoma salteri*	4½
Dove-colored limestone with *Scolithus columbina*	2
Blue-gray fine-grained limestone with *Leperditia* and *Tetradium fibratum*	4
Massive dove-colored limestone; upper half with *Scolithus columbina*	8
Dark blue-gray limestone with *Isochilina*	3
Blue to brown clayey limestone in 8 to 12 inch layers with thin partings, *Tetradium fibratum*, *Stromatocerium pustulosum*, gastropods, and *Cyrtodonta* abundant	9
Hermitage formation: Shales and nodular shaly limestone	53
Lowville limestone: Thin-bedded dove-colored limestone and shale with massive dove-colored limestone below.	

In this section the Bigby limestone, whose stratigraphic position is between the Hermitage and Cannon formations, is missing. The Bigby limestone is present near Mooresville, in the west-central part of the county, where it consists of coarse granular laminated limestone. It may also be represented by about 15 feet of coarse

[50] Bassler, R. S., The stratigraphy of the central basin of Tennessee: Tennessee Div. Geology Bull. 38, pp. 33-34, 1932.

131880—36——10

crystalline fossiliferous brown limestone that comes above the Hermitage shales and underlies the dove-colored limestone members of the Cannon limestone near Petersburg.

The Hermitage formation ranges from a shaly nodular limestone to a pink siliceous limestone, weathering to sandstone, as at the site of the Lewisburg Reservoir.

The Lowville limestone is a dove-colored dense medium- to thick-bedded limestone. It crops out south of Lewisburg. The somewhat shaly and thin-bedded Lebanon limestone crops out over most of the county from Lewisburg north. Its thickness is of the order of 100 feet. Below it, exposed in a few small areas of the county, is the thick-bedded Ridley limestone.

The following log represents the subsurface stratigraphy in the southern part of the county. The well started at about the top of the Hermitage formation.

Log of G. W. Gower well, 3 miles southeast of Cornersville

[Drilled for Morris Oil Co. by Dodson Bros., Fayetteville. Completed July 20, 1928. Log by J. W. Young, of Fayetteville]

	Thickness (feet)	Depth (feet)
Soil; fresh water	8	8
Light sandy limestone	32	40
Light-brown limestone	5	45
Light flesh-colored limestone	20	65
Gray limestone	30	95
Muck; Pencil Cave (bentonite)	(?)	95
Gray limestone; fresh water at 120 feet	30	125
Drab limestone	5	130
Dark-drab to gray limestone	30	160
Light-gray limestone	5	165
Dark-gray limestone	30	195
Drab-gray limestone	65	260
Drab limestone with dark stains; struck salty "sulphur" water at 270 feet; rose 80 feet in 5 hours	10	270
Drab limestone	7	277
Light-drab limestone	23	300
Dark-drab limestone	25	325
Gray limestone	5	330
Gray and drab limestone	20	350
Flaky gray cap	5	355
Flesh-colored limestone	25	380
Dark-gray and drab mixture	25	405
Dark-gray muck	5	410
Dark-gray limestone mixed with white	5	415
Brown and white limestone	45	460
Limestone, dark drab when wet	145	605
Dove-colored limestone	20	625
Dark dove-colored limestone	5	630
Light-drab limestone	5	635
Dark limestone	15	650
Light flesh-colored limestone	20	670
Light-gray limestone	10	680
Limestone, light dove-colored when wet	45	725
Green and brown variegated limestone	55	780
Green limestone	5	785
Hard flesh-colored cap	35	820
Same, with little blue mixture	5	825
Fine hard flesh-colored limestone	5	830
Light hard crystallized limestone	5	835
Same, bnt finer and harder with little blue specks	25	860
Harder and darker limestone, same color	10	870
Light-colored crystallized limestone, like Vermont marble	10	880
Light-brown and white limestone	5	885
Highly crystalline limestone	5	890
White and brown mixture with fine white water sand; water rose 290 feet in 12 hours and continned to rise until 8 feet from top	55	945
Light-bluish very hard limestone	15	960

GROUND WATER

Marshall County presents the same ground-water characteristics as the other counties of the Nashville Basin. Water for domestic use is generally found at shallow depths throughout the county. Wells drilled in the hope of obtaining large supplies are generally disappointing, although a few have obtained fair-sized outputs. Well 338, drilled at the site of the Lewisburg Reservoir, in an attempt to obtain a ground-water supply for Lewisburg, was put down to a reported depth of 1,860 feet and was dry throughout its depth, according to report. Well 328a, south of Lewisburg, drilled to a depth of 600 feet, is reported to yield a maximum of 22 gallons a minute, probably from the Murfreesboro limestone. A well drilled by the railroad at Cornersville (well 337), 212 feet deep, probably drawing from the Pierce limestone, is reported to have furnished 25 gallons a minute but was later abandoned. The water yielded by the wells generally contains calcium carbonate and often carries considerable hydrogen sulphide. A few wells yield acid and highly mineralized water.

As in the other counties of the Nashville Basin, springs are generally small. Spring 341, at Farmington, flows about 75 gallons a minute. Other springs seen have flows of 5 gallons a minute or less.

Lewisburg obtains the water for its public supply from a reservoir impounding a small surface stream about 4 miles southwest of the city.

Records of wells in Marshall County

[All drilled wells]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
315	Holtland	M. M. Brown	Plain	790	50	5
316	do	J. M. Suttle	do	795	37	6
317	do	R. A. Manier	do	800	900+	8
318a	Chapel Hill, 4 miles northwest	J. G. Cromer	do	780	255	(?)
318b	do	do	do	780	265	7
319	Chapel Hill	Houston & Liggett Co	do	710	150±	
320	do	W. T. Hurt	do	700	42	
321	Caney Spring	E. B. Neill	do	640	29	5
[a] 322	Chapel Hill, 2½ miles south	Henry Horton	Terrace	680	96	6
323	Verona	Mrs. W. T. McCurdy	do	650	36	5
324	do	Henry McQuiddy	do	670	125	5
325	Farmington	Robinson & Liggett	Plain	680	40	6
[a] 326	Lewisburg, 3 miles northwest	Mrs. Estelle Orr	do	705	990	8½
327	Lewisburg	Louisville & Nashville R. R.	Open valley	760	150	6
328a	Lewisburg, ½ mile south	J. W. Cowden	Plain	750	600+	9
328b	do	do	do	750		9
[a] 329	Lewisburg, 2 miles southeast	W. D. Fox	do	800	21	5
330	Belfast	J. F. Callahan	do	825	69	5
331	do	Mrs. Sally Pickles	do	820	48	5
332	Petersburg, 6 miles southwest	J. B. Mauldin	Small hill	820	38	5
333	Cornersville, 5 miles east	J. W. Lowrance	Valley	860	32	6
334	Cornersville, 3½ miles southeast	H. C. Robertson	Terrace	860	113	5
335	Cornersville, 3 miles southeast	—— Gower	Valley	800	996	
336	Cornersville, 2 miles southeast	B. C. Meadows	Terrace	880	345	
337	Cornersville	Louisville & Nashville R. R.	do	870	212	12
338	Lewisburg, 3½ miles southwest	City of Lewisburg	Valley	915	1,860 ?	
339	Cornersville, 3 miles southwest	Sam A. Smith	Small hill	845	1,100±	

[a] Analysis given in table of analyses.

No. on pl. 1	Water-bearing beds			Water level		Use of water	Total hardness as $CaCO_3$ (parts per million) [b]	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)			
315	50±	Limestone	Lebanon limestone	−27.0	Oct. 30	Stock	20	Water contains H_2S.
316	37±	do	do	−20.5	do	Domestic	375	Do.
317								Oil test.
318a	200±	Limestone	Pierce limestone or Ridley limestone.					Do.
318b	200±	do	do	−37.6	Oct. 31			Do.
319		do	do	(?)				
320	42±	do	Lebanon limestone (?)	(?)		Domestic	365	
321	29±	do	do. (?)	−21.5	Oct. 31	do	350	
322	96±	do	Lebanon limestone or Ridley limestone.	−70.0		Domestic; stock	255	
323	36±	do	Lebanon limestone	−20.0	Oct. 31	Domestic	330	
324	125±	do	Ridley limestone (?)	−30.0	do	do	365	
325	40±	do	Lebanon limestone	−14.4	Oct. 30	Domestic; stock	340	
326				−100(?)		do	230	Water contains H_2S. Several streams of water encountered during drilling. Drilled as oil test.
327	150±	Limestone	Ridley limestone (?)	−30				
328a	300±	do	Murfreesboro limestone (?)	−18		Domestic; stock	215	Water contains some H_2S. Reported to furnish maximum of 22 gallons a minute.
328b				−31.2	Nov. 5			Drilled in attempt to get adequate ground-water supply for Lewisburg. Unsuccessful.
329	21±	Limestone	Lowville limestone	+1.0	Nov. 1	Domestic; stock	5	Water contains H_2S.
330	69±	do	Lowville or Lebanon limestone.	−21.9	do	Stock	600+	Water is salty; contains H_2S.
331	48±	do	Lowville limestone	−20.0	do	Domestic	295	Water is salty, astringent; contains H_2S.
332	38±	do	do	−23.5	Nov. 3	Domestic; stock	210	
333	32±	do	do. (?)	−7.4	do	do	170	
334	113±	do	Lebanon limestone			Domestic	290	
335	125	do	Lowville limestone			None		Well drilled as oil test.
	270	do	Stones River group			do		Water is salty and contains H_2S. Rose 80 feet in 5 hours.
	870	Fine sand		−8±	Nov. 4	do		Water rose within 8 feet of surface.
336	35	Limestone	Bigby limestone (?)			do		Well drilled as oil test. Heavy flow reported at this depth.
	180	do	Lowville limestone			do		Salt water.
	320	do	Stones River group	−6±	Nov. 4	do		Heavy flow.
337	212	do	Ridley limestone or Pierce limestone.	−12		do		Reported tested to give 25 gallons a minute.
338								Drilled as an attempt to furnish ground-water supply for Lewisburg. Reported absolutely dry throughout.
339								Drilled as oil test but furnished water. No further information available.

[b] Determined in field with standard soap solution.

Records of springs in Marshall County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
340	Caney Spring	J. F. Floyd		610	Limestone	Lebanon limestone (?).
341	Farmington	Dr. W. T. Sharp	Plain	680	do	Lebanon limestone.
[a] 342	Lewisburg, 3 miles south	Will H. McLean	Base of low hill	820	Shaly limestone	Hermitage formation.
343	Belfast, 3½ miles southeast	Maggie Wurley	Hillside	870	Limestone	Cannon limestone.
344	do	do	Base of hill	860	do	Do.
345	Petersburg, 4 miles west	R. J. Sowell	do	825	do	Lowville limestone.
346	Petersburg, 6½ miles southwest	J. B. Mauldin	do	810	Sandy limestone	Hermitage formation.
347	Mooresville	Dan Ingram	do	695	Limestone	Do.

No. on pl. 1	Openings		Approximate yield		Use of water	Total hardness as $CaCO_3$ (parts per million) [b]	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)			
340	1	Enlarged joint crack	2±	Oct. 31		245	
341	1	Solution channel	75	Oct. 30	Stock	210	Reported that spring furnished 33,000 gallons a day during drought.
342	2	Bedding planes	5±	Nov. 5	Domestic; stock	115	
343	1	Bedding plane	½	Nov. 1	do	205	
344	1	do	½	do	do	345	
345	1	Solution channel	8	Nov. 3	do	200	
346	1	Concealed	½	do	do	115	
347	1	do	½±	Nov. 4	do	170	

[a] Analysis given in table of analyses.

[b] Determined in field with standard soap solution.

Analyses of ground waters from Marshall County

[No. 329 analyzed by Margaret D. Foster, U. S. Geological Survey; the rest by D. F. Farrar, Tennessee Geological Survey. Parts per million. Numbers at heads of columns correspond to numbers in tables of well and spring data]

	322	326	329	342	Lewisburg [a]
Silica (SiO_2)	9.8	12	11	10	6.8
Iron (Fe)	1.4	2.1	.09	.85	.84
Calcium (Ca)	85	122	3.2	32	34
Magnesium (Mg)	10	16	1.5	4.0	3.0
Sodium (Na)	5.0	17	233	3.3	3.4
Potassium (K)	1.0	4.0	5.6		
Carbonate (CO_3)	0	0	57	0	0
Bicarbonate (HCO_3)	292	294	420	100	101
Sulphate (SO_4)	5.3	108	67	12	11
Chloride (Cl)	8.5	32	18	5.5	5.5
Nitrate (NO_3)	.67	1.3	1.3	.15	.60
Total dissolved solids	[b] 270	470	609	121	115
Total hardness as $CaCO_3$ (calculated)	254	370	14	96	97
Date of collection (1930)	Oct. 30	Oct. 31	([c])	Nov. 5	Nov. 6

[a] Municipal water supply at Lewisburg; sample taken from private tap; impounded surface water.
[b] Calculated.
[c] Sample analyzed July 1931.

MAURY COUNTY

[Area 582 square miles, population 34,016]

Maury County lies in the north-central part of the area discussed in this report. It is bounded on the north by Williamson County, on the east by Marshall County, on the south by Giles and Lawrence Counties, and on the west by Lewis and Hickman Counties. The largest city is the county seat, Columbia, with a population of 7,882. Mount Pleasant (population 2,010), in the southwest corner, is the center of a large phosphate industry.

The Duck River flows northwestward through the middle of the county and drains the entire area.

The Louisville & Nashville Railroad connects the centrally located city of Columbia with Nashville, to the northeast, with Pulaski, to the south, and with Mount Pleasant and Lawrenceburg, to the southwest. The Nashville, Chattanooga & St. Louis Railway connects Columbia with Lewisburg, to the southeast. Paved highways radiate from Columbia approximately along the lines of the Louisville & Nashville Railroad, and graveled highways connect Columbia with Lewisburg and Centerville.

The county is predominantly rural in character. The phosphate industry centered about Mount Pleasant and near Williamsport is the largest basic industry, aside from agriculture, in south-central Tennessee.

GEOLOGY

Maury County is a part of the Nashville Basin, although spurs from the Highland Rim plateau project into it from the northwest, west, and southwest, and remnants of the rim are found in all but the most eastern portion. The plateau in the southwest corner lies 1,000 feet above sea level, and the Duck River leaves the county at about 500 feet, making the total relief 500 feet. The Highland Rim spurs are greatly dissected, and this portion of the county is topographically very rough. Throughout that part of the lowland lying west of Columbia the topography is rolling, but in the eastern part of the county the local relief is very small, and much of the area has the typical glade character.

Most of the high parts of the Highland Rim spurs, except along the Giles County line, are capped by the St. Louis limestone and the Warsaw formation. The maximum combined thickness of these formations in this county is probably close to 100 feet. Underneath these, making the steep slopes of the hills, are the Fort Payne chert and Ridgetop shale, reaching a maximum combined thickness of 250 feet. The Maury glauconitic member is generally present at the base of the Ridgetop shale. The Chattanooga shale crops out in the hillsides and is 10 feet or less thick. The Silurian is present in small areas in the western part of the county. It consists of shaly limestone and is thin in this area. The uppermost Ordovician, the Fernvale formation, also crops out in the western part of the county. Here it consists of light-colored shale and reddish crystalline limestone. It, too, is thin. The nodular shaly Leipers limestone is present on the lower hill slopes in the western part of the county and overlies the similar Catheys limestone. The combined thickness of these two formations ranges from a knife-edge to 200 feet.

Stratigraphically below the Catheys limestone comes the Cannon limestone. This formation is present only in the eastern part of the county, never having been deposited in the western part, in the Columbia quadrangle.[51] The Cannon limestone consists of dove-colored semilithographic limestone and argillaceous limestone and shale.

Stratigraphically, the Bigby limestone underlies the Cannon limestone, but it is best developed in the western part of the county, where the Cannon is absent, and pinches out in the eastern part of the county, where the Cannon is well developed. It has a maximum thickness of about 100 feet and is predominantly a semi-oolitic or granular crystalline laminated and locally cross-bedded limestone. Its type area is on Bigby Creek, in this county, and, in its typical facies at least, it does not extend far beyond the limits of the county except to the south in Giles County. Below the Bigby limestone is the Hermitage formation, a shaly limestone from 40 to 70 feet thick.

The Hermitage formation is underlain by the Lowville limestone, consisting in most of the county of the lower or Carters limestone member, typically a thick-bedded limestone, weathering into a red soil through which unweathered limestone bosses project. Its thickness is almost 50 feet. In the eastern part of the county the

[51] Bassler, R. S., op. cit., p. 86.

thinner-bedded upper limestone member wedges in between the Carters member and the overlying Hermitage formation according to Bassler.

The thin-bedded dove-colored and gray Lebanon limestone comes in below the Carters limestone and is widely exposed from Columbia eastward. The following sections, adapted from Bassler,[52] illustrate the rapid eastward change in stratigraphy:

Stratigraphic section at Columbia

[Lowville and Lebanon exposed in banks of Duck River, Hermitage, and Bigby from Santa Fe pike south west to West 7th and Armstrong Streets, remainder from that point to top of Mount Parnassus]

	Feet
Leipers limestone:	
Thin-bedded nodular blue limestone with intercalated blue and yellow shale crowded with Bryozoa and other fossils	15
Mostly covered, but limestone similar to underlying bed with upper layer granular, gray, and cavernous	28
Impure thin-bedded limestone with few fossils except in top layer, which is full of broken shells and Bryozoa	12
Shaly impure limestone in thin layers, crowded with *Rafinesquina alternata* and *Platystrophia ponderosa*	6
Catheys limestone:	
Rough-bedded dark thin argillaceous limestone weathering cavernous (small holes); fossils few and indeterminable	14
Fossiliferous shaly limestone crowded with the massive bryozoan *Cyphotrypa tabulosa*	4
Unevenly bedded granular and subgranular blue limestone; upper part contains *Escharopora falciformis* var	16
Blue massive subcrystalline limestone with *Cyclonema varicosum*	4
Thick-bedded fine-grained gray or blue clayey limestone with numerous gastropods and pelecypods—*Lophospira bowdeni*, *Orthorhynchula linneyi*, *Tetradium columnare*, and small *Stromatocerium pustulosum*	4
Shaly nodular and subcrystalline limestone, crowded with Bryozoa, especially *Escharopora flabellarius*, *Heterotrypa parvulipora*, and *Homotrypa centralis*	16
Granular and crinoidal limestone with abundant *Solenopora compacta* from 1 to 2 inches in diameter	5
Nodular blue clayey limestone with two layers (one at base and other above the middle) with abundant large *Stromatocerium pustulosum*. Many other fossils	18
Finely granular laminated unfossiliferous phosphatic limestone	6
Phosphatic limestone in thin beds; top layer covered with *Constellaria grandis* and other Bryozoa	6
Blue granular limestone crowded with *Constellaria teres* and *C. emaciata*	2

[52] Bassler, R. S., op. cit., pp. 28–29, 31–32.

Stratigraphic section at Columbia—Continued

	Feet
Catheys limestone—Continued.	
Blue to yellow shale with *C. teres*, *C. emaciata*, and other Bryozoa	4
Shaly limestone with few fossils	2
Bigby limestone:	
Gray to blue granular limestone crowded with *Rafinesquina*	1
Granular limestone with a few *Rafinesquina* and other fossils; hemispheric Bryozoa and *Eridotrypa briareus* at base	5
Granular gray-blue limestone with *Rafinesquina*	2
Subgranular unfossiliferous limestone	2
Gray granular limestone with *Rafinesquina* and several layers with *Ctenodonta subrotunda*, *Bellerophon clausus* var., *Lophospira*, *Rhynchotrema increbescens*, large *Dalmanella*, and *Hebertella frankfortensis*	5
Unfossiliferous shale	1
Thin-bedded subgranular gray limestone, yielding a little chert on weathering, with abundant *Rafinesquina*, rare *Dalmanella*, and cyclorid gastropods	17
Hermitage formation:	
Blue even-bedded subcrystalline limestone with abundant *Dalmanella fertilis*	50
Impure blue clayey limestone, fine-grained in upper half; *Dalmanella fertilis* rare, *Prasopora patera* common	15
Lowville limestone (Carters limestone member):	
Massive magnesian limestone, easily recognized by white color of its outcrop	12
Mottled thick-bedded magnesian limestone, locally with *Maclurea bigsbyi*, *Stromatocerium rugosum*, *Columnaria halli*, *Lophospira*, *bicincta*, and *Dystactospongia minor*	18
Single bed of mottled fine-grained dove-colored, nearly pure limestone with yellow magnesian spots; locally fossiliferous	4
Massive fine-grained mottled, rather pure dove-colored limestone with fossils weathering out siliceous, particularly *Streptelasma profundum*, *Columnaria halli*, *Stromatocerium rugosum*, and *Maclurea bigsbyi*	6
Mottled yellow massive limestone, low in magnesia; no fossils seen	3
Massive finely granular yellow, nearly pure limestone with *Stromatocerium rugosum*, *Columnaria halli*, *Tetradium columnare*, *T. carterensis*, and *Lichenaria carterensis*	5
Fine-grained yellow limestone; no fossils	1½
Lebanon limestone: Thin-bedded dove-colored limestone, in some places separated by shaly layers.	

Stratigraphic section on Bear Creek Pike, on west side of Loftus Hill, 8 miles east of Columbia

	Feet
Chattanooga shale	5
Leipers limestone:	
Nodular earthy calcareous shale with *Platystrophia ponderosa*	13
Shaly blue limestone crowded with Bryozoa	4½
Impure limestone with large *Platystrophia ponderosa* and *Strophomena planoconvexa*	7
Shaly limestone, not well shown, full of *Tetradium fibratum*, *Platystrophia ponderosa*, and Mollusca	7
Gray-blue limestone; no recognizable fossils	10
Blue limestone with *Bucania*, *Hebertalla sinuata*, and *Platystrophia ponderosa*	8
Catheys limestone:	
Shaly limestone with Bryozoa	2
Laminated granular limestone	4
Argillaceous limestone and shale with *Columnaria alveolata*, *Stromatocerium pustulosum* and *Tetradium fibratum*	4
Laminated granular limestone	4½
Gray subcrystalline limestone	3
Shale and clayey limestone, weathering cherty at top; *Stromatocerium pustulosum*, *Tetradium fibratum*, and *Columnaria alveolata* abundant in weathered debris	5½
Blue subcrystalline limestone and shale, full of Bryozoa, especially *Constellaria emaciata* and *C. teres*	4
Cannon limestone:	
Laminated granocrystalline limestone weathering into thin platy phosphate	10
White and gray oolitic limestone, with fossils, particularly the gastropods *Lophospira sumnerensis*, *Bucania*, *Oxydiscus*	10
Granocrystalline phosphatic limestone	9
Dove-colored limestone	8
Bigby limestone: Gray subcrystalline limestone	2

Maury County lies on the west side of the Nashville dome. The general dip of the rocks is a little north of west, the amount about 250 feet in the 25 miles across the county. There are local folds throughout the county, and some minor faulting has occurred. Between Columbia and Williamsport an area of about 1 square mile represents a graben in which the Fort Payne chert is brought into contact with the Hermitage formation, giving a maximum displacement of about 400 feet. A fault with the northern area downthrown about 50 feet runs eastward for several miles south of Santa Fe.

GROUND WATER

Ground water as found in Maury County conforms to the same generalizations found valid in the other basin counties. Shallow wells furnishing adequate supplies for domestic use are successfully drilled in most places in the county. In a few places, however, even a domestic supply is hard to obtain. In the vicinity of Match seven holes close together, the deepest 308 feet deep, failed to obtain any water. Deep wells in search of large supplies are sometimes successful and sometimes not. A well at the site of the old ice plant at Columbia (well 368) is reported to have yielded about 75 gallons a minute, probably from the Murfreesboro limestone. At the site of the present ice plant in Columbia six holes from 300 to 500 feet deep and one hole 1,105 feet deep (well 367) failed to strike any water, except a seep estimated at 1 gallon an hour. The deepest well should have passed through the horizon of the St. Peter sandstone, which yields water elsewhere in the basin. At the Arrow phosphate plant, near Mount Pleasant, well 360, about 700 feet deep, is reported to have furnished a continuous supply of about 300 gallons a minute. The water was obtained near the bottom of the well. This well has been abandoned because it did not satisfy the needs of the plant. Well 356 and a nearby well at the Armour Fertilizer Co.'s plant near Williamsport, both 155 feet deep, draw from 30,000 to 40,000 gallons a day from the Carters limestone at a depth of about 150 feet.

On the spurs of the Highland Rim water for domestic purposes is obtained from the weathered residue of the Mississippian limestones.

Springs are present throughout the county and vary in yield with the relief of the adjacent county. The largest spring seen is no. 390, near Southport. It issues from the Hermitage formation and was flowing about 400 gallons a minute when visited in July 1930.

The public water supply at Columbia is obtained from the Duck River. Carpenter and Kidd Springs, in Lewis County (nos. 262 and 263, p. 130) furnish the water supply of Mount Pleasant.

Records of wells in Maury County

[Nos. 353-355, 357, 380 dug; all others drilled]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
[a] 348	Santa Fe, 3 miles north	Will Stanfield	Ridge	880	80	5
349	Santa Fe, 4 miles north	Mrs. Maggie Wakefield	Creek terrace	715	30	----
350	Theta	G. W. Barnes	Ridge	945	28	6
351	Santa Fe	J. R. Dodson	Valley	670	20	6
352	Santa Fe, 2½ miles southeast	R. Y. McKee	Ridge	925	62	6
353	Williamsport	James R. Walker	Terrace remnant	625	35	----
354	do	Dr. H. O. Anderson	do	630	35	48
355	Williamsport, 4 miles southeast	Nick Farris	Small valley	795	24	42±
356	Williamsport, 5 miles southeast	Armour Fertilizer Co	Rolling	700	155	6
357	Hampshire, 5½ miles northwest	Herbert Farris	Ridge	880	62	----
358	Hampshire, 1½ miles west	R. M. Patton	Hillside	700	46	6
359	Hampshire, 2 miles northeast	W. S. Parkes	Valley	600	37	8
360	Mount Pleasant, 1½ miles southeast	Arrow Mines Co	do	700	700±	10
361	Mount Pleasant	Mount Pleasant Ice Co	do	630	110	8
362	Mount Pleasant, 1½ miles north	L. & N. R. R	do	635	60	----
[a] 363	Mount Pleasant, 6 miles southeast	E. J. Gilbreath	Gentle hillside	720	85	6
[a] 364	Columbia, 3½ miles southwest	W. J. Sheegog	do	690	70	6
365	Hampshire, 5 miles northeast	Geo. P. Webster	Low hill	590	51	5
366	Columbia, 4 miles southwest	John M. Gray	do	675	100	6
367	Columbia	Columbia Ice & Cold Storage Co	Plain	655	1,105	14
368	do	do	River terrace	600	300	6
369	Columbia, 5½ miles northwest	J. K. P. Timmons Estate	Base of hill	585	26	8
370	Carters Creek, 3 miles north	L. Sparkman	Plain	700	32	6
[a] 371	Carters Creek, 1 mile east	John Armistead	Open valley	610	29	36
[a] 372	Spring Hill, 4 miles southeast	W. M. Parham	Low hill	690	73	5
373	Match, 6 miles northeast	J. A. Crow	Gentle hillside	670	26	5
[a] 374	Match, 5 miles east	H. T. Chunn	Low hill	660	75	6
375	Match, 1 mile east	W. A. Harbison	Low ridge	740	308	5
376	Match	E. D. Minor	Hillside	825	66	6
377	Match, 3 miles south	Mrs. M. L. Barber	Low spur	725	40	6
378	Culleoka, 4 miles north	S. A. Sims	Terrace	580	83	5½
379	do	F. M. Landres	Low hill	610	116	5½
380	Silver Creek, 3 miles north	G. W. Tindell	Level	650	25	30
381	Silver Creek, 1 mile west	Dr. W. R. Orr	Base of hill	690	24	5
382	do	do	Hillside	720	1½	5
[a] 383	Silver Creek, 2 miles west	W. E. Cheek	do	730	115	5
384	Culleoka	Hobbs Bros	do	705	100	6

[a] Analysis given in table of analyses.

Records of wells in Maury County—Continued

No. on pl. 1	Water-bearing beds: Depth (feet)	Water-bearing beds: Lithologic character	Water-bearing beds: Stratigraphic position	Water level: Above or below surface (feet)	Water level: Date of measurement (1930)	Use of water	Total hardness as $CaCO_3$ (parts per million) [b]	Remarks
348	80±	Chert	Fort Payne chert	−71	July 17	Domestic		
349	30±	Shaly limestone	Leipers limestone	−19	do	do		
350	28±	(?)	St. Louis limestone	−23	do	do		
351	20±	Limestone	Bigby limestone	−15	July 16	do		
352	62±	Chert	Fort Payne chert	−54	July 17	do		
353		Limestone	Bigby limestone			do		Wells in Williamsport generally dug through about 20 feet of alluvial gravel and silt into bedrock below.
354	29±	do	do	−29	July 16	do		
355		Residual chert (?)	Fort Payne chert			do		
356	150±	Limestone	Lowville limestone	−10		Domestic; boiler		Water reported hard. This and another well close by and of same depth furnish 30,000 to 40,000 gallons a day.
357	58±	Residual chert (?)	Fort Payne chert (?)	−58	July 18	Domestic; stock		
358	46±	Shaly limestone	Catheys limestone	−41.5	July 10	do		
359	37±	do	do		July 10	do		
360	700±	Limestone		−20		Well abandoned		Reported to have produced at rate of 300 gallons a minute continuously. Abandoned because supply inadequate for needs. Sulphur water.
361	110±	do	Lowville limestone	−5½		Cooling		
362	60±	(?)	Hermitage formation	−30		Domestic		Reported ample for 4 families.
363	70	Limestone	Lebanon limestone (?)	−50		Stock		Sulphur water.
364	70±	do	Hermitage formation	−35		Domestic; stock		
365	51±	do	Bigby limestone	−38	July 18	Domestic		
366	97	do	Lowville limestone	−50±		Domestic; stock		
367				−40		None		Only water found was a seep, estimated at 1 gallon an hour, from 600-foot depth. Six other wells 300 to 500 feet deep obtained no water.
368	300±	Limestone	Stones River group			Cooling		Abandoned well at former location of ice plant on northwest edge of town. Reported to have yielded 75 gallons a minute.
369	26±		Hermitage formation	−15.5	July 17	Domestic		
370	32±	Limestone	do	−14	July 19	do		
371	28±	do	do	−28	do	do		Water low and unfit for use on July 19.
372	73±	do	Lebanon limestone	−1.8	Oct. 14	Domestic; stock	500	
373	26±	do	do	−14		do	270	

374	75±	do	do. (?)	−67	Oct. 14	Medicinal		Water contains H_2S and is salty.
375								Deepest of 7 holes drilled within radius of 500 feet without obtaining water. Formations passed through were Lebanon, Ridley, and Pierce.
376	66±		Catheys limestone	−53	Oct. 15	Domestic; stock	315	
377	40±	Limestone	Lowville limestone (?)	−31.3	do	do	440	
378	83±	do	Lebanon limestone (?)	−29.0	Oct. 16	Domestic	445	
379	116±	do	do	−42	do	Domestic; stock	345	
380	24±	do	Lebanon limestone	−24.2	Oct. 15	do	310	
381	24±	do	do	−18.9	do	do	155	
382		do	do	0	do	Stock	500±	Drill hole in abandoned quarry.
383	115±	do	do	−104	Oct. 16	Domestic		
384	100±	do	Lebanon limestone	−20		do		

[b] Determined in field with standard soap solution.

Records of springs in Maury County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
[a] 385	Theta	Oscar Peach	Small valley	925	Limestone	St. Louis limestone.
386	Santa Fe, 2 miles northeast	Charles Harris	Base of hill	680	do	Leipers limestone.
387	Santa Fe, 3 miles west	Village of Water Valley	Hillside	720	Shaly limestone	Do.
388	Mount Pleasant	Mount Pleasant Ice Co	Base of hill	630	Limestone	Hermitage formation.
389	Mount Pleasant, 5 miles southeast	Bob Benderman	do	780	do	Bigby limestone.
390	Culleoka, 6 miles west	Stella Horn	do	750	do	Hermitage formation.
391	Culleoka, 5 miles southwest	Mrs. V. A. Richardson	do	845	do	Bigby limestone.
[a] 392	Culleoka, 6 miles northwest	Moore & McLean	Creek	675	do	Lowville limestone.
[a] 393	Columbia, 2 miles northeast	Dr. O. J. Porter	do	625	do	Do.
394	Columbia, 3½ miles west	Dr. W. K. Sheddan	Head of drain	750	do	Hermitage formation.
395	Columbia, 4 miles southwest	John M. Gray	Branch	650	do	Do.
396	Columbia	Columbia Ice & Cold Storage Co	Bluff at edge of flood plain.	550	do	Lowville limestone.
397	Columbia, 2½ miles north	Public	Base of hill	560	do	Do.
[a] 398	Spring Hill	Branham & Hughes	do	680	do	Bigby limestone.
399	Match, 2 miles east	W. A. Hardison	Valley	690	do	Lebanon limestone.
400	Culleoka, 2 miles south	T. M. Hobbs	Base of hill	705	do	Lowville limestone.

[a] Analysis given in table of analyses.

Records of springs in Maury County—Continued

No. on pl. 1	Openings		Approximate yield		Use of water	Total hardness as $CaCO_3$ (parts per million) [b]	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)			
385	1	Enlarged bedding plane	3±	July 17	Domestic; stock		
386	1	Bedding plane	1	do	Domestic		
387	1	Joint crack (?)	10±	July 16	Domestic; stock		Furnishes water to about 12 houses in village ½ mile west.
388	1	Enlarged bedding plane	3±	July 11	Cooling		
389	1	Solution channel	12	Oct. 17	Domestic: stock	180	
390	1	do	400	July 15	do		Galloway Spring.
391	1	Enlarged bedding plane	8	do	do		
392	1	Enlarged joint plane	5±	do	do		Bigby Spring. Reported to have stopped flowing after each of several rains. Discussed on p. 40.
393	1			July 9	Medicinal		
394	1	Enlarged bedding plane	1	do	do		
395	1	do	1	July 14	Stock		
396	1	Solution channel	75±	July 9	Domestic		White Spring. Evidence of contamination at several points.
397	1	Enlarged joint crack	5±	July 17	Abandoned		
398	2	Enlarged bedding plane			Public supply		Except in summer supplies town. Supplemented by well in summer.
399	1	Concealed	2½±	Oct. 14	Domestic; stock	245	
400	2	Solution channel	75	Oct. 16	do	140	

[b] Determined in field with standard soap solution.

Analyses of ground waters from Maury County

[Nos. 372 and 374 analyzed by D. F. Farrar, Tennessee Geological Survey; the rest by Margaret D. Foster, U. S. Geological Survey. Parts per million. Numbers at heads of columns correspond to numbers in tables of well and spring data]

	348	355	363	364	371	372	374
Silica (SiO_2)	10	7.9	8.8	8.3	12	14	14
Iron (Fe)	.07	.17	.09	.06	.08	1.2	1.8
Calcium (Ca)	25	33	46	98	64	235	848
Magnesium (Mg)	4.2	4.9	30	5.2	3.8	27	52
Sodium (Na)	1.8	9.9	13	2.3	1.7	10	35
Potassium (K)	1.0	5.6	6.4	1.7	.7	3.0	4.1
Carbonate (CO_3)	0	0	0	0	0	0	0
Bicarbonate (HCO_3)	91	48	258	286	200	329	414
Sulphate (SO_4)	3.3	59	54	12	4.0	400	1,881
Chloride (Cl)	1.8	10	1.8	2.7	1.8	18	60
Nitrate (NO_3)	2.3	16	3.6	30	8.5	.60	.80
Total dissolved solids	95	177	290	311	200	955	3,283
Total hardness as $CaCO_3$ (calculated)	80	103	238	266	176	697	2,324
Date of collection (1930)	July 17	July 16	July 15	July 15	July 16	Oct. 14	Nov. 8

	385	392	393	398	Duck River [a]	Duck River [b]
Silica (SiO_2)	9.5	16	12	12	4.1	11
Iron (Fe)	.04	.06	.05	.04	.04	.04
Calcium (Ca)	12	86	38	69	38	40
Magnesium (Mg)	5.4	9.5	23	5.8	4.6	4.1
Sodium (Na)	1.8	2.3	58	5.0	2.3	1.7
Potassium (K)	1.0	1.3	4.3	1.3	.9	1.0
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	46	283	254	164	129	124
Sulphate (SO_4)	2.8	13	75	28	6.6	16
Chloride (Cl)	2.3	2.4	21	8.0	1.7	1.6
Nitrate (NO_3)	13	10	.75	36	1.3	.46
Total dissolved solids	74	284	349	249	124	138
Total hardness as $CaCO_3$ (calculated)	52	254	189	196	114	117
Date of collection (1930)	July 17	July 15	July 9	July 19	July 9	July 9

[a] Duck River at Columbia; sample taken just above dam of Tennessee Electric Power Co.; river at low stage.
[b] Duck River at Columbia; municipal water supply; sampled at clear well after sedimentation, alum treatment, and filtration.

MOORE COUNTY

[Area, 141 square miles; population, 4,037]

Moore County, the smallest county in the area of this report, is on the eastern border of the area, wedged in between Bedford, Coffee, Franklin, and Lincoln Counties. The county seat is Lynchburg (population 380).

Practically the entire area of the county is drained by a few small tributaries of the Elk River. The Duck River divide lies just about on its northern boundary.

No railroad enters the county. One hard-surfaced highway connects Lynchburg with the Shelbyville-Winchester highway, which passes through the northeastern part of the county. Others to Winchester and Fayetteville are under construction (1930).

Agriculture is the only industry. Large distilleries formerly operated in the county.

GEOLOGY

The east half of Moore County is occupied by a spur of the Highland Rim plateau. The western part lies in the Nashville Basin but is greatly broken by remnants of the Highland Rim. The relief of the county is about 400 feet, the altitude ranging from about 800 feet at Lynchburg to about 1,200 feet in the western tip of the county.

The eastern part of the county is capped by the St. Louis limestone or the Warsaw formation, generally seen only in weathered phases. The Fort Payne chert underlies the Warsaw formation. Apparently, only the Maury glauconitic member of the Ridgetop shale is present in this county. The black Chattanooga shale is found generally in the hillsides but is very thin, at least in many places, and may be absent in others. In the Lynchburg-Winchester road cut, near the junction of the road running south to Lois, it is only 3 inches thick. Underlying the Chattanooga shale is about 20 feet of siliceous limestone, with *Platystrophia* and cup and colonial corals, probably to be referred to the Silurian system. Below this is the Fernvale formation, representing the top of the Ordovician system. In the eastern part of the county the Fernvale, where seen, is about 25 feet thick and consists of a red crystalline limestone, with green shaly bands near the base. In the western part of the county it is probably somewhat thicker, as shown in the Fayetteville-Shelbyville road cut just beyond the county line, in Bedford County. The underlying Leipers limestone consists of rubbly limestone and shale. It overlies the Catheys limestone and that in turn overlies the Cannon limestone. The Catheys and Cannon limestones are more or less shaly and contain many beds of semilithographic dove-colored limestone. The Bigby limestone lies just above drainage level.

Moore County lies on the southeast side of the Nashville dome, and consequently the regional dip is southeastward, amounting to about 200 feet within the county.

GROUND WATER

The small county of Moore represents ground-water conditions similar to those of its neighboring counties. Water occurs in tubular passages in the limestone units, made available generally in this county by springs. Springs 404a and 404b, at Lynchburg, probably representing one solution channel, yield together about 175 gallons a minute from the Cannon limestone. Other springs in the Cannon formation yield smaller quantities. Wells in the higher portions of the county, on the ridges and remnants of the Highland Rim, are generally less than 100 feet deep and generally derive their water from the basal Fort Payne chert.

Records of wells in Moore County

[All drilled]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
[a]401	Hawthorn, 2 miles south	Mrs. B. F. Carriger	Ridge	1,220	93	6
402	Mulberry, 7 miles north	Edward Woodward	Low spur	755	54	5
403	Lynchburg, 6 miles southeast	F. M. Tucker	Ridge	1,125	84	5

No. on pl. 1	Water-bearing beds			Water level		Use of water	Total hardness as $CaCO_3$ (parts per million)[b]	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)			
401	93±	Chert	Fort Payne chert	−86.7	Oct. 28	Domestic; stock	25	Basal part of the Fort Payne is here very porous owing to interlacing solution cavities.
402	54±	Limestone	Cannon limestone	−24.5	Nov. 18	Domestic		
403	84±	Chert	Fort Payne chert	−74.2	Nov. 25	do		

[a] Analysis given in table of analyses.
[b] Determined in field with standard soap solution.

Records of springs in Moore County

No. on pl. 1	Location with reference to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
404a	Lynchburg	Lem Motlow	Base of hill	790	Limestone	Cannon limestone.
404b	do	do	do	785	do	Do.
[a]405	Lynchburg, 2 miles northeast	P. H. Wanslow	do	860	do	Do.
406a	Lynchburg, 6 miles northeast	Lem Motlow	Small valley	980	Shale	Chattanooga shale.
406b	do	do	do	980	do	Do.
406c	do	do	do	980	do	Do.
406d	do	do	do	980	do	Do.
407a	Lynchburg, 6 miles southeast	J. W. Embrey	Hillside	1,000	Chert	Fort Payne chert.
407b	do	W. T. Wiseman	do	980	do	Do.
408	Lynchburg, 5 miles north	Earnest Stone	Base of hill	850	Limestone	Cannon limestone (?).

No. on pl. 1	Openings		Approximate yield		Use of water	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)		
404a	1	Solution channel	75	Nov. 19	Domestic; stock	Cave Spring.
404b	1	do	100±	do	do	This opening probably is connected with previously noted one about 75 yards distant.
405	1	do	75±	do	Domestic; stock; public supply.	Source of small public supply for Lynchburg.
406a	1	Joint crack	1/10±	do	Medicinal	Cumberland Springs; water slightly chalybeate.
406b	1	do	1/10±	do	do	Cumberland Springs; water contains H_2S, and is slightly chalybeate.
406c	1	do	1/10±	do	do	Do.
406d	1	Bedding plane (?)	1/10±	do	do	Cumberland Springs; chalybeate water.
407a	1	Bedding plane	5	Nov. 25	Domestic; stock	
407b	1	Solution channel	6	do	do	
408	1	Cavern	50±	Nov. 19	do	

[a] Analysis given in following table.

Analyses of ground waters from Moore County

[D. F. Farrar, Tennessee Geological Survey, analyst. Parts per million. Numbers at heads of columns correspond to numbers in tables of well and spring data]

	401	405		401	405
Silica (SiO_2)	9.6	11	Sulphate (SO_4)	3.3	1.2
Iron (Fe)	.65	.95	Chloride (Cl)	2.8	2.5
Calcium (Ca)	3.2	38	Nitrate (NO_3)	.35	.60
Magnesium (Mg)	.68	6.0	Total dissolved solids	31	138
Sodium and potassium (Na+K).	1.7	1.7	Total hardness as $CaCO_3$ (calculated).	11	119
Carbonate (CO_3)	0	0	Date of collection (1930)	Oct. 28	Nov. 19
Bicarbonate (HCO_3)	8.2	144			

PERRY COUNTY

[Area 487 square miles, population 7,147]

Perry County is a roughly rectangular area in the northwest corner of the region described in this report, just east of the Tennessee River. Contiguous counties are, to the north, Humphreys County; to the east, Hickman and Lewis Counties; to the south, Wayne County; and to the west, Decatur County. The county seat is Linden (population 539).

No railroad enters the county, the nearest railroad point being Perryville, just west of the river, on a branch line of the Nashville, Chattanooga & St. Louis Railway. Hard-surfaced highways connect Linden with Hohenwald and Perryville. The new Nashville-Memphis highway, under construction in 1930 passes through Linden. Good gravel roads pass south and north through Linden and the county.

The only basic industry in the county is agriculture. Formerly some "white" phosphate, or highly pure tufaceous apatite, was obtained on Toms Creek.

GEOLOGY

Perry County, technically a part of the Highland Rim plateau, is an upland whose surface is tilted westward and deeply incised by the Tennessee and Buffalo Rivers and their tributaries. Altitudes of over 950 feet above sea level are reached on the ridges along the eastern county line, and the Tennessee River, on the western boundary, flows at an altitude of about 350 feet; hence the total relief is 600 feet. The local relief is large in comparison, reaching a maximum of about 300 feet in a distance of less than a mile.

The drainage pattern is unusual. The Buffalo River, a tributary to the Duck River and thus to the Tennessee, flows northward in outstanding subparallelism with the Tennessee River from the southern boundary to and beyond the northern boundary of the county. The distance between these two streams within the county is from 8 to 14 miles. Practically all the tributary drainage of this county goes westward. The divide between the Buffalo and Tennessee Rivers lies from 2 miles to less than 1 mile west of the Buffalo River. The divides between the tributaries of both rivers are long subparallel ridges trending east and sloping rather uniformly westward.

The apparent geomorphic history of this area may help to depict the topography more clearly. The Highland Rim peneplain is apparently nonexistent here, its level lying above the surface of the county. The high points of the present surface represent a peneplain developed in pre-Tuscaloosa time, which has since been gently arched from an altitude of about 950 feet in the eastern part of the county down to about 450 feet in Decatur County, where it passes under the Cretaceous deposits. The arched plain has lately been stripped of most of the Cretaceous deposits, which must once have covered its surface, although patches of the Tuscaloosa gravel remain on the high points throughout the area. On this arched surface the apparently antecedent Buffalo and Tennessee Rivers have entrenched themselves, side-slipping westward and leveling the spurs of the old pre-Tuscaloosa surface for a distance of a few miles east of the present location of the streams, and finally entrenching themselves within it. The tributary streams are apparently consequent on the slope of the pre-Tuscaloosa surface.

Sand, gravel, and silt deposits of probable Quaternary age [53] are present as terraces along the Buffalo and Tennessee Rivers, reaching a maximum thickness of about 30 feet. The most outstanding of these deposits is on a terrace at Flatwoods, though they also occur on the Buffalo River at Linden and Lobelville and along the Tennessee River.

Thin and patchy deposits of the Tuscaloosa formation occur on the high ridges but are of little importance in a ground-water study of this county, for their high position and the close dissection of this country make it probable that all such deposits are thoroughly drained.

The uppermost bedrock deposits are the St. Louis limestone and Warsaw formation, which are exposed almost entirely only in their weathered cherty clay equivalents. The combined thickness of these two formations is about 150 feet. Below them lies the Fort Payne chert, a practically nonfossiliferous chert in beds as much as 12 inches thick. It has a total thickness of 100 to 200 feet but is seldom seen in natural exposure. Toward the south it seems to merge into a siliceous, calcareous shale.[54] The Ridgetop shale is excellently represented along Cane Creek by gray calcareous shale as much as 120 feet thick. The Chattanooga shale is generally present and reaches a maximum thickness of 6½ feet. The Hardin sandstone member forms its base in many parts of the county. The underlying Devonian formations are represented in this county better than in any other

[53] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 25, 1921. Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, pp. 173-174, Tennessee Geol. Survey, 1914.

[54] Wade, Bruce, op. cit., p. 171.

county treated in this report. The uppermost formation exposed in this area is the Harriman chert (Harriman novaculite of Dunbar[55]). It consists of white to yellow and buff novaculite, a very fine-grained crystalline silica, generally fossiliferous in this area. It is seen best on Tom and Cypress Creeks and in a small exposure on Marsh Creek and is probably absent everywhere in this county outside these areas. It is from 30 to 50 feet thick. The formation stratigraphically just below the Harriman chert is the Quall limestone, which is apparently exposed in this county only at the Town Spring, in Linden, where it is only 2½ feet thick.[56] The Birdsong shale is a limestone and calcareous shale formation coming below the Quall limestone. It is exposed along Tom and Lick Creeks, along the Buffalo River in places from Linden to Beardstown, and on lower Cane Creek. The Devonian formations underlying the Birdsong are apparently not exposed in the county.

The Silurian formations are well exposed at and just above drainage level over most of the county. The Decatur limestone, the uppermost formation, is a massive, generally unfossiliferous limestone about 50 feet thick in the western part of the county. It is cut out eastward by erosion. Below the Decatur lies the Brownsport formation, exposed along the creeks in most of the area. The Brownsport formation approaches a maximum thickness of 100 feet and consists of generally very fossiliferous limestone and shale above (Lobelville shaly limestone member), succeeded downward by the more massive Bob crystalline limestone member, and this in turn by the Beech River shaly limestone member. Below the Brownsport formation is the Wayne formation, which is exposed on Cedar Creek and most of the tributaries of the Buffalo River in the southern part of the county. It consists of several members. The upper member is the Dixon earthy limestone, about 50 feet thick. Below this is the coarsely crystalline, locally massive Lego limestone member, which has a maximum thickness of about 35 feet. The persistent Waldron clay member, about 4 feet thick, separates the Lego limestone above from the very similar Laurel limestone, about 25 feet thick, below. At the base is the Osgood earthy limestone member, exposed on Cedar Creek and on Cane Creek, where it is about 12 feet thick. The basal formation of the Silurian system is the Brassfield limestone. This formation is about 25 to 30 feet thick where it has not been affected by erosion. It consists of coarsely crystalline crinoidal limestone below and hard gritty thin-bedded limestone above.

The Ordovician rocks are apparently exposed only in small patches on Cedar and Whiteoak Creeks, in the southwestern part of the county. The exposures consist of coarsely crystalline limestone and

[55] Dunbar, C. O., Stratigraphy and correlation of the Devonian of western Tennessee: Tennessee Geol. Survey Bull. 21, pp. 71-77, 1919.

[56] Idem, p. 113.

shale belonging to the Fernvale formation, which is from 20 to 40 feet thick, overlying the Hermitage formation, consisting of alternating limestone and shale, the intervening Bigby, Cannon, Catheys, Leipers, and Arnheim limestones being absent.

GROUND WATER

Ground water in Perry County, as elsewhere in south-central Tennessee, occurs chiefly in solution channels in the calcareous rocks underlying the county practically everywhere. The ridges of the county are not thickly settled, and therefore the chert residues of the Mississippian limestone have not been extensively prospected for water. Dug wells from 50 to 75 feet deep may be expected to yield domestic supplies here, as in similar situations in the surrounding country.

Drilled wells in the valley portions generally yield domestic supplies from depths of 30 to 100 feet or more. Large supplies of water are difficult to find. Well 422, at the courthouse in Linden, is 235 feet deep and does not yield sufficient water for the personal consumption of those there employed. Dug wells in the alluvial materials of the terraces along the rivers generally yield domestic supplies. However, in many portions of the county cisterns form the chief source of supply.

The mature dissection of the county assures a great number of springs of good size in the valleys. These issue from practically all formations wherever they are suitably located topographically. The town spring at Linden (no. 458) issues from a limestone bed of the Birdsong shale. Its flow was about 150 gallons a minute when visited. This spring, though reported to carry *Bacillus coli*, furnished the main water supply of Linden during the summer of 1930, when many of the cisterns failed in the early summer. Another good spring issuing from the limestone basal bed of the Birdsong shale is that at Hinson's mill, about 3 miles east of Beardstown, on Cane Creek (spring 464). Its flow of about 1,000 gallons a minute is used to operate a gristmill.

Sinking and interrupted creeks are common. The largest spring in the county (no. 449b) is formed by a rise of Sinking Creek. It issues from a large solution passage in the concealed calcareous strata below the Hardin sandstone member, at the base of the Chattanooga shale. Its flow in August 1930 was about 1,800 gallons a minute, and the temperature was 60° F., about normal for springs of this vicinity. A natural well north of Lobelville (well 429) is in use. This naturally uncovered solution channel is 76 feet deep and is carrying at this point about 40 feet of water. It is reported that the diameter of the surface opening of this cavern is constantly increasing, having been when first found only about 1 foot, whereas now it is 12 feet.

Records of wells in Perry County

[Nos. 416–418, 420, 422–424, 426, 427 drilled; 429 natural; all others dug]

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Depth (feet)	Diameter (inches)
409	Britts Landing, 4 miles north	A. L. Daniel	Terrace	375	20	24
410	Britts Landing, ½ mile north	C. L. Britt	do	410	33	30
411	Britts Landing, 6 miles northeast	W. H. Daniels	Flood plain	525	11	27
412	Britts Landing, 4 miles east	D. H. Daniel	Base of hill	515	21	36
413	Britts Landing, 2 miles south	H. M. Haynes	Terrace	380	34	42
414	Pope, 2 miles west	W. C. Nix	do	360	43	(?)
415	Pope, 1 mile southwest	C. C. Westbrooks	Flood plain	430	14	24
416	Pope, 2 miles southeast	Albert Grooms	Valley	455	76	5
417	Pope, 9 miles south	J. R. Walker	Terrace	375	90	5
418	Flatwoods, 7 miles west	Miss Sallie Evans	do	450	31	5
419	Flatwoods	Dr. W. E. Boyce	do	570	20	48
420	Linden, 5 miles southeast	F. F. Warren	do	540	31	5
421	Linden, 8 miles southeast	R. W. Dabbs	Base of hill	650	42	(?)
422	Linden	Perry County	Terrace	550	235	5
423	Linden, 5 miles east	A. R. Warren	Creek	525	575	(?)
424	Linden, 8 miles east	Clay Campbell	Low terrace	570	36	5
425	Linden, 3 miles north	J. W. Vaughan	do	490	21	30
426	Linden, 7 miles northeast	Paul Duncan	Hillside	605	41	5
[a] 427	Beardstown	Perry County	Terrace	495	137	5
428	Lobelville	Elsie Carroll	do	510	33	42
429	Lobelville, 3 miles northwest	W. T. Loggins	do	495	76	144
430	Lobelville, 5 miles north	A. P. Poole	do	500	63	42

[a] Analysis given in table of analyses.

Records of wells in Perry County—Continued

No. on pl. 1	Water-bearing beds: Depth (feet)	Water-bearing beds: Lithologic characcter	Water-bearing beds: Stratigraphic position	Water level: Above or below surface (feet)	Water level: Date of measurement (1930)	Use of water	Remarks
409	20±	Chert	Fort Payne chert	−19.6	Aug. 8	Domestic	
410	30±	Alluvium	Quaternary alluvium	−29.3	do	do	
411	8±	Gravel	do	−8.3	do	do	Reported that well cannot be drawn dry.
412	17±	Chert	Fort Payne chert	−16.8	do	Domestic; stock	
413	29±	Gravel (?)	Quaternary alluvium	−29.2	Aug. 7	Domestic	
414	43±	do	do	−42.7	July 31	do	Well 47 feet above river. Water in well reported to rise and fall with river.
415	9±	do	do	−9.2	do	Domestic; stock	
416	76±	(?)	Brownsport formation	−63.5	do	Stock	
417	90±	(?)	Wayne formation (?)	−35±		None	Well now plugged. Reported that water was first found at depth of 90 feet; but rose to river level and followed its fluctuations.
418	31±	(?)	Wayne formation	−19	July 30	Domestic	
419	18±		Quaternary (?) alluvium	−17.5	July 24	do	
420	31±	Shalylimestone (?)	Brownsport formation (?)	−25.7	Aug. 1	do	
421	40±	(?)	Ridgetop shale (?)			Domestic; stock	
422	218	(?)	Wayne formation (?)	−125±		Domestic	Courthouse well.
423	300(?)	(?)	Upper Ordovician	0+		Domestic; stock	Water reported to be sulphur water. At time of visit creek was overflowing it.
424	36±	Shalylimestone (?)	Brownsport formation	−24.6	Aug. 11	Domestic	Very weak well.
425	18±	(?)	Quaternary alluvium	−18.0	Aug. 9	do	
426	41±	(?)	Brownsport formation	−34.2	do	do	
427		(?)	do	−67.7	Aug. 12		School well. Water too highly mineralized for use.
428	25±	(?)	Quaternary (?) alluvium	−25	Aug. 6	Domestic	
429		Shaly limestone	Brownsport formation (?)	−37	Aug. 8	Domestic; stock	A natural well due to partial collapse of roof of cave.
430	49±	Chert	Fort Payne chert	−49	Aug. 6	do	

Records of springs in Perry County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
431	Britts Landing, 3 miles northeast	L. B. Walker	Flood plain	405	Gravel	Quaternary alluvium.
432	Britts Landing, 7 miles east	John D. Daniel	Base of hill	515	do	Do.
[a]433	Britts Landing, 4 miles southeast	R. D. Lewis	do	360	Limestone	Decatur limestone (?).
434	Britts Landing, 6 miles southeast	Emmet L. Cotham	do	460	do	Do. (?).
435	Beardstown, 5 miles west	J. W. Watkins	Flood plain	530	Gravel	Quaternary alluvium
436	Beardstown, 4 miles west	do	do	605	do	Do.
437	Mousetail	W. H. Raney	Base of hill	350	Limestone	Wayne formation (?).
438	Mousetail, 3 miles east	John Simmons	do	390	do	Decatur limestone.
439	Mousetail, 6 miles east	Roy Greenway	Hillside	500	Chert	Harriman chert.
440	Pope, 1 mile east	Wm. Starbuck	Base of hill	400	Shaly limestone	Brownsport formation.
441	Linden, 5 miles west	John Kirk	do	470	Chert	Fort Payne chert.
442	Pope, 5 miles east	Mrs. M. E. Sutton	Hillside	410	Calcareous shale	Brownsport formation (?).
443	Pope, 7 miles southeast	Mrs. Fannie Mayberry	Base of hill	445	Limestone	Wayne formation.
444	Pope, 7½ miles southeast	W. R. Bunch	do	415	do	Do.
445	Pope, 8 miles southeast	John Howell	do	490	do	Do.
446	do	Joe Graham	do	495	do	Do.
[a]447	Pope, 9 miles southeast	Mrs. Lu Wiley	do	470	do	Brownsport formation (?).
448	Flatwoods, 6 miles west	G. S. Sewell	do	580	do	Brownsport formation.
449a	Flatwoods, 4 miles northeast	Lloyd Tatum	Hillside	625	Cherty shale	Ridgetop shale.
449b	do	do	Base of hill	605	Limestone	Brownsport formation (?).
[a]450	Flatwoods, 6 miles northeast	A. C. Graves	Creek bed	695	Calcareous shale	Ridgetop shale.
451	Linden, 5 miles southeast	F. F. Warren	Gully in terrace	585	do	Do.
452	Linden, 4½ miles southeast	Frank Warren	Hillside	540	Shaly limestone	Brownsport formation (?).
453	Linden, 6 miles southeast	Mrs. Mijah Barber	Base of hill	585	Calcareous shale	Ridgetop shale.
454	Linden, 7 miles southeast	I. R. Cotton	Creek bed	530	Shaly limestone	Brownsport formation.
455	Linden, 8 miles southeast	R. W. Dabbs	Base of hill	730	Chert	Fort Payne chert.
456	Linden, 2 miles south	Charles L. Pearson	Hillside	525	Shaly limestone	Brownsport formation.
457	Linden, 4 miles north	Mrs. Wm. Rainy	Base of hill	440	do	Do.
[a]458	Linden	Mrs. John W. Taylor	do	465	Limestone	Birdsong shale.
459	Linden, 6 miles east	J. H. Barber	do	?	Shaly limestone	Brownsport formation.
460	Linden, 3 miles north	J. W. Vaughan	do	475	Limestone	Decatur limestone (?).
461	Linden, 5 miles northeast	Mrs. Ella Warren	do	485	Shaly limestone	Brownsport formation.
462	Linden, 7 miles northeast	Paul Duncan	Hillside	670	Shale	Ridgetop shale.
463	Beardstown		Base of hill	430	Limestone	Brownsport formation.
[a]464	Beardstown, 3 miles east	J. H. Hinson	do	485	do	Birdsong shale.
465	Beardstown, 6 miles east	Dan Dyer	do	520	Shale	Ridgetop shale.
466	Lobelville, 3 miles north	J. H. Ledbetter	do	445	Limestone	Brownsport formation.
467	Lobelville, 3 miles northeast	Douglas Tate	Base of hill	460	do	Do.
468	Lobelville, 4 miles north	A. P. Poole and J. G. Rains	do	400	Chert	Fort Payne chert.

[a] Analysis given in following table.

Records of springs in Perry County—Continued

No. on pl. 1	Number	Character	Approximate yield: Gallons a minute	Approximate yield: Date of measurement (1930)	Use of water	Remarks
431	1		7	Aug. 8	Stock	Spring issues from above conglomeratic bed in the gravel.
432	1		3±	do	Domestic; stock	
[a]433	1	Enlarged bedding plane	30	Aug. 7	do	
434	1	do	7	do	do	
435	1		35	do	Stock	
436	1		10±	do	Domestic; stock	
437	1	Concealed	10±	do	do	
438	1	Solution channel 30 feet wide and 5 feet high.	275	do	do	
439	1		2±	do	do	
440	1	Concealed	¼±	July 31	Domestic	
441	1		1	Aug. 1	Domestic; stock	
442	1	Enlarged bedding plane	15±	July 31	do	
443	1	Partially collapsed cavern	25	Aug. 3	do	Mayberry Spring.
444	1	Enlarged joint crack	225	July 30	do	Cave Spring.
445	1	Concealed	2±	Aug. 2	do	
446	1	Enlarged bedding plane	1±	do	do	
447	1	Cavern	75	July 30	do	
448	1	Small cavern	½	do	do	A strongly blowing small cave.
449a	1	Joint plane	1±	Aug. 1	Domestic; stock	
449b	1	Collapsed cavern	1,800	do	Stock	One rise of Sinking Creek.
450	?	Concealed	200	do	Domestic; stock	Spring rises from alluvial gravel in creek bed.
451	1	Joint crack	½	do	Stock	
452	1	Concealed	2±	July 31	Domestic	
453	Several	Extensive seep from bedding plane.	2	Aug. 1	Domestic; stock	
454		Concealed	2	do	do	
455		Enlarged bedding planes	25	do	do	
456	1	Enlarged bedding plane	75±	July 31	do	
457	3	Local enlargements of bedding plane.	35	Aug. 12	do	
458	1	Solution channel	150	Aug. 2	do	Town spring; during drought furnished most of the water used in Linden.
459	1	Concealed	2	Aug. 11	do	
460	1	Solution channel	35±	Aug. 9	Stock	
461	1	do	2	do	Domestic; stock	
462	1	Joint crack	3	do	do	
463	1	Enlarged bedding plane	2±	Aug. 12		Spring reported to have produced a quantity of light-yellow oil.
464	1	Cavern	1,000	Aug. 11	Domestic; stock, power	
465	1	Solution channel	4	Aug. 15	Domestic; stock	
466	1	do	100	Aug. 6	do	
467	1	do	75	do	do	Warren Spring; water emerges from one opening and disappears into another 50 feet away.
468	2	Concealed	50±	do	Stock	

Analyses of ground waters from Perry County

[Margaret D. Foster, U. S. Geological Survey, analyst. Parts per million. Numbers at heads of columns correspond to numbers in tables of well and spring data]

	427	433	447	450	458	464
Silica (SiO_2)	6.8	11	13	9.1	9.9	10
Iron (Fe)	.66	.12	.12	.08	.12	.08
Calcium (Ca)	83	26	30	15	32	22
Magnesium (Mg)	39	3.1	3.9	3.2	3.7	3.2
Sodium (Na)	903	} [a] 2.2	} [a] .9	} [a] .7	} [a] 1.8	} [a] 1.4
Potassium (K)	15					
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	194	90	105	56	108	79
Sulphate (SO_4)	1,538	4.8	4.1	4.3	5.8	4.4
Chloride (Cl)	402	1.6	1.5	1.0	3.0	1.0
Nitrate (NO_3)	20	1.8	.43	.29	.19	.43
Total dissolved solids	3,121	93	108	58	118	79
Total hardness as $CaCO_3$ (calculated)	367	78	91	51	95	68
Date of collection (1930)	Aug. 12	Aug. 7	July 30	Aug. 1	Aug. 2	Aug. 11

[a] Calculated.

WAYNE COUNTY

[Area 749 square miles, population 12,134]

Wayne County is a roughly rectangular area lying in the southwest corner of the region covered by this report. It is bounded on the north by Perry and Lewis Counties, on the east by Lawrence County, on the south by Lauderdale County, Ala., and on the west by Hardin and Decatur Counties. Waynesboro, the county seat (population 775), and Collinwood (population 698) are the chief towns.

The county is drained entirely by the Tennessee River, which touches it at the northwest corner. The Buffalo River is the intermediate drainage line for the northeastern part of the county, and minor tributaries carry the remainder of the drainage to the Tennessee.

Agriculture is the chief industry. There is a wood-products plant at Collinwood, and considerable lumbering is done in the neighboring area.

GEOLOGY

Technically Wayne County is entirely within the Highland Rim plateau. Actually, however, it marks the overlap of the Coastal Plain geomorphic type upon the Highland Rim. The rugged submature and mature topography in the northern part of the county grades into postmature topography along Cypress Creek, in the southern part, which is developed upon unconsolidated Cretaceous sediments.

The highest points of the county are slightly more than 1,050 feet above sea level. The Tennessee River at Clifton is at an altitude of less than 350 feet, so that the total relief is in excess of 700 feet. The proximity of the Tennessee River has caused strong local relief in the northern part of the county. Southward and also westward from the vicinity of Collinwood the general upland level begins to slope gradually away to the Tennessee River. Topographic maps are not available for the district west of the Waynesboro quadrangle, but to the south this gentle and uniform slope continues to and beyond the Tennessee River, decreasing to 500 or 600 feet above sea level just south of the Tennessee River, beyond which the levels abruptly rise to 850 to 1,000 feet. This slope is apparently due chiefly to southward side-slipping of the Tennessee, but some of the northern portion probably represents also a stripped pre-Tuscaloosa peneplain.

The outstanding feature of the stratigraphy of Wayne County, compared to other counties in south-central Tennessee, is the extensive and thick cover of Upper Cretaceous sediments in the southern part of the county. The uppermost of these deposits in this area is the Eutaw formation. This is a red sand, weathering gray, about 50 feet thick. It is confined to the tops of the ridges in the southwest corner of the county. Underlying the Eutaw and extending much farther northeastward is the Tuscaloosa formation. The Tuscaloosa is almost entirely gravel and is made up of pebbles, generally chert, as much as 4 inches in diameter. Interbedded with the gravel is an inconspicuous amount of sand and clay. This formation is 150 feet thick in the southwestern part of the county and extends continuously along the ridges to the latitude of Waynesboro. Elsewhere in the county it is represented by outliers capping high points.

The youngest of the consolidated rocks of the county is the St. Louis limestone. This and the very similar Warsaw formation underlying it reach a maximum thickness of 200 feet. The unweathered limestone is rarely seen in this county but is represented by its weathered facies of clay and chert. Beneath the Warsaw formation lies the Fort Payne chert. This formation, from 100 to 200 feet thick, ranges from a calcareous, somewhat shaly chert to a shaly cherty limestone. At the top of the Fort Payne chert or in the base of the overlying Warsaw limestone there occurs a bed of tripolite, a fine-grained porous silica, formed by the weathering of a siliceous limestone.

The Ridgetop shale is typically present in the northern part of the county and ranges from a knife-edge to 90 feet in thickness. It is a gray and platy shale, becoming more siliceous and calcareous southward. Beds of fossiliferous limestone and shale which Miser [57] considers a part of the Ridgetop formation occur in the southeast corner of the county. These have some of the lithologic characteristics of the New Providence formation. As beds at this horizon in Lauderdale County, Ala., just south of Wayne County, carry lower Burlington fossils,[58] these may represent the New Providence formation. However, Miser,[59] after an intensive study of these beds in this area, believes that they represent a facies of the Ridgetop shale.

[57] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 24, 1921.

[58] Butts, Charles, Geology of Alabama: Alabama Geol. Survey Special Rept. 14, p. 164, 1926.

[59] Miser, H. D., oral communication.

The Chattanooga shale crops out in the deeper creek valleys throughout the county. The black shale attains a thickness of 22 feet, and the basal Hardin sandstone member 15 feet. The underlying Devonian rocks consist of small scattered outcrops of the Pegram limestone and the Ross limestone member of the Olive Hill formation. The Pegram is exposed on Mill Creek, in the northern part of the county; the Ross is exposed near Clifton. The Ross limestone attains a thickness of 55 feet but has a very small areal extent.

Silurian shales and limestones are well developed on the larger creeks throughout the county. The uppermost formation, the Decatur limestone, a gray coarsely crystalline or fine-grained limestone, attains a thickness of 60 feet. It is present in the west-central and northwestern parts of the county. Beneath this is the Brownsport formation, which is found in the northern and western parts of the county. Its three members—the Lobelville shaly limestone, from a featheredge to 100 feet thick (uppermost member), the Bob crystalline limestone, as much as 35 feet thick; and the Beech River shaly limestone, as much as 85 feet thick—are all present. The underlying Wayne formation is present throughout the county. The uppermost or Dixon earthy limestone member of the Wayne, which is red near Clifton, ranges from 10 to 45 feet in thickness. The compact pinkish and gray limestone of the Lego and Laurel members, separated by the thin Waldon clay member, are together about 65 feet thick. The Osgood earthy limestone, the lowest member, is about 15 feet thick. The basal formation of the Silurian is the finely crystalline, glauconite-speckled Brassfield limestone, which has a maximum thickness of 25 feet.

The Ordovician rocks are represented chiefly by the Fernvale formation, which is generally present where its horizon is exposed. It is from 20 to 40 feet thick and consists of a lower coarsely crystalline limestone and an upper greenish shale. The Arnheim limestone is present only near Clifton and is only about 3 feet thick. The Hermitage formation, consisting of alternating thin shale and siliceous limestone occurs in the vicinity of Clifton, where a maximum of 80 feet of the formation is exposed. The formations between the Hermitage and the Arnheim are absent in this section. They have been found in wells in the southwestern part of Lawrence County.

GROUND WATER

Ground water in Wayne County occurs in openings of the same type and exhibits the same general phenomena as are found in the other counties treated in this report, and in addition it occurs in the primary openings in Tuscaloosa gravel. This gravel is very porous, the pores are comparatively large, and as a result the permeability is high. The high permeability and porosity combine to make it a good ground-water reservoir. Ample storage space is present, and probably a large part of the rainfall penetrates to the water table. However, the high permeability has one disadvantage—the water in general descends rapidly to the general drainage level, so that at many places on the uplands wells must be very deep. Correlated with this fact are large and omnipresent springs at drainage level where these deposits have not been entirely cut through. Along the main Cypress Creek north of Cypress Inn these springs are almost continuous. Larger flows are localized in places, probably by horizontal variations in the clay and sand content of the gravel, by various degrees of cementation of the gravel, and by deeper incision by the branches. Spring 526 is a typical spring near the base of the Tuscaloosa formation at drainage level. It was flowing about 100 gallons a minute when visited. The water from these springs is crystal-clear, soft, and of great chemical purity compared with typical waters from the limestone areas of south-central Tennessee.

Wells on the upland drawing from this aquifer apparently furnish abundant supplies of water when carried down almost to drainage level in the vicinity. According to report, well 499, about 1 mile west of spring 526, just noted, withdraws about 2,500 to 3,000 gallons of water a day, with no effect upon the water level, which is about 25 feet above the level of the spring. The well is a dug well 56 feet deep. Wells in Collinwood are of diverse depths, but many furnish abundant water for domestic purposes from depths of 30 to 40 feet (well 484b). Other wells, especially those near deep drainage lines, have more difficulty in obtaining water. Well 494, a dug well 78 feet deep, had only 3 inches of water in it when visited in July 1930.

The chert derived from the weathering of the St. Louis and Warsaw formations is erratic in its water-bearing properties. Well 486, in Collinwood, described by Miser,[60] is reported to have yielded 18,000 gallons a day from this deposit. Well 485, 116 feet deep, with the lower half in the weathered St. Louis limestone, obtained only a seep of water. Gravel stringers in this material probably serve to localize the movement of water in it. Sometimes a well strikes a filled solution channel in the weathered St. Louis limestone or Warsaw formation. For example well 501, originally 73 feet deep, apparently entered about 15 feet into the St. Louis limestone and after passing through chert layers struck water in a clayey material containing much-weathered chert. It is reported that this well when first dug held about 4 feet of water, which entirely disappeared over night. It was deepened several times, finally reaching a depth of 79 feet, and each time water was struck, but the water remained for only a short time and then suddenly disappeared. The materials and action of the well suggest that it is in a sink in the underlying rock. The successive workings in

[60] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 26, 1921.

it probably puddled the bottom of the well thus forming a comparatively impervious seal, so that it retained water for a time, after which, however, the water began to work through the impervious layer, opened up a passage, and rapidly drained away.

The remaining rocks of the county are calcareous and present the same ground-water phenomena as in the other counties of the area reported on here. Wells for domestic supplies are generally drilled and are generally successful at depths less than 100 feet. Good-sized springs are found in most of the creek valleys. The Waynesboro Spring, at Waynesboro, produces about 100 gallons a minute from the Ridgetop shale.

A fine example of the interrelations between the subsurface and surface drainage is presented by the double natural bridge in Fortyeight Creek, called locally "The Courthouse," about a quarter of a mile south of spring 511. A large solution channel at one time made a right-angled bend near the present location of Fortyeight Creek. In the continued development of the solution channel the roof at the point of the bend was undermined and caved, as did also the remaining portions of the cavern roof except two slabs near the bend. Today these slabs form two natural bridges approximately perpendicular to each other. The bridges are in the Osgood and Laurel members of the Wayne formation.

131880—36——12

Records of wells in Wayne County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Type of well	Depth (feet)	Diameter (inches)
469	Clifton	J. L. Thompson	Terrace	405	Dug	25	60±
470	do	J. E. Patrick	do	405	Drilled	68	6
[a] 471	Clifton, 3 miles northeast	A. L. Steele	do	390	do	42	5
472	Clifton, 5 miles northeast	Chester Peavihouse	Valley	415	do	25	5
473	Clifton, 3 miles southeast	M. I. Brown	Hillside	560	do	116	5
474	Clifton, 5 miles southeast	J. R. Thompson	do	560	do	34	5
475	Clifton, 8½ miles east	Widow Worley	Terrace	470	Dug	14	
476	Flatwoods, 1 mile east	J. E. Bastin	Ridge	750	do	44	48
477	Waynesboro, 6 miles north	C. D. Gill	Terrace	670	Drilled	33	5
478	Waynesboro, 3 miles north	G. N. Davis	do	750	Dug	41	48
479	Waynesboro, 7 miles northeast	W. J. Barnett	Ridgetop	900	do	12	48
480	Waynesboro, 6 miles northeast	Rich. Brewer	Spur	775	do	47	48
481	Waynesboro, 7 miles east	Western Oil & Gas Co	Ridge	985	Drilled	1,801	(?)
482	Waynesboro, 6 miles southeast	E. S. Stockard	Spur	900	Dug	35	
483	Collinwood, 3 miles north	Luther & Middleton	Ridge	1,070	do	38	
484a	Collinwood	Wayne County	Plateau	1,060	do	67	36
484b	do	J. L. Burns	do	965	do	36	42
485	Collinwood, 1 mile east	N. B. Shepard	do	1,030	do	116.6	36
486	Collinwood	(?)	do		Drilled	260	(?)
487	Waynesboro	Amos Hassel	Terrace	745	Dug	18	36
488	Waynesboro, 4 miles south	J. H. Brewer	do	830	do	38	20
489a	Waynesboro, 4 miles southwest	Wayne County	Valley	575	do	10	(?)
489b	do	do	Hillside	590	Drilled	48	5
490	Lutts	J. H. House	Base of hill	560	Dug	12	30
491	Lutts, 4 miles southeast	Charles Patterson	Flood plain	660	do	9	30
492	Lutts, 8 miles south	E. J. McFall	Base of hill	635	do	19	60
493	do	Mattie McFall	do	730	do	18	48
494	Cypress Inn, 5 miles northwest	Hassel Lumber Co	Ridge	950	do	78.1	36
495	McGlamerys Stand	R. A. Robertson	Plateau	1,005	do	24	42
496	do	do	do	1,040	do	58	36
497	Cypress Inn, 6 miles north	W. D. Shepard	Ridge	990	do	74	36
498	do	do	do	995	do	58	48
499	do	do	do	985	do	56	36
500	Cypress Inn	F. J. Darby	Hillside	750	do	21	24
501	Iron City, 7 miles northwest	W. R. Bratcher	Plain	850	do	79	36
502	Iron City, 6 miles west	Wayne County	do	835	do	60	30

[a] Record from Miser, H. D., Mineral resources of Waynesboro quadrangle; Tennessee Geol. Survey Bull. 26, p. 36, 1921. Analysis given in table of analyses.

Records of wells in Wayne County—Continued

No. on pl. 1	Water-bearing beds: Depth (feet)	Water-bearing beds: Lithologic character	Water-bearing beds: Stratigraphic position	Water level: Above or below surface (feet)	Water level: Date of measurement (1930)	Use of water	Remarks
469	21±	Gravel	Quaternary (?) alluvium	−21	July 24	Domestic	
470	63	Limestone	Silurian	−33		do	
471	42±	Shaly limestone	Wayne formation (?)	−21	July 24	Domestic; stock	
472	25±	Limestone	Wayne formation	−21	do	Domestic	
473	116±	do	do. (?)	−58	July 22	do	
474	34±	Shaly limestone	Brownsport formation	−24.5	do	Domestic; stock	
475	13±	Fine sand (?)	Quaternary alluvium	−13.5	July 24	Domestic	
476	42±	Residual chert (?)	Fort Payne chert (?)	−42.0	July 25	do	
477	33±		Brownsport formation (?)	−27		do	
478	36±	Residual chert	Fort Payne chert	−36	July 25	do	
479	9±	do	St. Louis limestone (?)	−8.7	July 23	Stock	Well not now in use. Reported to have furnished all water needed by 300 head of sheep and 30 head of cattle.
480	41±	do	Fort Payne chert	−41	do		
481	(?)	(?)	do				Drilled as oil test in 1929 and 1930; 10-inch casing to 123 feet. No information about upper aquifer.
	1,390	"Sand"	Lower Ordovician (?)				Aquifer 3 feet thick according to driller's description.
	1,738	"Soft sand"	do				Aquifer 2 feet thick and "approximately 60 percent sand", according to driller's description. May represent St. Peter sandstone.
482	33±	Residual chert	St. Louis limestone (?)	−33.7	July 28	Domestic	
483	27±	Gravel	Tuscaloosa formation	−26.7	do	Domestic; stock	Furnishes water for 20 head of stock.
484a	45±	do	do	−45.2	Sept. 12	Domestic	Furnishes water for high school.
484b	30±	do	do	−30.2	do	Domestic; stock	Well furnishes 8 stores and all transients. Never been dry. Other dug wells in Collinwood have various depths.
485	116±	Residual chert	St. Louis limestone	−115.6	Sept. 13	None	Quantity insufficient for any use.
486	44	Gravel	Tuscaloosa formation				Water reported in loose gravel at this depth.
	64	Residual chert	St. Louis limestone				Reported to yield 18,000 gallons a day (=12 gallons a minute).
	210	Chert	Fort Payne chert				Reported 75 gallons an hour.
	240	do	do				"Good flow" of water.
487	17±	do	do	−17	Sept. 15		In course of construction. Abundant water obtained in very porous chert developed along joint crack in line with one of the large springs 150 feet distant.
488	32±	Tripolite	do	−31.6	Sept. 13	Domestic	
489a	9±	Limestone	Wayne formation	−9		do	Furnishes water for 12 people on county farm.
489b	48±	do	do	−35.6	July 22	Stock	
490	11±	Residual chert	Fort Payne chert	−11.0	July 26	Domestic; stock	
491	8±	Gravel	Quaternary alluvium	−8	do	Domestic	
492	18±		do	−17.7	Sept. 9	do	
493	15±	Tripolite (?)	Fort Payne chert (?)	−14.4	do	Domestic; stock	

Records of wells in Wayne County—Continued

No. on pl. 1	Water-bearing beds			Water level		Use of water	Remarks
	Depth (feet)	Lithologic character	Stratigraphic position	Above or below surface (feet)	Date of measurement (1930)		
494	78±	Gravel	Tuscaloosa formation	−77.8	July 26	Domestic	
495	21±	do	do	−20.8	Sept. 12	Domestic; stock	
496	51±	do	do	−51.1	do	do	
497	64±	do	do	−64.3	Sept. 9	Domestic	
498	57±	do	do	−56.8	do	do	
499	51±	do	do	−51.0	do		Reported to yield 2,500 gallons a day to 60-horsepower boiler and water for 14 mules and 2 families.
500	18±	do	do	−18.1	do	Domestic	
501	78±	do	St. Louis limestone (?)	−78.6	Sept. 12	Domestic; stock	Water found in probably gravel-filled solution channel in St. Louis limestone. Leaks developed which drained off water.
502	51±	Residual chert (?)	do. (?)	−50.5	do	Domestic	Well supplies 2-room schoolhouse.

Records of springs in Wayne County

No. on pl. 1	Location with respect to nearest map point	Owner or lessee	Topographic situation	Approximate altitude (feet)	Kind of rock	Stratigraphic position
503	Flatwoods, 2 miles east	M. H. Thomason	Base of hill	670	Cherty shale	Ridgetop shale.
504	Clifton, 5 miles northeast	Eunice Riley	do	410	Limestone	Wayne formation.
505	Flatwoods, 3 miles southeast	D. E. Warren and others	Head of drain	640	Shale	Ridgetop shale.
506	Flatwoods, 5 miles southeast	Ed Copous	Base of hill	630	Shaly limestone	Brownsport formation.
507	Waynesboro, 6 miles north	C. D. Hill	do	645	do	Do. (?).
508	Waynesboro, 4 miles northwest	Wes. Simmons	do	585	Limestone	Wayne formation.
509	Riverside, 6 miles west	John Raspberry	do	620	do	Do.
510	do	do	Hillside	700	Chert	Fort Payne chert.
[a] 511	Riverside, 5 miles southwest	B. T. Young	Base of hill	650	Limestone	Wayne formation.
512	West Point, 9 miles northwest	T. A. Kelley	do	730	Calcareous shale	Ridgetop shale.
[a] 513	West Point, 7 miles northwest	Mrs. L. N. Austin	do	700	Shaly limestone	Do.
514	Collingwood, 5 miles east	Brother Ramsey	do	720	Chert	Fort Payne chert.
515	Collinwood, 2 miles north	John Shands	Drain in plateau	1,010	Gravel	Tuscaloosa formation.
516	Collinwood	Wayne Land Co	do	1,035	do	Do.
517	Collinwood, 2 miles east	J. W. Bryson	Valley	810	do	Quaternary alluvium.
[a] 518	Collinwood, 5 miles northwest	Nancy Scott	Base of hill	610	Limestone	Brownsport formation.
[a] 519	Waynesboro	Wayne County	do	725	Chert	Fort Payne chert.
520	Waynesboro, 8 miles west	Herbert Haggard	Hillside	525	Calcareous shale	Brownsport formation.
521	Clifton, 7 miles south	Wm. Davidson	Base of hill	530		Wayne formation.
522	Martins Mills, 4 miles northeast	G. W. Eaton	Hillside	630	Chert	Fort Payne chert.
523	Martins Mills, 3 miles northeast	Russ. Yeiser	do	560	do	Do. (?).
524	Martins Mills	D. D. Wilkerson	Base of hill	530	Shaly limestone	Brownsport formation.
525	Victory	J. F. Wilson	do	700	Chert	Fort Payne chert.
[a] 526	Cypress Inn, 6 miles north	Ode Berry	do	905	Gravel	Tuscaloosa formation.
527	Cypress Inn, 5 miles northeast	A. W. Bratchett	Gentle hillside	790	do	Do.
528	Collinwood, 6 miles southeast	J. R. Daniels	Hillside	735	Chert	Fort Payne chert.

[a] Analysis given in following table.

Records of springs in Wayne County—Continued

No. on pl. 1	Openings		Approximate yield		Use of water	Remarks
	Number	Character	Gallons a minute	Date of measurement (1930)		
503	1	Joint crack	12	July 30	Domestic; stock	
504	1	Bedding plane	2	July 24	do	
505	1	do	1	July 25	Domestic	
506	1	do	6±	do	Domestic; stock	
507	1	Enlarged joint crack	2±	do	do	
508	1	do	2	July 24	do	
509	1	Enlarged bedding plane	7	July 23	do	
510	1	Concealed	1/16	do	Domestic	
511	1	Large cavern	50±	do	do	"The Courthouse" spring; the underground stream feeding this spring is accessible through a joint crack ¼ mile northeast.
512	1	Bedding plane	1	July 28	do	
513	1	Enlarged bedding plane	3	do	Domestic; stock	
514	1	Joint crack	¼	do	Domestic	
515	1		5	Sept. 12	Domestic; stock	
516	1		4	do	Community supply	
517	1		15	July 28	Domestic; stock	
518	1	Cavern 30 feet high	5⅛	July 26	Domestic	
519	Several	Enlarged joint cracks	100±	July 22	Domestic; stock	Waynesboro Spring; flow increases after a hard rain; water becomes dingy.
520	1	Bedding plane	⅛	do	do	
521	1	do	1	do	Domestic	Water stands in small pool.
522	1	Jointed zone	2	July 26	do	
523	1	Joint plane	⅛	do	do	
524	1	Concealed	10±	do	do	
525	1	do	3	Sept. 13	Domestic; stock	
526	1		100	Sept. 9	do	
527	1		2	Sept. 12	do	
528	1	Concealed	4	Sept. 13	do	

Analyses of ground waters from Wayne County

[Margaret D. Foster, U. S. Geological Survey, analyst. Parts per million. Numbers at heads of columns correspond to numbers in tables of well and spring data]

	471	511	513	518	519	526
Silica (SiO_2)	13	7.4	14	13	8.3	6.7
Iron (Fe)	.31	.03	.03	.15	.05	.15
Calcium (Ca)	60	21	28	51	7.7	2.2
Magnesium (Mg)	29	4.1	4.6	6.2	1.7	1.2
Sodium (Na)	[a] 75	([b])	[a] 1.0	[a] 1.1	1.7	([b])
Potassium (K)					.8	
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	360	76	101	162	23	4.0
Sulphate (SO_4)	120	5.1	4.9	17	3.5	3.8
Chloride (Cl)	4.1	1.7	1.6	1.4	3.2	2.0
Nitrate (NO_3)	6.8	.38	1.0	3.4	3.2	1.2
Total dissolved solids	481	78	104	170	43	22
Total hardness as $CaCO_3$ (calculated)	269	69	89	153	26	10
Date of collection (1930)	July 24	July 23	July 28	July 26	July 22	Sept. 9

[a] Calculated.
[b] Less than 5.

INDEX

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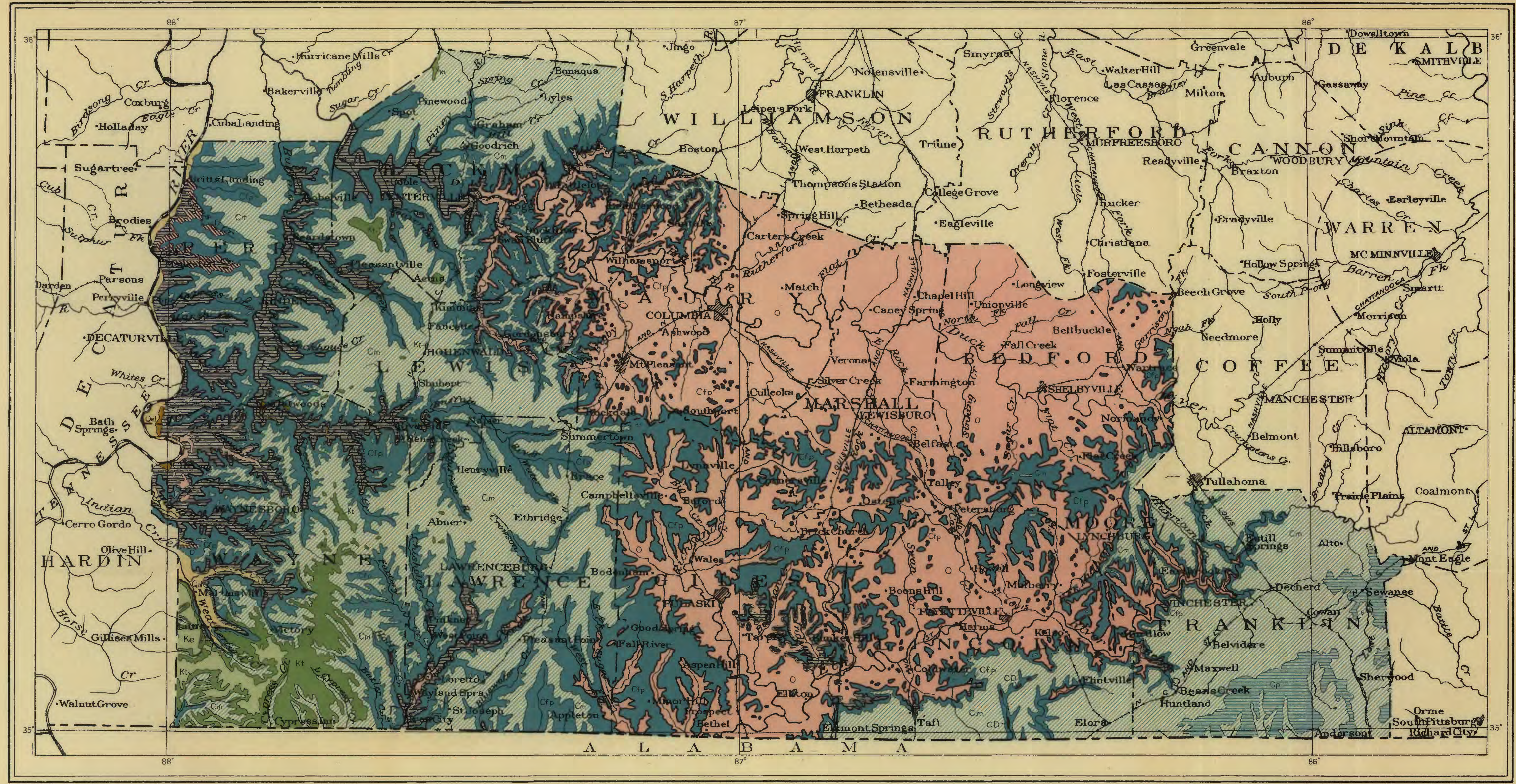


Base from U. S. G. S. 1:500,000 scale map of Tennessee

Lith. A. Hoen & Co.

Geology from Geologic map of Tennessee, 4th edition, by Tennessee Division of Geology

EXPLANATION

QUATERNARY

Recent

Qal

Alluvium
(Gravel, sand, and silt on flood plains of streams)

QUATERNARY (?)

Qt

Terrace deposits
(Gravel, sand, and silt on terraces of streams in western part of area)

CRETACEOUS

Upper Cretaceous

Ke

Eutaw formation
(Unconsolidated red and gray sand with thin clay layers)

Kt

Tuscaloosa formation
(Unconsolidated gravel of chert pebbles with subordinate sand and clay)

CARBONIFEROUS

Pennsylvanian

Cp

Whitwell shale (at top), Sewanee conglomerate, and Gizzard formation (at bottom)

Mississippian

Cm

Pennington shale (at top), Bangor limestone (restricted), Hartselle sandstone (restricted), Golconda (?) shale, Gasper formation, Ste. Genevieve limestone (all confined in this area to the Cumberland escarpment in Franklin County), St. Louis limestone, and Warsaw formation (at base)

Cfp

Fort Payne chert (at top) *(siliceous limestone and shale)* and Ridgetop shale in part of area *(gray and green siliceous and calcareous shale; probably includes at top beds representing the New Providence formation)*

CARBONIFEROUS OR DEVONIAN

Mississippian or Upper Devonian

CD

Chattanooga shale
(Fissile black bituminous shale with the Hardin sandstone member at its base)

DEVONIAN

Middle or Lower Devonian

D

Pegram limestone (at top), Harriman chert, Quall limestone, Decaturville chert, Birdsong shale, and Olive Hill formation (all confined to Tennessee and Buffalo River Valleys).

SILURIAN

S

Decatur limestone (at top) Brownsport formation, Wayne formation, and Brassfield limestone (at base).

ORDOVICIAN

Upper, Middle and Lower Ordovician

O

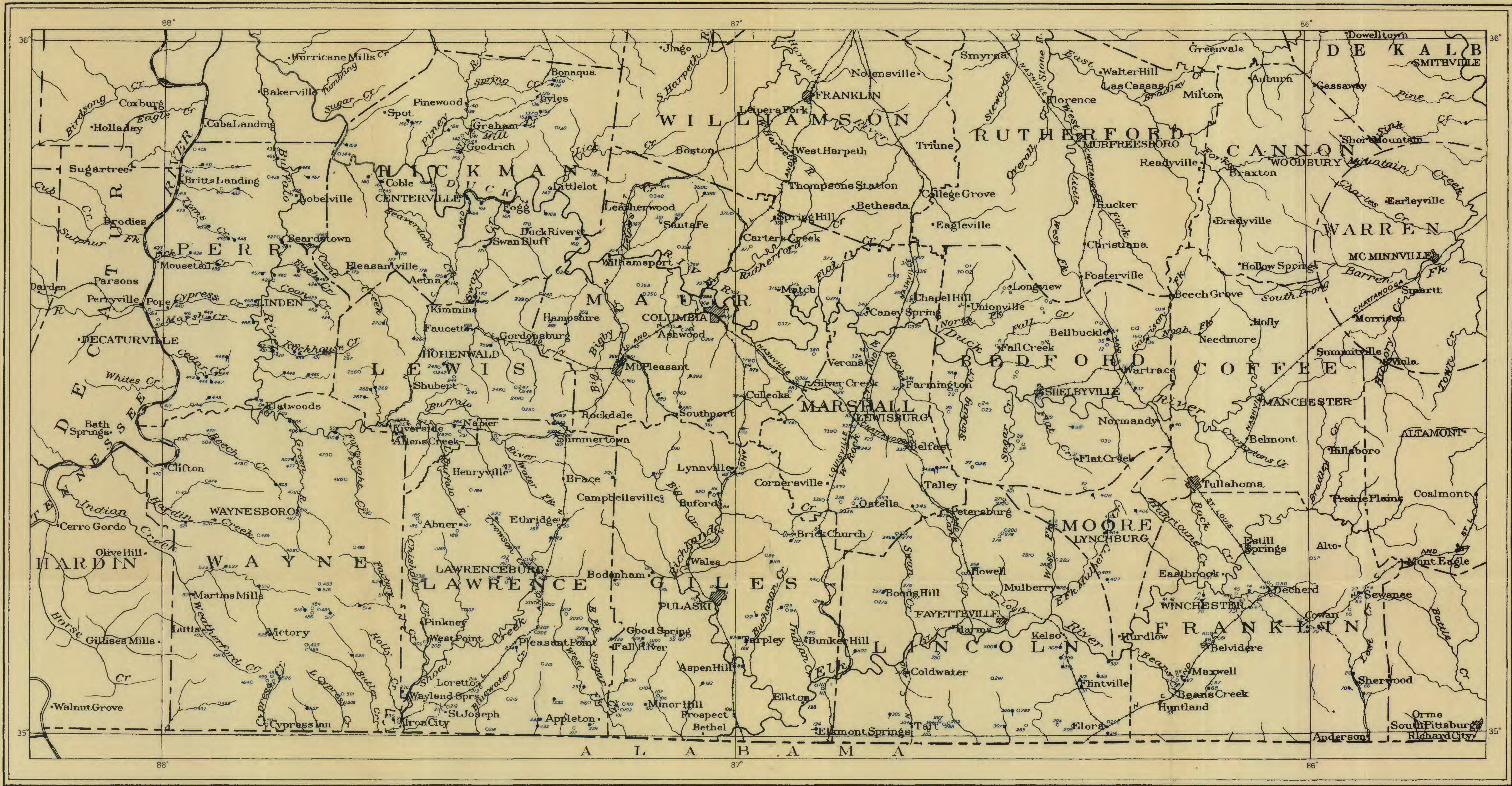
Fernvale formation (at top), Arnheim limestone, Leipers limestone, Catheys limestone, Cannon limestone, Bigby limestone, Hermitage formation, Lowville limestone, Lebanon limestone, and Ridley limestone (at base).

GEOLOGIC MAP OF SOUTH-CENTRAL TENNESSEE

Scale $\frac{1}{500000}$

10 0 10 20 30 40 Miles

1936



o Well

Spring

MAP OF SOUTH-CENTRAL TENNESSEE

SHOWING THE LOCATIONS OF WELLS AND SPRINGS MENTIONED IN THIS REPORT

Scale 1/500000

10 0 10 20 30 40 Miles

1936

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