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UNDERGROUND WATERS OF MISSOURI

THEIR GEOLOGY AND UTILIZATION

BY

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UNDERGROUND WATERS OF MISSOURI: THEIR GEOLOGY AND UTILIZATION.

By EDWARD M. SHEPARD.

INTRODUCTION.

With the advance in sanitary science the value and importance of a pure water supply for towns and cities, as well as for country districts, are being each year more strongly emphasized. The rapid settling of the country has made surface waters very liable to contamination, and the demand for water from deeper sources, less exposed to organic impurities, is becoming more and more marked.

The rapid growth of Missouri—the 1900 census placing her fifth in population among the States of the Union—has brought this demand into particular notice in this State. Many villages have grown to towns and are looking for a suitable supply of water, not only for domestic uses, but also as a means of protection from fire. Many cities have wholly outgrown the capacity of their source of water supply and need additional or new and larger sources. The largest cities have constantly to face the increasing contamination of the rivers from which their water is derived, and the necessity of seeking some new source has stimulated inquiries for information in regard to artesian conditions in the State. In the hope of answering such inquiries to some extent this report has been prepared.

Those who have studied the subject of artesian wells understand the difficulties which confront the geologist in attempting to explain or describe the conditions which govern their distribution. These difficulties are especially apparent in Missouri, as so little has been done toward elucidating the problems incident to the folding and faulting of the geologic horizons of this great State. The sinking of deep wells has been largely confined to the mining districts, and they have been comparatively few in number, while it is but recently that the development of the oil fields of Kansas has stimulated prospecting in the northern and western parts of Missouri.

It is unfortunate that the geologist can not be present to collect for himself the drillings from deep wells and note the thicknesses of the strata passed through, since, as a rule, the records are rather negligently kept. Samples of cuttings are carelessly preserved, the labels are either lost or destroyed, and even the records themselves often disappear. Little or no attention is paid to the different flows or to the quality of the water. In some cases these wells are grouped in or near certain mining localities and in others a considerable distance, covering several counties, intervenes between them, for which reasons deductions made by the geologist from cross sections based on well-record data may not be strictly accurate. Fortunately, however, there are a few wells in Missouri which were drilled under the careful supervision of geologists, and the writer has been able to study a number of cases where samples of drillings and an accurate log have been carefully preserved by intelligent drillers. On the other hand, the valuable information that might have been given by many deep wells, drilled at great expense, has been wholly lost. Records that would have been of inestimable value to the geologist and the public have disappeared, and in some cases the well has been abandoned. It is to be hoped that in the future not only drillers, but owners of such wells will see to it that records and samples of drillings are preserved and that information regarding them is given either to the State or to the United States Geological Survey.

The writer wishes here to express his appreciation to Mr. M. L. Fuller, under whose direction this work has been done; to Mr. W. B. Johnson, of Memphis, Tenn., who rendered invaluable assistance in making many well records accessible; to Mr. C. B. Bailey, of Wynne, Ark.; Mr. Thomas Beckwith, of Charleston, Mo.; Messrs. W. G. Lanhan and W. C. Davis, engineers for the Memphis Water Company; Mr. W. E. Pratt, of Samburg, Tenn.; Mr. W. B. Beckman, of Blytheville, Ark.; to Dr. E. R. Buckley, State geologist of Missouri; to Mr. R. Hawkins, of Chillicothe; and many others who have cheerfully given the result of their observations.

HISTORICAL FACTS.

The term "artesian" is derived from the province of Artois, France, where one of the first wells of this character was sunk, and it dates back probably to the twelfth century. Norton, in his Artesian Wells of Iowa,[a] calls attention to the fact that at Modena, in northern Italy, are wells of about the same antiquity as those of Artois. They have been in use for many centuries in Austria. It is believed that they have a great antiquity in China; and Tchihatchef affirmed, in an address before the British Association in 1882, that the ancient Greeks sunk artesian wells in Sahara, at Baalbek, and at other points. One

[a] Norton, W. H., Ann. Rept. Iowa Geol. Survey, vol. 6, 1897, p. 123.

of the earliest wells sunk in this country, so far as it has been possible to determine, was bored for salt at Spalding, near Rensselaer, Ralls County, Mo., about 1823.

It is most unfortunate that the term artesian is used so loosely. Originally it designated flowing wells only, but in later years it has been also applied to deep wells that do not flow. Norton has suggested the term "subartesian" for nonflowing deep wells, and it is very desirable that some such distinction should be made. In this report each well will be designated as "flowing" or "nonflowing."

REQUISITE CONDITIONS FOR FLOWING ARTESIAN WELLS.

In a general way the principal requisite for the production of a flowing-water well is the direct opposite of that for a gas well. Both require, first, a reservoir—that is, a stratum of coarse-grained or granular rock, which may be either a sandstone or a coarse-grained limestone; second, an impervious protecting cap rock, which is generally a shale or a very compact limestone; but the third and most important point, in which the two classes of wells differ, is that the gas collects at the crest of a fold of strata, *i. e.*, at the summit of an anticline, while the water accumulates in a basin or synclinal trough. These two classes of wells differ also in the source from which they are derived. The gas usually originates in the carbonaceous shale that underlies the reservoir, while the source of the water is frequently many miles away, at the point where the rock which forms its reservoir outcrops, necessarily always at a higher level than that from which the well starts. A sufficient rainfall in its catchment basin is also an essential condition for the existence of a successful artesian well. Williams[a] has shown that—

> A rainfall of 30 inches per year, which is well within the average rainfall of the eastern United States [as well as of the State of Missouri], would supply to the gathering area of a 100-foot stratum, dipping at an angle of 1°, 3,400 barrels of water a year for every foot in width across the outcrop, of which, if but one-third is taken up by the stratum, upward of 1,100 barrels per year will be stored in every foot of its width. Hence the enormous flow from some noted artesians need excite no surprise. An artesian well in the city of Louisville is said to yield 330,000 gallons every twenty-four hours, from a depth of 2,086 feet. One in the city of Paris, the Grenelle well, discharges over half a million gallons per day from a depth of 1,806 feet, while one bored by a French engineer in the Sahara Desert is said to have yielded at the outset 1,000 gallons per minute, or about 1,500,000 gallons per day.

Gas fields are, as a rule, confined to certain geologic horizons. For example, in Kansas and Missouri gas is found only at the base of the Pennsylvanian, in the Cherokee shale. It is also true that certain geologic horizons are eminently water bearers. Later in this report, for example, it is shown that the St. Peter sandstone, where the other conditions are favorable, is one of the most prominent reservoirs for

[a] Williams, S. J., Applied Geology, New York, 1886, p. 62.

artesian waters. Further, different water-bearing horizons vary decidedly in the quality of waters produced. In the loose incoherent sands of the Tertiary is found an abundance of good water, though it is inclined to be somewhat chalybeate. In the sandstones of the Pennsylvanian sulphur and saline waters may be expected. In the Hannibal formation of the Kinderhook group magnesium-sulphate (Epsom salts) waters are the general rule. At the base of the porous upper part of the Burlington hard but pure waters are found. The water of the St. Peter sandstone, if it has not traveled too far and become laden with impurities, is likely to be soft and fresh.

As has been stated, artesian waters are sometimes found in basins—that is, in old lake or estuary beds. Under such conditions the water falling on surrounding outcropping strata drains into the basin from all sides. The accompanying diagram (fig. 1), modified from Williams, gives an idea of a basin which has been faulted on one side. The catchment area is higher on each side than in the middle, and the upturned edges of the strata outcrop there. The porous sandstone

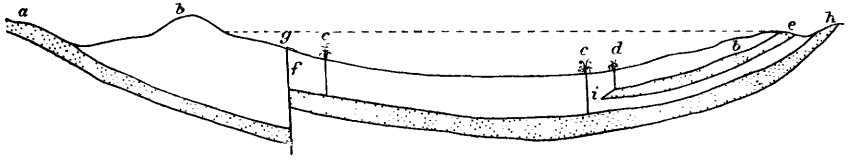

FIG. 1.—Diagram illustrating essential conditions for artesian wells and springs.

beds *a*, *e*, and *h* are covered above and below by impervious shale beds. Wells drilled through the upper shale at any point in the basin, below the outcropping edges, will tap the water under pressure and will flow. Sometimes strata gradually change in character, as illustrated in *e* in the diagram, the sandstone bed merging into shale. This sandstone bed, when tapped, as at *d*, will yield flowing water. It is clear that the rainfall soaking into the outcropping edges of the porous strata passes downward in these beds and, being under pressure, will rise, when tapped, as at *c* and *d*, and flow to the surface with a force proportionate to the height of the head above the mouth of the well. If a well were sunk at *b*, water would not flow, because *b* is at the same height as the head *a*. At *g* the strata have been faulted, and those to the left have gone down. Such a fault line as this frequently marks the passage of water that rises in springs, as at *g*. Water from a well drilled at *c* would rise with much greater force than from a well at *d*, because the head at *c* is higher.

If a basin was formerly an estuary of the sea, which has been tilted so that the mouth has been elevated, or if the mouth has been filled

up with impervious deposits so that the salt water has slowly evaporated, leaving the basin to be subsequently filled with alternating deposits of sand and clay, all the conditions requisite for brine wells will be found. Such conditions explain the brine wells and springs of Saline and Howard counties, and are more fully described in the text (pp. 80–81).

Another common condition favoring the collection of artesian waters is found in basins which contain sand, with an impervious clay layer above, and into which the drainage comes from three directions. As an example of this the conditions in southeastern Missouri may be cited. The valley of the Mississippi lies in a trough, between the Ozarks on the west and the Kentucky and Tennessee plateau on the east. Here powerful drainage flows in from the north, the west, and the east. This is one of the strongest artesian basins in the interior States.

Again, the source of artesian waters may be from one direction only—as, for example, on the long, gentle slope of a fold, where the head is higher than the point at which the well is drilled. Such is commonly the case in many parts of the State.

Faulting may produce artesian conditions where they would not otherwise be present, the displacement bringing an impervious stratum against the porous, water-bearing stratum.

Another consideration of much importance as regards the abundance of water supply is the area of the outcrop of the porous beds, or the breadth of the absorbing surface exposed. Williams [a] has shown the great extent of the catchment area where only a slight dip is found. He says: "The breadth of exposure on a level surface of beds 100 feet thick with a dip of 1° would be a trifle more than a mile, and for 2° dip about one-half mile, the breadth of surface exposed varying inversely as the dip. Hence a moderate degree of dip will give a greater extent of gathering ground, or area of catchment, as it is often termed."

VARIATION IN THE FLOW OF ARTESIAN WELLS.

Artesian wells sometimes vary in their flow. Some gradually weaken until their flow ceases altogether; others stop flowing when wells near by are pumped, as illustrated by those of the De Soto group; and still others have periodic variations or fluctuations in their discharge. Such fluctuations are due in many cases, no doubt, to barometric variation in pressure; near the seashore they may be due to tidal influence; in some cases they are believed to be due to a siphon action, when the conditions in the waterway are favorable.

[a] Williams, S. J., Applied Geology, New York, 1886, p. 61.

The uses of artesian wells, aside from their value in supplying water for domestic purposes, are, among others, as a source of mineral waters; to furnish water for irrigation; for protection against fire; for the development of power for manufacturing purposes; for the production of heat. Last, but not least, the importance of the artesian well as a geologic agent is a matter which challenges attention and which has heretofore been entirely overlooked.[a]

The waters of certain wells possess mineral constituents which render them valuable therapeutic agents, both for internal and external use, and these give rise to the establishment of health resorts. Some of the finest of such resorts in the West are located in this State and derive their water from deep wells.

The abundance of rainfall in Missouri, as shown by the table at the close of this section, and its excellent drainage system render irrigation unnecessary; but the value of artesian wells for such a purpose in the far West is largely recognized. One of the most important services rendered by the water resources branch of the United States Geological Survey is the location of storage reservoirs and the outlining of artesian districts for the irrigation of the arid regions of the West. The basins located between many of the ranges of the Rocky Mountain system are deserts. Fortunately the strata sloping from the frequently snow-capped mountains present favorable conditions for artesian waters, and large areas are now being irrigated by means of flowing wells.

In several cases, where the water from an artesian well has proved too saline for domestic purposes it has been found that this characteristic has rendered it of particular value in extinguishing fires.

Darton,[b] in his report on "Artesian wells of a portion of the Dakotas," describes the utilization of power from some artesian wells in producing electrical energy and running mills. The pressure in a number of cases reaches 100 to 150 pounds. There are a number of wells in Missouri that have a considerable pressure, but are not utilized for power.

None of the wells of this State have water of a high temperature, though some of them reach a considerable depth.

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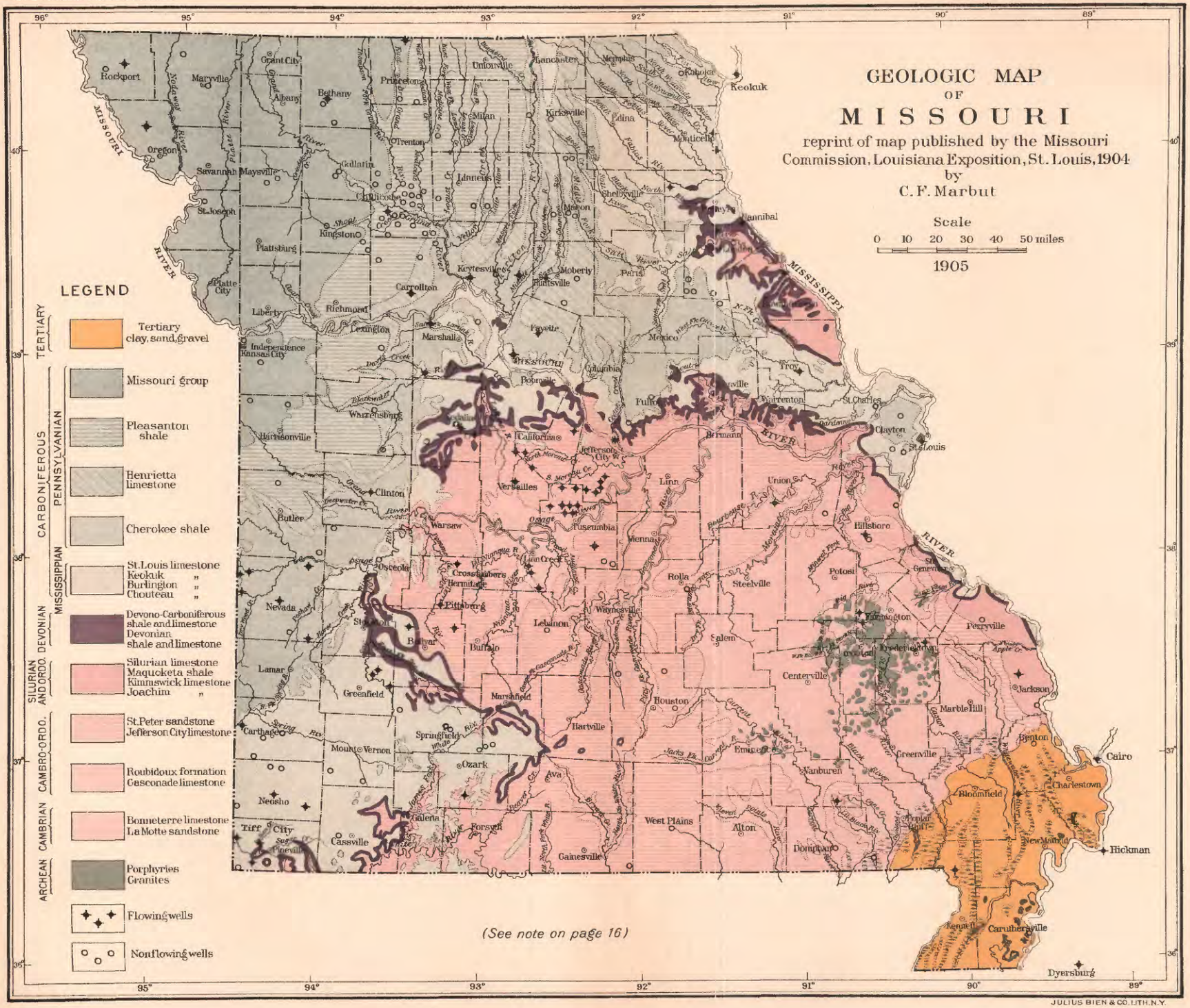
[a] See Shepard, E. M., New Madrid earthquake: Jour. Geol., vol. 13, 1905, p. 45.

[b] Darton, N. H., Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 690-691.


GEOLOGIC MAP
OF
MISSOURI
reprint of map published by the Missouri Commission, Louisiana Exposition, St. Louis, 1904
by
C. F. Marbut
Scale
0 10 20 30 40 50 miles
1905
LEGEND
TERTIARY
Tertiary clay, sand, gravel
CARBONIFEROUS
PENNSYLVANIAN
Missouri group
Pleasanton shale
Henrietta limestone
Cherokee shale
MISSISSIPPIAN
St. Louis limestone
Keokuk "
Burlington "
Chouteau "
DEVONIAN
Devono-Carboniferous shale and limestone
Devonian shale and limestone
SILURIAN AND ORDO.
Silurian limestone
Maquoketa shale
Kimmswick limestone
Joachim "
CAMBRO-ORDO.
St. Peter sandstone
Jefferson City limestone
CAMBRIAN
Roubidoux formation
Gasconade limestone
Bonneterre limestone
La Motte sandstone
ARCHEAN
Porphyries
Granites
Flowing wells
Nonflowing wells
Rockport
Maryville
Grant City
Albany
Bethany
Princeton
Unionville
Lancaster
Memphis
Kahoka
Keokuk
Oregon
Savannah
Maysville
Trenton
Milan
Kirksville
Edina
Monticello
Cameron
Shelbyville
Hannibal
St. Joseph
Chillicothe
Linneus
Kingston
Plattsburg
Platte City
Liberty
Richmond
Carrollton
Keytesville
Brunswick
Moberly
Huntsville
Paris
Lexington
Marshall
Fayette
Mexico
Independence
Kansas City
Columbia
Troy
Pulaski
Warrenton
St. Charles
Clayton
St. Louis
Warrensburg
Harrisonville
California
Jefferson City
Bernaum
Versailles
Linn
Union
Clinton
Butler
Warsaw
Osceola
Tuscumbia
Vienna
Hillsboro
Crosstimbers
Hermitage
Lynn Creek
Rolla
Steelville
Potosi
Nevada
Pittsburg
Waynesville
Farmington
Perryville
Lebanon
Buffalo
Salem
Bolivar
Lamar
Greenfield
Centerville
Jackson
Marshfield
Houston
Marble Hill
Carthage
Springfield
Hartville
Benton
Cairo
Mount Vernon
Ozark
Ava
Greenville
Vanburen
Charlestown
Bloomfield
Neosho
Galena
Forsyth
West Plains
Alton
Poplar Bluff
Tiff City
Cassville
Gainesville
Dompiano
New Madrid
Hickman
Kennett
Caruthersville
Dyersburg
(See note on page 16)
JULIUS BIEN & CO. LITH. N.Y.

Average annual precipitation in Missouri for ten years, by counties.

	Inches.		Inches.		Inches.
Adair	38	Greene	43	Ozark	44
Andrew	35	Grundy	36	Pemiscot	45
Atchison	34	Harrison	36	Perry	42
Audrain	39	Henry	40	Pettis	37
Barry	47	Hickory	43	Phelps	42
Barton	46	Holt	37	Pike	38
Bates	40	Howard	37	Platte	35
Benton	40	Howell	43	Polk	43
Bollinger	45	Iron	45	Pulaski	42
Boone	36	Jackson	36	Putnam	36
Buchanan	34	Jasper	46	Ralls	37
Butler	45	Jefferson	41	Randolph	37
Caldwell	37	Johnson	37	Ray	37
Callaway	39	Knox	36	Reynolds	43
Camden	42	Laclede	44	Ripley	45
Cape Girardeau	44	Lafayette	37	Saline	35
Carroll	37	Lawrence	47	Schuyler	35
Carter	44	Lewis	36	Scotland	35
Cass	38	Lincoln	38	Scott	44
Cedar	43	Linn	37	Shannon	43
Chariton	36	Livingston	36	Shelby	38
Christian	45	McDonald	47	St. Charles	41
Clark	34	Macon	37	St. Clair	42
Clay	35	Madison	45	St. Francois	43
Clinton	35	Maries	41	Ste. Genevieve	42
Cole	38	Marion	38	St. Louis	39
Cooper	37	Mercer	37	Stoddard	46
Crawford	42	Miller	41	Stone	47
Dade	45	Mississippi	43	Sullivan	37
Dallas	43	Moniteau	38	Taney	46
Daviess	37	Monroe	38	Texas	41
Dekalb	36	Montgomery	39	Vernon	42
Dent	42	Morgan	39	Warren	40
Douglas	44	New Madrid	46	Washington	42
Dunklin	46	Newton	46	Wayne	44
Franklin	40	Nodaway	36	Webster	43
Gasconade	39	Oregon	43	Worth	35
Gentry	36	Osage	40	Wright	43

TOPOGRAPHY.

Topographically Missouri is naturally divided into six great districts—the northwest plateau, the north-central prairie region, the Ozark-St. Francis dome, the Ozark border, the southeastern lowlands, and the Lincoln Ridge, all of which are outlined on the accompanying map (fig. 2).

NORTHWEST PLATEAU DISTRICT.

The northwest plateau includes the elevated portion of the northwestern third of the State and is bounded, approximately, by the 900-

foot contour indicated on the map. This plateau gently rises in altitude to the northwest corner of the State, where its elevation is over 1,200 feet. Geologically, however, the strata generally dip about 10 or 15 feet to the mile in a northwesterly direction, thus burying to a considerable depth the Pennsylvanian rocks, which outcrop on the southern border of the district. The surface is relatively smooth and gently rolling, slightly trenched by the rivers which drain it and covered with a mantle of drift, which is composed on the surface of a fine sandy silt and clay. Along Missouri River, however, are large deposits of loess. The valleys of the smaller streams are usually broad, with gentle slopes, owing to the character of the underlying rocks, which are largely shales and sandstones. Rarely, where the streams cut into thin limestone beds, a greater irregularity of the surface is noticed.

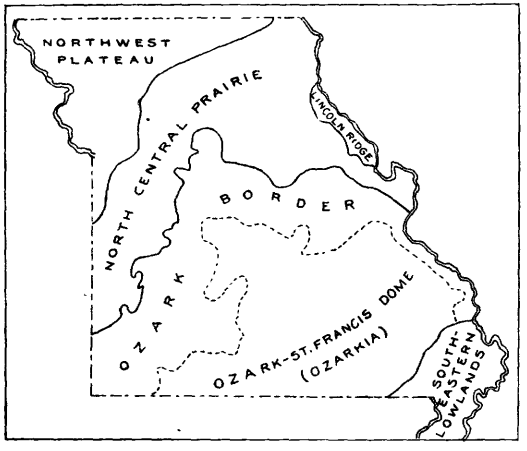


FIG. 2.—Map showing topographic districts of Missouri.

NORTH-CENTRAL PRAIRIE DISTRICT.

The north-central prairie is bounded on the south by an arbitrary line that starts on Mississippi River, in St. Charles County, and runs in a northwesterly direction until it strikes the southern 900-foot contour north of Cooper County. Thence this line runs in a southerly and southwesterly direction, leaving the State in Barton County. This irregular prairie district is deeply bisected by Missouri River and is trenched on the north and south by the tributaries of the Missouri. The altitude of the flood plain of the river at the lowest point in this district is a little over 600 feet. It rises gradually to the northeast as far as the Iowa line, where its altitude is about 1,200 feet. From the Missouri southwest to the Kansas line it reaches an altitude of from 800 to 900 feet.

OZARK-ST. FRANCIS DOME DISTRICT.

The Ozark-St. Francis dome district includes an elevated elliptical plateau, having a northeast-southwest trend. It extends in a broad belt from a point near Mississippi River to the Arkansas line. The northwestern limit of this district is marked on the topographic map (fig. 2) by an irregular line. The general axis extends from Iron

County southwestward, and leaves the State near the southeast corner of Barry County. As a rule, the strata dip gently at right angles to this axis. The highest point in this district, as well as in the State, is Taum Sauk, the crest of the St. Francis Mountains, in Iron County, which reaches an elevation of 1,800 feet. The crest of the Ozarks is reached at Cedar Gap, in Wright County, at an elevation of 1,700 feet. The geologic formations involved in the Ozark dome are mainly hard silico-magnesian limestone and more or less indurated sandstones. The drainage to the north and west of the main axis is into Osage and Missouri rivers. To the south it is mainly through James Fork, Bryants Creek, Current River, and Black River into White River, and through St. Francis River into the Mississippi. The Current, flowing southeastward, and Piney Fork of the Gasconade, flowing northward, nearly bisect the dome. The streams flowing across the dome on either side have cut less deeply than those along the border of the Ozarks. This is due to the nature of the rocks and the slope of the streams.

OZARK BORDER DISTRICT.

The Ozark border district is a region marked by a deeper trenching of the streams and by numerous sink holes, which are a striking characteristic of the region. Near the inner margin of this area are found many of the great springs of the Ozarks, which, in a number of cases, are the outlets of underground rivers and are of phenomenal size. The scenery along this margin is unique. It is here that the valleys are deepest and the bluffs most abrupt and picturesque. The outer margin of the district gradually merges to the north into the prairie district.

SOUTHEASTERN LOWLANDS DISTRICT.

The southeastern lowlands district includes that part of the State which lies southeast of a line running from a point near Cape Girardeau southwestward to a point in the southeast corner of Ripley County and approximately marked by the 400-foot contour. The line of demarcation between the Ozark dome and the lowlands is somewhat abrupt, as there is no border district on the southeast of the dome. This is, in some respects, the most striking topographic district in the State. It has a width of about 50 miles. In a general way the surface is nearly a level plain, broken by the irregular Crowleys Ridge, which extends northeastward from Arkansas to Commerce, Mo., on the Mississippi. This ridge is broader at the south and gradually narrows to the northeast, being finally broken into several isolated elevations, such as Ringer Hill, Cow Hill, Lost Hill, Birds Hill, and Benton Ridge, that stand up boldly in the midst of the general plain. It is a remnant of a former coastal

plain and is being rapidly reduced by erosion. The slope is more gentle toward the east, with a rather abrupt escarpment in places on the west, facing the St. Francis Valley. Marbut [a] has shown how Crowleys Ridge was left by the change in the channel of Mississippi River, which formerly flowed between the Ozark highlands and this ridge and emptied into what was then Ohio River, near Helena, Ark. Later, after several changes in its course, the Mississippi was captured by the Ohio, and its present flood plain is the low region east of Crowleys Ridge. It should be remembered that the drainage of the Ozarks empties into this lowland and helps, with the drainage from Illinois on the north and from Kentucky and Tennessee on the east, to form a very remarkable artesian basin. The majority of the streams on the southern slopes of the Ozarks bend abruptly at right angles on entering the St. Francis basin. The flood plain of the Mississippi east of Crowleys Ridge is from 100 to 150 feet lower than the present top of the ridge, and shows the amount of erosion that has taken place from the original level of the coastal plain, which was undoubtedly considerably higher than the present altitude of the ridge. The sections given across this district (p. 35) show the striking manner in which Crowleys Ridge rises from the dead level of the lowlands, like an island in the sea. With the exception of a low dome about New Madrid, elevated from 20 to 30 feet, the general level is unbroken, save by low ridges alternating with narrow, tortuous lakes, rivers, and swamps running in more or less irregular parallel lines between Crowleys Ridge and Mississippi River. Toward the south of the lowland district there is a general gentle slope away from the Mississippi to the southwest.

LINCOLN RIDGE DISTRICT.

Lincoln Ridge is an anticlinal axis entering Missouri in Lincoln County from Calhoun County in Illinois. This anticline has been called the Cap au Grès fault. Its main axis has a general northerly course, diverging slightly to the west. It may be traced in an irregular line through Lincoln, Pike, Ralls, and a part of Marion counties. The uplift has given rise to a characteristic topography throughout this region. The eastern side, toward the Mississippi, is more or less abrupt, being seamed and scored by deep, narrow valleys alternating with rounded and in many cases conical hills. The different geologic formations, from their varying texture, illustrate the changing degrees of erosion, the shales giving gentle slopes, while the harder limestones and sandstones form steep terraces and declivities. The surfaces of these hills, which stand up several hundred feet above the river, rapidly merge into a prairie plateau toward the west. The drainage

[a] The evolution of the northern part of the lowlands of southeastern Missouri: Univ. Missouri Studies, vol. 1, No. 3, 1902.

on the east is directly into the Mississippi. On the west, south of Salt River, it runs into streams that are more or less parallel with the uplift and, turning abruptly to the east just south of the anticline, enters the Mississippi.

Topographically, Missouri presents a considerable diversity, in striking contrast to those States which lie to the northeast, north, and west. The broad prairies of Illinois and Iowa and the plains of Nebraska meet in the northern half of this State. In the Ozark plateau and border is some of the most picturesque scenery to be found in the Mississippi basin, scenery that combines the most striking features of the mountainous regions of Kentucky, Tennessee, and Arkansas. In the southeastern lowlands are anticipated the broad coastal plains of the Southern States.

GEOLOGY.

ROCK FORMATIONS.

GENERAL STATEMENT.

The diversified topography of this State and the combination of features characteristic of surrounding States indicate a wide range of geologic horizons. In southeastern Missouri the oldest and the most recent formations are seen almost side by side.

The St. Francis Mountains were in the earliest Paleozoic period, the Cambrian, an archipelago of islands far distant from any other land of that primitive time. They formed a nucleus for the development of this portion of the continent.

The rocks of the State may be divided into the two groups, crystalline and sedimentary. The nomenclature of Missouri geologic formations has been heretofore in a very unsettled condition. Although this was one of the first States in the interior to establish a geological survey, later and more complete surveys have been made in surrounding States, with the result that many of the names first given to Missouri formations have had to be abandoned, for the reason that they were largely based on lithologic characters—a method of nomenclature no longer permissible. It is the intention in this report to give a brief résumé of the different formations of the State, emphasizing those which have an important relation to the water resources of the region under discussion.

Three of the five great eras of geologic history are represented in Missouri, viz, the Archean, Paleozoic, and Cenozoic; and while the rocks of the Mesozoic do not outcrop in the State, they are represented in deep-well sections in the southeast corner. The following table gives a list of the geologic formations, as complete as it is possible to make it at the present day. The writer is indebted to Dr. E. O. Ulrich for the synonymy of the Cambrian, Ordovician, Devonian, and Mississippian.

Geologic formations of Missouri.

System.	Series.	Group.	Formation.
Quaternary	Recent		Alluvium and residual soil.
	Pleistocene		Terrace gravel.
			Loess.
			Till.
			Columbia clay.
Tertiary	Pliocene		Lafayette gravel.
	Eocene		Lagrange formation.
			Porters Creek formation.
Cretaceous			Ripley sand.
Carboniferous	Pennsylvanian	Missouri	Undifferentiated.
		Des Moines	Pleasanton shale.
			Henrietta limestone.
			Cherokee shale.
			Graydon sandstone.
	Mississippian	Chester	Birdsville formation.
			Tribune limestone.
			Cypress sandstone.
			Ste. Genevieve limestone.
		Meramec	St. Louis limestone.
			Spergen limestone.
			Warsaw formation.
		Osage	Keokuk limestone.
			Burlington limestone.
		Kinderhook	Chouteau limestone.
			Hannibal formation.
			Louisiana limestone.
Devonian			Chattanooga shale.
			Callaway limestone.
			Clear Creek chert.
Silurian			Bailey limestone.
			Bainbridge limestone.
Ordovician			Girardeau limestone.
			Maquoketa shale.
			Polk Bayou limestone.
			Kimmswick limestone.
			Plattin limestone.
Cambro-Ordovician			Joachim limestone.
			St. Peter sandstone.
		Potosi	Jefferson City limestone.
			Roubidoux sandstone.
			Gasconade limestone.
			Elvins formation.
Cambrian			Bonneterre limestone.
			La Motte sandstone.
Archean			Iron Mountain porphyry.
			Knob Lick granite.

ARCHEAN.

The Archean rocks are confined entirely to the St. Francis Mountains in the southeastern part of the State. They consist of granites and porphyries, mainly the latter. About 700 or 800 feet of these rocks are exposed. They are the oldest in the Mississippi Valley, as well as in Missouri. Around this early land area are grouped in concentric bands the later geologic formations. The porphyries are usually found near the surface and the granites underneath, the two gradually merging into each other, indicating that they were probably formed from the same magma, their differences being largely due to the variation in the physical conditions under which they were formed.

These rocks outcrop in Madison, St. Francois, Iron, Washington, Wayne, Reynolds, Shannon, Carter, Ste. Genevieve, Butler, and Crawford counties. Keyes [a] classifies these crystalline rocks into

[a] Keyes, C. R., Report on Mine la Motte sheet; Missouri Geol. Survey, vol. 9, 1896, p. 19.

the Iron Mountain porphyry, 300 feet thick, and the Knob Lick granite, 400 feet thick.

Knob Lick granite.—This granite has its maximum development around Knob Lick, in St. Francois County. It is usually reddish in color, is composed mainly of quartz and feldspar, and is as a rule rather coarse grained. Biotite mica and hornblende are rarely present. It frequently weathers in characteristic rounded masses, well shown near the quarries at Arcadia.

Iron Mountain porphyry.—This rock is usually found capping the granite, except where it has been removed by erosion. The porphyries are more abundant on the west and the granites on the east of the Archean district. Haworth[a] has very fully described these rocks. He divides the porphyries into two great classes—the porphyries proper and the porphyrites. The first are made up of quartz and orthoclase, with microcline phenocrysts, the red variety having no phenocrysts. The second group includes those which have prominent phenocrysts composed of the varieties of triclinic feldspars, usually greenish in color, due to the minute dissemination of epidote crystals. As might be expected, springs are rare, and the water supply, as a rule, is poor in the granitic region.

Other igneous rocks.—Numerous dikes of basic eruptives are found, mainly of diabase, in the St. Francois region. These dikes vary from less than 1 inch up to 50 or 100 feet in width, and are usually vertical, or nearly so.

In Camden County, just south of the middle of the State, is an exceptional dike or boss of pegmatite, made up mainly of microcline feldspar, with some albite or oligoclase and numberless small masses of quartz. From this dike the strata dip in every direction. This is the only outcropping of igneous rocks, so far as known, outside of the district already described. For a fuller description of this locality the reader is referred to the paper by the writer on "The spring system of the Decaturville dome."[b]

CAMBRIAN.

The Cambrian rocks overlying the Archean are represented by the Bonneterre limestone, 500 feet thick, and the La Motte sandstone, 300 feet thick.

La Motte sandstone.—This sandstone, which usually surrounds the granite and porphyry outcrops, was first given the above name in the description of the mines at Mine la Motte. It probably has a total thickness, in the Archean area, of 200 to 300 feet. It is a soft, rather fine-grained, compact sandstone, cemented with calcareous

[a] Haworth, Erasmus, The crystalline rocks of Missouri: Missouri Geol. Survey, vol. 8, 1895.

[b] Contributions to the hydrology of the eastern United States, 1904: Water-Sup. and Irr. Paper No. 110, U. S. Geol. Survey, 1905, pp. 113–125.

and dolomitic material. It varies in color from white to yellow, brown, deep red, and purple, being usually darker where it comes into contact with the granite. The base of this sandstone is in many places a coarse gravel or even a conglomerate of granite and prophyry pebbles. As a rule, this is a good water bearer, though the water frequently carries iron. It is probably the source of some of the chalybeate springs of the district.

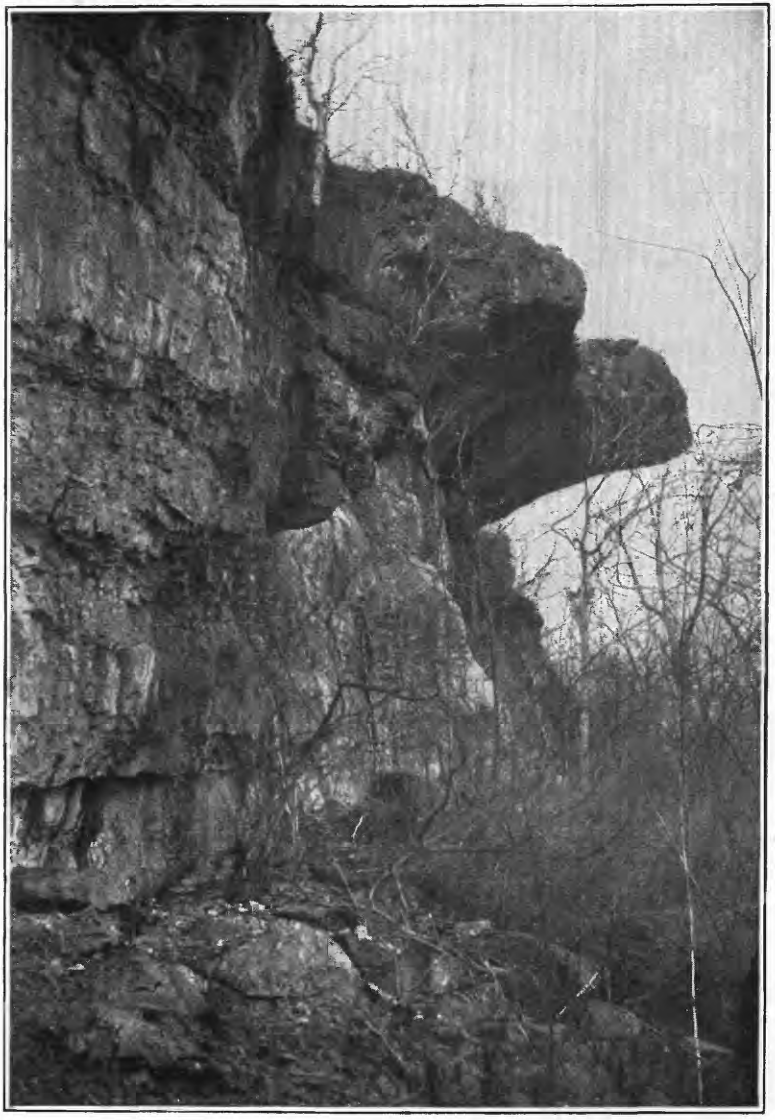
Bonneterre limestone.—The La Motte sandstone frequently merges, by degrees, into the Bonneterre dolomitic limestone, which includes the Fourth Magnesian limestone of Swallow, in part; the St. Joseph limestone, in part; the Fredericktown dolomite, in part, and the Decaturville limestone. The Bonneterre has a thickness of 300 to 500 feet. The lower beds are usually a gray limestone, here and there siliceous and in some places shaly. The upper beds are a yellowish dolomite, merging upward into thin-bedded and shaly rocks. This formation is usually free from chert and is thus sharply distinguishable from the distinctly cherty Gasconade limestone, which overlies it when the shaly Elvins formation is absent. Fossils are rare. One brachiopod, *Lingulella lamborni* Meek, and a few other Upper Cambrian forms have been found in the lower part.

CAMBRO-ORDOVICIAN.

The following formations are, for the present, grouped as undifferentiated Cambro-Ordovician beds: Joachim limestone, up to 125 feet thick; St. Peter sandstone, up to 200 feet; Jefferson City limestone, 100 to 250 feet; Roubidoux sandstone, 100 to 225 feet; Gasconade limestone, 450 to 650 feet; Elvins formation, up to 150 feet.

Elvins formation.—This formation (the basal part of the Potosi limestone of Nason) outcrops around the Bonneterre limestone in the St. Francis Mountains district. It is prevailingly shaly, especially in its lower two-thirds. The basal part generally contains from one to five or six thin bands of limestone conglomerate—the "edgewise beds" of Nason. Locally the upper 60 feet or more consists of massive to thin-bedded, more or less earthy, noncherty dolomite. The formation is often wanting even in the southeastern mining district, and in such cases the cherty Gasconade limestone rests on the Bonneterre. These beds were also identified by Dr. E. O. Ulrich in Camden County, around Pegmatite Hill, where they are overlain by a very coarse-grained, friable, reddish to yellow sandstone. The formation has a maximum thickness of 150 feet.

Gasconade limestone.—This formation includes the Fourth Magnesian limestone, in part, and the Third sandstone of Swallow; the Osage limestone and the Cole Camp sandstone of Winslow; the Gunter sandstone and the Proctor limestone of Ball and Smith, and the Potosi limestone, in part, of Nason. It has a thickness of from 450



MATHERLY BLUFF, SAC RIVER, GREENE COUNTY.

Jefferson City limestone capped by St. Peter sandstone.

to 650 feet. It is made up of more or less heavy-bedded limestones, which in many places merge into dolomite, and may contain nodular, disseminated, or thin-bedded chert. Here and there are irregular lenses of sandstone, and the writer believes he has found throughout the State a well-defined and persistent bed of sandstone—the Third sandstone of Swallow. The Gasconade limestone is widely distributed throughout the southeastern quarter of the State, around the Archean rocks. A long strip of it extends through Texas, Pulaski, Phelps, and Maries counties. Another strip extends northeastward through Dallas, Camden, Morgan, and Miller counties, and narrow strips outcrop along some of the streams that run through Douglas and Ozark counties. This formation is an important water bearer, as is shown by the great springs that issue from its cavernous beds.

Roubidoux sandstone.—This formation includes the Second sandstone of Swallow, the Moreau sandstone of Winslow, and the Bolin Creek member of the St. Elizabeth formation of Ball and Smith. It is from 100 to 225 feet thick. The sandstone of this formation is made up of waterworn, well-rounded grains of quartz, and varies in color from white to yellow, reddish, or almost black, according to the amount of iron that it contains. Much of it exhibits false bedding, ripple marks, and sun cracks. It varies in thickness, but the writer has found it remarkably persistent and outcropping above the exposures of the Gasconade limestone. It is somewhat porous, though locally cemented with silica into a compact mass. It is a prominent water horizon in the counties mentioned in the preceding paragraph as containing the Gasconade limestone, and is the reservoir source of most of the large springs of the southeastern part of the State.

Jefferson City limestone.—This formation, which is from 100 to 400 feet thick, is equivalent to the Second Magnesian limestone of Swallow and the Winfield limestone of Keyes. It is a dolomitic limestone, usually more or less heavy bedded, rather soft when freshly broken, fine grained, compact, and grayish white. Locally, especially in its upper part, it is thin bedded. Most or all of the upper thin-bedded part is rather generally absent in Missouri, having been removed by erosion prior to the deposition of the Devonian and Carboniferous rocks which, especially in the southwestern part of the State, generally overlie this formation. The remaining lower beds are highly siliceous, and frequently, in weathering, exhibit jagged honeycombed peaks or block-like masses (Pl. II). They are also frequently pitted with geode-like cavities. When honeycombed by weathering they leave siliceous skeletons in strangely contorted forms, and many hillsides underlain by this formation are abundantly covered with chert. Here and there beds of thin sandstone are found near the middle of this formation. In the mining districts it is not unusual to find

intercalated beds of thin variegated blue and white shale, called by the miners "the soapstone layer." It is very probable that both the chert and the siliceous beds are usually examples of replacement of limestone by percolating waters holding silica in solution.[a]

The Jefferson City limestone has a wide distribution throughout the Ozarks.[b] It varies decidedly in thickness, probably reaching a maximum of nearly 400 feet in the Lebanon deep well, while 60 miles to the south, in the Metropolitan deep well at Springfield, it seems to be but 90 feet thick. The porous beds of this formation are the source of some of the smaller springs of the Ozarks.

St. Peter sandstone.[b]—This formation is the equivalent of the First or Saccharoidal sandstone of Swallow, the Cap au Grès sandstone of Keyes, the Pacific sandstone of Ball and Smith, the Crystal City sandstone of Winslow, and in part the Key sandstone of Adams. The Marshfield sandstone and the Bolivar sandstone of southwestern Missouri are commonly believed to represent the same formation, but Ulrich regards them as lenses within the Jefferson City limestone. Ulrich maintains further that the true St. Peter sandstone is rarely or never present when late Devonian or Carboniferous rocks are in contact with the Cambro-Ordovician.

This formation is the most important water bearer in the States north of Missouri and one of the most important in this State. It has a thickness of 10 to 200 feet and is brought to the surface in Ralls and Lincoln counties and in some of the counties north of Missouri River to a point nearly halfway across the State. It also outcrops in the counties just west of Mississippi River and south of St. Louis County. Its presence to the west and southwest of the Ozarks is doubted by some geologists, but, although it may not come to the surface, the writer believes that it occurs under cover all around the Ozark Island in Missouri. It is a rock that forms a prominent landmark in the correlation of the different horizons. It is made up of highly polished, rounded, waterworn grains of limpid to translucent quartz, rather loosely cemented together. While it is generally somewhat friable, it seems to possess to a high degree the power to resist the elements. Its durability is exhibited by the manner in which it stands out in ledges and forms benches and overhanging shelves in the bluffs along streams. It varies in color from white to a yellowish brown or red, the coloration being largely due to iron, which commonly forms part of the cementing material, but does not affect the grains.

This sandstone is remarkably persistent and covers a large area. The water yielded by it is usually pure and soft when it has not

[a] See Shepard, E. M., Spring system of the Decaturville dome, Camden County, Mo.: Water-Sup. and Irr. Paper No. 110, U. S. Geol. Survey, 1905, p. 124.

[b] The Jefferson City and St. Peter formations cover smaller areas than those shown on the map. The St. Peter, in the western and southern areas shown, contains many bodies of younger sandstones.

percolated through the formation for long distances. Here and there minute particles of marcasite are found, which tend to impregnate the water with sulphur and iron.

Joachim limestone.—This formation is the equivalent of the First Magnesian limestone of Swallow, the Folley limestone of Keyes, and probably of the Finley limestone of the writer. It varies greatly in thickness, ranging from a knife edge to 125 feet. Its distribution corresponds somewhat to that of the St. Peter sandstone. It is generally a thin, evenly bedded, fine-grained, compact dolomitic limestone, varying from white to yellowish in color; much of it is so soft and white as to be called "cotton rock." The upper beds are locally silico-magnesian in character and so uneven in texture that in weathering the softer portions are worn away, leaving an irregularly pitted surface.

ORDOVICIAN.

According to the prevailing definition of the Ordovician, this system should include the formations between the top of the Girardeau limestone and the base of the Jefferson City limestone, the latter being, as interpreted by Ulrich, equivalent to the Beekmantown or Calciferous rocks of New York. Indeed, according to Ulrich, the lower limit of the Ordovician might be extended downward to the base of the Gasonade without serious modification of the present conception of the Cambrian. However, for reasons that need not be stated here, it has seemed wise to the writer to place in the Ordovician only those formations about which there can be no doubt, and to refer the underlying rocks down to the top of the Bonneterre limestone, provisionally to a "Cambro-Ordovician" system. The Ordovician, then, includes the following: Girardeau limestone, up to 50 feet thick; Maquoketa shale, up to 40 feet; Polk Bayou limestone, 1 to 3 feet; Kimmswick limestone, 40 to 90 feet; Plattin limestone, 100 to 200 feet. These Ordovician rocks are almost wholly confined to the eastern part of the State, south of Hannibal; except the Maquoketa shale and Kimmswick limestone, they are rarely found in well sections to the northwest and southwest. They are of little importance as water carriers and have so limited a distribution that it will be unnecessary, so far as the purpose of this report is concerned, to give them further attention.

SILURIAN.

The Silurian rocks, like the Ordovician, have a somewhat limited range throughout the State. They are confined mainly to the few counties south of St. Louis, but extend westward for a short distance along Missouri River. In only a few cases, near the areas of outcrop,

has it been possible to recognize them in well sections. They consist of the Bailey limestone, 70 to 150 feet thick, and the Bainbridge limestone, up to 125 feet.

For the same reasons as those given in connection with the Ordovician, it will not be necessary to consider the Silurian rocks further.

DEVONIAN.

The Devonian rocks form a very narrow penumbral margin around the Ozark Island. Except in the counties south of St. Louis and along Missouri River, the beds are very thin, irregularly distributed, and of little or no importance from the standpoint of water supply. The different formations are the Chattanooga or Ohio shale, up to 30 feet thick; Callaway limestone, up to 50 feet; Clear Creek chert, up to 150 feet.

The Callaway limestone north of St. Louis is in part the equivalent of the Chattanooga shale, and south of St. Louis of the upper part of the Grand Tower limestone.

CARBONIFEROUS.

MISSISSIPPIAN.

The Mississippian series of the Carboniferous bears a most important relation to the water resources of Missouri. It forms a broad belt running in an irregular diagonal across the State from southwest to northeast and a very narrow strip southward from the mouth of Missouri River along the banks of the Mississippi to Cape Girardeau County. The following formations are comprised in the Mississippian: Birdsville formation, up to 300 feet thick; Tribune limestone, 100–150 feet; Cypress sandstone, 50–100 feet; Ste. Genevieve limestone, 150–150 feet; St. Louis limestone, 300 feet; Spergen limestone, 100 feet; Warsaw formation, up to 50 feet; Keokuk limestone, 200 feet; Burlington limestone, 300 feet; Chouteau limestone, 70 feet; Hannibal formation, 30–100 feet; Louisiana limestone and equivalent formations, up to 100 feet.

Louisiana limestone.—This is the equivalent of the Lithographic limestone of Swallow, who named it for its supposed lithographic qualities, which, however, were never realized in this State. So far as the writer has observed, it reaches its maximum thickness, 100 feet, at Louisiana and the best exposures are found along Mississippi River between Louisiana and Hannibal. In this region it is a fine-grained, compact, thin-bedded, dolomitic limestone, usually ash colored. It is generally underlain by a sandy shale, which is more or less fossiliferous. It thins out and becomes coarse grained elsewhere in the State. In the counties west of Pike it is much thinner, is coarser grained, and has a slightly bluish tinge. It has been recognized in Cedar and St.

Clair counties, and Swallow found 30 feet of it in Jasper County. In Greene and Webster counties the Hannibal formation is underlain by four thin but lithologically distinguishable beds that are regarded by Ulrich as representing the Louisiana limestone. The uppermost of these beds has long been correlated with that limestone by the writer. It is widely distributed in the southwestern part of the State, ranges from 8 to 22 feet in thickness, and is so compact in texture as to ring like bell metal when struck. The other beds are much more local in their distribution. They were described by the writer, who called them Phelps sandstone, King limestone, and Sac limestone of the Hamilton stage (Devonian). Few fossils are found in these beds, though the weathered surfaces expose depauperate forms of crinoid stems.

Hannibal formation.—This is the equivalent of the Vermicular sandstones and shales of Swallow. It is from 30 to 150 feet thick. In the type locality, in Marion County, this formation consists of beds of bluish to greenish argillaceous shale, frequently calcareous or dolomitic, with impure layers of limestone or dolomite. The rocks vary greatly in composition, containing a number of mineral salts which tend to impregnate the water. Many of the strongest mineral waters have their source in this formation. It is somewhat widely distributed throughout the State, becoming more calcareous to the west of Marion County and represented by several distinct rocks in the southwest and south. For example, in Greene, Polk, Lawrence, and Webster counties it consists in many places of three members. In northern Greene and Polk counties is found a heavy deposit of fine-grained buff sandstone, penetrated everywhere by worm-like borings that are filled with less indurated matter. This sandstone is fairly durable, and in weathering usually forms benches or terraces. It graduates through beds that become less and less arenaceous into compact silico-magnesian shales. These shales are usually grayish to blue, but locally greenish. In many places they are shattered and the veins are filled with a white, soft substance, like kaolin. The shales and sandstones locally exhibit cauda-galli markings and, near their contact, nodular elliptical masses of impure iron pyrites are found. On the south side of the Ozark dome, the watershed that extends through Greene County, the sandstone gradually disappears and the shale predominates. Farther south, in adjoining counties, the shale merges into an impure limestone. It is uncertain whether these rocks occur in southeastern Missouri. Some variegated clay shales below the Burlington limestone in Ste. Genevieve County have been doubtfully assigned to this formation.

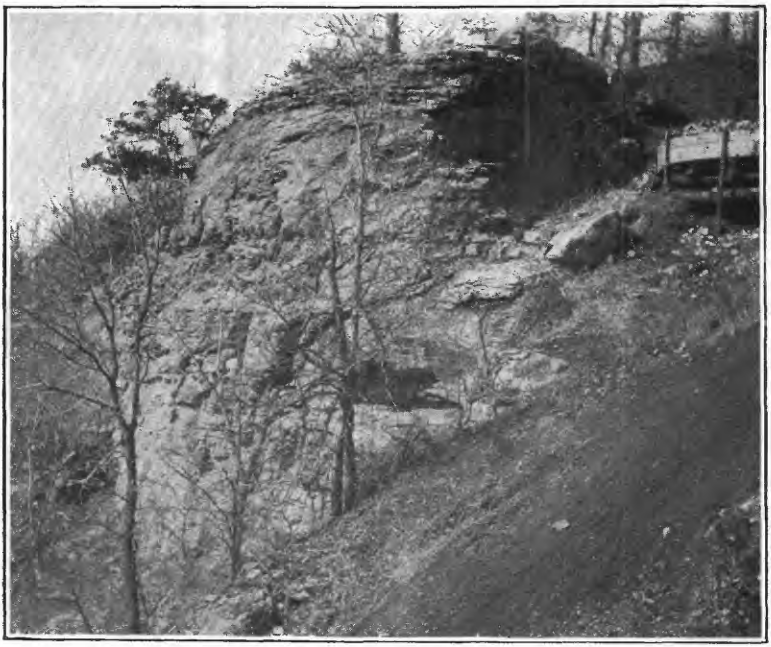
A more extended account of this horizon has been given than its distribution would justify, because it is one of the most important in its relation to underground waters. It contains a large proportion of

impurities and is the source of some of the strongest mineral waters of the State.

Chouteau limestone.—This peculiar buff to dark-yellow rock received its name from Chouteau Springs, in Cooper County, being first described by Swallow. In color and texture the rock throughout the State varies greatly from that at the type locality, where it is ashy gray in appearance and of the nature of a shaly limestone. In Marion and Pike counties it is from 10 to 15 feet thick, buff colored, and somewhat arenaceous. In Pettis County it reaches a thickness of 100 feet. In Webster County it is about 40 feet thick. In the southwest it is usually heavy bedded, hard, and compact, and in many places very arenaceous. The beds generally contain small, geode-like cavities lined with minute calcite crystals. Here and there crystals of pyrites are disseminated through the rock, and some chert is also found in the southwest. The rock indurates on exposure, and this fact, together with its striking color, causes it to form a noticeable topographic feature. The Chouteau is usually too compact to be counted as a water carrier, yet in places springs of somewhat mineralized water rise from fissures in it. As a rule the Chouteau forms a more or less impervious bed beneath the Burlington limestone.

Burlington limestone.—This formation is usually a coarse-grained, highly crystalline, and very pure limestone. It varies considerably in thickness and in other characteristics in different parts of the State. It has a rather wide distribution in the counties bordering the Mississippi on the west, extending in an irregular diagonal to the southwest corner of the State, where it covers a broad area. In the southwest it has two distinct parts—the upper and the lower. Here the upper bed is usually from 200 to 300 feet thick and similar in fauna and structure to the beds in the northern part of the State, while the lower bed, which is much less persistent, varies from 20 to 60 feet in thickness and consists of a very dense, hard, and impure rock that has a bluish slate color and breaks with a conchoidal fracture. The fossils of the lower bed are much smaller than those of the upper, the crinoids in particular being of the more delicate varieties, in strong contrast with the large robust forms of the upper bed.

Between these two Burlington beds is a transition layer of chert, varying from 5 to 40 feet in thickness. This chert is usually seamed, shattered, and irregularly bedded, very hard, compact, and white. The intercalated chert of the upper part of the Burlington is very soft, impure, and fossiliferous, of reddish shades of color, and usually disposed in lens-shaped masses. Where the lower bed of the Burlington is present, the intervening shattered chert is the source of many large, fine springs, the water having been derived from the upper bed, which is one of the great water carriers of the State. It is very probable that



A. BLUFF OF BURLINGTON LIMESTONE NEAR JUNCTION OF SHOAL RIVER AND CAPS CREEK.

B. CHARACTERISTIC WEATHERING OF GRAYDON SANDSTONE AT EUDORA SPRINGS, POLK COUNTY.

this transition chert has been formed by replacement of the original limestone through the action of the large quantities of siliceous waters that are constantly passing through the upper bed of this formation.

Topographically, the upper part of the Burlington is marked everywhere by the presence of large sink holes, and it forms the largest and most important basin and reservoir for collecting water in the State. As the limestone is very pure and porous and the intercalated chert impure and soft, percolating waters dissolve out large quantities of lime and silica from the chert and, encountering the impervious lower Burlington or Chouteau below, issue in the valleys as great springs.

This formation is honeycombed with great caves in which flow underground streams. It also forms striking topographic features in the mural and castellated bluffs along the great rivers in the region where it outcrops. (See Pl. III, *A*.)

Keokuk limestone.—This limestone, which is largely distributed over Illinois, is represented in Missouri mainly in the northeastern part. It is about 200 feet thick and made up of rather compact layers of bluish limestone at the base of the formation, varying with shaly masses intercalated with thinner beds of limestone above. Its presence south of Missouri River is disputed. The fauna of the Burlington and overlying beds in the southwest seems to be a mixture of Keokuk and Burlington types, so much so that other names, such as Cherokee and Encrinital have been proposed for these transition beds. It is probable that most of the upper Mississippian is absent in the southwestern part of the State, the Pennsylvanian deposits resting unconformably upon the Burlington at various points in that region. The Keokuk is not a prominent water carrier in Missouri.

Warsaw formation.—This formation, confined mainly to the northeastern part of the State, is problematic in its relations. It is described by Hall[a] as being made up, near Keokuk, of magnesian limestone of variable thickness, which is in places absent, overlain by argillaceous limestone with shaly partings, followed by coarse calcareous yellow sandstone in thick heavy beds. Some authors include it with the Keokuk and others with the St. Louis. Ulrich regards it as a distinct formation overlying the Keokuk and forming the basal division of his Meramec group. (See table of formations, p. 12.) The Warsaw is of very little importance as a water bearer in Missouri.

Spergen limestone.—This formation is confined in Missouri to the counties bordering the Mississippi below the mouth of Missouri River. Here, as in the States to the east and southeast, it consists chiefly of massive oolitic limestone, parts of which afford a handsome building material. In St. Louis County its thickness is about 100 feet, but in Ste. Genevieve and Perry counties it seems to be not less than 200 feet.

[a] Hall, James, Geology of Iowa, vol. 1, 1858, p. 101.

So far as known the Spergen limestone has no special connection with the water problems of the State.

St. Louis limestone.—This formation is well developed along the Mississippi from Iowa to Cape Girardeau County. Keyes describes it as being more or less brecciated to the north of St. Louis County, while south of Missouri River it is an evenly bedded, cherty gray limestone. It reaches a considerable thickness, the maximum development within the State being nearly 300 feet. While more largely developed than some other formations, it is not an important water bearer.

Chester group.—The formations belonging to the Chester group have so small a distribution in Missouri that they will not be considered separately in this report except to state that good water is usually obtained from the Cypress sandstone and the Ste. Genevieve limestone. The group consists of the Birdsville formation, up to 300 feet thick; Tribune limestone, 100–150 feet; Cypress sandstone, 50–100 feet; and Ste. Genevieve limestone, 100–150 feet.

PENNSYLVANIAN.

The Pennsylvanian series of the Carboniferous is divided into two groups—the Des Moines and the Missouri.

DES MOINES GROUP.

One of the most important sources of water supply is in the basal formations of the Des Moines, which is represented by the Pleasanton shale, up to 200 feet thick; Henrietta limestone, up to 100 feet; Cherokee shale, up to 300 feet; and Graydon sandstone, up to 75 feet.

Graydon sandstone.—This formation consists of several members, the most prominent of which is a coarse-grained, friable, usually micaceous, ferruginous sandstone, with scattering intercalated patches or beds of highly inclined shales, from blue to greenish black in color and in many places mixed with thin seams of carbonaceous matter. Its thickness ranges from a feather edge to 75 feet. The sandstone locally merges into a fine to coarse cemented gravel, and finally into a coarse, polished bowlder conglomerate. This formation seems to fill old erosion channels or basins and is almost invariably tilted and unconformable to the beds upon which it rests. It probably marks the beginning of the submergence which resulted in the deposition of the Pennsylvanian rocks. It apparently skirts the Ozark Island and has been traced from Fulton, Callaway County, where it is finely exhibited in a bluff on the outskirts of the town, down to southern Missouri. Its best development is perhaps in Cedar, Polk, Dade, Lawrence, Greene, and Christian counties. Ball and Smith[a] have described a number of interesting outcroppings in Miller

[a] Ball, S. H., and Smith, C. F., Geology of Miller County: Rept. Missouri Bureau Geology and Mines, 2d ser., vol. 1, 1903, p. 95.

County, some distance from the borders of the coal field, where it is most commonly exhibited. (See Pl. III, *B*.)

This sandstone is an important water bearer, many of the most valuable chalybeate springs of the State having their origin in it. A number of so-called sulphur springs come from this formation, but owe their apparent sulphurous odor to minute traces of petroleum derived from the intercalated carbonaceous shales.

Cherokee shale.—The Cherokee shale is a very important formation in Missouri, being the source of practically all the workable coal, gas, and oil. From it also are obtained most of the brines and sulphosaline waters. The formation was named by Haworth from Cherokee County, Kans., where it is particularly well developed. It is made up largely of sandstones and shales, the shale members being perhaps the more persistent. The sandstone is usually more abundant at the base of the formation. Besides numerous coal seams a few thin beds of limestone occur. These are usually restricted in area and are in many places fossiliferous and carbonaceous. Some of the most interesting problems connected with the water supply of the State arise from the study of this formation.

The Cherokee shale is distributed in an irregular diagonal strip, forming an outside border to the Mississippian rocks from the southwestern part of the State through to the northeast corner. These rocks dip strongly to the northwest at the rate of from 10 to 20 feet to the mile, and their thickness varies considerably, being in some places 300 feet.

Henrietta limestone.—The Henrietta limestone is a composite formation somewhat like the Cherokee shale and is made up of arenaceous shales and thin beds of sandstone and limestone. In places it is 100 feet thick. The name was given by Marbut to the associated beds with the limestone members, which, though thinner than the shales and sandstones, form escarpments that run through the State, making pronounced topographic features.

The limestone members are essentially the extension of the Pawnee and Fort Scott limestones of the Kansas Survey. The formation may be traced from Bates County, on the Kansas line, to Missouri River in Lafayette County and for some distance north of the river. It is not an important water bearer, there being no springs of any size along its course; but a small supply of water is obtained by sinking wells to the limestone beds.

Pleasanton shale.—This is the equivalent of Marbut's Marais des Cygnes shale. The formation is made up of argillaceous and arenaceous shales, some sandstones, and several small veins of coal. It forms a belt 15 or 20 miles wide, extending from Bates County, on the Kansas line, to Lafayette County, where it crosses the river and passes on northward through the State. Springs are rare in this

formation. Wells sunk to the sandstone or limestone beds usually give a fair amount of water.

MISSOURI GROUP.

The Missouri, the uppermost group of the Carboniferous rocks, is usually made up of heavy alternating beds of shales, limestones, and sandstones, the shales largely predominating. No good supplies of water are found in the 1,000 feet of this formation, that obtained being usually saline and in many cases strongly impregnated with other mineral salts.

The beds of the Missouri group are confined to the northwest quarter of the State. The lowest forms an escarpment extending from southern Cass County northward through Mercer County into Iowa.

CRETACEOUS.

While the Cretaceous rocks nowhere outcrop within the limits of the State, they undoubtedly extended up the Mississippi embayment a short distance into Missouri and were subsequently covered by Tertiary deposits. A number of deep wells in the embayment area of Missouri and the adjoining portions of Tennessee and Kentucky penetrate, at varying depths, loose sand and clay which, from their situation and structural characters, are probably the equivalent of the Ripley sand. These sand beds are usually nonfossiliferous, but in many places contain fragmentary particles of lignite. They vary in color from white to black, but are more commonly red or yellow, owing to the presence of iron. They are from 25 to 50 feet thick in well sections at Cairo, Ill., and 224 feet thick in the well at Morehouse, where they are reached at a depth of 466 feet. In the Campbell artesian well, at a depth of 940 feet, a very fine black sand with a large percentage of mica in small pieces was struck. The boring penetrated 20 feet of this material and stopped at a depth of 960 feet. The Ripley sand is a water bearer and has a thickness of 400 feet in southern Tennessee.

TERTIARY.

The Tertiary rocks outcrop in the extreme southeast corner of the State, where they fill the old valley of Mississippi River.

Porters Creek formation.—Lying above the Ripley sand of the Cretaceous, as already described, is the Porters Creek formation—probably of Eocene age. This consists of a loose, green sand or clay at the base, with scattered beds from 1 to 4 feet thick of indurated calcareous green sand or impure limestone, and a few layers of fine micaceous sandstone. The clay is usually dark when wet

and a light gray when dry. Safford gives its thickness as from 200 to 300 feet in Tennessee. Glenn states that it is not there a bearer of good water. It forms, however, an impervious layer over the waters of the Ripley sand. It has been identified in Missouri wells at but one point. It was reached in the Morehouse well at a depth of 248 feet, where is consisted of 197 feet of bluish gumbo.

Lagrange formation.—Overlying the Porters Creek formation is the Lagrange formation. This consists of great masses of loose sand intercalated with beds or lenses of blue clay. It varies greatly in thickness, being 963 feet at Memphis, Tenn.; 785 at Campbell; 740 at Hickman, Ky.; 542 at Caruthersville, and over 200 feet at Morehouse. The only fossils found are imperfect leaf impressions. Those in the lower beds are believed to be Eocene, while those in the upper are probably Pliocene. Authorities are, however, inclined to consider this as one formation. It includes the Lagrange and Bluff of Safford. It is the great water reservoir for the artesian and deep wells of this district.

Lafayette gravel.—Above the Lagrange rests the thin bed of the Lafayette. This varies from 10 to 60 feet in thickness. Along the bluffs of the larger streams a basal deposit of cemented gravel is found. This conglomerate is made up of rounded, waterworn, and polished chert pebbles which are apparently glazed with a yellow iron stain. Percolating waters charged with iron have cemented these pebbles near the rivers into a hard ferruginous conglomerate. Small chalybeate springs are not uncommon along this deposit. Away from the larger streams the gravel is less abundant, not cemented, and gradually merges into an orange-colored sand and irregular deposits of clay. This is the equivalent of Saffords Bluff gravel and, in part, of his Orange sand.

QUATERNARY.

Columbia clay.—Upon the Lafayette gravel rests the Columbia, at the base of which, along the bluffs, is usually found from 10 to 15 feet of sand and gravel. Above this deposit is from 20 to 60 feet of loess, which is in turn overlain by a varying amount of loam. Crowleys Ridge and its continuation, Benton Ridge, show fine sections of the Columbia and Lafayette.

Alluvium, etc.—Irregularly distributed over the flood plain of the Mississippi are later deposits than the Columbia—the Recent alluvium, which overlies the Columbia clay, and large patches of sand, of varying thickness, which has all the structural and microscopical characteristics of the Lagrange formation, and has probably been thrown up through the fissures caused by the New Madrid earthquake.

GEOLOGIC HISTORY.

Before closing this section, a brief outline of the geologic history of the State should be given, as that history is of considerable importance in its bearing on the location of artesian areas, the varying chemical composition of the waters, and a more complete understanding of the many and varied topographic and geologic features. While it is not possible, in all cases, to give the correct sequence of events, and while some conclusions may be modified by wider study of this region, it seems desirable to present an outline that is sustained by the facts now available. Winslow, Broadhead, and Buckley have each given such a history in brief, and they have been freely consulted in the preparation of this sketch.

ARCHEAN.

During Archean time a large part of Missouri and extensive portions of the continent to the north and south of this State were dry land. It is impossible, at present, to outline the extent of this area. The erosion must have been great and the time long, to have sufficed for the accumulations of the succeeding age. The few isolated peaks in the St. Francis Mountains are all that is left to-day of this original land area in Missouri. It is doubtful if there are any Algonkian rocks in this State. A general submergence of a large part of the area brought in the Cambrian.

CAMBRIAN AND CAMBRO-ORDOVICIAN.

These ages are represented by coarse sandstones and conglomerates forming narrow fringes around the small islands now represented by the Archean outcrops in the St. Francis Mountains. These shore deposits were, at first, largely of fragmental origin, but in the quieter waters around the archipelago alternating deposits of limestones and sandstones, indicating periods of elevation and depression, with occasional erosion intervals, were laid down. It is probable that the nucleus of this varying land surface was an area around the St. Francis Mountains. It is generally believed that at the close of the deposition of the Jefferson City limestone a large area was elevated and a somewhat extended erosion period began. This was followed by a submergence, during which the St. Peter sandstone was laid down. It is doubted, by many, whether this submergence extended over the whole of what now constitutes the Ozarks or not. At any rate, the St. Peter sandstone practically surrounds the Ozarks in Missouri; but whether it covered the larger portion and has been subsequently removed by erosion or whether it formed only an off-

shore deposit around Ozarkia[a] is a question that, with the data now obtainable, can not yet be decided. A considerable elevation took place just preceding the Ordovician period.

ORDOVICIAN.

There is also a doubt as to the former extension of the "Trenton" and other typical Ordovician rocks in the Ozarks. Like the St. Peter sandstone, they may have been deposited over a much larger area, from which they were removed by subsequent erosion, or their limits may always have been, practically, what they are to-day. The determination by Ulrich of a small patch of cherty Maquoketa shale in Camden County, far in the interior of the Ozarks, would indicate a wider distribution of at least the latest of the Ordovician formations than has heretofore been supposed. There is strong evidence that south of Missouri River there was a very large land area during the most of Ordovician time. Small deposits of this age are found east of the St. Francis Mountains and along Mississippi River northward toward Iowa. They also extend, to a limited degree, along an embayment now occupied by Missouri River.

SILURIAN AND DEVONIAN.

With slight modifications, the conditions prevailing during the Ordovician continued through the whole of Silurian and the greater part of Devonian time. Toward the close of the Devonian a gradual embayment of Ozarkia set in that culminated in the early part of the Carboniferous. Silurian deposits occur only along the Mississippi in Perry and Cape Girardeau counties. Devonian sediments are also but sparingly represented in the State. Thin beds of Devonian limestone and shale are found north of St. Louis and along Missouri River, while local deposits of the blue Chattanooga shale have been noted on the southwestern flanks of the Ozark uplift.

CARBONIFEROUS.

The close of the Devonian was marked by a considerable depression west of the Mississippi in the northern part of the State and along the slopes of the Ozarks to the west. The ocean invaded the Ozarks, forming a considerable embayment in what is now Green County, penetrating the western slopes so as to form many patches lying unconformably on the Cambro-Ordovician. This subsidence was

[a] The term "Ozarkia" is a convenient name proposed by Ulrich (Prof. Paper, U. S. Geol. Survey No. 24, 1904, p. 111) for the ancient land mass that at various times during the Paleozoic era formed a large island or groups of small islands in the area of southern Missouri and northern Arkansas now exposing the Cambrian and Cambro-Ordovician rocks. In a measure, the term is an alternative for "Ozark uplift," "Ozark dome," or "Ozark Island."

rapid at first, during which time deposits of coarse material, such as the "Phelps" and Hannibal sandstones and shales and the impure Chouteau limestones, were laid down. The depauperate forms of the Hannibal and Chouteau fossils indicate rather impure water, possibly brackish in places. This condition was followed by steady depression and by deeper and purer waters and the deposition, successively, of the Burlington and Keokuk in the southwest, west, and northwest; to the east and northeast these were followed, in turn, by the Warsaw, Spergen, St. Louis, Ste. Genevieve, and other limestones of the Mississippian. Most of these heavy beds of limestone are rich with fossil forms. From the fact that small patches of the Burlington, together with its chert, are found scattered as far east as Texas and Howell counties, it is probable that the Springfield embayment reached these points. The greater part of the Ozarks has remained above water since Burlington time.

Toward the close of the Mississippian the great ocean floor to the west was slowly elevated, becoming a nearly level area, covered with marshes and estuaries. This movement was apparently accompanied by a slight depression in the region now included in Miller and Morgan counties, which permitted the formation of the coal pockets now found lying uncomformably in erosion basins on the Cambro-Ordovician rocks. Along this low-lying land, in old basins and estuaries, conditions were favorable for the development of great swamps in which were accumulated the extensive deposits of coal characteristic of the Pennsylvanian period. It was during this depression that some of the great rivers which drained the Ozarks were filled up by sands and gravels. Where the rivers emptied into estuaries, large deposits of conglomerates are found, as is well illustrated by the ancient Schoolcraft River, which extended from Arkansas through Stone, Christian, Greene, and Polk counties, and in which the Graydon sandstone and conglomerate were laid down. That the extent of the Pennsylvanian rocks was greater than at present is shown by the number of outliers in the form of coal pockets scattered over the adjoining counties and resting unconformably upon other terranes.

This period, while one of gentle oscillations, was yet, on the whole, one of steady depression, being characterized by the deposition of thick alternating beds of limestones, shales, and sandstones.

The close of the Paleozoic, which was brought about in the East by the Appalachian revolution, was manifested in Missouri by a bulging up of the Ozarks, a great dome, or quaquaversal fold, being thereby formed.

MESOZOIC.

With the exception of the small deposit of Ripley sands in the Mississippi embayment, reached by deep drilled wells, the Mesozoic,

which followed the Carboniferous, has no representative in this State. It was probably a period of erosion and land sculpturing.

TERTIARY.

During the early Tertiary the Lafayette (Winoka) gravel, which is represented in scattered patches high up above the present river courses, was deposited. These gravels mark the outline of early Tertiary drainage systems. The elevation of the great Mesozoic deposits west and southwest of Missouri extended into this State, changing the direction of the drainage systems and developing, probably for the first time, Missouri River, the source of which seems to have been not far beyond the northern boundary of the State.

QUATERNARY.

During Pleistocene time the northern part of the State, approximately bounded by Missouri River, was covered with the drift of the Pleistocene, which, in some places, reached a thickness of nearly 300 feet. The general southward movement of the ice sheet greatly modified the surface of this part of the State, eroding large areas and filling up old channels. Since Pleistocene time this area has been subjected to the erosive action of the elements. Deep valleys have been formed and the more porous rocks have been honeycombed by numerous channels, forming underground streams and the outlets of the great springs which characterize this State.

DESCRIPTIONS OF GEOLOGIC SECTIONS.

SECTION FROM GLENWOOD, IOWA, TO BRUNSWICK, MO.

Well sections in the northwestern part of the State show a deep depression or trough extending in a southwesterly direction from Iowa through Missouri and into Kansas. Section 1 (Pl. IV) is taken approximately at right angles to this depression in order to show the development of the trough. Norton[a] gives the following record of the well at Glenwood, Iowa, 2,000 feet deep:

Summary of log of well at Glenwood, Iowa.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	175	175
Missouri	670	845
Des Moines	390	1,235
Mississippian	230	1,465
Devonian (?)	135	1,600
Silurian	400	2,000
Maquoketa (?)		2,000

[a] Norton, W. H., Artesian wells of Iowa: Geol. Survey Iowa, vol. 6, 1897, p. 347.

Well No. 1 of the Nodaway Valley Oil, Gas and Mineral Company, at Burlington Junction, Nodaway County, 1,903 feet deep, has the following record:

Summary of log of well at Burlington Junction.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	68?	68?
Missouri	910	978
Des Moines	722	1,700
Mississippian	186	1,886

This well was sunk for oil.

A diamond-drill well, sunk to a depth of 500 feet at Gentryville, Gentry County, struck a bed of coal 26 inches thick at a depth of 477 feet. At the farm of G. H. Lawson, near Utica,[a] Livingston County, a well was sunk to a depth of 421 feet, at which point Mississippian limestone was struck. In a well on the farm of John R. Williams, south of Dawn, in the same county, the Mississippian was reached at 433 feet.

At Chillicothe, just north of the two points last named and in the same county, the following section was obtained; probably the same rocks might also be found at Utica and Dawn:

Summary of log of well at Chillicothe.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	56	56
Des Moines	425	481
Mississippian, Devonian, and Silurian	509	990

There is, probably, 100 feet of St. Peter sandstone at the bottom of this well.

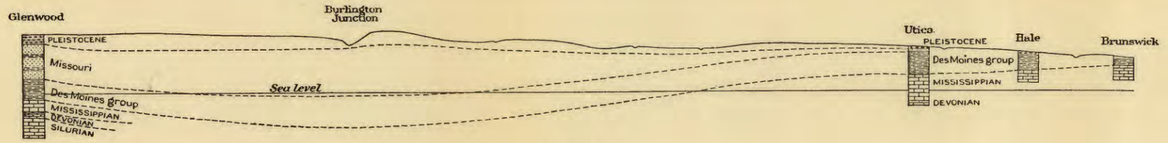
The well at the creamery near Hale, Carroll County, passed through 290 feet of Des Moines and 40 feet of Mississippian, giving a depth of 330 feet.

At the C. W. Nuss well, at Tina, Carroll County, the following section was obtained:

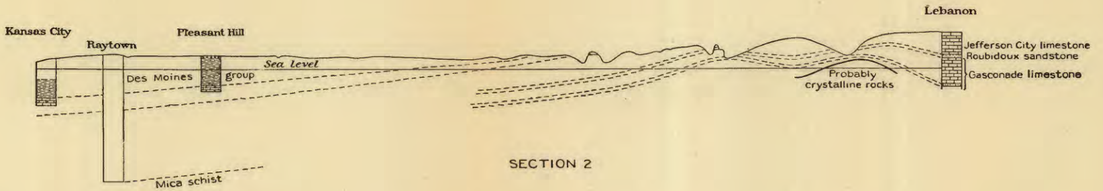
Summary of log of well at Tina.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	40	40
Des Moines	345	385
Mississippian	290+	675

[a] Data in regard to the wells at Utica, Dawn, Hale, and Tina were obtained through the courtesy of Mr. R. Hawkins, of Chillicothe, to whom the writer is indebted for a large amount of information concerning the wells of the northern part of the State.



SECTION 1



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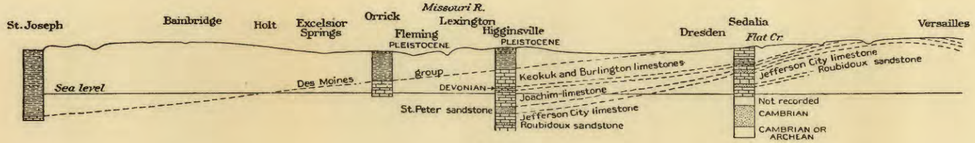

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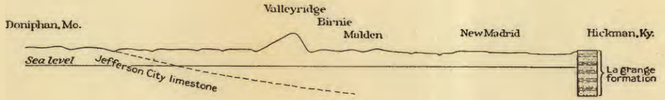
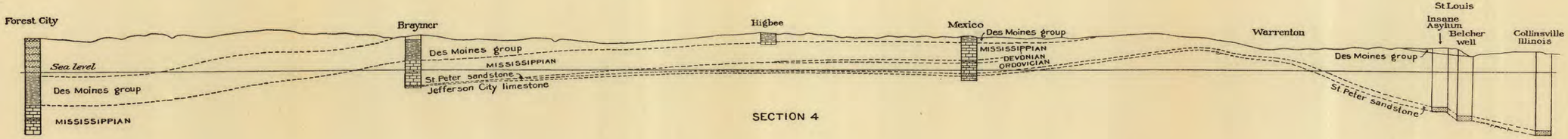
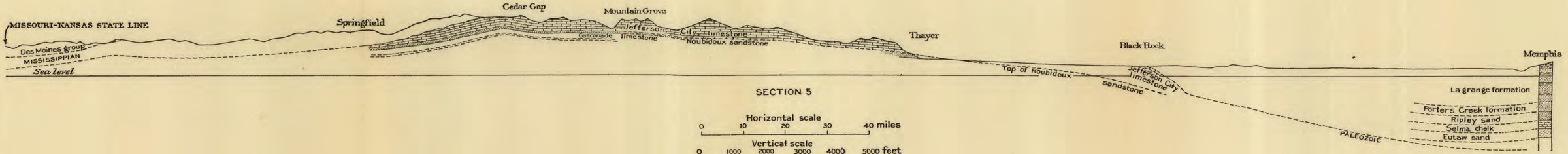


SECTION 6



SECTION 4



SECTION 5

Horizontal scale
0 10 20 30 40 miles

Vertical scale
0 1000 2000 3000 4000 5000 feet

GEOLOGIC CROSS SECTIONS.

At Brunswick, Chariton County, a drill hole was sunk to a depth of 1,505 feet. Unfortunately the record is not obtainable, but it is said that 130 feet of Des Moines was passed through. The water began to flow at 1,400 feet and continued to flow at a decreasing rate for several years, until it finally stopped.

A study of section 1 in connection with the map of the State showing the locations of the artesian wells (Pl. I) shows that conditions favorable for flowing wells are found along the eastern slope of the trough extending southwestward from Iowa, as previously mentioned, at points where the elevation of the surface is not greater than 725 feet. As the surface of the country rises to the northwest, this northeast-southwest belt has a somewhat limited extent. Nearly all wells in this belt that penetrate to the base of the Des Moines—i. e., through the sandstone at the base of the Cherokee shale—have an abundant supply of water under sufficient pressure to force it to the surface. The water from this horizon is rather saline, running from 300 to 500 grains of salt to the United States gallon. Mr. Hawkins states that this saline water is used extensively by stock raisers, who believe it to be well adapted to their needs.

Water from the sandstone beds in the Missouri group, as well as from other porous beds in the Des Moines, is much more saline, and in many cases contains iron and other salts. It is probable that wells extended down to the St. Peter sandstone in this artesian belt would yield much purer water.

SECTION FROM KANSAS CITY TO LEBANON.

Section 2 (Pl. IV) shows the continuation of the trough appearing in section 1 and the western slopes of the Ozarks.

Broadhead[a] describes a diamond-drill well at Kansas City, which was sunk to a depth of 758 feet in the bottoms not far from the union railway station. The following summary is taken from the log of that well:

Summary of log of well at Kansas City.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	37	37
Des Moines	708	745
Mississippian	13+	758

Section 2 shows the northeast-southwest trend of the Iowa syncline described under section 1. It also shows the axis of the syncline to be some distance to the west, in Kansas. Winslow[b] describes a deep-well section at Raytown, Jackson County, southeast of Kansas City.

[a] Broadhead, G. C., Preliminary report on iron ores and coal fields . . . 1872, pt. 2, Missouri Geol. Survey, 1873, p. 86.

[b] Winslow, Arthur, Geologic history of Missouri: Am. Geologist, vol. 15, 1895, p. 85.

He says: "Here the base of the Paleozoic rocks was reached at a depth of 2,430 feet, and below this 36 feet of crystalline rocks were penetrated. A specimen of this core, examined by the writer, is a highly micaceous schist composed almost entirely of black mica. It is different from any rocks found in the Archean of the Southwest, and is more like rock elsewhere referred to the Algonkian." It is greatly to be regretted that Doctor Winslow did not give the full record of this well, as it is now unobtainable.

A deep drill hole at Pleasant Hill shows the top of the Mississippian at 530 feet. These rocks outcrop near the western edge of Benton County. At Decaturville, about 14 miles north of a point near Eldredge on section 2, pegmatite granite outcrops, and a study of the strata in that district shows that it is quite probable that the crystalline rocks reach an altitude of about 750 feet above sea level. A portion of the Decaturville quaquaversal is well shown in section 2, for at the deep well at Lebanon the following section is obtained:

Summary of log of well at Lebanon.

	Thickness.	Depth.
	Feet.	*Feet.*
Jefferson City limestone	427	427
Roubidoux sandstone and Gasconade limestone	580	1,007

SECTION FROM ST. JOSEPH TO VERSAILLES.

The Mississippian was reached in a well near St. Joseph at a depth of 1,250 feet. The same rocks were struck at Orric at a depth of 545 feet. At Higginsville the following general section has been obtained from the deep well of the Higginsville Prospecting Company:

Summary of log of well at Higginsville.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	68	68
Des Moines	302	370
Keokuk	87	457
Burlington	63	520
Kinderhook	195	715
Devonian (?)	55	770
Cambro-Ordovician	743	1,513

The following section was obtained from the waterworks well about 3 miles south of Sedalia and about 100 feet lower than the city:

Summary of log of waterworks well near Sedalia.

	Thickness.	Depth.
	Feet.	*Feet.*
Bottom of M ss ss pp'an		226
Devonian (?)	23	249
Cambro-Ordovician	1,151	1,400

In section 3 (Pl. IV) the waterworks-well section is combined with that of a deep well about a mile to the northwest in which, according to the statement of the driller, white sandstone was struck at a depth of 1,000 feet and continued to the bottom of the well, a distance of 1,612 feet.

The various horizons down to the Jefferson City limestone outcrop successively toward the town of Versailles, which stands near the crest of an anticlinal fold, the strata having an eastward dip to the east of the town.

Section 3 crosses over the synclinal trough outlined in the sections 1 and 2. It also illustrates artesian conditions along the western slope of the Ozark Island.

SECTION FROM FOREST CITY TO ST. LOUIS.

At Forest City, Holt County, a diamond-drill hole was sunk to the depth of 2,400 feet, and the writer is indebted to Dr. E. R. Buckley for the carefully prepared record which he made from the core. The complete log of this well, together with those of other wells mentioned in the description of the cross sections, is given in another part of this report. The summary is as follows:

Summary of log of well at Forest City.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	64	64
Missouri	866	930
Des Moines	690	1,620
Mississippian	293	1,913
Devonian (?)	128	2,041
Silurian	359+	2,400+

In an oil prospect hole on the farm of Robert Davis, 3 miles northwest of Braymer, Caldwell County, the Mississippian is reported to have been struck at 650 feet and the St. Peter sandstone at 1,250 feet. A complete record was not preserved.

At Brunswick, Chariton County, the Mississippian was reached at 180 feet. This shows the steady dip of the Pennsylvanian over the Mississippian floor to the northwest. From this point to Mexico the crest of the Ozark Island is nearly level. At Higbee the Mississippian is reached at a depth of 240 feet. At Mexico the following section is obtained:

Summary of log of well at Mexico.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	15	15
Des Moines	145	160
Mississippian	405	565
Devonian	65	630
Ordovician and Cambro-Ordovician	395	1,025

The St. Peter sandstone, 10 feet thick, was struck at 670 feet. The Des Moines comes to the surface a few miles east of Wellsville.

In Warren County the St. Peter sandstone is reached at a depth of 390 feet. Thence it dips strongly along the east edge of Ozarkia and is struck at a depth of 1,580 feet in the insane asylum well at St. Louis, where it reaches a thickness of about 133 feet. At the Belcher well in St. Louis it is reached at a depth of 1,500 feet and is 135 feet thick. In St. Louis County is a small patch of Pennsylvanian, which is 80 feet thick in the insane asylum well, and is not found in the Belcher well.

Section 4 (Pl. IV) shows the synclinal trough of the Pennsylvanian in the northwestern part of the State, the approximate contour of Ozarkia, and the St. Louis basin.

SECTION FROM ARCADIA, KANS., TO MEMPHIS, TENN.

Section 5 (Pl. IV) is made from the profile of the St. Louis and San Francisco Railroad and illustrates the dip of the Pennsylvanian to the west; one of the culminating points of the Ozarks, at Cedar Gap (the highest point reached by any railroad in the State); a general outline and cross section of Ozarkia in the southern part of the State; and the old Mississippi estuary from Black Rock, Ark., through to Memphis. Section 5 also shows Crowleys Ridge, the marked topographic prominence which is a most striking feature of the broad alluvial plain of the Mississippi and which extends from eastern Arkansas through a point south of Cape Girardeau in Missouri. This ridge is an erosion remnant of the vast Quaternary deposits that have been removed from this region, the Mississippi having flowed through the basin to the west previous to its capture by the Ohio, as already described (p. 10). The ridge is over 100 feet high throughout most of its length and of varying width.

Various mine sections and prospect drill holes in Barton County show a varying thickness of the Pennsylvanian averaging about 200 feet, the westerly dip bringing the Mississippian to the surface a little west of Golden City. At Ash Grove the Devonian is reached at a depth of 250 feet, and a sandstone, believed to be the St. Peter sandstone, at a depth of 275 feet. At Springfield several wells, drilled within a few hundred feet of each other, show the supposed St. Peter sandstone at an average depth of 320 feet. At Cedar Gap this sandstone is only slightly exposed in the sides of the ravines, and the country is capped by thin patches of the Mississippian. At Thayer the lower part of the Jefferson City limestone is well developed. The dip from Cedar Gap is generally to the southeast, and in the vicinity of Black Rock, Ark., the upper part of the Jefferson City limestone is the surface rock except at the tops of some of the highest hills, which are

capped with St. Peter sandstone. Mr. William B. Johnson gives the following section at Marked Tree, Ark.:

Section at Marked Tree, Ark.

	Thickness.	Depth.
	Feet.	*Feet.*
Lafayette sand	220	220
Lagrange formation	178+	398+

SECTION FROM DONIPHAN, MO., TO HICKMAN, KY.

Doniphan is underlain by the Jefferson City limestone. The record of a deep well which was sunk there a few years ago has, unfortunately, been lost. The Jefferson City limestone extends about 18 miles eastward to the Mississippi embayment. Crowleys Ridge is crossed by section 6 (Pl. IV) at a point where its elevation reaches about 300 feet. At New Madrid a well 295 feet deep goes for some distance into the Lagrange formation.

Prof. L. C. Glenn, of Nashville, Tenn., has kindly furnished the log of the Hickman well, with the following correlations:

Summary of log of well at Hickman, Ky.

	Thickness.	Depth.
	Feet.	*Feet.*
Loess	80+	80
Lafayette	10	90
Lagrange	740+	830+

Section 6 gives, approximately, the Mississippi embayment and a cross section of Crowleys Ridge at one of its highest points.

SECTION FROM DONIPHAN, MO., TO CAIRO, ILL.

The Jefferson City limestone extends from Doniphan to Poplar Bluff, where the old Mississippi embayment begins. Section 7 (Pl. V) illustrates the shallower northern contour of the Mississippi embayment. The following section and correlation at Morehouse are given by Professor Glenn:

Summary of log of well at Morehouse.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay (probably alluvial)	30	30
Coarse sand (?)	110	140
Gravel	10	150
Lagrange	98	248
Porters Creek (Tertiary)	218	466
Ripley (Cretaceous)	224	690
Mississippian limestone (?)	90	780

At Cairo, Ill., the correlation of a record furnished by Mr. Otto Kochtitzky, of Cape Girardeau, furnished the following summary:

Summary of log of well at Cairo, Ill.

	Thickness.	Depth.
	Feet.	*Feet.*
Loess	50	50
Lafayette (?)	59	109
Lagrange	237	346
Porters Creek (Tertiary)	187	533
Ripley sands (Cretaceous)	45	578
Mississippian limestone (?)	276	854

SECTION FROM PLEASANT HILL TO LOUISIANA.

Section 8 (Pl. V) is drawn not only to illustrate the western dip of the Pennsylvanian toward the St. Joseph syncline, but also the irregularity of the northwestern border of Ozarkia; the development of the northeastern anticline which has turned the course of Missouri River in Saline County to the north; the synclinal basin in Saline and Howard counties, which is shown on page 81 to be the probable cause of the saline waters of that district; and the eastern slope of the Ozark Island, which forms a part of the synclinal valley of the Mississippi at Louisiana.

Between Fayette and Louisiana no well records could be obtained, and except in regard to the outcrop of the different formations, section 8 is somewhat theoretical.

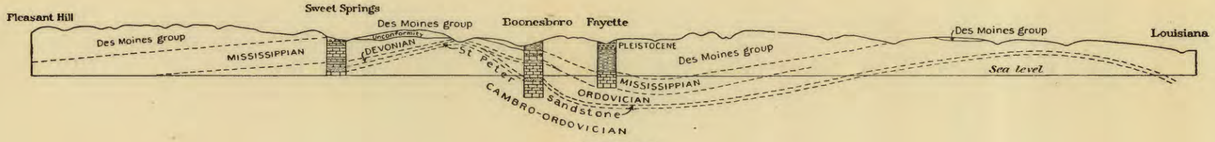
At Pleasant Hill, as already stated, a drill well struck the Mississippian at 530 feet.

The record of the fair grounds artesian well at Sweet Springs, 1,074 feet deep, furnishes the following summary:

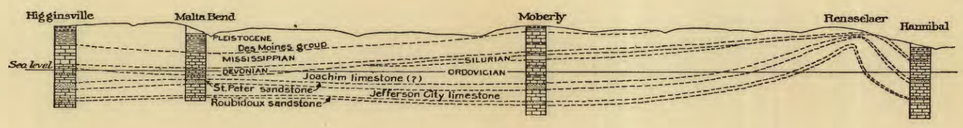
Summary of log of well at Sweet Springs fair grounds.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	29	29
Mississippian	326	355
Devonian and Cambro-Ordovician	719	1,074

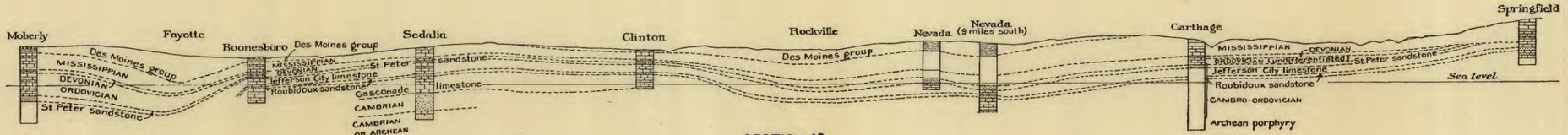
The St. Peter sandstone was reached at a depth of 549 feet and had a thickness of 67 feet. It outcrops near Missouri River, which cuts across the anticline after having been deflected some distance to the north.



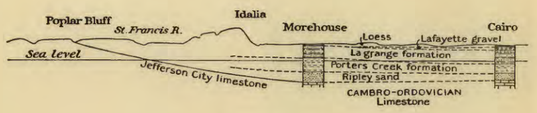
SECTION 8



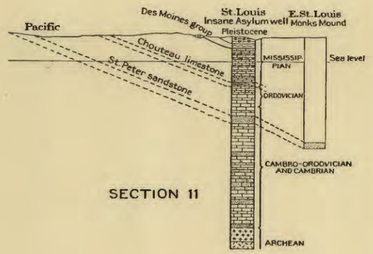
SECTION 9



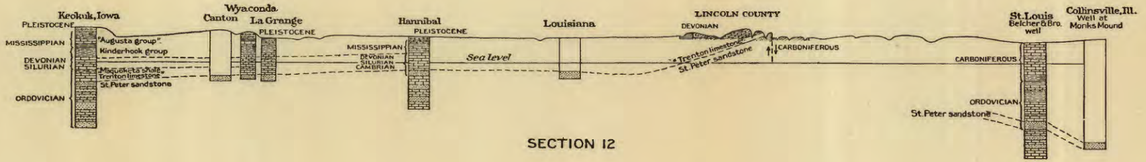
SECTION 10



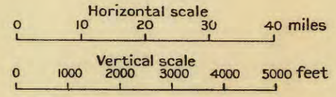
SECTION 7



SECTION 11



SECTION 12



GEOLOGIC CROSS SECTIONS.

The old deep well at Boonslick, near Boonesboro, Howard County, has the following section:[a]

Summary of log of well at Boonslick.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	22	22
Des Moines	68	90
Mississippian	216	306
Devonian and Cambro-Ordovician	696	1,002

The St. Peter sandstone was probably reached at 607 feet and had a thickness of 101 feet.

At Fayette, Howard County, the artesian well shows 135 feet of Pleistocene and 599 feet of Des Moines and passes 271 feet into the Mississippian. Section 8 shows a very strong dip of the Mississippian rocks to the east, with a steady rise north of Fayette, where they reach the surface near North Fork of Salt River, on the line of this section. This interesting basin is referred to further in the discussion of the salt waters of Saline and Howard counties (pp. 81–82).

At Louisiana, Pike County, the Thespian artesian well, 1,350 feet deep, strikes the St. Peter sandstone at 600 feet.

SECTION FROM HIGGINSVILLE TO HANNIBAL.

Section 9 (Pl. V) is given tentatively, being one of the most difficult to correlate, and only a possible development of the horizons is outlined. The section runs through Higginsville, Malta Bend, Moberly, Rensselaer, and Hannibal. It shows the general dip of the strata to the west from Moberly to Rensselaer and a sharp anticlinal axis of Cambrian rocks at Rensselaer. Considerable disturbance and some faulting have also been noted at this point. These can not be indicated in the section. The abrupt eastern slope of the Mississippi syncline is shown between Rensselaer and Hannibal, and on each side of Rensselaer the Devonian and Ordovician rocks are indicated. The Devonian probably extends entirely through the section. The Ordovician rocks thin out between Moberly and Malta Bend, apparently not being represented in the Malta Bend record.

[a] The writer is indebted to Prof. J. W. Kilpatrick, of Fayette, and Prof. A. F. Hendrix, of Lawrence, Kans., for this section and for the Fayette section on p. 83.

The log of the deep well of the Higginsville Prospecting Company, furnished by Mr. J. H. Burgan, of Higginsville, gives the following summary:

Summary of log of well at Higginsville.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	68	68
Des Moines	302	370
Mississippian	345	715
Devonian	55	770
Ordovician and Cambro-Ordovician	743	1,513

The St. Peter sandstone, 150 feet thick, was struck at the depth of 1,071 feet.

The deep artesian well at Malta Bend gives the following partial summary:

Summary of log of well at Malta Bend.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	119	119
Des Moines (record incomplete)	230±	349±
Mississippian (record incomplete)	300±	649±
Devonian (record incomplete)	200±	849±

The St. Peter sandstone was struck at 900 feet and was 30 feet thick.

A portion of this record was given from memory by some of the drillers and is, probably, only approximately correct. The well is 1,300 feet deep. It has been impossible to obtain the complete record.

SECTION FROM MOBERLY SOUTHWEST TO NEVADA, THENCE SOUTH TO CARTHAGE AND EAST TO SPRINGFIELD.

Section 10 (Pl. V) shows the synclinal basin in Howard County, crossing over a portion of Ozarkia from Boonesboro to Clinton, showing the coal basins at Rockville, just south of Nevada, and again touching Ozarkia at Carthage and Springfield. It is also given for the purpose of showing the continuation of the St. Peter sandstone from Hannibal and Louisiana, on the Mississippi, westward to Fayette and around the Ozark Island on the west and south of this section to Springfield. It further demonstrates the thinning out of the Ordovician all around the Ozarks. The Ordovician rocks seem to be well developed at Macon, Moberly, and Higginsville, in an outer ring around Ozarkia; but on the slopes of the uplift they thin and abruptly disappear. This is well shown in sections 9 and 10. The Ordovician system seems also to be well developed along the west side of the

Ozark Island and northward into Iowa. It evidently once formed a penumbral margin around this elevation.

The record of the well at Moberly, 1,170 feet deep, submitted through the courtesy of Mr. W. H. Jones, of that city, gives the following summary:

Summary of log of well at Moberly.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	38	38
Des Moines	89	127
Mississippian	390	517
Devonian	68	585
Silurian (Niagara)	95	680
Ordovician	365	1,045
Cambro-Ordovician	655	1,700

The correlations in this record are based on McGee's summary of the formations found in the deep well at Macon, Macon County, a few miles north of Moberly.[a]

The same basin structure is shown in section 10 as was shown in section 8—a fact that is discussed further in the study of the saline waters of Howard and Saline counties (pp. 81–82).

The Fayette and Boonesboro wells have already been described (p. 37).

The well section at Sedalia is made by combining the records of two wells situated about a mile apart:

Summary of logs of wells at Sedalia.

	Thickness.	Depth.
	Feet.	*Feet.*
Mississippian	226	226
Devonian	23	249
Cambro-Ordovician	± 1,151	± 1,400
Cambrian or Archean	± 212	± 1,612

The St. Peter sandstone is found at a depth of 289 feet, and is 40 feet thick.

From Sedalia to Clinton the horizons are fairly uniform. At Clinton the following section was procured through the courtesy of Dr. J. H. Britts:

Summary of log of well at Clinton.

	Thickness.	Depth.
	Feet.	*Feet.*
Des Moines	40	40
Mississippian	± 150	± 190
Devonian	± 40	± 230
Cambro-Ordovician	± 570	± 800

[a] McGee, W J, Geology of Macon County: Trans. St. Louis Acad. Sci., vol. 5, No. 1, 1888, p. 327.

The St. Peter sandstone is 20 feet thick and was encountered at a depth of 290 feet.

From Clinton to Nevada, as indicated by the very imperfect record of a deep well at Rockville, there is a sag in the strata and a thickening up of the St. Peter sandstone.

The record of the Nevada deep well is very incomplete and difficult to correlate. A thickness of 170 feet of Des Moines is noted, and the St. Peter sandstone, 93 feet thick, is reached at a depth of 775 feet. About 9 miles south of Nevada an oil prospect well was put down to a depth of 1,447 feet. The imperfectly kept record of this well shows the existence of another slight synclinal trough, and a thickening up of the Des Moines to 294 feet. The St. Peter sandstone was reached at 907 feet, with a probable thickness of 100 feet. From this point southward, the Des Moines rapidly rises, the base reaching the surface beyond Lamar.

Winslow[a] gives an approximate section of a drill hole 2,005 feet deep at Carthage. It is unfortunate that his description is so incomplete as to render it impossible to correlate the section. The summary would be about as follows:

Probable summary of log of drill hole at Carthage.

	Thickness.	Depth.
	Feet.	*Feet.*
Mississippian	400	400
Devonian	50	450
Cambrian and Cambro-Ordovician	1,300	1,750
Archean (porphyry)	255	2,005

The St. Peter sandstone was reached at a depth of 560 feet, and was about 85 feet thick.

The traveler going northward from Carthage to Springfield passes up the slope of the Ozarks. Several imperfect well records show a steady dip upward on this slope. At Springfield the combined records of several adjacent wells give the following general summary:

Summary of logs of wells at Springfield.

	Thickness.	Depth.
	Feet.	*Feet.*
Mississippian	300	300
Devonian	40	340
Cambro-Ordovician	660	1,000

The supposed St. Peter sandstone was reached at a depth of 350 feet, and has a thickness of 16 feet.

[a] Winslow, Arthur, Lead and zinc deposits, pt. 2: Missouri Geol. Survey, vol. 7, 1894, p. 405.

SECTION FROM PACIFIC, MO., TO GREENVILLE, ILL.

The log of the insane asylum well at St. Louis, one of the best records to be found in the State, gives the following summary:[a]

Summary of log of well at insane asylum, St. Louis.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	40	40
Des Moines	80	120
Mississippian	763	883
Ordovician	421	1,304
Cambrian and Cambro-Ordovician	2,254	3,558
Archean	285	3,843

The St. Peter sandstone was struck at 1,452 feet, and was 133 feet thick.

Section 11 (Pl. V) follows, from Pacific, the line of the Missouri Pacific Railway to St. Louis. At Pacific the St. Peter sandstone outcrops in the bluff, thus having the great dip of 1,452 feet in about 30 miles.

The different formations above this sandstone outcrop, successively, between Pacific and St. Louis, and are very well correlated in the Belcher well, situated on the bank of Mississippi River in the city of St. Louis, about 6 miles east of the insane asylum well.

Across the river, toward Caseyville and as far as Greenville, Ill., on an easterly line, the Mississippian and Pennsylvanian successively outcrop under the loess, dipping gently to the east. The structural conditions of the beds between Mississippi River at St. Louis and Caseyville, Ill., are only conjectural. There may be a low anticline, or there may be faults. The Mound City well section would indicate a gentle dip to the east as more probable. As no well sections from this area are available, the existence of a low anticline can only be assumed.

At Godfrey, Ill., a few miles to the northeast of section 11, a well was sunk to a depth of 1,703 feet, in which St. Peter sandstone was struck at 1,625 feet. The writer is indebted for this section to Mr. D. W. Maxfield, of Monticello Seminary.

SECTION FROM KEOKUK, IOWA, TO ST. LOUIS, MO.

A summary of the formations in the well of the Keokuk Poultry Company, at Keokuk, Iowa, is taken from Norton's Artesian Wells of Iowa.[b]

[a] Broadhead, G. C., Trans. St. Louis Acad. Sci., vol. 3, No. 2, 1878, p. 219.
[b] Iowa Geol. Survey, vol. 6, 1897, p. 235.

Summary of log of well at Keokuk, Iowa.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	5	5
Keokuk	130	135
Montrose cherts (Mississippian)	30	165
Burlington, upper part of (Mississippian)	22	187
Burlington, lower part of (Mississippian)	103	290
Kinderhook (Mississippian)	206	496
Devonian	85	581
Silurian	120	701

The St. Peter sandstone, 110 feet thick, was struck at a depth of 1,050 feet in the Hubinger well, not far from the well of the Keokuk Poultry Company. Norton estimates that this sandstone would be struck in the latter well at 1,250 feet.

At Canton, Lewis County, an artesian well was sunk in 1890 to a depth of 906 feet. The St. Peter sandstone was struck at 846 feet, and drilling was stopped in this rock at 906 feet, showing a thickness of 60+ feet.

At Lagrange, in the same county, two artesian wells were sunk. The Thomas well on the bluff at an altitude of 580 feet struck St. Peter sandstone at 800 feet, and the Wyaconda at an altitude of 481 feet struck this rock at 700 feet, passing into it for 115 feet.

The well of Dr. A. Vernet, near Hannibal, Marion County, was sunk to a depth of 1,340 feet. The record was furnished the writer by Mr. R. Hawkins, of Chillicothe, and from it the following summary was made:

Summary of log of Vernet well, near Hannibal.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene	41	41
Mississippian	259	300
Devonian (?), Silurian, and Ordovician to St. Peter sandstone	301	601
St. Peter sandstone	96	697
Jefferson City limestone	253	950
Roubidoux sandstone	290	1,340

At Louisiana, Pike County, the Thespian artesian well has a depth of 1,350 feet. Unfortunately the record of this well has been lost, but it is known that the St. Peter sandstone was struck at a depth of 600 feet.

From Louisiana southward to St. Louis the country is very much broken and disturbed. The Cap au Grès fault crosses the river near Winfield. As there are no well sections between Hannibal and St. Louis only a theoretical outline of the geology can be shown in section 12 (Pl. V). The St. Peter sandstone comes to the surface in Lincoln County and then dips sharply to the south, being found in the insane asylum well, as described on page 41, at a depth of 1,452 feet.

East of Hannibal, at Barry, Ill., in a well 2,500 feet deep,[a] the St. Peter sandstone was struck at 1,125 feet. The altitude of Barry is 617 feet and that of Hannibal 472 feet. The sandstone was struck at Hannibal at 601 feet.

UNDERGROUND WATERS.

ARTESIAN DISTRICTS.

The State may be conveniently and somewhat arbitrarily divided into the following ten districts: (1) The northeastern, (2) the north central, (3) the south central, (4) the Decaturville dome, (5) the Clinton-Nevada, (6) the southeastern, (7) the St. Louis basin, (8) the St. Francis Mountains, (9) the southeastern swamp, (10) the drift.

NORTHEASTERN DISTRICT.

GENERAL ARTESIAN CONDITIONS.

The northeastern district includes the portions of the counties north of St. Charles County that lie between Mississippi River and the ridge a few miles to the west. The artesian wells obtain their flow from the eastern slope of the northern extension of the Ozark uplift. In the northeast corner of the State for some miles back from the river the Des Moines group forms the country rock. Along the Mississippi from the Iowa border nearly to Louisiana, Mo., and for some distance inland farther south, Missouri rocks outcrop. In the vicinity of Louisiana a narrow belt of Silurian appears. The dip is strongly to the east. The St. Peter sandstone rises steadily from Iowa toward the south. In this district the drillers' records are meager and poorly kept. There are flowing wells at or near Canton and Lagrange, Lewis County; Hannibal, Nelsonville, and Oakwood, Marion County; Spalding, Ralls County; Louisiana, Pike County; and Troy, Lincoln County.

Flowing artesian water in this district may be found in a narrow belt extending from Keokuk probably to a point a little south of Louisiana. The belt is limited because of the more or less abrupt slope toward the river and the relative nearness of the crest of the divide to the river valley, as shown in sections 8 and 9 (pp. 36–37). The water is derived mainly from the St. Peter sandstone, which, so far as can be learned, is the highest horizon yielding flowing water. As a rule potable nonflowing water may be found at the base of the Mississippian. It is not probable that water will rise to an altitude of much over 600 feet in this district, and owing to the high elevation of the towns along the divide it is questionable whether that will be within proper pumping distance.

[a] Leverett, Frank, Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 810.

It is rather interesting to notice the general increase in mineral constituents in the water southward from the Iowa line, as shown by the following table:

Statistics of wells in northeastern district.

Well.	Depth (feet).	Temperature (° F.).	Total solids (parts per million).	Sodium chloride (parts per million).
Canton	906	60	385.76	266.2497
Wyaconda	850	60	373.266	286.834
Lagrange	800	61	395.571	320.607
Spalding	300	57	700.3112	533.2613
Louisiana	1,350	63.5	552.2904	410.7212

An increase in the amount of the other mineral constituents as well as of salt is noticed in these wells. Samples of St. Peter sandstone, procured from several shallow wells in Ralls County, show the presence of minute disseminated grains of marcasite (iron pyrites) which will perhaps account for the increasing amount of sulphureted hydrogen. The catchment basin for the St. Peter sandstone is probably in Wisconsin, the water flowing through Iowa and meeting with a gentle upward dip, as noted in the sections, so that when it reaches Missouri it undoubtedly has its mineral constituents concentrated, as is indicated by the foregoing table.

CLARK COUNTY.

KAHOKA.

The following is the log of one of three deep nonflowing wells at the pickle plant of the Clark County Canning Company, Kahoka:

Log of Clark County Canning Company well, Kahoka.

	Thickness.	Depth.
Pleistocene (157 feet):	*Feet.*	*Feet.*
Gumbo	20	20
Yellow clay	20	40
Sand	10	50
Blue clay	20	70
Gray clay	30	100
Yellow clay	40	140
Blue clay	10	150
Sand	7	157
Keokuk (131 feet):		
Rock, shelly	2	159
Solid rock	31	190
Limestone	10	200
Gray limestone	10	210
"Soapstone"	13	223
Water-bearing rock	11	234
Shale	6	240
Sandstone	16	256
Shale	2	258
Rock	12	270
Soft rock	18	288
Burlington (72 feet):		
Limestone	22	310
Shale	5	315
Limestone	45	360

The first water was struck at a depth of 60 feet, and a still larger body was encountered in the honeycombed limestone at a depth of 198 feet. The well was shot with dynamite at different depths, after which it was cleaned out. Excellent water stands at 72 feet below the surface.

The Kahoka city water supply is obtained from a well 509 feet deep. Drilling was started in December, 1901, by George C. Morgan, of Chicago, and the well was finished in March, 1902. The water, which is wholesome, abundant, rather hard, and usually clear, rises within 90 feet of the surface or to the top of the rock, as the Pleistocene is 90 feet thick. A reservoir with a capacity of 75,000 gallons provides water, with direct pressure, for city consumption. No log of this well has been preserved, and no analysis has been made. The cost of the well and pump was $3,000 and the supply of water is ample for the needs of a city of 2,500 people.

LEWIS COUNTY.

CANTON.

At Canton a well is situated on the grounds of the Christian University, about 1 mile west of the river, at the summit of a picturesque bluff. Its elevation is about 600 feet; depth, 900 feet; 6-inch casing to 100 feet; temperature of water, 60°; of air, 80°; flow, 72 gallons per minute; pressure, 12 pounds; date of completion, 1890; cost, $1,812. The first water was struck at a depth of 90 feet, and rose within about 10 feet of the top. At a depth of 870 feet, in the St. Peter sandstone, a strong flow of water was struck, which had a gaged pressure of 12 pounds. Mr. L. H. Condit, the postmaster at Canton, superintended the drilling. He states that when the drill struck the sandstone, which was spongy and water-logged, it went down several feet. No record of the well was kept. Although this well is located on the grounds of the Christian University, it was drilled at the expense of the city under a lease for forty-nine years, and Messrs. Griffith and Maggard, of the Aqua Vitæ Mineral Springs Company, have sub-leased the right to ship the water for medicinal purposes. The water possesses mildly laxative qualities. The well was originally put down by the city for fire protection, and its saline properties made it of especial value for this purpose, as fire once under control by this water has little chance of reignition. Insurance companies have recognized this fact and have cut their rates about one-half for this town.

The water is used for all domestic purposes, except that of watering lawns, and there are about 9 miles of mains. It is clear and sparkling, with a slight sulphur odor, and is strongly charged with sulphureted hydrogen. This well is interesting from the fact that its

flow has steadily increased. When first tested it flowed 53 gallons per minute. In 1903 it was opened and water and gas issued with great force, due to the accumulation of gas. It was again tested and found to flow 72 gallons per minute.

An analysis of this water, made by Prof. Harrison Hale, of Drury College, resulted as follows:

Analysis of water from Canton, Lewis County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	5.3	Carbonate radicle (CO_3)	21.0
Iron (Fe)	Trace.	Bicarbonate radicle (HCO_3)	500
Calcium (Ca)	252.0	Sulphate radicle (SO_4)	919
Magnesium (Mg)	142	Chlorine (Cl)	2,838
Sodium (Na)	1,858		6,621.3
Potassium (K)	86		

It will be noticed that this water somewhat resembles the sulphosaline water of Excelsior Springs. It is gaining a considerable reputation.

LAGRANGE.

Close to the west side of the Burlington Railway track, at Lagrange, a short distance from the railway station, is a well owned by the Lagrange Mineral Well Prospecting Company. The depth is 800 feet; elevation above tide at well mouth, 481 feet; casing, 6-inch, 850 feet; temperature of water, 61° F.; of air, 86° F.; flow, 60 gallons per minute; date of completion, 1887; cost, $1,500; surface formation, Keokuk limestone.

This well is 2,500 feet deep and was sunk with the expectation of finding some profitable mineral. The first water was reached at 400 feet. At 800 feet a strong flow was struck, and at 850 feet it became so strong that the driller could go no farther. This flow comes from the soft, water-logged St. Peter sandstone, and no perceptible change has ever been noticed in either its volume or force. Mr. R. N. Blackwood states that the force was sufficient to carry the water to the summit of the bluff, a distance of over 100 feet. This well has recently been sold to Mr. Thomas, the owner of the Wyaconda well, and the product of both wells is shipped under the name of Wyaconda water.

The Wyaconda well is on the summit of a bluff overlooking the town of Lagrange, about 1 mile north and about 100 feet above the well just described. The owner is William H. Thomas; depth, 850 feet; diameter, 8 inches; altitude at well mouth, 580 feet above tide; casing, 5⅝-inch, 150 feet; temperature of water, 60° F.; of air, 80° F.; flow, 40 gallons per minute; date of completion, January, 1888; cost, $1,500; surface formation, Keokuk limestone.

[a] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

The main flow of water was reached at 800 feet, in the soft, white St. Peter sandstone; it is steadily decreasing in volume. In both this and the Lagrange well the flow increased when the St. Peter sandstone was reached. The following is the incomplete log of the well:

Log of Wyaconda well, Lagrange, Lewis County.[a]

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (15 feet):		
Soil	15	15
Mississippian (480 feet):		
Limestone	200	215
Shale	65	280
Soft limestone	65	345
Soft shale, slate, or soapstone	150	495
Devonian (?) (150 feet):		
Dry "Trenton" (?) rock	150	645
Silurian and Cambrian, including St. Peter sandstone (205 feet):		
Limestone	155	800
White sandstone	50	850

[a] The writer is indebted to Mr. William H. Thomas for the logs of the Wyaconda and Lagrange wells.

Two analyses of this water have been made, one of which, by Prof. Paul Schweitzer, is as follows:

Analysis of Wyaconda mineral water.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	40	Bicarbonate radicle (HCO_3)	2.9
Iron (Fe)	1.3	Sulphate radicle (SO_4)	1,055
Calcium (Ca)	293	Chlorine (Cl)	2,975
Magnesium (Mg)	89		6,392.2
Sodium (Na)	1,934	Free CO_2	260
Potassium (K)	Trace.		
Lithium (Li)	Trace.		

But an imperfect record of the drillings was kept, and only the following data can be given:

Partial log of Wyaconda well, Lagrange, Lewis County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (15 feet):		
Soil	15	15
Mississippian (360 feet):		
Limestone	80	95
Shale	70	165
Soft limestone	55	220
Soft slate, shale, or soapstone	155	375
Devonian (110 feet):		
Dry limestone	110	485
Silurian and Cambrian, including St. Peter sandstone (315 feet):		
Trenton rock (?)	200	685
Very soft white sandstone	115	800

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

With this meager record it is difficult to correlate the various formations passed through, but a comparison with the well at Keokuk makes the above determinations probable.

An analysis of this water, made by C. A. Crampton, Washington, D. C., shows the following results:

Analysis of water of Wyaconda well, Lagrange, Lewis County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	49	Carbonate radicle (CO_3)	664
Iron (Fe)	Trace.	Sulphate radicle (SO_4)	107
Aluminum (Al)	.8	Chlorine (Cl)	3,326
Calcium (Ca)	246		6,767.8
Magnesium (Mg)	101	Free CO_2	288
Sodium (Na)	2,214		
Potassium (K)	60		

LINCOLN COUNTY.

TROY.

Near Troy, Lincoln County, is a well owned by N. Hanni, of which the depth is 136 feet; altitude, 15 feet above the railway station; casing, 6-inch, 10 feet to rock; flow, a small stream, about 1 gallon per minute; date of completion, 1893; surface formation, Burlington limestone. In this well flowing water was struck in an open crevice between 125 and 130 feet. The supply decreases with pumping, and consequently the well flows only after the pumps have been stopped for some time. No log was kept; but it is stated that chert and an easily drilled, fine-grained white limestone were passed through. It is probable that drilling was stopped in the lower part of the Burlington. Another well in Troy, 100 feet deeper, does not flow.

The following analysis of the water of the Hanni well was furnished by Mr. E. E. Ellis:

Analysis of water of Hanni well, Troy, Lincoln County.

	Parts per million.		Parts per million.
Iron	0	Total carbonates	341
Sulphates	29	Alkaline carbonates	0
Chlorine	7.47	Alkaline and earthy carbonates	341
Total hardness	208.5	Calcium	228

MARION COUNTY.

HANNIBAL.

On the west edge of the city of Hannibal, about $1\frac{1}{4}$ miles west of the railroad station, is a well owned by Mrs. Vernet. The depth is 1,435 feet; altitude, 608 feet, or 135 feet above the union railroad station at

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Hannibal; diameter of casing, 6 inches; temperature, 57.2° F.; water stands within 12 feet of top of well; date of completion, 1894; surface formation, lower part of the Burlington. The writer is indebted to Mr. R. Hawkins, of Chillicothe, for the following record of this well:

Log of Vernet well, Hannibal, Marion County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (41 feet):		
Soil and clay	41	41
Mississippian (259 feet):		
Shales, limestone, and hard water	154	195
Blue limestone	105	300
Devonian (?), Silurian, and Cambrian to St. Peter sandstone (301 feet):		
Black slate	33	333
Salt-water sand; water rose within 70 feet of surface	14	347
Solid limestone	254	601
St. Peter sandstone (96 feet):		
Mineral-water sand; water rose within 30 or 40 feet of surface	96	697
Jefferson City limestone (253 feet):		
Limestone and hard, fine sand at intervals; water rose within 20 feet of surface	253	950
Roubidoux sandstone (439 feet):		
Hard limestone	50	1,000
Soft white sand; water rose within 7 feet of surface	5	1,005
Limestone	50	1,055
Limestone with interstratified sand	150	1,205
Sand	20	1,225
Magnesian limestone	50	1,275
Hard white sand; water stands within 4 feet of surface	10	1,285
Magnesian limestone; water flowing	104	1,389
Unaccounted for	46	1,435

This well was put down by Dr. Fred. Vernet for the purpose of obtaining mineral water. The water is very saline, being similar to that of the Stilwell well in Hannibal. The following analysis is taken from an advertising circular published by Doctor Vernet; the analyst and date of analysis are unknown:

Analysis of water of Vernet well, Hannibal, Marion County.[a]

	Parts per million.		Parts per million.
Iron (Fe)	41	Carbonate radicle	422
Calcium (Ca)	49	Sulphate radicle (SO_4)	790
Magnesium (Mg)	108	Chlorine (Cl)	58
Sodium (Na)	363		
Lithium (Li)	26		1,857

In 1889 J. M. Tracy drilled a well for oil on the same tract of land as that on which the Vernet well is situated. The elevation was 50 feet above the railroad station at Hannibal and 85 feet below Doctor Vernet's well. Fresh water was found at the bottom and rose within a few feet of the surface.

In an alley near Front street, corner of Hill street, close to the steamboat wharf, is a well owned by the Richard Stilwell Meat and Ice Company. The depth is 950 feet; altitude, 475 feet; casing, 8-inch, 200 feet; temperature of water, 60° F.; of air, 88° F.; flow,

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

fairly strong, 208 gallons per minute; pressure by steam gage, 50 pounds; date of completion, 1890; surface formation, Louisiana limestone. The first water, nonflowing, was struck at 40 feet; the next stream, flowing, was encountered at 800 feet, in the soft, white St. Peter sandstone; and it is claimed that for 100 feet in this sandstone alternating streams of fresh and salt water were struck. The water is highly charged with saline ingredients, and sulphureted hydrogen bubbles up freely. The flow is estimated at 300,000 gallons in twenty-four hours. No log of this well could be obtained. The following analysis of the water was made by E. E. Ellis, May 31, 1905:

Analysis of water of Stilwell well, Hannibal.

	Parts per million.		Parts per million.
Iron	Trace.	Alkaline earthy carbonates	274.4
Calcium	150+	Sulphates	522
Alkalinity	274.4	Chlorides	Very high.
Alkaline carbonates	0		

Turbidity, none; color, none.

The water is very salty and contains a large amount of sulphureted hydrogen.

NELSONVILLE.

The following data have been collected about the wells at Nelsonville. Well No. 1 is in sec. 28, T. 59, R. 8 W.; owner and driller, C. H. Mohr; first flow at about 650 feet. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well No. 1, Nelsonville, Marion County.

	Thickness.	Depth.
	Feet.	*Feet.*
Blue shale; fresh water	165	165
Hard limestone	60	225
Gray shale	72	297
Limestone, very hard	188	485
Red sandstone	10	495
Limestone	30	525
Sandstone	10	535
Limestone	10	545
Sandstone	140	685
Blue shale	15	700
Sandstone	20	720

Well No. 2 is 3 miles south of Nelsonville, in sec. 21, T. 59, R. 8; owner and driller, C. H. Mohr. The well was drilled with 4½-inch tools. It flows 10 gallons per minute, and the water rises 12 feet above the mouth. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well No. 2, Nelsonville, Marion County.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	45	45
Blue shale	150	195
Limestone	60	255
Gray shale	35	290
Limestone	220	510
Red sand; some oil and gas	15	525
Limestone	125	650
White sandstone; mineral water	10	660
Hard rock	2	662
Sandstone	213	875

PALMYRA.

At Palmyra a well was sunk to a depth of 1,683 feet. The water is said to have flowed at 700 feet. The analysis here given was made by Prof. Paul Schweitzer in 1887.

Analysis of water of well at Palmyra, Marion County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	19	Sulphate radicle (SO_4)	814
Calcium (Ca)	515	Chlorine (Cl)	6,443
Magnesium (Mg)	234	Bromine (Br)	4
Sodium (Na)	3,542		11,571.9
Lithium (Li)	.9		

OAKWOOD.

A deep well was sunk in 1890 at Oakwood, 3 miles southwest of Hannibal, on the land of C. G. Price, but it ceased to flow some years since. The log was lost. This well was about 800 feet deep and located 150 feet above the river. It had a very strong flow, but it was stopped up because the highly saline water injured vegetation. The following analysis of this water, furnished by Mr. Price, was made by R. Chauvenet & Brother:

Analysis of water of well at Oakwood, Marion County.[a]

	Parts per million.
Calcium (Ca)	634
Magnesium (Mg)	249
Sodium (Na)	5,233
Sulphate radicle (SO_4)	3,401
Chlorine (Cl)	7,388
	16,905

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

PIKE COUNTY.

LOUISIANA.

A well, now called the "Thespian Spring," is located in the small valley of Town Branch, corner of Fifth and Kentucky streets, in the town of Louisiana. Owner, C. W. Crudson; depth, 1,275 feet; altitude, 470 feet; date of completion, 1887; casing, 6-inch, to 910 feet; temperature of water, 63.5° F.;[a] of air, 92° F.; cost, $3,000.

The water is strongly saline and charged with sulphureted hydrogen. It is clear, sparking, and bubbling with gas, and has corroded the rock basin into which it empties. The water comes up with considerable force, having a head, probably, of about 8 feet. It is stated that when the well was first opened it threw a jet 40 feet high. The flow is said to be stronger after a wet period and weaker in dry weather. A sanitarium, with bottling facilities, has been established near the well, and the water was once bottled and shipped to St. Louis. It is now used for bathing and, to a limited extent, for drinking.

Schweitzer[b] gives the following meager log, which he obtained from William H. Suda:

Log of Thespian Spring, Louisiana, Pike County.

	Thickness.	Depth.
	Feet.	*Feet.*
Loose soil	90	90
Sandstone	560	650
Limestone	120	770
Sandstone	30	800
Undetermined	10	810
Sandstone	70	880
Undetermined	395	1,275

This record is so manifestly incorrect that no satisfactory correlations can be made. It was stated that the first flow of water was struck at 600 feet, in sandstone. Prof. R. R. Rowley gives the following geologic data: "At Louisiana the Hudson River limestone is 40 feet thick, and under that is 100 feet of Trenton limestone. The St. Peter sandstone would probably be reached at about 600 feet."

[a] This temperature was obtained July 15, 1903. Schweitzer, in his report on Mineral waters of Missouri (Missouri Geol. Survey, vol. 3, 1892), gives a temperature of 62.2° F., with air temperature 74° F., probably taken in 1892.

[b] Missouri Geol. Survey, vol. 3, 1892, p. 94.

The following analysis, date and name of chemist unknown, is given on the circular published by the owners of the well:

Analysis of water from Thespian Spring, Louisiana, Pike County. [a]

	Parts per million.		Parts per million.
Silica (SiO_2)	0.4	Chlorine (Cl)	4,774
Calcium (Ca)	410	Bromine (Br)	34
Magnesium (Mg)	200		9,459.5
Sodium (Na)	2,796	H_2S	478
Potassium (K)	17	CO_2	805
Lithium (Li)	3.1		10,742.5
Bicarbonate radicle (HCO_3)	345		
Sulphate radicle (SO_4)	879		

Schweitzer [b] gives the following analysis:

Analysis of water of Thespian Spring, Louisiana, Pike County. [a]

	Parts per million.		Parts per million.
Silica (SiO_2)	4.9	Bicarbonate radicle (HCO_3)	186
Calcium (Ca)	420	Sulphate radicle (SO_4)	1,051
Magnesium (Mg)	165	Chlorine (Cl)	4,677
Sodium (Na)	2,775		9,341.9
Potassium (K)	63		

RALLS COUNTY.

RENSSELAER.

Mr. J. M. Johnson, of Rensselaer, gives the record of a stock well 270 feet deep, situated on his farm 1½ miles from Rensselaer station in Ralls County. He also sent samples of drillings to accompany the log, which follows:

Log of Johnson well, Rensselaer, Ralls County.

	Thickness.	Depth.
	Feet.	*Feet.*
1. Pleistocene	28	28
2. Limestone and shale	172	200
3. Brown shale	60	260
4. Limestone and fresh water		
5. Soft white sandstone	10	270

Of these samples, No. 2 corresponds with Swallow's Onondaga limestone. No. 5 is, without doubt, the St. Peter sandstone; it is made up of incoherent, fine, rounded, polished, and waterworn grains of limpid quartz. Occasional specks of marcasite (iron pyrites) were found, which might possibly account for the sulphureted hydrogen and sulphates that abound in the waters of this region.

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

[b] Op. cit., p. 96.

SPALDING.

About 5 miles south of Rensselaer station, on the Missouri, Kansas and Texas Railway, in sec. 25, T. 56, R. 6 W., at the post-office of Spalding, is a very interesting well, owned by R. M. Spaulding. Depth, 330 feet; altitude at well mouth, about 590 feet above tide; temperature of water, 57° F.; of air, 86° F.; flow, 400 gallons per hour; date of completion, about 1823; drillers, Hager & Muldrow; drilled by hand. This well is on an old French grant known as the Boovat Lick. Several salt springs are situated a few hundred feet to the north. Some time after 1821, probably about 1823, the State engaged Messrs. Hager & Muldrow to sink the well. Several veins of water, some soft and some salt, were struck. The first strong flow was obtained at 300 feet in soft sandstone, which was penetrated to a depth of 30 feet. Various attempts were made to case this well with wooden tubing, but the pressure was too strong, and with the exception of a wooden tube passed through the soil and firmly anchored to rock no casing was put in. The source of the water was the St. Peter sandstone. So far as observed the pressure has always remained the same. Salt was obtained from this well and the adjoining springs for many years. The water is very strongly saline and is charged with sulphureted hydrogen, so that white precipitate forms about the boards and pipes connected with the well. This place has long been a summer resort.

No record was kept of the geologic horizons passed through, but there is no doubt of the fact that the source of supply is the St. Peter sandstone. The strata in the vicinity of the well are greatly disturbed. North of the well the rocks dip 15° SW., with a strike of N. 40° W. At the farm owned by Mr. Spaulding's son, about a mile southeast of the well, the strata are much more disturbed. The St. Peter sandstone stands with upturned edges and is overlain by ledges of Joachim limestone. An anticline having a northwesterly trend passes through this portion of the country and the artesian well is situated on its southern slope. Geologically this is a region of great interest. Three miles northwest of Spalding, in the road near the Tompkins's place, the rock dips strongly to the northeast. This is probably near the axis of the anticline just mentioned.

The following analysis of this water is taken from Schweitzer's report:[a]

Analysis of water from well at Spalding, Ralls County.[b]

	Parts per million.		Parts per million.
Silica (SiO_2)	5.8	Bicarbonate radicle (HCO_3)	162
Calcium (Ca)	544	Sulphate radicle (SO_4)	1,181
Magnesium (Mg)	213	Chlorine (Cl)	6,242
Sodium (Na)	3,596		
Potassium (K)	78		12,021.8

[a] Missouri Geol. Survey, vol. 3, 1892, p. 96.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

NORTH-CENTRAL DISTRICT.

GENERAL ARTESIAN CONDITIONS.

The north-central district includes the portion of Missouri north and northwest of the Atchison, Topeka and Santa Fe Railway, which crosses the State in a northeast-southwest direction, from Des Moines River to Kansas City. The wells in this district obtain water from the Des Moines group, the basal formation of which is usually a porous sandstone. The waters have their head on the western slope of the great divide which runs in a north-south direction through the northern part of the State and which is probably the northeastern extension of the Ozark dome. The water is generally strongly saline and often chalybeate, but it is considered excellent for the use of stock, though it is not generally desirable for drinking. There is sufficient pressure to bring the water to the surface where the surface elevation does not exceed 730 feet. Very few wells have reached the St. Peter sandstone. Those that have been drilled to this formation have a surface elevation too high to admit of flow.

The general dip is to the northwest toward the St. Joseph trough, but this dip is not uniform. Near Utica, Livingston County; Jamesport, Daviess County; and Bethany, Harrison County, are anticlinal folds and faultings. The average dip is from 10 to 15 feet to the mile. The land rises regularly in this direction, so that the Des Moines group is deeply buried. The flowing wells are found in this district at or near the following places: Carrollton, Carroll County; Utica, Livingston County; Gallatin, Daviess County; Bethany, Harrison County; and in Mercer County, near Lineville, Iowa.

ADAIR COUNTY.

KIRKSVILLE.

At Kirksville is a well that was sunk for the purpose of obtaining a city supply. The writer is indebted to Hon. Thomas J. Dockery for the following log of this well:

Log of deep well at Kirksville, Adair County.

	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Pleistocene (170 feet):		
Clay	170 0	170 0
Des Moines (280 feet):		
Limestone	8 0	178 0
Coal	1	178 1
Clay shale	30 0	208 1
Sandstone	22 0	230 1
Shale	15 0	245 1
Hard limestone	2 0	247 1
Shale, about	20 0	267 1
Coal	1 6	268 7
Shale	30 0	298 7
Shelly broken limestone	20 0	318 7
Soft, mushy, blue clay	20 0	338 7
Limestone	15 0	353 7
Coal	2 0	355 7
Shale	50 0	405 7
Fine white sandstone	45 0	450 7
Mississippian (840+ feet):		
Solid limestone	700 0	1,150 7
Flint, very hard limestone, and sandstone	140 0	1,290 7

As Kirksville is situated on the crest of the dividing ridge between Missouri and Mississippi rivers, at an altitude of 975 feet, there was no possibility of obtaining flowing water. Water was struck at a depth of 1,150 feet and rose within 240 feet of the surface. It was highly impregnated with sulphur and iron.

CALDWELL COUNTY.

BRAYMER.

The following record of a well on the farm of Dan Braymer was furnished by Mr. R. Hawkins, of Chillicothe. The surface elevation at the well is about 765 feet.

Log of well of Dan Braymer, near Braymer, Caldwell County.

	Thickness.	Depth.
Pleistocene (26 feet):	*Feet.*	*Feet.*
Dirt	8	8
Shale	8	16
Blue shale	10	26
Des Moines (420 feet):		
Red shale	10	36
Limestone	6	42
Blue shale	8	50
Limestone	10	60
Blue shale	10	70
Flint rock	13	83
Hard white shale	10	93
Limestone	4	97
Sand rock	4	101
Hard white shale	12	113
White limestone	11	124
Blue shale	14	138
Sand rock	40	178
Limestone	6	184
Slate	6	190
Blue shale	27	217
Limestone	2	219
Slate	1	220
Coal	1	221
White shale	4	225
Limestone	4	229
Blue shale	2	231
Limestone	1	232
Slate	6	238
Blue shale	4	242
Hard white sand rock	14	256
Shale	57	313
Limestone	3	316
Red shale	2	318
Limestone	2	320
Blue shale	15	335
Sand rock	20	355
Slate	2	357
Brown sand rock	13	370
Coal	3	373
Saline water stratum	65	438
Black shale to Mississippian limestone; drilled 11 feet into this limestone	8	446

CARROLL COUNTY.

CARROLLTON.

One-half mile northeast of the city of Carrollton, on the west bank of Brush Creek, is a well owned by Hugh K. Rea.[a] Altitude, about 660 feet above tide (about 70 feet lower than the Carrollton public square); depth, 241 feet; flow, feeble; date of completion, 1890; driller, J. C. Ferrie, of the Mallory Diamond Drill Company, Chariton, Iowa; surface formation, Des Moines; cost of well, $900.

The distance to the principal source of water in the basal sandstone of the Cherokee shales is 200 feet. The last 7 feet are in the chert of the Mississippian. The flow is estimated to be about a gallon in three minutes and is uniform, having neither increased nor decreased.

Another well, similar in character, was sunk about 1,200 feet southwest of the above. The following log was preserved by Mr. Wilcockson:

Log of well at Carrollton, Carroll County.

	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Pleistocene (25 feet)	25 0	25 0
Des Moines (234 feet):		
Gray shale	13 0	38 0
Dark shale	11 0	49 0
Limestone	1 0	50 0
Gray shale	3 0	53 0
Limestone	1 0	54 0
Dark shale	5 0	59 0
Limestone	1 0	60 0
Dark gray shale	6 0	66 0
Sandstone	3 0	69 0
Shale, with 12 inches slaty coal	21 0	90 0
Shale	30 0	120 0
Sandstone	4 0	124 0
Shale	17 0	141 0
Sandstone	3 0	144 0
Shale	47 0	191 0
White, soft sandstone; water rose to surface	20 0	211 0
Dark shale	5 0	216 0
Red sandstone	6 0	222 0
Dark shale	10 0	232 0
Coal	5	232 5
Dark shale	1 7	234 0
Mississippian (7 feet):		
Hard chert	7 0	241 0

A flow of saline water was struck between 200 and 210 feet. The water has no odor, but the contained gas will blow a cork from a bottle of it in a few minutes. This water is used for drinking purposes and for stock. It is slightly laxative. No analysis has been made.

[a] The writer is indebted to Mr. J. M. Wilcockson, of Carrollton, for data concerning this well.

TINA.

A prospect hole for oil, drilled on the farm of C. W. Nuss, at Tina, at an elevation of about 706 feet, gave the following record, which was furnished by Mr. R. Hawkins, of Chillicothe:

Log of prospect hole at Tina, Carroll County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (40 feet):		
Clay and sand	40	40
Des Moines (345 feet):		
Flint	4	44
Coal	4	48
Shales	20	68
Limestone	5	73
Coal	2	75
Shales	215	290
Sand rock	40	330
Black slate	55	385
Mississippian (290 feet):		
Brown limestone	40	425
Flint (probably cherty limestone)	95	520
"Slate"	5	525
Gravel	2	527
Flint, "hog chawed"	40	567
"Slate" and black limestone	75	642
Gravel and sand, with water	5	647
Very hard, flinty limestone, interstratified with other beds; water from bottom slightly alkaline	28	675

CLAY COUNTY.

EXCELSIOR SPRINGS.

Near the town of Excelsior Springs, in the northeast corner of Clay County, about 30 miles northeast of Kansas City, are two deep drilled wells—the sulphosaline, 1,460 feet deep, and the salt-sulphur, 1,370 feet deep. It is unfortunate that no record of these wells has been preserved. The waters are in all probability mainly derived from the Jefferson City limestone and the base of the Pennsylvanian. The information regarding these wells was furnished by Mr. C. W. Fish, general manager of the Excelsior Springs Company.

The sulphosaline well is located about 1 mile north of the town of Excelsior Springs in a narrow valley on the west bank of Fishing River; owner, Excelsior Springs Mineral Water Company; depth, 1,460 feet; altitude above tide, about 925 feet; diameter of casing, 34 inches; temperature of water, 67° F.; of air, 84° F.; date of completion, 1888; cost, $1,200; surface formation, upper part of Des Moines. The water stands within 150 feet of the top of this well and is pumped by a Eureka pump run by a 10-horsepower engine. It is very corrosive, and ordinary pipes last only about three years; galvanized pipes last ten years. The water is clear and sparkling, with a saline taste and a slight odor of sulphur. It contains a small amount of carbon dioxide gas.

The salt-sulphur well was sunk by W. S. Pryor, of Kansas City. The water is pumped to the Music Hall bath house, which has a swimming pool 60 by 32 feet. The owners are E. L. and E. I. Morse; depth, 1,327 feet; altitude, about 925 feet; cased to bottom; date of completion, 1899; water stands within 60 feet of surface; surface formation, upper part of Des Moines.

The following analyses of water from these two wells are given in Schweitzer's report:[a]

Analysis of water from sulphosaline well, Excelsior Springs, Clay County.[b]

	Parts per million.		Parts per million.
Silica (SiO_2)	10	Bicarbonate radicle (HCO_3)	234
Iron (Fe)	.7	Sulphate radicle (SO_4)	1,126
Aluminum (Al)	21	Chlorine (Cl)	3,808
Calcium (Ca)	239		8,189
Magnesium (Mg)	98	Residue on ignition	8,093
Sodium (Na)	2,610		
Potassium (K)	42		

Analysis of water from salt-sulphur well, Excelsior Springs, Clay County.

(Analyst, E. H. S. Bailey.)

	Parts per million.		Parts per million.
Silica (SiO_2)	11	Sulphate radicle (SO_4)	396
Iron (Fe)	4.7	Chlorine (Cl)	6,684
Calcium (Ca)	210	Bromine (Br)	14
Magnesium (Mg)	109	Iodine (I)	12
Sodium (Na)	4,392	Sulphur (S)	1.9
Potassium (K)	11		12,590
Carbonate radicle (CO_3)	69		
Bicarbonate radicle (HCO_3)	675		

Temperature of water, 64.4° F.

In connection with these wells it may not be out of place to refer briefly to the neighboring mineral springs, which, together with the wells, constitute the most popular health resort in the State. Of these springs the best are the Regent and Siloam springs, both ferromanganese waters, derived from the Pennsylvanian. In the Regent the manganese bicarbonate (16.8 parts per million) aids in the assimilation in the human system of the high percentage of ferrous bicarbonate (58.8 parts per million). The sulphosaline waters of the drilled wells counteract the astringent properties of the ferromanganese waters of the springs, and the two furnish a fortunate combination.

[a] Missouri Geol. Survey, vol. 3, 1892, p. 99.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

KEARNEY.

The following is a log of a well drilled by A. W. Stubbs near Kearney:

Log of well, 6 miles west of Kearney, Clay County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	25	25
Limestone	56	81
Sandstone	10	91
Shale	35	126
Sand; water	15	141
Limestone	20	161
Shale, muddy	28	189
Limestone	12	201
Shale	6	207
Limestone	24	231
Shale	6	237
Sandstone	12	249
Limestone	120	369
Shale	22	391
Sandstone	22	413
Shale	28	441
Sandstone	40	481
Flinty limestone, dark	10	491
Light shale	4	495
Brown limestone	4	499
Shale	4	503
Gray limestone	10	513
Black shale	12	525
Gray sandstone	12	537
Shale	24	561
Limestone	6	567
Shale	6	573
Sandy shale	40	613
Sandstone	10	623
Thin coal seam		
Shale	12	635
Limestone and coal, good	6	641
Limestone	6	647
Sandstone	24	671
Shale	6	677
Sandstone	18	695
Shale	131	826
Coarse white sandstone	12	838
Blue shale	18	856
Sandstone	30	886
Oil sandstone	12	898
Black "slate"	18	916
Sandstone; traces of oil	36	952
Salt sandstone	40	992
Black rotten shale	30	1,022
Mississippian limestone	10	1,032

DAVIESS COUNTY.

GALLATIN.

Seven miles east of Gallatin, near the head of a small draw, is a well on the farm of W. C. Macy. Depth, 22 feet; altitude above tide, about 794 feet; casing, 1¼-inch, 22 feet; temperature of water, 61° F.; of air, 82° F.; flow, feeble; date of completion, 1895; bored by farm hands; cost of well, $25. This well passed through the clay and sandstone of the Des Moines group. It may be a drift well. On entering the sandstone water was struck, which rose 8 feet above the surface. The flow is uniform. The water is clear and hard and is used for watering stock. No analysis has been made.

HARRISON COUNTY.

BETHANY.

About 1 mile west of Bethany, in sec. 16, T. 63, R. 28, on the east bank of Big Creek, is a well owned by the Bethany Improvement Company. Depth, 654 feet; altitude above tide, about 916 feet; casing, 3-inch, 45 feet to rock; flow, 5+ gallons per minute; date of completion, 1885; surface formation, Missouri group. The water is used by the Heilbron Sanitarium. It is said to be especially valuable in rheumatism. It is clear and bubbles with carbon dioxide. The log of the well is as follows:

Log of deep flowing well at Bethany, Harrison County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (45 feet):		
Earth and clay	45	.....
Missouri (53 feet):		
Hard gray limestone	11	56
Dark "slate"	8	64
Limestone	12	76
Dark "slate"	5	81
Gray limestone	17	98
"Marais des Cygnes" shale (Pleasanton) (156 feet):		
Sand shale	81	179
Limestone	5	184
"Soapstone"	4	188
Sand shale	32	220
Slaty shale	18	238
Black slate	1	239
Coal	1	240
Gray "slate"	14	254
Henrietta limestone (149 feet):		
Limestone (coal 4 inches)	3	257
Dark gray "slate"	19	276
Limestone	5	281
"Slate"	4	285
Fire clay	10	295
Limestone	16	311
"Slate" (coal 1 inch)	30	341
"Slate"	29	370
Coal	1	371
"Slate"	32	403
Cherokee shales (251 feet):		
Sand shale	11	414
"Slate"	27	441
Sand shale	9	450
Black "slate"	11	461
Blue clay	3	464
Gray "slate"	3	467
Sand shale	3	470
"Slate" (mixed)	64	534
Dark sandstone	2	536
Black "slate" (coal 7 inches)	16	552
Clay	2	554
"Slate" (mixed)	20	574
Sand shale	62	636
Bowlder	8	644
Sand shale	10	654

It is very probable that the Mississippian would have been reached had the drilling been continued 50 or 60 feet farther. The first flow of water was struck at 200 feet, and it was continuous. The last and strongest flow was reached at the bottom of the well. No analysis of this water has been made.

HOLT COUNTY.

FOREST CITY.

Near Forest City, Holt County, is a deep diamond-drill prospecting well, made in 1901. The core is preserved at the office of the State geological survey, at Rolla, Mo.

Log of prospecting well near Forest City, Holt County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pleistocene (65 feet):				
Sandy clay	65	0	65	0
Missouri (866 feet):				
Clay and bowlders	10	0	75	0
Clay shale	15	0	90	0
Blue shale	4	0	94	0
Limestone	5	7	99	7
Fossiliferous limestone	1	5	101	0
Blue shale	3	6	104	6
Limestone	11	0	115	6
Blue shale	4	0	119	6
Limestone	3	6	123	0
Limestone	2	6	125	6
Blue shale	16	6	142	0
Blue limestone	4	3	146	3
Clay shale	3	9	150	0
Blue shale	10	0	160	0
Limestone	30	0	190	0
Bark blue shale	3	0	193	0
Limestone	2	6	195	6
Blue shale	12	6	208	0
Limestone	8	0	216	0
Sand shale	17	0	233	0
Limestone	4	8	237	8
Blue shale	12	8	250	4
Sandstone, shale partings	54	8	305	0
Blue sand shale	16	0	321	0
Dark blue shale	14	0	335	0
Clay shale	33	0	368	0
Blue shale	50	0	418	0
Limestone	27	0	445	0
Black shale	9	0	454	0
Limestone	2	0	456	0
Shale	12	0	468	0
Limestone	20	0	488	0
Black shale	2	0	490	0
Limestone	10	6	500	6
Sand shale	2	0	502	6
Sandstone	3	0	505	6
Blue shale	3	0	508	6
Limestone	4	6	513	0
Dark shale	2	0	515	0
Limestone	7	0	522	0
Sandy shale	3	6	525	6
Dark shale, mixed with limestone	16	6	542	0
Limestone	15	0	557	0
Blue shale	1	9	558	9
Black "slate"	1	5	560	2
Blue shale	12	10	573	0
Limestone-conglomerate	5	6	578	6
Blue shale	4	0	582	6
Limestone	3	6	586	0
Conglomerate	9	6	595	6
Dark shale	1	0	596	6
Limestone	7	0	603	6
Black shale and limestone	3	0	606	6
Limestone-conglomerate	13	10	620	4
Bastard limestone and shale	7	10	628	2
Blue shale	4	3	632	5
Clay	2	1	634	6
Limestone	34	2	668	8
Shale	6	2	674	10
Limestone	23	2	698	0
Dark shale	3	2	701	2
Limestone and shale	2	5	703	7
Black shale	3	4	706	11
Shale and limestone	3	5	710	4
Shale and limestone	1	4	711	8

Log of prospecting well near Forest City, Holt County—Continued.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Missouri—Continued.				
Limestone	13	0	724	8
Dark shale	1	3	725	11
Sand shale	4	0	729	11
Dark shale	1	0	730	11
Coal, poor		6	731	5
Clay to dark shale	3	0	734	5
Limestone	4	2	738	7
(Iron pyrites 737 feet 6 inches to 740 feet.)				
Sandstone	3	2	741	9
Clay shale	5	2	746	11
Sandstone and a little shale	4	6	751	5
Sandstone and shale	1	4	752	9
Dark shale	13	11	766	8
Limestone	2	4	769	0
Dark shale	2	4	771	4
Limestone	3	10	775	2
Clay, shale, and a little limestone	3	10	779	0
Limestone	3	2	782	2
Dark shale	1	0	783	2
Clay shale	3	11	787	1
Clay shale and fragments	4	6	791	7
Limestone	4	10	796	5
Limestone and black shale	2	2	798	7
Black shale		10	799	5
Sandy shale	7	0	806	5
Clay shale, broken and soft	[a] 4	9	843	11
Limestone	5	5	849	4
Shale	16	11	866	3
Sandstone, fossiliferous	5	2	871	5
Sand and shale	10	0	881	5
Shale	1	4	883	4
Blue fossiliferous limestone	3	6	886	10
Blue shale with 8-inch vertical seam (silica)	2	6	889	4
Coal, fair quality		4	889	8
Sandstone	5	6	895	2
Shale	4	3	899	5
Limestone	8	11	908	4
Shale	8	4	916	8
Clay shale and lime	3	0	919	8
Limestone	2	9	922	5
Blue shale, last foot fossiliferous	4		926	5
Limestone, last 6 inches fossiliferous	2	6	928	11
Blue shale, with a little sandstone	1	3	930	2
Des Moines (690 feet):				
Blue limestone		8	930	10
Black shale, with a little thin sandstone	3	3	934	1
Clay shale, broken	2	9	936	10
Alternating sandstone and shale	14	2	951	0
Sand shale, broken	9	10	960	10
Blue shale	23	6	984	4
Fossiliferous sandstone	1	10	986	2
Coal, poor		4	986	6
Blue shale	6	4	992	6
Sandy shale	1	9	994	7
Coal, poor	1	2	995	9
Clay shale	1	4	997	1
Sandstone	5	0	1,002	1
Dark shale	8	11	1,011	0
Carbonaceous shale		5	1,011	5
Clay shale	4	0	1,015	5
Blue shale, a few lime nodules	5	9	1,021	2
Shale	15	1	1,036	3
Limestone		9	1,037	0
Black slate	1	8	1,038	8
Coal, fair quality	1	3	1,039	11
Clay shale	3	1	1,043	0
Blue limestone	2	0	1,045	0
Sandstone	3	10	1,048	10
Sand shale	5	5	1,054	3
Black shale	3	8	1,057	11
Coal, poor	1	0	1,058	11
Sandstone	4	4	1,063	3
Black shale	7	0	1,070	3
Coal, poor		9	1,071	0
Clay shale, soft	2	9	1,073	9
Clay, with some limestone	4	6	1,078	3
Shale	6	2	1,084	5
Clay shale, with sandstone and limestone	1	9	1,086	2

[a] Error in original record; probably should be 37 ft. 6 in.

Log of prospecting well near Forest City, Holt County—Continued.

	Thickness.		Depth.	
Des Moines—Continued.	*Ft.*	*in.*	*Ft.*	*in.*
Sandstone, hard, fine-grained	8	2	1,094	4
Soft, dark shale		4	1,094	8
Sandstone, shale partings	12	6	1,107	2
Dark shale, with sandstone partings	9	9	1,116	11
Shale	24	1	1,141	0
Coal, poor, with iron pyrites		9	1,141	9
Shale	18	0	1,159	9
Sandstone	5	9	1,165	6
Shale	7	4	1,172	10
Dark shale; a little pyrites at 1,182 feet 4 inches	10	0	1,182	10
Sandstone		6	1,183	4
Dark shale	3	4	1,186	8
(Block for waste in drilling out last core)	2	2	1,188	10
Sand shale	2	0	1,190	10
Shale, dark and slaty	16	1	1,206	11
Shale, with limestone nodules		3	1,207	2
Shale	7	2	1,214	4
Sandstone	1	3	1,215	7
Shale; iron pyrites from 1,216 to 1,217 feet	8	2	1,223	9
Sandstone, with some limestone	4	0	1,227	9
Soft shale		10	1,228	7
Carbonaceous shale		9	1,229	4
Blue shale		8	1,230	0
Hard, sandy shale	2	8	1,232	8
Hard gray shale	3	9	1,236	5
Blue shale	15	1	1,251	1
Coal		5	1,251	16
Blue shale		9	1,252	8
Gray shale, with coal partings; nearly 45° to axis of core		9	1,253	5
Shale	10	0	1,263	5
Coal		3	1,263	8
Light bluish sandstone	13	11	1,277	7
Blue shale	3	9	1,281	4
Sandstone	4	10	1,286	2
Coal		3	1,286	5
Sandstone	57	5	1,343	10
Blue sandy shale	3	2	1,347	0
Dark shale	9	5	1,356	5
Sandstone, coarse-grained, hard	1	1	1,357	6
Dark shale, slaty and hard	3	6	1,361	0
Sandstone	20	6	1,381	6
Dark shale	3	0	1,384	6
Coal		5	1,384	11
Shale	5	2	1,390	1
Coal		10	1,390	11
Soft clay shale, irregular cleavage	1	1	1,392	0
(Block for wasted core)	1	4	1,393	4
Shale	6	9	1,400	1
Blue shale, turning to gray sandstone in last foot	17	0	1,417	1
Sandstone	6	0	1,423	1
Fossiliferous sandstone	2	3	1,425	4
Sandstone	9	6	1,434	10
Shale	5	11	1,440	9
(Pine block for wasted core)	3	0	1,443	9
Sandstone, gray, medium to coarse grained	2	1	1,445	10
Blue shale	4	2	1,450	0
"Steatite" 3 inches, blue shale 6 inches, sandy shale 6 inches	1	3	1,451	3
Blue shale, sometimes sandy	14	9	1,466	0
Black shale, similar to above	14	0	1,480	0
Dark shale, cleavage up to 35° of core axis	4	8	1,484	8
Blue shale	4	0	1,488	8
Coarse gray sandstone with a little limestone	4	9	1,493	5
Clay shale	2	4	1,495	9
Gray sandstone	4	3	1,500	8
Sandstone	6	8	1,506	8
Black shale; patches of sandstone at 1,511 feet 4 inches	11	6	1,518	2
Sandstone	10	6	1,528	8
Hard, sandy shale	1	4	1,530	0
Coal		2	1,530	2
Sandstone, light, with two steatitic partings	4	0	1,534	2
Sandy shales, with partings of white sandstone	5	10	1,540	0
Shale and sandstone	3	1	1,543	1
Light-blue shale, with thin streaks of white sandstone	8	8	1,551	9
Sandstone, light blue	3	8	1,555	5
Sandstone and shale	1	11	1,557	4
Shale	2	8	1,560	0
Light sandstone, fine grained and hard	6	0	1,566	0
Blue shale with steatite sections and partings, and some diagonal displacements, with highly polished surfaces	14	0	1,580	0
Sandstone, coarse, irregular, with iron pyrites, mica granules, and small fossil fragments	2	0	1,582	0

Log of prospecting well near Forest City, Holt County—Continued.

	Thickness.		Depth.	
Des Moines—Continued.	*Ft.*	*in.*	*Ft.*	*in.*
Blue shale, sandy and harder in last foot	4	2	1,586	2
Fossiliferous sandstone	1	6	1,587	8
Fossiliferous sandy shale, with horizontal partings	2	4	1,590	0
Blue shale, with vegetable remains; iron pyrites at 1,602 feet 2 inches, 1,605 feet 9 inches, 1,608 feet 1 inch, and 1,608 feet 10 inches	21	5	1,611	5
Shale and sandstone, with vegetable partings	1	10	1,613	3
Fine-grained sandstone, parting freely into small, clear crystals	3	7	1,616	10
Sandstone with a little limestone	3	3	1,620	1
Mississippian (293 feet):				
Limestone (marble ?) with some sandstone	10	0	1,630	1
Blue limestone	3	5	1,633	6
Sandstone and limestone	2	10	1,636	4
Limestone	3	10	1,640	2
Limestone with many partings	20	0	1,660	2
Limestone	8	6	1,668	8
Limestone, with several masses of quartz up to 7 inches in diameter	11	5	1,680	1
Ragged quartz and limestone	11	5	1,691	6
Sandy shale and limestone	1	5	1,692	11
Limestone and sandstone	5	1	1,698	0
(Block for wasted core)	2	0	1,700	0
Limestone with thin partings	18	6	1,718	6
Blue shale with horizontal partings	1	6	1,720	0
Limestone with few partings; fossils from 1,738 feet 8 inches to 1,740 feet	30	0	1,750	0
Hard, light limestone, with fossils and quartz crystals	10	0	1,760	0
Limestone, with irregular partings at 1,761 feet and 1,778 feet 6 inches to 1,780 feet	20	0	1,780	0
Limestone	2	5	1,782	5
Very hard quartzite		7	1,783	0
Limestone	11	6	1,794	6
Chert		2	1,794	8
Sandy limestone		10	1,795	6
Chert		9	1,796	3
Hard and sandy limestone	1	8	1,797	11
Broken chert and limestone		10	1,798	9
Limestone, sandy and hard	1	3	1,800	0
Fossiliferous limestone	1	6	1,801	6
Chert		3	1,801	9
Fossiliferous limestone	1	5	1,803	2
Chert ending in quartzite	1	0	1,804	2
Magnesian limestone; quartz at 1,805 feet 6 inches	5	10	1,810	0
Limestone, chert, and quartzite, with fossils	3	7	1,813	7
(Block for wasted core)	7	5	1,821	0
Sandstone, light, with some lime	1	3	1,822	3
Bluish sandstone, with lime	7	9	1,830	0
Sandstone, bluish, lime increasing	7	0	1,837	0
Limestone	3	0	1,840	0
Limestone with some marble (?); a few spots of sandstone and chert	73	5	1,913	5
Devonian (128 feet):				
Blue shale mixed with a little lime	6	7	1,920	0
Sandy shale	3	10	1,923	10
Shale, blue, green-brown, and red, containing iron oxide	80	4	2,004	2
Shale, with lime	19	10	2,024	0
Shale, fine grained, increasing in hardness	16	0	2,040	0
Blue shale	1	1	2,041	1
Silurian (359+ feet):				
Fossiliferous limestone	16	9	2,057	10
Blue shale	4	9	2,062	7
Limestone	17	5	2,080	0
Limestone, some thin partings	40	0	2,120	0
Limestone, "half-inch shale"	23	0	2,143	0
Limestone	19	5	2,162	5
White and blue chert		4	2,162	9
Limestone	34	3	2,197	0
Coarse limestone; cavities lined with quartz crystals	3	0	2,200	0
Limestone	80	00	2,280	0
Dark-gray limestone, sandy, hard	13	10	2,293	10
Limestone; many cavities; black-shale partings	7	3	2,301	1
Limestone; 2 inches of chert and quartz at 2,335 feet 7 inches	18	11	2,320	0
Limestone, white, fine grained	12	2	2,332	2
Limestone; small quartz crystals in last 4 feet	7	10	2,340	0
Limestone; many cavities, often with small quartz crystals; occasional spots of chert	10	0	2,350	0
Gray limestone, chert increases	1	4	2,351	4
Dark limestone, some chert	2	0	2,353	4
Dark limestone, sharp sand with fossils	6	8	2,360	0
Limestone; solution cavities and fossil molds abound	40	0	2,400	0
(No return of water below 2,350 feet.)				

LINN COUNTY.

BROOKFIELD.

A shaft and boring at Brookfield gave the following section:

Section of shaft and boring at Brookfield, Linn County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Surface deposits (the rhomboidal limestone should have come in here, 17 feet below the surface, but for some reason it was not found)	30	0	30	0
Hard rock, next below No. 42, and found in the bed of the creek near by	1	10	31	10
Fire clay and shales	16	0	47	10
"Soapstone"	25	0	72	10
Coal (Nutter's)	1	3	74	1
Fire clay and shales	14	0	88	1
Concretions	6	0	94	1
Hard rock	1	8	95	9
"Soapstone"	52	8	148	5
Coal (working seam)	2	4	150	9
Brown fire clay and shales	16	0	166	9
Concretions	14	0	180	9
Fire clay	10	0	190	9
Sand rock (lowest rock at Joabs Creek)	8	0	198	9
Fire clay	3	0	201	9
"Soapstone"	4	0	205	9
"Slate"		8	206	5
Fire clay (bottom of shaft)	5	0	211	5
Below this a boring penetrated the following:				
"Soapstone"	8	0	219	5
Fire clay	4	0	223	5
"Soapstone"	14	0	237	5
Fire clay	4	0	241	5
"Soapstone"	2	0	243	5
Coal	2	1	245	6
Fire clay		5	245	11
Coal		6	246	5
Fire clay and shales	15	0	261	5
Sandstone	8	0	269	5
"Soapstone"	10	0	279	5
Hard rock; pyrites		8	280	1
"Soapstone"	10	0	290	1
"Slate" and shales		6	290	7
Concretions	4	0	294	7
Hard rock (not bored through)	2	0	296	7

ST. CATHERINE.

A shaft and boring at St. Catherine showed the following section:

Section of shaft and boring at St. Catherine, Linn County.[a]

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Clay	14	0	14	0
Rotten "slate"	6	0	20	0
Flinty sandstone	3	0	23	0
Coal	1	4	24	4
Clay	2	5	26	9
"Soapstone"	22	0	48	9
Hard limestone	1	0	49	9
Blue sand	6	0	55	9
"Soapstone"	40	0	95	9
Coal (bottom of shaft)	2	3	98	0
Below this a boring was made and passed through the following:				
Fire clay	3	0	101	0
Hard, flinty sand rock	8	0	109	0
"Soapstone"	60	0	169	0
Black "slate"	4	6	173	6
Coal	2	6	176	0
Fire clay	4	0	180	0
"Soapstone"	35	0	215	0
Coal	3	0	218	0

[a] This section and the one at Brookfield are taken from Broadhead, G. C., Missouri Geol. Survey, vol. 1, 1874, p. 267.

LIVINGSTON COUNTY.

CHILLICOTHE.

About 3 miles from Chillicothe, in sec. 28, T. 58, R. 23, is a gas prospect hole whose mouth is at an altitude of about 825 feet. The following log has been furnished by Mr. R. Hawkins, of Chillicothe:

Log of gas prospect hole about 3 miles from Chillicothe, Livingston County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (56 feet):		
Yellow clay	0	30
Soft yellow sandstone	15	45
Light-colored shales	11	56
Des Moines (425 feet):		
Hard conglomerate; cased from top, 8¼ inch	2	58
Black "slate"	3	61
Soft light-colored gray shales	69	130
Sandstone, with 6-inch coal	3	133
Light-colored shales	57	190
Black "slate"	4	194
Gray shales	36	230
Red and greenish-gray shale; caved	8	238
Dark shales with barren coal seam; cased from top, 7½-inch	13	251
Limestone	1	252
Gray shales	45	297
Brown "smut"	3	300
Drab and purple clays and shales, with coal particles	48	348
Soft, nearly white sandstone, rounded grains	3	351
Black sand shales; saline water at 406 + feet	79	430
Porous conglomerate; saline water	12	442
White, plastic fire clay	10	452
Sandy coal and fire clay, gray to purplish	29	481
Keokuk and Burlington (319 feet):		
White, very hard, flinty limestone	3	484
Soft white limestone, with flinty layers and a soft white substance (gypsum?) not a carbonate	38	522
Sandstone, fire clay, "slates," and pebbles; saline water	62	584
Soft, chalky limestone	12	596
Flint or quartzite sandstone, shales, etc	6	602
Black shales, very little lime	14	616
Soft sandy gray calcareous rock	20	636
White and blue calcareous shales and flint	9	645
Soft sandy gray calcareous rock	69	714
Dark plastic to hard joint clay, caved badly; cased, 4½ inch, at 762 feet	48	762
White limestone	4	766
Dark "hydraulic" limestone	13	779
Pure, soft white limestone	21	800
Chouteau (81 feet):		
Brownish mealy limestone; saline water	46	846
Crystalline limestone	8	854
Dark impure limestone; saline water	27	881
Hannibal formation (101 feet):		
Fine yellowish-gray lime sand	25	906
Light to dark gray limestone, with some yellowish sand	11	917
Gray to orange sandstone, with some lime; gas	65	982
Devonian (94 feet):		
Limestone, with black organic matter	8	990
Limestone, with gray sandstone at top	75	1,065
Fine brown lime sand, with pyrite, etc	11	1,076
St. Peter sandstone (25 + feet):		
Hard quartzite	20	1,096
Pure white sand, with saline water; caved	5	1,101

UTICA.

In sec. 2, T. 25, R. 56, in the valley of a small branch which empties into Shoal Creek, about 5 miles southwest of Utica, Livingston County, is a well owned by G. H. Lawson. Depth, 421 feet; altitude above tide, about 660 feet; casing, 5⅝ inch; 400 feet (partially cased); temperature of water, 59° F.; of air, 76° F.; flow, weak; date of completion, 1897; driller, C. P. Thomas, of West Bend, Iowa; cost of well, $1,000; surface formation, lower Pennsylvanian. The principal

source of the water is at a depth of 360 to 370 feet, in the soft basal sandstone of the Cherokee shales. A nonflowing vein of water was reached at a depth of 35 feet. The present flow is feeble, the water rising only about 10 feet above the surface. The well was sunk to obtain water for stock, but the flow was so weak—only about 40 barrels per day—that the owner put in a $1,500 pumping plant. The water is saline, with a small amount of hydrogen sulphide and some iron, which is precipitated around the well. No record was kept. The drill, however, passed through the Des Moines into the Mississippian. The following is a copy of the analysis of this water made by Professor Schweitzer, no date being given:

Analysis of water of Lawson well, near Utica, Livingston County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	13	Potassium (K)	45
Iron (Fe)	10	Sulphate radicle (SO_4)	1,589
Calcium (Ca)	312	Chlorine (Cl)	4,250
Magnesium (Mg)	136		
Sodium (Na)	2,728		8,783

This water, though strongly saline, is said to be excellent for stock, and is a good example of the waters that are derived from the base of the Cherokee shales.

MERCER COUNTY.

WASSON CREEK.

Two and one-half miles south of Lineville, Iowa, in Mercer County, Mo., in the east half of lot 2, NW. ¼ sec. 1, T. 66, R. 24, in a valley about 100 feet from Wasson Creek, is a well owned by M. B. Haver & Son. Depth, 153 feet; altitude above tide, about 672 feet; depth of casing, 27 feet; temperature of water, 53° F.;[b] of air, 65° F.; flow feeble; date of completion, 1879; driller, J. H. Reger, Lineville; cost, $150; surface formation, Des Moines, under Pleistocene.

The partial record of this well which follows was given from memory by the driller:

Log of Haver well in Mercer County, near Lineville, Iowa

	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Pleistocene	27 0	27 0
Blue bastard limestone	1 0	28 0
"Marias des Cygnes" shales (Pleasanton) (125 feet):		
"Soapstone"	8 0	36 0
Gray "slate"	35 0	71 0
Coal	2	71 2
Fine clay	5	71 7
Sandstone	3 0	74 7
Gray "slate"	30 0	104 7
Coal	3	104 10
"Slate" and thin coal seams	45 2	150 0
Sandstone	3 0	153 0

[a] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

[b] In Sweitzer's report on Mineral Waters, vol. 3, Missouri Geol. Survey, 1892, p. 128, A. E. Woodward gives the temperature of this well in 1892 as 52° F., air temperature 71° F.

It is possible that the 1 foot of limestone is the base of the Missouri group. At the bottom of the well the drillers struck a quicksand that was so difficult to penetrate that they stopped work. Water was struck at 27 feet and in the sandstone at 150 feet. The water came up slowly during the night and flowed gently over the top of the pipe. The flow, although constant, is very feeble when not pumped. The analysis here given was made by Woodward and Schweitzer:[a]

Analysis of water from Haver well, near Lineville, Iowa.[b]

	Parts per million.		Parts per million.
Silica (SiO_2)	2	Potassium (K)	16
Aluminum (Al)	2.6	Sulphate radicle (SO_4)	2,245
Calcium (Ca)	9.6	Chlorine (Cl)	171
Magnesium (Mg)	11		
Sodium (Na)	1,047		3,504.2

This water has a local reputation and is shipped to various points. It is esteemed as especially valuable for constipation and stomach and kidney troubles. Schweitzer places this well in the Glauber salt (sodium sulphate) group of the sulphatic waters, or those containing sulphates as their main constituents. He has shown that dolomitic limestone containing gypsum, as associated with marls rich in alkalies, or other rocks containing alkaline carbonates or silicates are favorable for the formation of Glauber salt springs or wells.

About 250 feet southwest of the Haver well is a well owned by J. H. Reger. Depth, 158 feet 8 inches; altitude above tide, about 680 feet; temperature of water, 54° F.; of air, 65° F.; water rises nearly to the surface; date of completion, February, 1892; driller, J. H. Reger; surface formation, Des Moines, under Pleistocene. The water is strongly chalybeate, and in this respect differs from that of the Haver well, which contains no iron. It is valued as a tonic and in kidney troubles.

A well in the immediate vicinity owned by J. S. Haymaker has a depth of 202 feet; altitude above tide, 672 feet; casing, 6-inch, 92 feet; temperature of water, 53° F.; of air, 65° F.; water rises nearly to the surface; date of completion, March, 1902; drillers, Frank Bowles and Ed Jumper; cost, $250; surface formation, Des Moines, under Pleistocene. The first water was struck at a depth of 134 feet and rose within 26 feet of the top of the well; a second vein of water was struck at a depth of 175 feet which rose within 23 feet of the surface. The log of this well corresponds to that of the Haver well; the water also is similar and apparently has the same composition.

[a] Missouri Geol. Survey, vol. 3, 1892, p. 128.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

PRINCETON.

The following record of a well 10 miles southeast of Princeton, Mercer County, was obtained by Mr. R. Hawkins, of Chillicothe:

Log of well 10 miles southeast of Princeton, Mercer County.

	Thickness.	Depth.
Pleistocene (180 feet):	*Feet.*	*Feet.*
Clay	180	180
Des Moines (321 feet):		
Hard rock, about	10	190
Conglomerate	30	220
Not reported	20	240
Coal	4	244
Hard white sand rock	13	257
Coal	5	262
Shales	3	265
Not reported	236	501

No water was obtained.

NODAWAY COUNTY.

BURLINGTON JUNCTION.

At Burlington Junction, Nodaway County, one-half mile south of the Chicago, Burlington and Quincy Railway station, is a well owned by the Nodaway Valley Oil, Gas, and Mineral Company. Elevation of curb, 969 feet; driller, Sherman Burdick; date of completion, 1905; kind of water, saline. The following log is taken from the original record of J. N. Maupin:

Log of the well of Nodaway Valley Oil, Gas and Mineral Company, Burlington Junction, Nodaway County.

	Thickness.	Depth.
Pleistocene (68 feet):	*Feet.*	*Feet.*
Soil	68	68
Missouri (910 feet):		
Coal		68
Blue shales	459	527
Yellow ocher	18	545
Sand shells	100	645
Salt sand	20	665
Lime shells	30	695
Shale	40	735
Hard blue limestone	30	765
Lime shells	15	780
Shale	66	846
Limestone	25	871
Shale	40	911
Limestone	15	926
Shale	30	956
Limestone	20	976
Brown sand	2	978
Des Moines (722 feet):		
White Trenton rock	117	1,095
Gas sand	30	1,125
Black shale	114	1,239
Brown sand	1	1,240
Black shale	17	1,257
White "talc"	3	1,260
Lime shells	10	1,270
Black shale	300	1,570
Lime shells	30	1,600
Black shale sand	40	1,640

Log of the well of Nodaway Valley Oil, Gas and Mineral Company, Burlington Junction, Nodaway County—Continued.

	Thickness.	Depth.
Des Moines—Continued.	*Feet.*	*Feet.*
Black shale and sand mixed	30	1,670
Red Dakota sand	2	1,672
Black shale and fine sand	20	1,692
Brown sand	5	1,697
Black shale, sand, peacock colors, and traces of oil	20	1,717
Mississippian (186+ feet):		
Lime sand	11	1,728
Pebble sand	10	1,738
Red Trenton rock or cap rock	165	1,903

This well was sunk for oil, and no record was kept of water horizons.

MARYVILLE.

On the west side of the road leading north from the Burlington Railway station, in the NE. ¼ SE. ¼, sec. 17, T. 64, R. 35, is a well owned by Miss Alice Beal. This well is about 15 feet above the level of the railroad track. It was drilled in 1884 by Thomas Brown, of the Diamond Drill Company, Chicago, Ill., to a depth of 1,003 feet. It has a 4-inch bore, and is cased 300 feet to solid rock. A good vein of water was struck at 600 feet. The driller's record book was loaned to the Missouri State geologist in 1885 and was subsequently lost.

SOUTH-CENTRAL DISTRICT.

GENERAL ARTESIAN CONDITIONS.

The south-central district includes the area between the Atchison, Topeka and Santa Fe Railway and a line running from Kansas City through Sedalia, Versailles, and along Osage and Missouri rivers to Warren County, thence northward along the ridge that bounds the northeast district to Iowa. Geologically this district is divided by Missouri River into two well-marked sections. Except for narrow patches of Mississippian in Harrison and Boone, the Pennsylvanian rocks underlie the northern section. The great dividing ridge, or northeastern extension of the Ozark dome, running across the northern half of the State, dips gently to the northwest, although it is broken here and there by slight anticlinal folds and disturbances. Flowing wells are generally confined to the area along Missouri River, where erosion has cut down the surface to such a degree that there is sufficient head for the underground water. South of Missouri River, Cambrian rocks are exposed on the west slope of the Ozark dome, but the dip to the northwest brings successively to the surface the Mississippian, Des Moines, and Missouri rocks. Along this slope, which is decidedly broken and disturbed in Saline and Cooper counties, conditions are favorable for artesian waters. The development of anticlinal folds along the western side of the Ozark Mountains has left its impress on the topography and especially on

the course of the rivers. An anticline that enters Missouri from Kansas just south of Kansas City has deflected Missouri River at that point from a southerly to an easterly course, across several anticlinal ridges with a northeast-southwest strike, which pass from Vernon County through Saline County and deflect Missouri River to the north. One of these axes is well defined one-fourth of a mile east of Napton, on the Missouri Pacific Railway, and near Lisbon, on the other side of the river, the continuation of the axis is exposed. At Higbee a well 300 feet deep reached the Mississippian series at 240 feet, showing that one of these anticlinal folds probably stands near this point. It is likely that this anticline has an important bearing on the saline waters of Saline and Howard counties. There are flowing wells at or near the following places: Brunswick and Salisbury, Chariton County; Randolph Springs, Randolph County; Malta Bend and Sweet Springs, Saline County; Boonslick and Fayette, Howard County; Sedalia and Smithton, Pettis County; Fortuna, Moniteau County; Olean, Miller County; California, Moniteau County; Cedar City, Callaway County, and in southeastern Cole County.

AUDRAIN COUNTY.

MEXICO.

At Mexico, Audrain County, the waterworks company drilled a well 1,025 feet deep to supply the city with water. The altitude of Mexico, at the Chicago and Alton Railway station, is 811 feet. The following log was obtained:

Log of waterworks company well, Mexico, Audrain County.

	Thickness.	Depth.
Pleistocene (15 feet):	*Feet.*	*Feet.*
Soil	15	15
Des Moines (130 feet):		
Limestone and fragments of gray quartz or gravel	10	25
Limestone, soft, drab, earthy	10	35
Limestone, darker and harder, with black shale	15	50
Black shale	2	52
Limestone, soft, light bluish gray	13	65
Shale, black, bituminous	5	70
Limestone, fine grained, with fragments of black shale	50	120
Limestone, fine grained, soft, light gray, no shale	20	140
Coal, bituminous	5	145
Mississippian (420 feet):[a]		
Chert, hard, gray, yellowish coating on some fragments	15	160
Chert, hard, gray hornstone, some white and opaque	40	200
Limestone with some chert and shale	250	450
Sandstone, rounded, white, translucent quartz grains; some limestone and chert	80	530
Limestone, soft, gray, earthy	35	565
Limestone, soft, gray, with green shale	65	630
Sandstone, white quartz, chert, limestone and shale	40	670
Limestone, gray, compact, earthy; some shale	10	680
Chert, white, iron stained; a few grains of quartz sand	25	705
Limestone, compact, earthy; some shale and chert	135	840
Chert; some limestone and shale	20	860
Limestone and soft yellowish-white powder	10	870
Sandstone, white quartz, with considerable limestone	10	880
Limestone, soft, gray	90	970
Limestone in soft white powder	55	1,025

[a] The correlation below 565 feet becomes too uncertain to be of any value.

The following is a sanitary analysis of water from this well, made by Prof. Charles R. Sanger, of Washington University, St. Louis:

Sanitary analysis of water from waterworks well, Mexico, Audrain County.

[Samples collected October 5, 1896.]

	Parts per million.
Total residue from unfiltered water	531
Loss on ignition from unfiltered water	52
Fixed residue from unfiltered water	479
Total residue from filtered water	479
Loss on ignition from filtered water	42
Fixed residue from filtered water	437
Nitrogen as free ammonia	558
Nitrogen as nitrates	.06
Oxygen consumed	98
Chlorine	45.7
Permanent hardness	None.
Temporary hardness	275
Lime (CaO)	99.5
Magnesia (MgO)	52.5
Alkali carbonate	54.8
Turbidity, slight.	
Sediment, very slight.	
Color, none.	
Taste, slightly alkali.	
Odor, none.	
Bacteria after 96 hours culture, 378 per cubic centimeter.	

VANDALIA.

There are about 45 drilled wells near Vandalia, Audrain County, varying from 120 to 450 feet in depth. It has been impossible to obtain the logs of any of these wells, but it is stated that they furnish an abundance of water for stock and farm purposes, and that water rises within 25 to 75 feet of the surface. The water-bearing formations in these wells are usually gravel or sandstone, and the water is commonly hard, with occasionally some sulphur.

BOONE COUNTY.

COLUMBIA.

Two miles northeast of Columbia, Boone County, is a well owned by the city of Columbia and drilled by Cliff Rummons. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well near Columbia, Boone County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soft yellow clay	40	40
White lime	40	80
Soapstone blue, with gravel	4	84
Blue shale, light in color	36	120
Shale, mundic, some sand mixed; caving; casing driven from 300 to 450 feet	330	450
Blue lime rock, easy drilling	100	550
Blue flint rock, with crevices and a light showing of zinc ore	25	575
White sand and lime rock	100	675
Soft light flint rock	85	760
Open crevice; full of water, which was analyzed at Missouri University and proved to be of a fine quality	15	775
White and blue flint	25	800

CALLAWAY COUNTY.

CEDAR CITY.

A well at Cedar City, owned by F. M. Pease & Co., of Chicago, was drilled by Charles York, of Allentown, Allegany County, N. Y. It is situated in a stream bed about half a mile from the Missouri River bottoms, at an altitude of about 560 feet. It was drilled to a depth of 1,282 feet, with a 10-inch bore, and completed in 1902. Water was found in sand, and flowing water was reached at depths of 182, 220, and 423 feet. The flow from the 423-foot level was strong. The force increased at 700 and 800 feet and was strongest below 1,200 feet. Mr. S. W. Cox states that the flow was so strong at 1,282 feet that the drill could make no headway, and work was stopped. The water is clear, cold, and soft. The drilling was started in the Jefferson City limestone.

FULTON.

At Fulton, Callaway County, there are a number of deep wells, from two of which the city derives its water supply. Well No. 1 was drilled in 1888 to a depth of 785 feet with a 9-inch bore. Well No. 2 was drilled in 1895 to a depth of 703 feet with a 9-inch bore. The following information was secured through the kindness of Mr. D. K. Greger, of Fulton:

The temperature of the water from these wells is 58° F., the air temperature 72° F. The altitude is 814 feet above tide. A strong flow was struck at a depth of 450 feet. The well was cased to this depth, and the water rose within 240 feet of the surface. Both of these wells are located inside of the pump house, and they obtain water from the same bed, as when No. 2 was drilled below 450 feet the cuttings caused the water in No. 1 to be discolored. The stratum struck at 450 feet was the St. Peter sandstone. As the beds dip north by northwest this formation comes to the surface toward the southeast in the Ozarks. The following log gives the record for both of these wells:

Log of wells Nos. 1 and 2, Fulton, Callaway County.

	Thickness.	Depth.
Pleistocene (40 feet):	*Feet.*	*Feet.*
Soil, clay, shale, shaly sandstone	40	40
Graydon sandstone (80 feet):		
Graydon sandstone conglomerate	80	120
Burlington (20 feet):		
Limestone, light gray	12	132
Limestone, red-brown	8	140
Kinderhook (3 feet):		
Sandy, yellow shale	3	143
"Hamilton"[a] (70 feet):		
Shale, white, in cuttings	31	174
Limestone	39	213

[a] This Hamilton has been described by D. K. Greger (Am. Geologist, vol. 12, 1893, p. 204) from outcroppings in the county. Mr. Greger further states that the Chouteau limestone is not developed in this region; that the Trenton and Hudson River are likewise missing; and that the Devonian rests directly on the magnesian series—in some places on the Joachim limestone and in others on the St. Peter sandstone.

Log of wells Nos. 1 and 2, Fulton, Callaway County—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Joachim limestone (42 feet):		
Buff magnesian limestone	42	255
St. Peter sandstone (120 feet):		
Sandstone	120	375
Jefferson City limestone (214 feet):		
Buff magnesian limestone; strong water at 450 feet	214	589
Roubidoux sandstone (65 feet):		
Sandstone	65	654
Gasconade limestone (131 feet):		
Limestone	[a] 126	780
Sandstone	5	785

The following analysis[a] was made April 5, 1904:

Analysis of water from well No. 1 at Fulton, Callaway County.

	Parts per million.
Total residue after evaporation	531
Chlorine	12.5
Oxygen consumed	1.75
Free ammonia	.48
Albuminoid ammonia	.55
Nitrates	.31
Nitrites	None.

Color, clear.

Odor, none.

Bacteria in 1 cubic centimeter (¼ teaspoonful of water, agar pits counted the third day), 118,115.

Growth of bacteria in beef tea at 40°–42° C., cloudy.

Intra-peritoneal injection of beef-tea culture, incubated at 40° C. for twenty-four hours, killed guinea pig.

At the State hospital No. 1, one-half mile east of Fulton, are two deep drilled wells, one on a hill and one on a plain, 960 and 904 feet deep, respectively. The principal vein of water was found in both at about 800 feet in black porous sandstone. The water rises within 180 feet of the surface.

Another well is located at the deaf and dumb asylum and still another at the tobacco factory, but no data for either of these could be obtained.

CHARITON COUNTY.

BRUNSWICK.

One-fourth of a mile north of the Brunswick city hall, in sec. 3, T. 53, R. 20, on a bluff overlooking Missouri River, is a well owned by S. Benecke & Co. Depth, 1,505 feet; altitude above tide, 712 feet; casing, 8-inch, 600 feet; temperature of water, 53° F.; date of completion, 1887; surface formation, Des Moines. This well was sunk in the hope of obtaining natural gas. As this was not found at a depth of

[a] Bull. Missouri State Board of Health, April, 1904.

1,505 feet, the well was cased to 700 feet, and since then the mineral water has been used for drinking and bathing purposes. The log of the well has been lost. The following information was given from memory by the owner of the well:

Solid Mississippian limestone was struck at a depth of 130 feet, everything down to that point being Des Moines. "At a distance of about 300 feet [a] we struck a very strong salt water, one tin cupful of which when evaporated left a teaspoonful of salt. When we reached 1,400 feet, the water began to flow freely and continued to do so long after we abandoned the well." The flow has, however, been decreasing from year to year, and at present the water stands within 10 feet of the surface. It is probable that the main flow was derived from the St. Peter sandstone at a depth of 1,400 feet. Mr. Benecke further states that a bed of fine white marble was found somewhere in the neighborhood of 900 feet. This was probably dolomite. The following analysis is given by Schweitzer in his report on the mineral waters of Missouri:

Analysis of water from well at Brunswick, Chariton County.[b]

	Parts per million.		Parts per million.
Silica (SiO_2)	5	Bicarbonate radicle (HCO_3)	597
Calcium (Ca)	740	Sulphate radicle (SO_4)	1,304
Magnesium (Mg)	329	Chlorine (Cl)	8,228
Sodium (Na)	4,706		15,909
Lithium (Li)	Trace.		

This water, which is strongly saline and highly charged with sulphureted hydrogen, comes under the second division of Schweitzer's muriatic waters and is somewhat similar to that of the Louisiana well. At one time this well was a popular resort. A bath house, since destroyed, was built, and the water was also used internally because of its aperient qualities. The well cost about $3,500, of which the city paid $2,000 and the citizens the remainder.

SALISBURY.

In the southeastern part of Salisbury, on a gentle southern slope, is a well owned by the city. Depth, 852 feet; altitude, above tide, 740 feet; casing, 6-inch, 100 feet; temperature of water, 58° F.; flow, weak; date of completion, 1896; cost, $2,500; surface formation, Des Moines. The city of Salisbury started this well in 1895 and finished it in 1896. No record of the drilling was kept. It is stated that the drill passed through 6 feet of soft loam, about 70 feet of soft sand, and 60 feet of

[a] This was probably in the Hannibal shales.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

white sandstone. The first water was reached at 150 feet and the second at 210 feet, both being fresh. At a lower level, below 600 feet, a flow of salt sulphur water was obtained. The flow has not materially changed. The water is used medicinally for drinking and baths. The following is an analysis of this water made by Schweitzer in 1896:

Analysis of water from well at Salisbury, Chariton County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	21	Lithium (Li)	.56
Iron (Fe)	5	Carbonate radicle (CO_3)	454
Manganese (Mn)	1.2	Sulphate radicle (SO_4)	1,346
Calcium (Ca)	491	Chlorine (Cl)	6,030
Magnesium (Mg)	396	Bromine (Br)	12
Sodium (Na)	3,538		12,356
Potassium (K)	61		

The water is a muriatic water of value. Its salts of iron, manganese, magnesia, and lithium, as well as the bromide, give it therapeutic effects. The source of this water is doubtful. It is greatly to be regretted that the drillers of several important wells in this district have either kept no logs or lost those which were kept.

COLE COUNTY.

EUGENE.

Three miles southwest of Eugene, Cole County, in sec. 13, T. 41, R. 14, is a well owned by the Bell Tunnel Mining Company, and drilled by Charles E. Miller. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well of Bell Tunnel Mining Company near Eugene, Cole County.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and chert	17	17
Lime, with clay openings, water	38 (?)	55
Hard, blue lime	5	60
Open ground in limewater	5	65
Blue lime and calcite	13	78
Gray magnesia lime with layers of flint at intervals; water stronger as greater depth is reached	158	236

This well is probably in Jefferson City limestone.

MISCELLANEOUS WELLS.

In southern Cole County, and in Miller County adjoining, a number of prospect holes sunk for mineral struck water that rose to the surface. Two of these are located on the farm of Dell Karr, about one-

[a] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

half mile east of Bass post-office on the south line of sec. 31, T. 43, R. 12. One of these wells was 110 feet deep with a 6-inch bore, and was drilled about 1901 by Mr. Groover, of Jefferson City. The water flowed feebly at the surface. Twenty-five feet away another well was sunk to a depth of 50 feet. Both of these probably obtain water from the Gasconade limestone. No log was kept.

One-half mile south of the Karr place, on the farm of Daniel Schreiber, two prospect holes were sunk. In the one in the valley the water rose 5 feet above the casing; but the one on the ridge, about 50 feet higher, did not flow. One-half mile southwest of the Karr place, on the farm of Mrs. Annie Barnhardt, a prospect hole sunk to the depth of 100 feet resulted in a flowing well. One mile due south of the same place Mr. Marstellar has two flowing wells, each about 100 feet deep.

About 2½ miles south of Hickory Hills post-office, on the Wallace Scott property, near the middle of T. 42, R. 13, on Bob Druly Creek, three prospect holes within half a mile of each other were sunk to a depth of 100 feet each. These were all 6-inch holes made by a churn drill. Of these wells the one near the mining shaft has a feeble flow; another, a quarter of a mile to the east, is much stronger, and a third, a quarter of a mile to the southeast, gives a good stream of water. The temperature of the water in these wells is 58° F., with the air temperature 93° F. The water is clear, with a slight odor of sulphureted hydrogen. All of these wells probably obtain water from the Gasconade limestone. Another well, three-fourths of a mile northeast of Hickory Hills, obtains flowing water at a depth of 217 feet.

HOWARD COUNTY.

BOONSLICK.

In a narrow valley a few hundred feet below the old Boonslick salt springs, where Daniel Boone settled and manufactured salt, is a well owned by W. M. Marshall, of Boonesboro. The writer is indebted to Prof. A. F. Hendrix, of Kansas State University, for the log of this well and for assistance in various other ways: Depth, 1,002 feet 4 inches; altitude above tide by aneroid barometer, 599 feet; casing, 1½-inch, 400 feet; temperature of water, 62° F., of air, 88° F.; flow, 20 to 30 gallons per minute; date of starting, 1869; of completion, 1872; surface formation, Des Moines, under Pleistocene.

Log of Marshall well, Boonslick, Howard County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pleistocene (22 feet):				
Soil (wooden conductor 10 inches square)	22	0	22	0
Des Moines (66 feet 11 inches):				
Flint rock	2	10	24	10
Hard limestone	2	0	26	10
Hard gravel		11	27	9
Soft limestone	2	2	29	11
Dry crevice		7½	30	6½
Hard flint; fresh water	6	9	37	3½
Slate rock		8	37	11½
"Stone coal"	2	6	40	5½
"Slate"		10	41	3½
"Soapstone"	19	6	60	9½
Blue limestone	4	3½	65	1
White limestone; small vein of salt water	3	0	68	1
Soft white limestone	5	6	73	7
Flint bowlder	1	6	75	1
White limestone	6	9	81	10
"Stone coal"		7	82	5
"Soapstone"	4	2	86	7
Flint and limestone	1	2	87	9
"Soapstone"	1	2	88	11
Mississippian (217 feet 1 inch):				
Black flint		5	89	4
Coarse gray limestone	13	7	102	11
White limestone and flint	3	0	105	11
Coarse gray limestone	2	0	107	11
Red flint		5	108	4
Coarse gray limestone	1	7	109	11
White shale, flint	2	10	112	9
Gray limestone and spar	10	4	123	1
Black flint		4	123	5
White limestone	1	6	124	11
Hard white flint	1	1	126	0
Soft limestone		9	126	9
Hard gray flint		7	127	4
Gray limestone	4	0	131	4
Black flint		4	131	8
Gray limestone	1	0	132	8
White flint		4	133	0
White limestone		5	133	5
White flint		3	133	8
White limestone		5	134	1
White sandstone	3	3	137	4
White flint		7	137	11
White sandstone	4	6	142	5
White flint	1	5	143	10
Blue sandstone		9	144	7
White flint	1	3	145	10
White sandstone	1	4	147	2
White sand and flint mixed		8	147	10
Crystallized white flint		9	148	7
Coarse gray sandstone		9	149	4
Blue flint		3	149	7
White sandstone		6	150	1
Blue flint		9	150	10
Brown sandstone		5	151	3
Blue flint		4	151	7
Black sandstone		9	152	4
White limestone and spar	1	3	153	7
Fine white sandstone	1	3	154	10
Blue flint		5	155	3
White sandstone	2	3	157	6
White flint	1	0	158	6
Gray flint	1	3	159	9
White sandstone		9	160	6
Gray flint		6	161	0
White flint; water and gas	3	9	164	9
White sandstone	25	3	190	0
Black sandstone and shale	12	6	202	6
Gray sandstone	9	0	211	6
Coarse sandstone and shale	1	6	213	0
Hard white sandstone	3	0	216	0
Gray sandstone and shale mixed	54	0	270	0
Black and white sandstone and shale	36	0	306	0
Devonian and Cambrian (696 feet):				
Blue sandstone	7	0	313	0
Fine white sandstone	4	0	317	0
Brown sandstone and shale	11	0	328	0
Black sandstone	5	0	333	0
Brown sandstone and shale	9	0	342	0
White flint		9	342	9

Log of Marshall well, Boonslick, Howard County—Continued.

	Thickness.		Depth.	
Devonian and Cambrian—Continued.	*Ft.*	*in.*	*Ft.*	*in.*
Gray sandstone	13	0	355	9
White flint	8	1	363	10
White sandstone	34	0	397	10
Hard white flint	2	0	399	10
Blue sandstone	1	6	401	4
White sandstone	4	0	405	4
White limestone and flint	3	3	408	7
Sandstone	13	0	421	7
White flint	1	6	423	1
Soft white sandstone	24	0	447	1
White flint	3	0	450	1
Brown sandstone	1	6	451	7
White shaly flint	3	6	455	1
White soft sandstone	3	0	458	1
White flint	5	0	463	1
Sandstone, lime, and flint	9	9	472	10
Blue sandstone	8	0	480	10
White sandstone and shale; salt water; stream increased one-third at 482 feet 1 inch	1	3	482	1
Sandstone	21	0	503	1
White sandstone and flint	11	0	514	1
White "cotton rock"	5	0	519	1
Soft white sandstone	31	0	550	1
Blue flint bowlder	1	3	551	4
White sand and flint	4	6	555	10
Blue sandstone and shale	23	0	578	10
White sand and flint	21	0	599	10
White sandstone	5	0	604	10
White flint	2	6	607	4
White sandstone	34	0	641	4
White shaly flint	6	3	647	7
Soft white sandstone; small addition of water, very strong and offensive with gas	61	0	708	7
Sandstone	262	0	970	7
Coarse white sandstone; fresh water said to have come in here	31	0	1,001	7
Crevice		9	1,002	4

The water from this well is strongly saline and highly charged with sulphureted hydrogen. The ground around the ditch is covered with a black and white deposit. When visited by the writer, July 28, 1904, the well had an estimated flow of 20 gallons per minute. The following data were obtained: At 37 feet water was obtained; at 68 feet weak salt water; at 164 feet 9 inches the size of the stream had increased one-fourth, with the amount of salt about the same as the outside stream, or 4½ per cent; at 482 feet a vein of salt water was reported, with an increased strength of one-third; at 708 feet 7 inches a small amount of water was reached which was very strong and offensive with gas, with a corresponding increase in strength of brine—from 4½ to 9 per cent. A 10-inch square wooden conductor was put down to the bottom of the quicksand, a distance of 22 feet. Below this a 1½-inch pipe was inserted (Schweitzer states that a 3-inch pipe was inserted to a depth of 400 feet). The volume of water is sufficient for a 2½-inch pipe.

The log states that fresh water came in at 1,001 feet. Mr. Price Cooper informed the writer that he was on the ground when the well was sunk and that no fresh water was obtained. Others make a positive assertion that there was fresh water. This question has an important bearing on the possibility of a fresh-water supply in the

A. BIG SALT SPRING, SALINE COUNTY.

B. SINKING CREEK, SHANNON COUNTY, ISSUING FROM UNDER NATURAL BRIDGE.

immediate vicinity, and it has already been discussed at Fayette, where the problem of city water supply is serious and where the advisability of sinking the present deep well down to the supposed fresh-water supply found in the Boonslick well has been considered. The following is an analysis of the water from this well, made by Woodward, probably in 1891, and published in Schweitzer's report on the mineral waters of Missouri.[a]

Analysis of water from Marshall well, Boonslick, Howard County.[b]

	Parts per million.		Parts per million.
Silica (SiO_2)	18	Sulphate radicle (SO_4)	1,392
Calcium (Ca)	967	Chlorine (Cl)	12,071
Magnesium (Mg)	413		
Sodium (Na)	6,580		21,441

While this is only a partial analysis of this spring, it indicates some very important conclusions. The saline springs of Saline, Howard, and Ralls counties have, it is believed, a deep-seated origin, and the deep wells at Sweet Springs, Malta Bend, Spalding, Boonslick, and Fayette are either adjoining or near salt-spring marshes. The wells at Spalding, Boonslick, and Fayette are located on such marshes. The Big Salt Spring (Pl. VI, *A*), one of a group of brine springs between the deep wells at Malta Bend and Sweet Springs, has been described by the writer as follows:[c]

> The surface rock is near the base of the Mississippian, and the spring proper is an oval pool about 25 feet in diameter. The water boils up all over the surface of this pool, and is impregnated with sulphur. Its source is undoubtedly at a great depth.

After a brief discussion of the fluctuations of these springs in temperature and of the varying amounts of sulphureted hydrogen, as revealed by examinations made at different times, the writer continues:[d]

> This central section seems to be a basin which receives the flow from the Ozarks from the southeast, being apparently inclosed on the south by the Sedalia fold and probably on the west by smaller folds which have not yet been fully outlined. If this view can be fully verified it might account for the concentration of salines in these waters. The presence of a considerable amount of calcium chloride in all the deep wells and brine springs of this district would presuppose the theory that this was a basin early shut off from the sea, in which the original sea water became concentrated.

The view quoted above has been more fully substantiated by the studies of the past few months.

Section 8 (Pl. V, p. 36) shows the structure, from west to east, of the Fayette basin in Howard County and of a part of the Sweet

[a] Missouri Geol. Survey, vol. 3, 1892, p. 71.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

[c] Shepard, E. M., Water-Sup. and Irr. Paper No. 114, U. S. Geol. Survey, 1905, p. 213.

[d] Op. cit., p. 214.

Springs basin in Saline County. To the south the horizons rise rapidly toward the Ozark Island, and to the north shallow well sections extending through the Pennsylvanian show a rise of the Mississippian floor in that direction, thus outlining the two well-defined basins just mentioned. These basins were probably developed early in the geologic history of the region, possibly at the close of the Cambrian, the flexures which had a northeast-southwest trend being more or less parallel with the old coast line of the Ozark Island and developing lines of weakness which were accentuated by further uplifts. The presence of these folds is indicated by deflections of Missouri River, as has previously been described (p. 36). The Ozark Island has probably been divided at times, and water connection between the great east and west seas has existed along what is now the line of Missouri River. Subsequent elevations of these anticlines to the north shut off these basins and left therein the fossil brines of ancient oceans, in which the present deposits were afterwards laid down.

The analyses of the water from the Boonslick spring and the Boonslick deep well, which are about 400 feet apart, show a striking similarity. The two are given below for convenience of comparison:

Analyses of water from Boonslick well and Boonslick spring.[a]

[Parts per million.]

	Well.	Spring.
Calcium (Ca)	968	1,105
Magnesium (Mg)	418	.....
Sodium (Na)	6,590	6,077
Sulphate radicle (SO_4)	1,391	1,440
Chlorine (Cl)	12,040	10,238
	21,407	18,860

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

The similarity of these two waters is striking. The log of the Boonslick well gives a record of the varying amounts of saline water found at different depths, and not until 708 feet was reached was water found having a composition similar to that which comes to the surface in the adjoining spring, a fact which seems in this case to demonstrate the deep-seated origin of the water. Moreover, the valleys where these brine springs occur are flat and seem to have been filled, to some degree, by deposits from the springs.

The Boonslick spring rises from a slightly elevated platform of muck. The water is highly charged with sulphureted hydrogen. The mound which the spring has apparently built up around itself is stained a beautiful purplish-red, the material consisting of clay, algæ, and slime. The purplish algæ seem to be covered in places by a dark

slaty-colored sediment. Mr. J. N. Newman, who resides in the vicinity, states that in the winter the flow from the spring is much greater, the water boiling up to the height of 1 foot.

FAYETTE.

One hundred yards south of the Missouri, Kansas and Texas Railway station at Fayette is a well owned by the Fayette Mineral Well Company. Depth, 860 feet; altitude above tide, 655 feet; diameter of casing, 4 inches; temperature of water, 61.5° F.; of air, 78° F.; surface formation, Des Moines. This well was sunk for the purpose of obtaining a supply of water for the city, but at a depth of 860 feet so strong a flow of salt water was encountered that the original idea was abandoned. The well is in close proximity to the Fayette salt springs, at the head of a small salt branch. The area occupied by these springs is about 50 feet in diameter. The Howard and Saline County basins are both characterized by numerous irregular salt marshes and springs of the same character.

The following log and analysis of the water of the Fayette well have been furnished by Prof. E. E. Wildman, of Fayette College. The log was made from samples of drillings preserved by the late J. W. Kilpatrick, formerly professor of geology in that institution:

Log of well of Fayette Mineral Well Company, Fayette, Howard County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (135 feet):		
Loess and sandstone	25	25
Clay	12	37
Slate and gravel	34	71
"Soapstone" (?)	19	90
Blue clay	10	100
"Soapstone" (?)	35	135
Des Moines (464 feet):		
Flint and limestone	80	215
Gray flint, soft limestone, and coal	25	240
Salt and sandstone	35	275
White and brown limestone	225	500
Salt and sandstone	22	522
Sandstone with sulphur	49	571
Blue limestone	14	585
White and gray sandstone	14	599
Mississippian (Keokuk-Burlington) (271 feet):		
Lime and sandstone	146	745
White sandstone	10	755
Lime and sandstone	75	830
Brown flint and sandstone	20	850
Iron and sandstone	6	856
Gray sandstone	14	870

The great thickness of the Des Moines, which fills the Howard basin, as shown in section 8 (Pl. V, p. 36), is to be noted in this log.

Analysis of water from Fayette mineral well.[a]

[Analyst, Kennicott Water Softener Company, Chicago, Ill.]

	Parts per million.		Parts per million.
Silica (SiO_2)	20	Sodium (Na)	8,197
Iron and aluminum oxides (Fe_2O_3 $+Al_2O_3$)	14	Bicarbonate radicle (HCO_3)	146
		Sulphate radicle (SO_4)	1,343
Calcium (Ca)	1,042	Chlorine (Cl)	14,440
Magnesium (Mg)	340	Suspended matter	128
			25,670

The suspended matter is, to a considerable extent, sulphur. The analyst did not give the sulphur or the sulphureted hydrogen. The water has a feeble flow and contains a considerable amount of the gas. From this analysis it is seen that the water resembles a fossil brine from an ocean basin that has never been leached out since the area was originally shut off from the sea.

At present the water from this spring is used for medicinal purposes. A small bath house, with hot and cold water, and a swimming pool 30 by 64 feet adjoin the well. The water is recommended for rheumatism and skin and blood troubles.

JACKSON COUNTY.

KANSAS CITY.

Dr. G. C. Broadhead gives the log of a well at Kansas City, Jackson County, located not far from the union station:

Log of well at Kansas City, Jackson County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Pleistocene (37 feet):				
Loess from surface to bed rock	37	0	37	0
Des Moines (708 feet):				
Fine-grained bluish limestone	21	0	58	0
Light-blue clay	1	0	59	0
Dark-colored clay	4	0	63	0
Gray limestone	13	0	76	0
Dove-colored clay shale	100	0	176	0
Bituminous sand clay; bitumen rose to surface	4	0	180	0
Clay	84	0	264	0
Bituminous limestone, brown	4	0	268	0
"Soapstone"	5	0	273	0
Limestone; increase of water	18	0	291	0
Arenaceous clay and soft drab sandstone	4	0	295	0
Light-buff limestone	23	0	318	0
Dove-colored "soapstone"	24	0	342	0
Dove-colored arenaceous clay	23	0	365	0
Dark clay, shales, shelly coal, fossils	5	0	370	0
Dark-blue micaceous clay	25	0	395	0
Dark-blue fine-grained sandstone	37	0	432	0
Dark shales; salt water	1	0	433	0
Coal	0	4	433	4
Fire clay	10	0	443	4
Clay and limestone, marlite	5	8	449	0
Dark "slate" and coal; fossil plants; salt (flowing)	1	6	450	6
Coal, dense and bright	0	6	451	0
Clay and limestone	16	0	467	0
Coarse gray sandstone; strong brine	12	0	479	0
Gray, fine sandstone	10	6	489	6
Blue clay	3	6	493	0
Clay or "soapstone"	7	0	500	0
Dark, dove-colored fine-grained sandy clay	119	0	619	0
Black shale	3	0	622	0

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Log of well at Kansas City, Jackson County—Continued.

	Thickness.	Depth.
Des Moines—Continued.	*Ft. in.*	*Ft. in.*
Coal	1 0	623 0
Clay, with sand	50 0	673 0
Thin laminated dark clay with shales	6 0	679 0
Black bituminous shales	3 0	682 0
Coal	1 8	683 8
Clay and mud	16 4	700 0
Mud	34 10	734 10
Dark, mottled crystalline sandstone	10 2	745 0
Mississippian (13+ feet):		
Vitreous crystalline limestone	13 0	758 0

The log of a deep well in Jackson County was furnished by Messrs. M. L. Fuller and S. Sanford. It is believed to be the record of a well recently sunk in Kansas City, though the specific location was not given.

Log of well in Jackson County.

	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Earth	14 6	
Yellow shale	2 0	16 6
Fire clay	35 0	51 6
Limestone, hard	9 0	60 6
Fire clay, light to dark	7 0	67 6
Brown umber, good	4 6	72 0
Sandy limestone, hard	2 0	74 0
Limestone, hard	36 0	110 0
"Soapstone"	6 0	116 0
Limestone, very hard	8 0	124 0
Fire clay, dark, shaly	1 0	125 0
Limestone	6 0	131 0
Fire clay, dark	6 6	137 6
Limestone	8 6	146 0
Shale	11 0	157 0
Sandstone	4 0	161 0
Black slate; salt water	0 6	161 6
Coal, first seam	1 6	163 0
Fire clay	2 0	165 0
Limestone	3 0	168 0
"Soapstone"	17 0	185 0
Sandy shale	1 0	186 0
Black slate (iron pyrites with gas, pressure 125 to 150 pounds)	1 0	187 0
Coal, second seam	4 0	191 0
Fire clay	5 0	196 0
Sandy shale	1 0	197 0
Fire clay	4 9	201 9
"Slate," black	1 3	203 0
Fire clay, light to dark	66 6	269 6
Sandy shale, hard	1 0	270 6
Black shale and "soapstone"	2 0	272 6
Fire clay	33 0	305 6
Black "slate"	0 6	306 0
Coal, third seam	1 0	307 0
Sandstone, with partings of clay	7 0	314 0
Fire clay	7 0	321 0
"Rock"	5 0	326 0
Fire clay	2 0	328 0
"Soapstone," soft, blue	20 6	348 6
Coal, fourth seam	0 6	349 0
Fire clay	16 6	365 6
Coal, fifth seam	0 2	365 8
Fire clay	29 4	395 0
"Soapstone"	4 0	399 0
Fire clay	14 0	413 0
"Soapstone," dark	7 0	420 0
Sandstone, soft, free	11 0	431 0
Kaolin, sandy	10 0	441 0
Sandy shale	4 0	445 6
Fire clay, shaly	7 6	452 0
Sandstone	17 0	469 0
Fire clay, dark	30 6	500 0
Shale, sandy	4 0	504 0
Fire clay	4 0	508 0
Shale, sandy crevice; strong brine in crevice, filled well within 100 feet of top	2 0	510 0

The above formations are all in the Des Moines group.

Record of diamond-drill well 10 miles northeast of Kansas City, Mo.

[Elevation of well mouth, 925 feet. Correlations by E. O. Ulrich.]

	Thickness.	Depth.
	Feet.	*Feet.*
Lower Coal Measures	750	750
Boone limestone (?):		
Limestone, shelly in places, with shale partings	75	825
Light-colored limestone, flinty layers	260	1,085
Dark limestone, with shelly layers	100	1,185
Dark reddish sand	15	1,200
Joachim (?): Bluish, fine-grained limestone, shelly in places	57	1,257
St. Peter: Sandstone, white at top, reddish at bottom	64	1,321
Cambro-Ordovician:		
Gray and brown limestone	129	1,450
Shelly and clayey limestone	10	1,460
Light, coarse, porous limestone	160	1,620
Shelly limestone	20	1,640
White sandstone	16	1,656
Flinty, light, porous limestone; water disappeared or was lost	74	1,730
Gray clayey and sandy limestone	20	1,750
Hard, gray, fine-grained limestone	70	1,820
Hard, gray, fine-grained sandstone	15	1,835
Gritty, porous, crystalline limestone, in places white and flinty	215	2,050
Hard, coarse sandstone	50	2,100
Cambrian:		
Limestone, with seams of gray and brown shale	40	2,140
Dark and light fine-grained limestone	110	2,250
Hard, coarse sandstone	98	2,348
Granite	53	2,401

JOHNSON COUNTY.

LEETON.

One-half mile southwest of Leeton, Johnson County, is a well owned by the Chicago, Rock Island and Pacific Railway and drilled by George Austin and W. E. Carner. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Chicago, Rock Island and Pacific Railway well near Leeton, Johnson County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	14	14
Limestone, very hard	18	32
Shale, medium	50	82
Coal, bituminous	2	84
Shale, medium	6	90
Coal	1	91
Shale; small flow of gas	623	714
Limestone, hard	500	1,214

LAFAYETTE COUNTY.

HIGGINSVILLE.

At Higginsville, Lafayette County, the Higginsville Prospecting Company in 1898 drilled a well near the Missouri Pacific Railway station to a depth of 1,512 feet. This well has a diameter of 10 inches at the top and 4½ inches at the bottom; it is cased all the way down.

The principal source of water is in sandstone, apparently the Kinderhook, at a depth of 656 feet; another strong flow was obtained at a depth of 1,350 feet in a sandstone that was probably the Roubidoux. A strong flow of salt water was struck at a depth of 1,070 feet in the St. Peter sandstone. The water rises within 80 feet of the surface, the supply seeming to be unlimited. The president of the company, Mr. J. H. Burgan, to whom the writer is indebted for this information, states that pumping 100,000 gallons per day for a week made no change in the level of the water. Salt water, charged with sulphureted hydrogen, now comes in through the casing and the well is not used. Mr. Burgan furnished the following log:

Log of well at Higginsville, Lafayette County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (68 feet):		
Earth and clay	68	68
Des Moines (302 feet):		
Sandstone	112	180
Asphaltic sand	8	188
Slate	5	193
Soapstone	157	350
Sandstone	20	370
Keokuk (87 feet):		
Gray limestone	67	437
White limestone	13	450
Asphalt and quartz rock	7	457
Burlington (63 feet):		
Coarser limestone	38	495
Dark limestone	5	500
Hard gray limestone	20	520
Kinderhook (195 feet):		
Brown limestone	36	556
Dark-brown limestone	100	656
Sandstone; heavy flow fresh water	35	691
Hard limestone	24	715
Devonian (55 feet):		
Hard white limestone	27	742
White sand; water	20	762
Darker brown sand	8	770
"Trenton" and Joachim limestone (281 feet):		
Limestone	201	971
Trenton rock, close grained; trace of oil	45	1,016
Trenton rock, hard; slight trace of oil	35	1,051
St. Peter sandstone (150 feet):		
Soft sandstone	20	1,071
St. Peter sandstone; salt water	130	1,201
Jefferson City limestone (145 feet):		
Limestone; salt water	145	1,346
Roubidoux sandstone (167 feet):		
Sandstone; fresh water	25	1,371
Very hard white limestone	142	1,513

A number of drill holes ranging from 80 to 250 feet in depth are noted in Marbut's report on the geology of the Lexington sheet, Lafayette County.[a]

[a] Marbut, C. F., Missouri Geol. Survey, vol. 12, pt. 2, 1898, pp. 196-247.

MACON COUNTY.

LA PLATA.

At La Plata, Macon County, the La Plata Electric Light Company drilled a well 435 feet deep one-eighth of a mile northeast of the town. The work was done by Durand, of Iola, Kans. La Plata is situated on the crest of the divide between Missouri and Mississippi rivers, at an altitude of 914 feet. The well has an 8-inch bore and was completed in 1902. The principal flow is from sandstone, at a depth of 140 feet, and the water rises within 90 feet of the surface. Another water-bearing sandstone was found at 430 feet. The supply is only about 3 gallons per minute and a little pumping soon lessens that amount. By hard pumping the well can be entirely drained. The water is used for boiler purposes.

The following analysis, neither date nor name of analyst being given, is furnished by the company:

Analysis of water from electric-light company's well, La Plata. Macon County.[a]

	Parts per million.		Parts per million.
Silica (SiO^2)	3.4	Carbonate radicle (CO_3)	283
Iron and alumina oxides ($Fe_2O_3+Al_2O_3$)	13	Sulphate radicle (SO_4)	195
Calcium (Ca)	109	Chlorine (Cl)	11
Magnesium (Mg)	38		698.4
Sodium (Na)	96		

MACON.

The following notes on the record of the deep well drilled by the mining company of Macon in the summer of 1887, which furnishes a key to the geology of this immediate vicinity, are taken from the account by W J McGee:[b]

The boring in Macon.—The prospect bore is located in the southeastern part of the city, in a ravine some 30 feet deep, where the drift was found to be 36 feet in thickness. An ordinary plunge drill was used. The diameter of the bore is 13 inches in the drift and 8 inches in the rock to 320 feet from the surface, where a strong flow of water was encountered and the diameter was reduced to 5 inches. Samples were taken by means of the "sand pump" at frequent intervals, particularly when change in character of material was indicated by the behavior of the drill; and special care was exercised in taking samples and in determining thickness of strata when borings indicated the proximity of coal seams. The samples were collected and preserved by the well driller and one or more representatives of the citizens' committee acting in conjunction with him; and the depth from which each was taken was indicated upon the box in which it was preserved. In the following notes the depths are transcribed from this record. The specimens were personally examined; and the notes represent the inferences then made as to the character of the strata from which specimens were derived rather than accurate descriptions of the specimens themselves.

[a] Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

[b] Trans. St. Louis Acad. Sci., vol. 5, 1888, pp. 326-333.

Log of the deep well at Macon, Macon County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
1. Drift (no specimens preserved)	36	0	36	0
2. Blue calcareous-argillaceous shale breaking down into clay with a few firm fragments	9	0	45	0
3. Hard, brittle blue limestone with conchoidal fracture, mixed with shaly débris and mud evidently derived from the breaking up of shale	1	0	46	0
4. Black shale breaking up into graphite-like mud	2	0	48	0
5. Coal, with a few fragments of shale	1	1	49	1
6. Blue shale or clay containing a little grit, breaking down into mud, with a few shaly scales	5	11	55	0
7. Tenacious blue clay with a few shaly flakes and a trace of grit	10	0	65	0
8. Gray calcareous shale with a few fragments of limestone, of which some are veined with calcite and exhibit conchoidal fracture	5	0	70	0
9. Black shale, the larger fragments of which exhibit parallel lamination	3	2½	73	2½
10. Coal	1	9½	75	0
11. Tenacious blue clay containing a little gritty matter	33	8	108	8
12. Black graphite-like clay with a few bits of gray clay, the whole containing a little gritty matter and scales of shale	17	4	126	0
13. Dark-gray or black clay evidently derived from slightly calcareous shale containing fragments of dark-blue limestone	0	6	126	6
14. Firm black carbonaceous shale	1	9	128	3
15. Slightly calcareous gray clay, with abundant shaly scales	8	3	136	6
16. Calcareous gray clay, with shaly scales	18	6	155	0
17. Slightly calcareous dark-gray shale	30	0	185	0
18. Light-gray limestone, pure, probably massive or thick bedded, with conchoidal fracture	28	0	213	0
19. Light-gray subcrystalline limestone, intermixed with dark-gray shale	7	0	220	0
20. Light-gray, slightly calcareous shale and clay	53	0	273	0
21. Dark-gray, slightly calcareous clay	3	0	276	0
22. Calcareous gray shale	5	6	281	6
23. Light-gray cherty limestone	5	0	286	6
24. Light-gray limestone, dark-gray calcareous shale, and chert	3	6	290	0
25. Light-gray cherty limestone	30	0	320	0
26. Blue-gray calcareous shale	5	0	325	0
27. Light cherty limestone and dark-gray calcareous shale	10	6	335	6
28. Light-gray and dark nodular calcareous shale	39	6	375	0
29. Light-gray siliceous limestone and chert	21	0	396	0
30. Light-buff pulverulent rock containing beautiful crystals of carbonate of lime and carbonate of iron, and leaving a considerable residue (probably siliceous and magnesian) after digestion in acid	14	0	410	0
31. Dark-gray arenaceous shale, light-gray calcareous shale, and crystals of calcite	72	0	482	0
32. Light-gray arenaceous and calcareous shale with light-buff powder like that at 410 feet	27	0	509	0
33. Blue sparry limestone with fossil markings	23	0	532	0
34. Shaly blue limestone	43	0	575	0
35. Light-gray and dark-blue shaly limestone	60	0	635	0
36. Blue limestone	17	0	652	0
37. Light-blue sparry limestone	112	0	764	0
38. Light-blue cherty and arenaceous limestone	36	0	800	0
39. Gray sparry limestone and fine fissile blue shale	95	0	895	0
40. Massive blue shale or indurated clay	100	0	995	0
41. Fine calcareous sand	5	0	1,000	0

The following summary of this log is in part taken from a table given by McGee, who compared the materials and thickness of the several strata penetrated with the general sections developed by the State surveys of Missouri, Illinois, and Iowa (a sort of composite of which was prepared for use in prognosticating the results of the boring):

Summary of log of well at Macon, Macon County.

System.	Formation.	Petrographic character.	Numbers in McGee's log.	Thickness.
				Feet.
Carboniferous	Lower Pennsylvanian.	Shales, clay beds, limestones, coal seams.	2–17	215
	St. Louis	Limestone	18–19	35
	Keokuk	Somewhat calcareous shales	20–22	62
	Burlington	Nodular calcareous shales	28	40
		Siliceous limestones, calcareous shales	29–33	157
	Kinderhook	Shaly, nonsiliceous limestones	34–37	232
Devonian	Hamilton [a]			
Silurian	Niagara	Cherty limestone, passing into shale	38–39	131
	Hudson	Shales or indurated clays	40	100
		Sandstone	41	
	Trenton [b]			[c] 450
	St. Peter [b]			[c] 50
				1,026

[a] Not recognized. [b] Not reached. [c] Estimated.

D. B. Moore, of Macon, has sunk a number of wells ranging from 125 to 210 feet in depth, and has preserved a careful record of them. He states that most of the wells driven to a depth of 150 to 200 feet are dry, and that most of the water used in that vicinity is from the drift. George Kohl sunk a well one-half mile west of Macon to a depth of 60 feet in drift, and it was perfectly dry. At a distance of 75 feet a well 20 feet deep struck water that rose within 8 feet of the surface. On the Pohlman's farm, 7 miles southeast of Macon, a well drilled 209 feet deep failed to get water.

Four miles southeast of Macon is a well owned by S. T. Brock and drilled by S. D. Harris. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Brock well near Macon, Macon County.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil	4	4
Joint clay	16	20
Sand, with a small vein of water	2	22
Red clay	18	40
Sand and water	3	43
Red clay	37	80
Blue clay	15	95
Fine sand, blue, with water all through the sand	20	115

The water rises within 20 feet of the surface and has been pumped for two years. The beds all belong to the Des Moines group.

Four miles northwest of Macon is a well owned by T. E. Wardell and drilled by S. D. Harris. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Wardell well near Macon, Macon County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (54 feet):		
Surface rock, soil to joint clay	54	54
Des Moines (110 feet):		
Gray sandstone	40	94
Soft shale, gray; small vein of water rises 20 feet	66	160
Hard slate	1	161
Coal	3	164
Mississippian (136 feet):		
Blue lime rock	26	190
White lime rock, very hard	70	260
Lime rock which was very hard to drill; struck water in seam of rock at 290 feet; water rises within 90 feet of surface	40	300

MILLER COUNTY.

OLEAN.

There are several wells in and around Olean, Miller County, on Blythes Fork. One, owned by the Olean Canning Company, in sec. 12, T. 42, R. 15, at an altitude of 746 feet above tide, is 56 feet deep. Flowing water was found at the bottom. The well was drilled in 1893 and no change in the flow has ever been noted. The water is softer than that in the shallow dug wells of the vicinity and is used for the boiler at the canning factory. The drill passed through 10 feet of soil and creek gravel and 40 feet of broken flint and sandstone. In order to make the water flow into the casing, the pipe is inclosed in a bag of flaxseed which was lowered beyond the gravel layer. The seeds swell and cut off the escape of water through the river gravel. The cost of the well was $50.

Another well is located near the flouring mill of Joseph Guttermeier, in sec. 1, T. 42, R. 15. It was drilled in 1893 with a 7-inch bore to a depth of 85 feet. The flow of water, about 110 gallons per hour, does not vary ordinarily, but it may be decreased by pumping. At a depth of 50 feet water was struck that rose within 4 feet of the surface; at a depth of 85 feet it flowed. The water is soft, with a slight odor of sulphur. It is used for drinking and for the boiler at the flouring mill. The altitude of the curb is 764 feet. The cost of drilling was 75 cents per foot, or $64 for the entire work. The following is the log of the well:

Log of Guttermeier well near Olean, Miller County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel	4	4
Limestone and flint	78	82
Shale	2	84
Sandstone	1	85

On his place near the railway station at Olean Mr. J. C. Johnston drilled a well, with a 6-inch bore, to a depth of 67½ feet. The water rose to the surface from the bottom of the well and flows 7½ gallons per minute. It is soft and is used for household purposes. The drill passed through 10 feet of soil and 57½ feet of chert and sandstone.

A second well, at an altitude of 754 feet above tide, was sunk in a farmyard adjoining the one just described. This well is the lowest in the group, and when allowed to flow full head it will, in a short time, cause all the others to stop flowing, except the one at the flouring mill one-half mile north of Olean. The water is soft. The well cost $80.

Another well, located at the Franklin, Lux & Proctor livery stable, was drilled in 1901, with a 6-inch bore, to a depth of 50 feet. At the depth of 25 feet the water rose to the surface. It is moderately soft and is used in the livery stable. The well cost $50. The wells at the livery stable and store have ceased to flow, owing probably to leakage in the pipe and to the sinking of neighboring wells at lower levels.

The general dip of the sandstone strata overlain by impervious shale in this region gives rise to conditions favorable to artesian flow; but it is probable that a flow could be obtained at no point in this vicinity having an altitude of over 775 feet above tide. All the Miller County wells probably obtain water from either the Roubidoux formation or the Gasconade limestone.

Ball and Smith[a] state that—

> One of the drill holes at the Son prospect, in sec. 19, T. 41, R. 15 W., is a flowing well. This is situated near the top of the Gasconade limestone and is 12 feet above the bottom of Little Gravois Creek. The hole is 140 feet deep, no water having been struck up to 100 feet. * * * In the bottom of Baileys Branch, 2½ miles northwest of Iberia, George Graves obtained a flowing well at 60 feet, in the Gasconade limestone.

MONITEAU COUNTY.

CALIFORNIA.[b]

About 7 miles east of California, in sec. 17, T. 45, R. 14, on the south side of the road leading to that town, is a well owned by Karl Messerli. It is in a valley somewhat lower than the town. The well was completed May 8, 1902, and is 265 feet deep, with a 5⅞-inch bore. The strongest flow was obtained at 90 feet and had its source in limestone and flint. Two water-bearing beds were found, at 30 and 60 feet.

[a] Ball, S. H., and Smith, A. F., Geology of Miller County: Missouri Bureau Geology and Mines, 2d ser., vol. 1, 1903, p. 196.

[b] For data regarding these wells the writer is indebted to Mr. E. B. Fulkes, of the Missouri Botanical Garden, St. Louis, who drilled them.

The water is clear, cold, and hard. This well is about 200 yards east of a dwelling house and cheese factory, both of which are supplied with water from a running spring. The well lessened the flow of the spring, but did not stop it. The following log of the well was obtained:

Log of Messerli well, near California, Moniteau County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
Flint bowlders	22	25
Limestone	113	138
Hard sandstone	8	146
Limestone	119	265

This well obtains water from the Jefferson City limestone. Another, on the same farm, about 1,000 feet farther west, near a small stream, was drilled in 1902 to a depth of 182 feet, with a 5⅞-inch bore. Water was struck first in limestone, at a depth of 40 feet. When the well reached 65 feet the water ran over the top of the pipe in a small stream, the force increasing to a depth of 105 feet, when the flow became strong enough to raise the full column of water to a height of 3 feet. The water is clear, cold, and hard. This well stopped the flow of the other well and of the cheese-factory spring. Later, a cap was placed on the top of the casing and the other well and spring again became active.

The Crown Mining Company, of California, drilled a well 1½ miles east of town, on the north side of the road, in the N.½ SE. ¼ sec. 23, T. 45, R. 15, in a valley which is considerably lower than the court-house. This well was drilled to a depth of 175 feet, with a 5⅞-inch bore, and completed in August, 1902. The water rises within 6 feet of the surface. It is clear, cold, hard, and charged with sulphureted hydrogen. The following log was obtained:

Log of Crown Mining Company well, near California, Moniteau County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and gravel	9	9
Limestone	41	50
Bowlders, blue clay, and iron pyrites	25	75
Limestone, flint bowlders, and some zinc at 80 feet	30	105
Solid limestone	35	140
Bowlders, limestone, flint, blue clay, and slate	14	154
Limestone	21	175

Flowing wells are also found in sec. 1, T. 43, R. 17; sec. 6, T. 44, R. 17, and sec. 10, T. 44, R. 14. All these wells obtain water from the Jefferson City limestone, and their artesian source is on the western slopes of the Ozarks.

MORGAN COUNTY.

FORTUNA DISTRICT.

In Morgan County and near Fortuna, Moniteau County, in T. 44, R. 17, according to the statement of Mr. E. A. Pettibone, there are about 20 flowing wells. These were all prospect holes sunk by lead and zinc mining companies. The water is obtained from flint beds at the base of the Burlington limestone. None of these wells are utilized, but they demonstrate the existence of another interesting artesian district. Their catchment area is to the southeast, and the rocks of

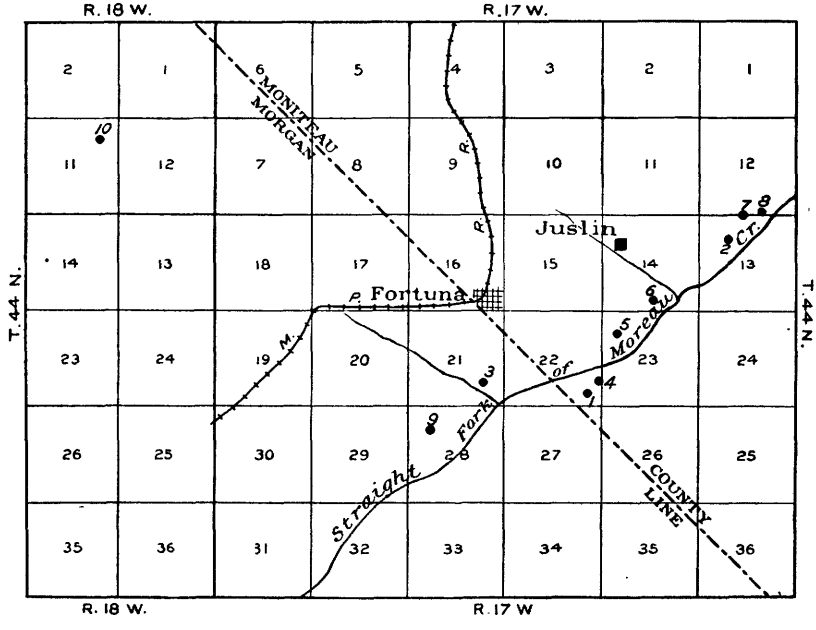


FIG. 3.—Group of artesian wells on Straight Fork of Moreau Creek, near Fortuna.

this region dip to the northwest along the western slope of the Ozark dome. The wells all lie along the valley of Straight Fork of Moreau Creek and may be located by means of the accompanying sketch map (fig. 3).

No. 1, the Singer well, and No. 2, on the Hutchinson tract, are 200 feet deep. The water was struck at a depth of about 140 feet, and the flow is strong. No. 3 is a group of three wells on the Capellar & Osier tract, each 200 feet deep, with a flow of water rising from a depth of 133 feet. No. 4 is a group of four wells on the Woodyard and Parkersburg Lead and Zinc Company's tract, all 200 feet deep, with water reached at about 40 feet. No. 5 is a group of four wells on the Missouri Lead and Zinc Mining Company's tract, each 200 feet deep, with a flow struck at 100 feet. No. 6 is a well on the Dug Hayes property,

200 feet deep, with flowing water reached at 40 feet. No. 7 is a well on the Newkirk tract, 200 feet deep, with flowing water reached between 156 and 160 feet. No. 8 is a well on the Dug Hayes tract No. 2, 200 feet deep, with flowing water at 120 feet. No. 9 is a well 100 feet deep, sunk by Milton McDaniel about 15 feet above the bed of a little draw and 40 feet above the middle branch of Moreau River. This is the farthest well to the south and has a barometric altitude of 869 feet, the altitude of Fortuna being 959 feet. The water in all these wells is clear, cold, and hard, typical of the Burlington limestone. The temperature of those tested is 59° F., with an air temperature of about 80° F.

Near Fortuna is a well owned by the Mary M. Mining Company and drilled by Charles E. Miller. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well of Mary M. Mining Company, near Fortuna, Moniteau County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	10	10
Rock	15	25
Limestone	25	50
Magnesia limestone	10	60
Magnesia limestone and mundic	10	70
Limestone, pink spar, and mundic	10	80
Limestone and flint	10	90
Limestone and flint, jack shines	10	100
Limestone, pink spar, jack shines	10	110
Limestone, black flint, very good jack and lead	11	121
Limestone, black flint, very good jack and betts	14	135
Limestone, white flint, small shines	15	150
Limestone, black flint, jack shines	10	160
All pink spar	6	166
Pink spar and black flint	15	181
Limestone and pink spar	5	186
Limestone, jack shines	5	191
Limestone and flint, jack prospect	20	211

This well is probably all in the Jefferson City limestone.

BLUFF SPRING AND GLENSTEAD.

Mr. J. F. Todd states that there is a strong flowing well in an old prospect hole in the NE ¼, sec. 11, T. 44, R. 18, in Morgan County, within a quarter of a mile of the Bluff Spring mines; also another a mile east and a quarter of a mile north of Glenstead, Morgan County, in sec. 6, T. 43, R. 17. Neither of these two wells was visited.

PETTIS COUNTY.

HUGHESVILLE.

Two miles northwest of Hughesville, Pettis County, is a well owned by Raymond Voigt and drilled by J. B. Ellison. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Voigt well, near Hughesville, Pettis County.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay, stiff	30	30
Blue clay, mud and sand mixed, stiff and waxy	170	200
Very hard cotton rock, gray	53	253

PETTIS.

At Pettis, Pettis County, is a well owned by Elijah Hatsenpiller and drilled by G. W. Yeager. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of the Hatsenpiller well, Pettis, Pettis County.

	Thickness.	Depth.
	Feet.	*Feet*
Soil	20	20
Clay	20	40
Bowlders and clay	78	118
Hard blue limestone, some gray	97	215
Blue clay, gravel, sand, flint rock, and particles of iron	15	230
"Cotton" rock, black sand	2	232

SEDALIA.

The former Sedalia water supply from Flat Creek having proved insufficient in time of drought, the Sedalia Water and Light Company drilled a deep well about 1 mile southeast of Forest Park in the valley of Flat Creek, 3 miles south of the city. Five other wells have been

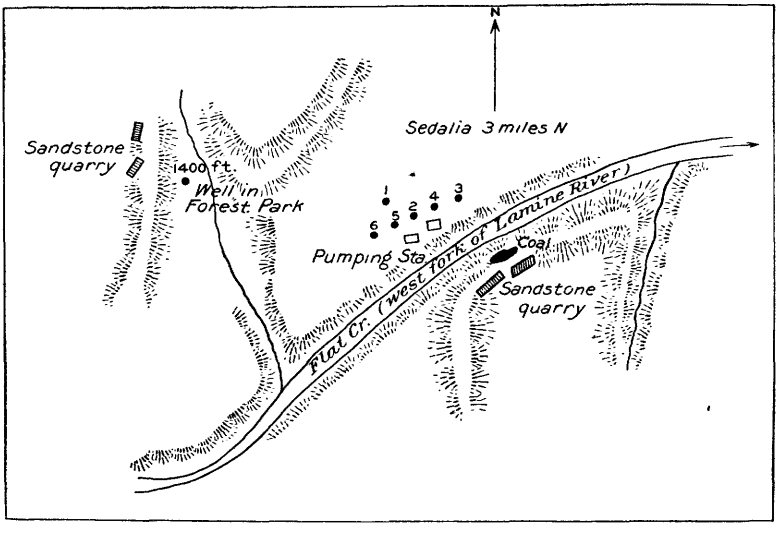


FIG. 4.—Diagram of the Sedalia waterworks wells.

sunk, as indicated in fig. 4. Well No. 1 was drilled to a depth of 670 feet. At 620 feet a gray sandy flint 12 feet thick was struck, then a softer gray sandy rock, with an intercalated bed of soft blue clay 8 feet thick. Under this was found a harder dark sandy formation in which drilling was stopped because of bad ground and the fear that the jars might get fast. Well No. 2, completed in 1901, is at an elevation of about 800 feet above tide. The diameter of the casing is 8

inches. The surface formation is Burlington limestone. The log of the well and other information concerning it have been furnished by Mr. L. P. Andrews, president of the water and light company.

Log of well No. 2 of Sedalia Water and Light Company, Sedalia, Pettis County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (25 feet):		
Soil	15	15
Sand and gravel	10	25
Mississippian (201 feet: Burlington 52 feet, Kinderhook 149 feet):		
Limestone (cotton rock)	27	52
Limestone and flint	20	72
Hard flint	5	77
Limestone and flint	87	164
Gray limestone	24	188
Sandy limestone	13	201
Cotton rock	25	226
Devonian (23 feet):		
Limestone and flint	23	249
Joachim limestone (40 feet):		
Hard flint	17	266
Limestone	23	289
St. Peter sandstone (71 feet):		
White sand rock	71	360
Jefferson City limestone (151 feet):		
Limestone	25	385
Limestone and flint	22	407
White limestone	50	457
Limestone and flint	54	511

The correlations in this log have been made by a comparison of the record of this well with those of well No. 1, 670 feet deep, and of the Forest Park well, 1,612 feet deep. The Jefferson City limestone extends to a depth of 620 feet, and is followed by 380 (?) feet of the Roubidoux and 612 feet of Cambrian or Archean. The driller who sunk the Forest Park well stated that he could not remember the whole log, but distinctly recalled the fact that the last 400 feet was in hard white sandstone.

The late Mr. R. A. Blair[a] gave the following section at Sedalia, and it checks remarkably well with the drill section:

Generalized section at Sedalia, Pettis County.

	Feet.
Burlington limestone	70
Chouteau (Kinderhook)	140
Devonian	30
Silurian (Cambrian)	75+

The water in well No. 2 rises 18 inches above the surface.

[a] The Sedalian, December, 1903, p. 20.

Analysis of water from deep well No. 2 at Sedalia.[a]

[Analysis by St. Louis Sampling Works, July 18, 1902.]

	Parts per million.		Parts per million.
Silica (SiO_2)	8.2	Chlorine (Cl)	2.7
Calcium (Ca)	62		294.7
Magnesium (Mg)	34	Residue on evaporation	316
Sodium (Na)	1.8	Residue on ignition	233
Carbonate radicle (CO_3)	164		
Sulphate radicle (SO_4)	22		

Water in shallow wells in Sedalia is too highly charged with lime and magnesia sulphates and carbonates to be good for either boiler or drinking purposes; but that city has now, with these inexhaustible deep wells, one of the best water supplies in the country. The main flow comes from the St. Peter sandstone, at a depth of 289 to 360 feet.

A deep well in Forest Park, about a mile north of the waterworks wells, was drilled in 1893. The following log was contributed by Mr. F. A. Sampson, of Columbia:

Log of deep well at Forest Park, near Sedalia, Pettis County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	30	30
Coarse sandy yellow limestone, with white chert	25	55
Gray shaly, earthy limestone, with some white chert and crinoid stems	55	110
Light-gray crystalline limestone, with some white chert	52	162
Fine-grained gray magnesian limestone	36	198
Darker-gray crystalline magnesian limestone, with bluish and white flint	62	260
Very fine white quartz sand	160	420
Grayish-white magnesian limestone; some shows oolitic structure with fine quartz grains and very little white flint	60	480
Fine white limestone and fine white quartz	35	515
Fine quartz sand, nearly pure	150	665
Whitish magnesian limestone, with some whitish flint	215	880
Whitish-gray magnesian limestone; resembles fine sand (may contain sand)	100	980
Fine white quartz sand	20	1,000
White and reddish crystalline limestone (marble)	150	1,150
Coarse white quartz sand	25	1,175
Fine-grained sand with a little flint	85	1,260
Olive-green shale and a little white calcite	40	1,300
Dark-gray magnesian limestone and white sandstone	95	1,395
Coarse sand, dark gray, with traces of a hornblende-like mineral	5	1,400
Olive and greenish-gray shale, with sand like preceding	15	1,415
Gray quartz sand, with greenish shale and fine grains resembling hornblende	15	1,430
Gray quartz sand, ferruginous	15	1,445
Fine quartz sand with mica; light quartz sand at 1,470 feet	25	1,470
Coarse round white sand; transparent, good glass sand	110	1,580
Fine reddish-white sand	32	1,612

This log differs somewhat from those of several of the waterworks wells, which check closely with each other. The large amount of sandstone shown in this record is difficult to account for. Several parties who saw the drillings state that the last 400 or 500 feet was

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

hard white sandstone. From the log, as given, the last 200 or 300 feet might be either the La Motte sandstone or, possibly, the Archean quartz or porphyry. This well is about 20 feet higher than the waterworks wells, and water rises within 6 feet of the surface. Correlations made from this record would vary somewhat from those of the waterworks wells.

The artesian pressure comes from the catchment basin in Morgan County, in the Ozarks. Section 3 (Pl. IV, p. 30) illustrates the artesian conditions in this vicinity.

SMITHTON.

On a farm near Smithton, Pettis County, in a stream bed in sec. 11, T. 45, R. 20, is a well owned by Dr. W. C. Page. It was drilled in 1901 to a depth of 146 feet, with a 6½-inch bore, and cased to a depth of 15 feet. Water was struck at the bottom in rock and rises to the surface. It is clear, cold, and soft, and has a mineral taste. No log was kept and no analysis has been made.

The description of another well in the immediate vicinity is given for the sake of the log. This well, which is not flowing because of its situation on a high plateau, is 4 miles west of Smithton, Pettis County, in sec. 7, T. 45, R. 20, on a farm owned by Mr. Gabbatt, of Sedalia. It was drilled to a depth of 215 feet, with a 6-inch bore, and cased 26 feet with a 6¼-inch casing. Water was found at 175+ feet in sand and at 198 feet in gravel. The water is reasonably soft. It rises within 140 feet of the surface. It is raised by a pump worked by a gasoline engine which cost $300. The water is used for stock and drinking purposes. The well was drilled by W. C. Ellison, of Smithton, at a cost of $150. The water of this well probably has its source in Devonian rock.

Log of Gabbatt well, near Smithton, Pettis County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Soil and yellow clay	20	0	20	0
Yellow limestone	15	0	35	0
Blue, gray, and black limestone	75	0	110	0
"Cotton rock"	65	0	175	0
Fine white sand		8	175	8
"Cotton rock," flint, and gray limestone	23	0	198	8
Gravel, white, gray, and black	1	4	200	0
Very dark lime and flint	15	0	215	0

At Smithton is a well owned by James Ringen and drilled by George Yeager. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Ringen well, Smithton, Pettis County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	3	3
Gravel	5	8
Clay	4	12
Gray limestone, yellow seams	28	40
Limestone and sand, some flint gravel	10	50
Crevice in rock; roar as if water running, but none was found.		
Cotton rock	20	70
Crevice; struck sand and plenty of water.		

RALLS COUNTY.

NADINE.

Three-eighths of a mile north of Nadine, Ralls County, in sec. 26, T. 53, R. 6, is a well owned by George W. Colvert. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Colvert well near Nadine, Ralls County.

	Thickness.	Depth.
	Feet.	*Feet.*
Solid clay	50	50
Gravel or shell rock	5	55
Hard rock, but not limestone	13	68
"Soapstone"	7	75
Slate	5	80
Coal	2½	82½
Fire clay	17½	100
Hard rock, limestone	89	189

PERRY.

Seven miles south of Perry, Ralls County, is a well owned by G. W. Allen and drilled by W. H. La Due. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Allen well near Perry, Ralls County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and yellow clay	40	40
Fire clay	40	80
Limestone rock	110	190
"Soapstone"	12	202
Brown lime rock	60	262
"Soapstone"	20	282
Lime rock	78	360
Sand rock	35	395

Six miles southwest of Perry is a well owned by John Clever and drilled by W. Smith. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Clever well near Perry, Ralls County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, clay, and drift	50	50
Flint and lime	16	66
Lime	124	190
Brownish-gray limestone	70	260
White limestone	62	322

RALLS.

At Ralls is a well owned by J. A. Clark and drilled by W. H. La Due. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Clark well, Ralls, Ralls County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and yellow clay	20	20
Fire clay, or potter's clay	25	45
Lime rock, with a thin streak of "Soapstone," at 90 feet	305	350
Oil and gas rock	12	362
Limestone	48	410
Red sand rock	15	425
Limestone	15	440
White sandstone; water	5	445

RANDOLPH COUNTY.

HIGBEE.

At Higbee, in sec. 17, T. 52, R. 14, is a well owned by the city. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well at Higbee, Randolph County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil		1
Soft clay	1	2
Hard clay	1	3
Sandy clay	7	10
Blue clay	10	20
Sand	5	25
Rock; water	3	28
Gravel	4	32
Clay	5	47
Sand rock	6	53
Limestone; water	7	60
Sandy clay	10	70
Sand rock	4	74
Limestone; water	6	80

The above beds all belong to the Des Moines group.

MOBERLY.

At Moberly, Randolph County, are several deep nonflowing wells. One-half mile west of the city the water company sunk two of these, 60 feet apart and 510 feet deep. The waters of these two wells are said to differ in composition and in amount. The deepest well in the immediate vicinity of these two is southwest of the waterworks and was drilled to a depth of 2,000 feet in search of oil. The writer is indebted to Mr. W. H. Jones, of Moberly, for the log of this well and other information. Mr. Jones states that salt water was struck between 800 and 900 feet. The percentage of salt steadily increased to a depth of 1,200 feet, below which the water became fresher. At a depth of 1,300 feet a hard magnesian water was struck, and at 2,000 feet the salt could scarcely be tasted. At 900 feet 5 gallons of water yielded, on evaporation, 1 pound of salt.

The meager records obtained from various wells drilled in this vicinity seem to indicate that there is a buried channel having a northeast-southwest trend, as wells situated a few hundred feet apart demonstrate the existence of an ancient valley or trough in the rock.

The log of the Moberly well is as follows:

Log of deep well at Moberly, Randolph County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (38 feet):		
Soil and gravel	38	38
Des Moines (79 feet):		
Shale	60	98
Fire clay	7	105
White sand	12	117
St. Louis limestone (19 feet):		
Blue and white limestone	19	136
Keokuk limestone (84 feet):		
Gray sand and limestone	84	220
Burlington limestone (75 feet):		
Blue and white marble	20	240
White marble	10	250
Limestone and sand	30	280
White limestone	15	295
Kinderhook (212 feet):		
Blue limestone	105	400
Blue limestone with slate seams	20	420
Blue slate	10	430
Gray limestone	5	435
Gray slate	2	437
Gray limestone	55	492
Blue sand	15	507
Devonian (68 feet):		
Gray limestone	45	552
Yellow sand	18	570
White slate	5	575
"Niagara" limestone (95 feet):		
White limestone	7	582
Blue limestone	12	594
Green slate	3	597
Gray limestone	5	602
White sand; water	20	622
Yellow sand	45	667
Slate; cased 9⅝-inch hole	3	670
"Hudson group" (234 feet):		
Limestone	42	712
Flake or egg-shell limestone; soft water	10	722
Gray limestone with flint and iron seams	70	792
Gray sand	30	822

Log of deep well at Moberly, Randolph County—Continued.

	Thickness.	Depth.
"Hudson group"—Continued.	*Feet.*	*Feet.*
Gray limestone	8	830
Pebble sand; showing of oil	10	840
Gray sand	20	860
Limestone	4	864
Gray sand	5	869
Yellow sand	10	879
Blue limestone	15	894
Blue sand	8	902
Blue slate	2	904
"Trenton" limestone (131 feet):		
Limestone	28	932
Sand	18	950
Flint and limestone	80	1,030
White sand	5	1,035
Joachim limestone (55 feet):		
Limestone, flint, and sand	55	1,090
St. Peter sandstone (135 feet):		
White sand and flint	15	1,105
Blue sand and gray limestone	35	1,140
Salt, sand, and water	10	1,150
White sand; some sulphur water	52	1,202
Honeycombed sand	8	1,210
White sand	15	1,225
Undifferentiated Cambrian (465 feet):		
Limestone and flint	15	1,240
White limestone	10	1,250
White limestone and gray sand	72	1,322
Gray sand	19	1,341
Gray sand and limestone	27	1,368
White sand	5	1,373
Fine gray sand	12	1,385
Gray limestone	31	1,416
White sand	42	1,458
Blue limestone	17	1,475
Sand	163	1,638
Dark limestone or Trenton rock	12	1,650
Gray sand	40	1,690
No record	310	2,000

It is very probable that most of the sandstone in this record through the last thousand feet is really a siliceous limestone. Samples for study could not be obtained.

At 632 feet the largest amount of water, which was excellent for drinking purposes, was reached, in a white, transparent sandstone, the grains of which resembled granulated sugar. This was probably Devonian sandstone. At 870 feet salt water was reached; at 1,180 feet magnesia water, and at 1,215 feet very salty water, probably from the St. Peter sandstone. Water stood within 70 feet of the surface.

RANDOLPH SPRINGS.

On the southern slope of a small valley adjoining an old salt lick, about 5 miles west of Huntsville, near the east fork of Chariton River, is a well owned by Charles Dameron. Depth, 965 feet; altitude above tide, about 708 feet; temperature of water, 59° F.; of air, 83.5° F.; flow, weak; date of completion, about 1869; surface formation, Des Moines.

A few feet from the well is a strong brine spring; about 200 feet to the south, and slightly higher, is a chalybeate spring; 100 feet southeast of the latter, and still higher, is a shallow alum well; this group

constitutes the Randolph Springs. At one time this was a popular resort. Considerable water was then shipped to various points, and as early as 1824 salt was manufactured. When the well was sunk a careful log was kept, but it has, apparently, been lost.

Mr. Jacob S. Hunter, a member of the original company that sunk this well, writes that he thinks a moderate flow of sulphur water came from the last 100 feet. It is interesting to note that the water of the deep well is much less saline than that of the enighboring brine spring. This well was sunk in the hope of finding oil. The water contains a small amount of sulphureted hydrogen, and deposits a white precipitate. The flow is about 120 gallons per hour.

Schweitzer[a] states that the temperature of the water was 58° F., and the air temperature 65° F. in 1892, this being 1° cooler than was noted by the writer in 1904. The same author states:[a] "A partial analysis of the water of this well made more than ten years ago is printed in the appendix." On page 233 of the appendix he gives an analysis which must be referred to this well, but which he says is of water from the "salt spring." The following is a copy of this analysis:

Analysis of water from salt spring at Randolph Medical Springs.[b]

[Partly analyzed in March, 1881.]

	Parts per million.		Parts per million.
Silica (SiO_2)	4.5	Sulphate radicle (SO_4)	435
Aluminum (Al)	144	Chlorine (Cl)	3,304
Calcium (Ca)	248		
Magnesium (Mg)	52		5,793
Sodium (Na)	1,606		

In another place (pp. 81, 82) attention is called to the relation of some of these deep wells to adjoining springs and to the presence of calcium chloride as indicating fossil brines that were formed in basins shut off from the sea at an early period.

SALINE COUNTY.

MALTA BEND.

At Malta Bend is a well owned by the Saline Oil and Development Company. Its depth is 1,250 feet; altitude, 690 feet; casing, 8¼-inch, 789 feet; flow, 320 gallons per minute; temperature of water, 61° F.; of air, 82° F.; date of completion, July, 1903; driller, Walker Morton, Malta Bend. When this well was visited, in 1903, only a few samples of drillings—from 900 to 1,250 feet—could be had for

[a] Missouri Geol. Survey, vol. 3, 1892, p. 73.

[b] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

examination. The driller gave the missing data from memory, as follows:

Log of well at Malta Bend, Saline County.

	Thickness.	Depth.
Pleistocene (119 feet):	*Feet.*	*Feet.*
Soil	19	19
Quicksand, rounded flint bowlders at base	100	119
Des Moines (230 feet):		
Shale and sandstone	230	349
Mississippian (400 feet):		
Limestone	300	649
Softer, sandy limestone, and 10 feet bluish shale	100	749
Devonian and Silurian (?) (190 feet):		
Limestone	100	849
St. Peter sandstone (80 feet):		
Dark sand	50	899
Soft, coarse white sandstone, with rounded grains	30	929
Jefferson City limestone (225 feet):		
Siliceous magnesian limestone, with chert or blue flint with calcite crystals	225	1,154
Roubidoux sandstone (90 feet+):		
Reddish-white sandstone, rounded, polished grains	20	1,174
Siliceous magnesian limestone, with calcite crystals and pyrite, dark gray	75	1,249
Gray sandstone, fine rounded grains	1	1,250

No analysis of this water has been made. It is very strongly saline and highly charged with sulphureted hydrogen. It is one of the strongest flowing wells in the State.

SLATER.

At Slater, Saline County, a well was sunk in 1898 to a depth of 650 feet. It was cased for 70 feet with 10-inch casing, and 400 feet farther with 6-inch casing. The water, which contains considerable iron, rises within 150 feet of the surface, the main supply coming from the sandstone at the bottom of the well. It is pumped and used for domestic purposes and protection from fire. The water level is slightly lowered after continuous pumping.

SWEET SPRINGS.

About a quarter of a mile west of Sweet Springs, on the banks of Black Water River, is a well about which the following information was obtained: Depth, 1,074 feet; altitude, about 670 feet; casing, 8-inch, 29 feet to rock; temperature of water, 62° F.; of air, 84° F.; date of completion, 1902; driller, Jack Hume; cost, about $3,000; surface formation, Burlington limestone, under Pleistocene.

Log of well at Sweet Springs, Saline County.

	Thickness.	Depth.
Pleistocene (29 feet):	*Feet.*	*Feet.*
Soil	27	27
Gravel and sand	2	29
Mississippian (326 feet):		
Limestone	41	70
Soapstone	10	80
Limestone	1	81
Soapstone	12	93
Brown limestone	92	185
Sandstone	42	227
Limestone	33	260
Bastard limestone and gravel	12	272
Gray limestone	48	320
White sandstone	35	355

Log of well at Sweet Springs, Saline County—Continued.

	Thickness.	Depth.
Devonian and Cambrian (719 feet):	*Feet.*	*Feet.*
Gray limestone	4	359
Gray sandstone	30	389
Soft limestone	3	392
Brown sandstone	8	400
Soft gray limestone	2	402
Sandstone	76	478
Gray limestone	2	480
Sandstone	59	539
Limestone and sandstone	10	549
Sandstone	75	624
Dark gray, very coarse sandstone	12	636
Gray sandstone	25	661
Coarse sandstone	2	663
Sandstone	411	1,074

According to the statement of the driller the first flow of water, which was weak, was struck at a depth of 300 feet, just above what is believed to be the Hannibal sandstone, this formation being found at depths of 320 to 355 feet. The St. Peter sandstone should be located either between 402 and 478 feet, which would give a thickness of 76 feet; or, as is more probable, between 557 and 624 feet, which would give a thickness of 67 feet. At 564 feet the strongest flow of water was obtained, and at 604 feet the first strong saline water was found, facts which would seem to indicate that the St. Peter sandstone is the water-bearing horizon in this section. It is quite probable that some of the strata marked "sandstone" in the driller's record may have been siliceous limestone. This has been the case in a number of other instances where the writer has had the opportunity of comparing the drillings with the log. Men who have been accustomed to drilling mainly in the sandstones and shales of the Pennsylvanian are very liable to confuse the siliceous limestones and cherts with sandstones.

The water gushes out with great force from an 8-inch pipe, which is 15 feet high, with an elbow at the top. The flow is about 840 gallons per minute. When the well was first opened a pipe 44½ feet long was attached, and the stream was carried with force above that height. The water is clear, strongly saline, and charged with sulphureted hydrogen. It deposits a white precipitate on pipe, stones, and soil. No analysis has been made.

WARREN COUNTY.

WARRENTON.

At Warrenton, Warren County, in sec. 28, T. 47, R. 2, there is a well 400 feet deep, at an altitude of 875 feet. It has a 6-inch casing for about 100 feet to rock. The well was completed in 1891. A small flow of water was struck at 150 feet, but the main supply was obtained at 360 feet. The water, which is rather hard, is used for a steam mill and town supply. The cost of the well and pumping

machinery was about $900. The following log, together with other information, was furnished by Prof. John H. Frick:

Log of well at Warrenton, Warren County.

	Thickness.	Depth.
	Feet.	*Feet.*
Drift clays	80	80
Chert, clay, and gravel	16	96
Limestone	50	146
Sandy limestone	1	147
Light gray limestone	13	160
Blue clay	40	200
Gray limestone	108	308
"Soapstone"	44	352
St. Peter sandstone	48+	400

This well started in the Mississippian.

DECATURVILLE DOME DISTRICT.

The Decaturville dome district includes an area in Camden, Hickory, Miller, and Polk counties within a radius of about 30 miles from Decaturville, Camden County. The district is small and is somewhat arbitrarily defined. Flowing wells are located at or near the following places: Carver, Decaturville, and Hahatonka, Camden County; Aurora Springs and Iberia, Miller County; Cross Timbers and Pittsburg, Hickory County; Cliquot and Goodson, Polk County.

CAMDEN COUNTY.

CARVER.

Two miles northwest of Carver, on the east side of the road between Climax Springs and Proctor, in sec. 29, T. 40, R. 18, in a valley about 60 feet above Osage River, is a well owned by James Hildebrand, and drilled by John Hays, of Versailles, with a diamond-core drill. This well was completed in 1901. It is 901½ feet deep, with a 2-inch bore. The water, which is clear, soft, and rather warm, rises 30 feet above the surface. No variation in flow has been noticed. The well probably started in the Gasconade limestone.

DECATURVILLE.

At Decaturville, on the southern border of Camden County, the intrusion of a dike of pegmatite has greatly tilted the rocks for 10 to 15 miles around, producing conditions favorable for artesian wells.[a]

Nine hundred feet west of Samuel Wheeler's place, near Decaturville, J. N. Kennett sunk a well 300 feet deep for mineral. A strong

[a] For further description of this interesting locality, see Shepard, E. M., The spring system of the Decaturville dome, Camden County, Mo.: Water-Sup. and Irr. Paper No. 110, U. S. Geol. Survey, 1905, p. 113.

flow was struck at a depth of 200 feet. This continued for several years, but gradually declined until all activity ceased. The mouth of this well is about 50 feet lower than Pegmatite Hill.

GUNTERS.

The Rust and Scott wells are situated on the land of Tip Webster, 1 mile west of Gunters, on the west side of Banks Creek, near its junction with Niangua River, and are separated from the Kellogg well by a ridge 200 feet high. These two holes were bored for mineral in 1900.

The Rust well, to the north, is 780 feet deep. The first flow of water was obtained at 680 feet. The temperature of the water is 59° F., and that of the air is 84° F. Colonel Scott states that the water, which is clear and sparkling, with a slight odor of sulphureted hydrogen, rises 30 feet above the surface. No decrease in pressure has been noted.

The Scott well is 740 feet deep, and is situated an eighth of a mile from the Rust well, on the same side of the branch and close to it. The first flow was struck at 680 feet. The original pressure was sufficient to raise the water 20 feet above the surface, but now (1905) it simply flows at the surface. The temperature and other physical characters are the same as in the Rust well.

Partial analyses of a number of wells and springs in this region, including Bennett's and Gunter's springs and the Lebanon well, show a similar character and composition in all, a fact which points to the deep-seated origin of all these waters, and seems to indicate a common source in the catchment basin around Pegmatite Hill. The presence in a number of these waters of a small amount of sodium carbonate apparently confirms this view, and shows that the pegmatite containing soda feldspar is of greater extent underground than at the surface.

HAHATONKA.

In 1902 Major Rush sunk a well in search of mineral on the southwest side of Hahatonka Lake, not far from the island and but a few feet above the level of the lake. It is 864 feet deep. The first flow of water was obtained at 840 feet. The water rose 36 feet above the surface. This well was started probably near the top of the Gasconade limestone and ended in 3 feet of soft sandstone, possibly of the Elvins formation. Unfortunately no record was obtainable. The flow has materially decreased. The temperature of the water is 63° F. with an air temperature of 87° F. The water is clear, but warmer than that of adjacent springs, and has a slight odor of sulphureted hydrogen.

HICKORY COUNTY.

CROSS TIMBERS.

Five miles due west of Cross Timbers, in the bottom of a small stream valley, in the NW. ¼ NW. ¼ sec. 24, T. 38, R. 22, are three wells owned by G. W. Crudginton that were drilled in September, 1899, in prospecting for lead and zinc, to the depths of 75, 90, and 110 feet. Water began to flow from a depth of 33 feet, and continued to do so all the way down. No perceptible change in the flow has ever been noted. The three wells are all within 50 yards of one another, and at about the same elevation, which is estimated, barometrically, as 535 feet. It is difficult to determine the flow of these wells, as a large amount of water leaks out from the base of the pipes. The well with the strongest pressure has a flow, from a 2½-inch pipe, estimated at about 8 gallons per minute. These drill holes had originally a 6-inch bore and were never cased. No log was kept, but it is stated that they passed through limestone all the way, probably starting in the Roubidoux. The following analysis of the water from the deepest of the three wells was made by Mr. E. E. Ellis, to whom the writer is indebted for these notes.

Analysis of water from well No. 3 at Cross Timbers, Hickory County.

	Parts per million.		Parts per million.
Iron	Trace.	Sulphates	88
Calcium	380	Chlorides	14.44
Total hardness	152.9	Temperature of air, 64.2° F.	
Total carbonates	470.4	Temperature of water, 57.2° F.	
Alkaline carbonates (normal)	0	Color, clear.	
Alkaline earthy carbonates (acid)	470.4	Odor, none.	

The water has a slight odor of sulphureted hydrogen.

PITTSBURG.

In 1896 the discovery of zinc in a shallow well started a large amount of prospecting in the neighborhood of Pittsburg, and several flowing wells were obtained from these prospect holes. These wells seem to be located on the northwestern slope of a fold extending northeast and southwest through this region, and have been placed, for convenience of description, in the Decaturville dome district.

Pittsburg is situated in the southeast corner of sec. 25, T. 36, R. 22, at an altitude, barometrically, of 1,155 feet, or 90 feet above the town of Bolivar. The first flowing well was struck on the land of J. A. Williams, in the northwest corner of sec. 25, T. 36, R. 22. It was drilled by Mr. Busby, of Iola, in August, 1901, with a 6-inch churn drill, to a depth of 100 feet, and cost $75. Water was encountered at

a depth of 20 feet, but the first flow came from near the bottom. The mouth of the well is a little less than 100 feet lower than the town of Pittsburg, and is probably in the Jefferson City limestone. No log was kept, but it is stated that the drill passed through limestone all the way. No variation has been noted in the flow, which is a small stream. The water is clear and odorless. The air temperature is 48° F., and the water temperature 53° F.

The well on the land of S. J. Martin, south of the center of the SW. ¼ sec. 25, T. 36, R. 22, was sunk in October, 1901, to a depth of 100 feet, with a 6-inch churn drill. This well had at first a stronger flow than any other in this group, but the force has gradually diminished until the water stands 3 feet below the surface.

The well on the land of Y. J. Petts, in the center of the W. ½ sec. 36, T. 36, R. 22, on the top of a hill, is 90 feet deep, and was made with a 6-inch churn drill. The well was started in the upper part of the Burlington limestone about 8 feet thick, then passed through 10 feet of yellow rock (Chouteau limestone) and 20 feet of blue (Hannibal) shale. The remainder of the record was lost. The absence of the lower part of the Burlington all through this region is noticeable. The air temperature is 48° F., the water temperature 53° F.

A well near the center of sec. 14, T. 35, R. 22, owned by Len. G. Mallonnee, of Pittsburg, was sunk to a depth of 110 feet, in October, 1901, with a 6-inch churn drill. This well was started in white, coarse-grained limestone (the upper part of the Burlington), 30 feet thick; it then passed through 30 feet of sandstone (Hannibal), 20 feet of blue shales (Hannibal), and flint to the bottom. It is noticeable that the Chouteau limestone is absent. The water is colorless and odorless. It was struck in the Hannibal sandstone, and did not flow until the sandstone was nearly passed through, after which the flow grew stronger until the bottom was reached.

MILLER COUNTY.

AURORA SPRINGS.

A little to the southeast of Aurora Springs, Miller County, in sec. 19, T. 41, R. 15, a shaft was sunk to a depth of 140 feet, in prospecting for lead and zinc. The well is situated about 12 feet above the bottom of Little Gravois Creek. No water was struck until a depth of 100 feet was reached; below this the well commenced to flow.

IBERIA.

Two and one-half miles northwest of Iberia, in the bottom of Baileys Branch, is a well on the farm of George Graves. A moderate flow of water was obtained at a depth of 60 feet, in the Gasconade limestone.

POLK COUNTY.

CLIQUOT.

Near Cliquot are two wells—one owned by the St. Louis and San Francisco Railroad and the other by M. C. Shelton.

The railroad well, in sec. 8, T. 34, R. 23, was drilled in 1901 by W. A. Hash, of Bolivar, to a depth of 262 feet, the first 196 feet with an 8-inch bore and the last 66 feet with a 6-inch bore. Water was struck at 40 feet, and the flow increased slowly with the depth. The pressure is sufficient to raise the water in a pipe 15 or 20 feet above the surface. A pump is, however, used to force the water into a water tank for engine purposes. The water is clear, colorless, odorless, and cool. The well starts in what is probably the base of the St. Peter sandstone. The altitude of Cliquot is about 995 feet.

The Shelton well is situated in the center of sec. 17, T. 34, R. 23, three-fourths of a mile southeast of Cliquot, and probably 50 feet higher than the well at that point. It is only 10 feet deep, and passed through a tough yellow clay and shale, striking a hard rock at 10 feet, from which point the water rose and flowed out at the surface. The shale was, undoubtedly, Hannibal shale, and the limestone either Louisiana or "Sac" limestone.

GOODSON.

Near Goodson post-office, 9 miles south and 3 miles east of Pittsburg, is a well that was originally a prospect hole for lead and zinc. It is 100 feet deep and has a good flow, the water rising 6 feet above the surface.

CLINTON-NEVADA DISTRICT.

GENERAL ARTESIAN CONDITIONS.

The Clinton-Nevada district includes portions of Henry, Vernon, Cass, Bates, St. Clair, and Cedar counties. The wells in this district have their catchment basin in the Ozarks. The uniform dip of the strata to the west and northwest is continued in this district as in the districts to the north. In this district, however, the conditions are more favorable for flowing wells than farther north, as the altitude of the country to the west does not increase so rapidly.

The upturned edges of the Pennsylvanian rocks outcrop successively through this district. Fairly good water is obtained from the sandstones and limestones of the Pennsylvanian, but that from the shales is liable to be strongly saline. The Mississippian forms a fine water table, and a strong body of water is usually found when the drill reaches that series.

Large shallow ponds or lakes and swamps extend in a long narrow belt from a point southwest of Nevada for a distance of 40 miles to the northwest. Some of these bodies of water cover several hundred

acres and are never dry. The peculiar topography and conditions so far south of the glaciated area immediately impress the observer. It is said that these ponds contain fresh, pure water and are spring fed. It is also stated that a person wading in them can feel the cold jets of water that come up from many points all over the bottom. This belt of lakes and swamps seems to be a flat, slightly depressed area with a somewhat abrupt eastern side that rises suddenly to a broad valley or plain from 40 to 60 feet above the lake valley. This outline suggests the possibility that the area has been undermined by the numerous springs brought up by artesian pressure, the phenomena being similar to those observed in the "sunk district" of southeastern Missouri. Flowing wells are found at the following places: Clinton, Henry County; Nevada, Richards, Sheldon, and Stotesbury, Vernon County; and near Horse Creek, Barton County.

BARTON COUNTY.

HORSE CREEK.

In the middle of the N. ½ sec. 2, T. 33, R. 29, just above the level of a little branch that flows into Horse Creek, is a well that was sunk in 1884 to a depth of 60 feet in search for mineral. It was started near the base of the Cherokee shales and stopped at the top of the Mississippian limestone. It flows a very small stream, which is piped laterally. The water contains a very small amount of gas. Its temperature was 64° F. when that of the air was 87° F.

BATES COUNTY.

ADRIAN.

In sec. 30, T. 42 N., R. 30 W., is a well owned by the Lawder estate and drilled by R. J. Lawder. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Lawder well, Adrian, Bates County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, red and yellow clay	37	37
Lime rock	3	40
Fire clay	20	60
Lime rock	11	71
Dark clay	4	75
Lime rock	3	78
Gray slate	10	88
Dark clay	3	91
Lime rock	5	96
Gray slate	14	110
Blue soapstone	20	130
Fire clay	17	147
Lime rock	7	154
Blue joint clay	10	164
Lime rock	8	172
Gray joint clay	4	176
Flint rock	8	184
Gray clay	2	186
Gray lime rock; affords about 2 barrels of water per day	74	260
Sand rock	15	275
White lime rock	25	300
Sand rock	20	320

ROCKVILLE.

In 1904 a well was drilled at Rockville to a depth of 1,550 feet. The driller declined to give a full record, but from his statement it was learned that the St. Peter sandstone was reached at a depth of 856 feet, with a strong body of saline water.

CASS COUNTY.

DREXEL.

In Drexel, Cass County, is a drilled well 64 feet deep. It penetrated 40 feet of limestone and 4 feet of carbonaceous shale, from which latter the water is derived. The water is pumped to the surface and has a temperature of 58° F.

Schweitzer, in his report on the mineral waters of Missouri,[a] gives the following analysis:

Analysis of water from well at Drexel, Cass County.[b]

	Parts per million.		Parts per million.
Silica (SiO_2)	11	Sulphate radicle (SO_4)	74
Iron (Fe)	2.8	Chlorine (Cl)	103
Calcium (Ca)	9.9	Sulphur (S)	4.1
Magnesium (Mg)	6.5		1,751.3
Sodium (Na)	481		
Bicarbonate radicle (HCO_3)	1,059		

PLEASANT HILL.

At Pleasant Hill, Cass County, there is a well 150 feet south of the Missouri Pacific Railway. The log, for which the writer is indebted to Dr. G. C. Broadhead, is as follows:

Log of well at Pleasant Hill, Cass County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Dark clay	30		30	
Gravel, water-bearing	2		32	
Clay, with thin layers of sandstone	43		75	
Black bituminous shale, with streak of coal	3		78	
Dark shales, with thin limestone layer	2		80	
Dove-colored shales	9		89	
Gray limestone	5		94	
Dove-colored calcareous shales	7		101	
Dark shales with red beds	2	6	103	6
Shales	28		131	6
Sandstone	3		134	6
Shales and limestone	17		151	6
Black shales, with thin coal seams	3		154	6
Shales and clay	3		157	6
Blue limestone	10		167	6

[a] Missouri Geol. Survey, vol. 3, 1892, p. 182.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

Log of well at Pleasant Hill, Cass County—Continued.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Dark shales and sandstone	7		174	6
Dark-blue and red shales	15		189	6
Hard blue limestone	2		191	6
Dark shales and coal	1	6	193	
Clay	2		195	
Sandstone	10		205	
Limestone	2		207	
Sandstone	3		210	
Shales and coal	1		211	
Alternating sandstone and shales	80		291	
Dark shales	1		292	
Shales	9		301	
Bituminous slate	3		304	
Sandstone and shales	18		322	
Shale, slate, and a foot of coal	2		324	
Sandstone and shales with pyrite	31		355	
Limestone	1		356	
Shales	3	6	359	6
Good bituminous coal	1	6	361	
Fire clay, with nodules of ironstone	5		366	
Clay, shales, and ironstone	10		376	
Micaceous sandstone with some clay	105		481	
Dark clay with 1 foot of coal	5		486	
Sandstone and blue shales with pyrites	47		533	
Shale	19		552	
Brown sandstone	28		680	
Lower Carboniferous limestone and chert	25		605	

All but the last 25 feet of this section is Des Moines.

HENRY COUNTY.

CLINTON.

At Clinton, Henry County (see fig. 5), the Clinton Light and Water Company has several wells.[a] Well No. 1, south of the city, in the NW. ¼ SW. ¼ sec. 10, T. 41, R. 26, was drilled in the summer of 1887. Depth, 800 feet; altitude, 700 feet above tide; casing, 8-inch to 425 feet, 5⅝-inch to 800 feet; flow, 400 gallons per minute; cost, about $2,500; surface formation, base of Cherokee shales. The first flow of water noted, 75 gallons per minute, was obtained at a depth of 310 feet in the St. Peter sandstone. At 425 feet the flow had increased to about 200 gallons per minute and the pressure was so strong that it was difficult to preserve the drillings. This water was charged with sulphureted hydrogen and was called sulphur water. At this depth the bore was reduced from 8 to 5⅝ inches, and continued thus down to 800 feet. The flow of water at 425 feet was cut off by casing, so that the two distinct flows could be obtained, that from the depth of 425 feet issuing from around the inner casing, which brought up the water from 800 feet. The water from the bottom was probably derived

[a] Acknowledgment is hereby made to Dr. J. H. Britts, of Clinton, for the drill samples, which the writer has examined, for records and analyses of this interesting group of wells and for other valuable information.

from the base of the Gasconade limestone and was fresh. The flow in both cases was measured and found to be about 200 gallons per

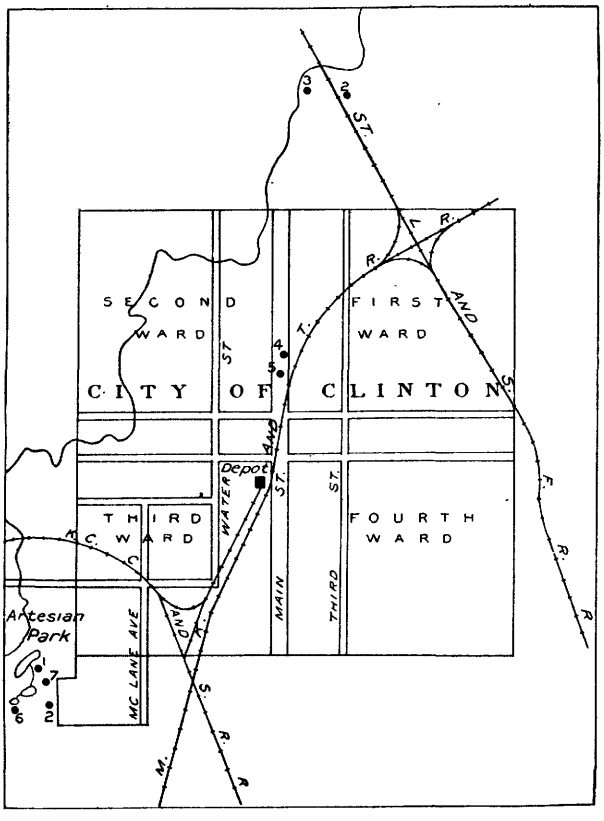


FIG. 5.—Map of the Clinton artesian district, Henry County.

minute each, or a total of 400 gallons. The inner casing has since been removed, and the waters mix. The following is the record of this well:

Log of artesian well (No. 1), Clinton, Henry County.

	Thickness.	Depth.
Des Moines (40 feet):	*Feet.*	*Feet.*
Blue shale	40	40
Keokuk and Burlington (80 feet):		
Chert and gray limestone	10	50
White chert	10	60
White chert and limestone	20	80
White shaly limestone	10	90
Gray limestone and white chert	10	100
Blue magnesian shale	10	110
Blue and gray siliceous limestone and chert	10	120

Log of artesian well (No. 1), Clinton, Henry County—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Chouteau limestone (70 feet):		
Light-gray crystalline magnesian limestone, little chert	25	145
Blue splintery, compact magnesian limestone	15	160
Blue splintery, shaly magnesian limestone	20	180
Same, with more chert	10	190
Devonian (40 feet):		
Same, with more chert and siliceous limestone	10	200
Blue and gray shaly, siliceous magnesian limestone	20	220
Gray siliceous magnesian limestone, some chert	10	230
Joachim limestone (50 feet):		
Light-gray "cotton rock," magnesian limestone	30	260
Same and some blue limestone	20	280
St. Peter sandstone (30 feet):		
Fine-grained blue chalcedonic flint, siliceous limestone with marcasite crystals and iron-stained sand (rounded grains of quartz)	10	290
Same, with finer rounded grains (probably St. Peter sandstone)	10	300
Coarser, more rounded grains of quartz, siliceous white magnesian limestone	10	310
Jefferson City limestone (190 feet):		
Quartz, flint, and siliceous magnesian limestone, minute marcasite crystals	10	320
Flint and quartz grains mixed with siliceous limestone	10	330
Same, with minute marcasite crystals and iron stain	10	340
Fine-grained siliceous dolomitic limestone, with some flint	30	370
Gray siliceous dolomite, white flint and marcasite	10	380
Gray siliceous dolomite, slightly coarser, no flint	10	390
Dark-gray siliceous dolomite, with few coarse particles of flint	10	400
Flint, quartz, and siliceous limestone; flow of water very strong; sulphur water at 425 feet	100	500
Roubidoux sandstone (25 feet):		
Fine white sandstone (probably Second sandstone of Swallow); flow very strong	25	525
Gasconade limestone (275 feet):		
(From 525 to 670 feet no cuttings could be had owing to force of water)	145	670
Light bluish-gray dolomite, with fine grains of white flint	30	700
Fine grains of quartz, white flint, and gray siliceous dolomite at bottom; fresh water	100	800

The following analysis is taken from Schweitzer's report.[a]

Analysis of water from artesian well (No. 1), Clinton, Henry County.[b]

[Analyst, A. E. Woodward, 1892.]

	Parts per million.		Parts per million.
Silica (SiO_2)	12	Bicarbonate radicle (HCO_3)	375
Calcium (Ca)	117	Sulphate radicle (SO_4)	110
Magnesium (Mg)	51	Chlorine (Cl)	719
Sodium (Na)	419		1,819
Potassium (K)	16		

This is a distinctly saline water, with a small percentage of carbonates present. The sample for analysis was obtained by plunging a gallon bottle into the mouth of the standpipe and allowing it to fill with the water. The bottle was then stoppered and sealed with melted paraffin.

Well No. 2 is a few hundred feet south of well No. 1. Depth, 800 feet; altitude above tide, 700 feet; casing, 5-inch to bottom; flow, about 200 gallons per minute;[c] date of completion, 1891; surface formation, base of Cherokee shales. The log of this well is essentially the same as that of No. 1. It is a curious fact, however, that the

[a] Mineral waters of Missouri: Missouri Geol. Survey, vol. 3, 1892, p. 86.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

[c] Since the sinking of well No. 7 the flow of this well has decreased fully one-half.

chemical composition of the water is decidedly different, as may be seen by a comparison of the accompanying analyses of the two.[a] This well was for a number of years the main source of water supply for the city of Clinton. The water is collected in large reservoirs and, together with that of several other wells more recently drilled, is pumped to the city.

Analyses of water from artesian well (No. 1) and waterworks well (No. 2), Clinton, Henry County.[b]

[Parts per million.]

	Artesian well.	Waterworks well.
Calcium (Ca)	116	80
Magnesium (Mg)	51	37
Sodium (Na)	420	204
Potassium (K)	17	42
Carbonate radicle (CO_3)	184	168
Sulphate radicle (SO_4)	110	91
Chlorine (Cl)	717	335
	1,615	957
Free H_2S	4.1	1.1
Free CO_2 and combined as bicarbonate	175	147

In connection with this comparison Woodward says:

Since the two wells are but a short distance apart and were both drilled to the same depth, a correspondence between the analyses of these waters is to be expected. A very considerable difference is found to exist, however. Thus, though both are characterized by a large percentage of sodium and chlorine, the water of this well [waterworks well] differs from the artesian-well water by containing larger amounts of carbonates and sulphates. These differences are produced probably by the mixing in the waterworks well of a greater quantity of surface waters with the chloride water, thereby decreasing the amount of total solids and increasing at the same time the amount of alkaline constituents. * * * Results of analyses of other well or spring waters directly comparable to these Clinton waters are not easy to find. The Fort Scott, Kans., artesian water yielded 1,868 parts per million; the Clinton artesian, 1,615 parts per million.

The following is a complete analysis of water from waterworks well (No. 2):[c]

Analysis of water from waterworks well (No. 2), Clinton, Henry County.[b]

[Analyst, A. E. Woodward, 1892.]

	Parts per million.		Parts per million.
Silica (SiO_2)	2.4	Bicarbonate radicle (HCO_3)	342
Calcium (Ca)	80	Sulphate radicle (SO_4)	91
Magnesium (Mg)	37	Chlorine (Cl)	335
Sodium (Na)	204		1.133.4
Potassium (K)	42		

[a] Woodward, A. E., Bull. Missouri Geol. Survey No. 3, 1890, p. 91.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

[c] Schweitzer, Paul, Mineral waters of Missouri; Missouri Geol. Survey, vol. 3, 1892, p. 120.

About 1 mile north of the wells previously described, in the bottom of the same creek and similar in character to No. 2, is a well (No. 3) owned by Dr. J. H. Britts. Depth, 913 feet; altitude above tide, 715 feet; casing, 8-inch to bottom; temperature of water, 64° F.; flow, 400 gallons per minute;[a] date of completion, 1891; cost, $2,000; surface formation, base of Cherokee shale. The log of this well differs slightly from those of the other wells in the first 60 feet, the first 40 feet of Cherokee shales being followed by 20 feet of Graydon sandstone, a formation which does not appear in any of the other wells about Clinton. The following is an analysis of the water of the Britts well:[b]

Analysis of water from Britts artesian well (No. 3), Clinton, Henry County.[c]

[Analyst, Paul Schweitzer.]

	Parts per million.		Parts per million.
Silica (SiO_2)	14	Bicarbonate radicle (HCO_3)	431
Calcium (Ca)	106	Sulphate radicle (SO_4)	91
Magnesium (Mg)	45	Chlorine (Cl)	560
Sodium (Na)	353		1,619
Potassium (K)	19		

At the Clinton ice plant, about 1,000 feet northeast of the courthouse, at one of the highest points in the vicinity, are two nonflowing wells (Nos. 4 and 5), 10 feet apart. One was drilled in 1894 and the other in 1896. Both are 650 feet deep and their altitude is 780 feet, which is probably 80 feet more than that of the flowing wells in the valley. The bore of one is 8 inches and of the other 2 inches. Water rises within about 100 feet of the surface. The wells are equipped with two deep-well pumps having a capacity of 240 gallons per minute, and they would undoubtedly supply two or three times the capacity of the pumps. No analysis of the water of either of these wells has been made, but it is stated that it is alkaline with an appreciable amount of sulphureted hydrogen, and similar in character to that of the other wells. Marbut[d] gives the following log of these wells:

Log of wells at Clinton ice plant (Nos. 4 and 5), Clinton, Henry County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Soil and clay	12	0	12	0
Sandstone and sandy shale	21	0	33	0
Coal	0	4	33	4
Shale	9	0	42	4
Sandstone, very hard	8	0	50	4
Shale and sandstone	87	0	137	4
Chert, lower Carboniferous	45	0	182	4
Shale, red	20	0	202	4
Limestone, Lower Carboniferous and Silurian	400	0	602	4
Sandstone, "Saccharoidal," with rounded grains of pure silica	40	0	642	4

[a] Since the completion of well No. 7, near Nos. 1 and 2, this well has ceased to flow.

[b] Missouri Geol. Survey, vol. 3, 1892, p. 121.

[c] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

[d] Marbut, C. F., Geology of the Clinton sheet: Missouri Geol. Survey, vol. 12, pt. 2, 1898, p. 101.

About 200 feet west of well No. 2 is a well (No. 6), owned by the Clinton Light and Water Company. Depth, 500 feet; altitude above tide, 700 feet; casing, 8-inch to bottom; flow, 200 gallons per minute;[a] date of completion, 1897; surface formation, base of Cherokee shales. The water of this well is similar in composition to that of well No. 2, and the two wells have similar logs. The water is collected in settling basins for city service.

Near the northeast corner of the new settling basin of the Clinton water station about 150 feet north of well No. 2 is another well (No. 7), owned by the Clinton Light and Water Company. Depth, 818 feet; altitude above tide, 700 feet; casing, 10-inch to bottom; flow, about 700 gallons per minute; date of completion, February, 1902; cost of well, $2,000; surface formation, base of the Cherokee shales. The flow of this well surpasses that of all of the other wells combined, and its effect on the others, as has already been mentioned, has been marked. The water resembles that of No. 2 more closely than that of any of the other wells. It may be classed as an alkaline water, with some sodium chloride and with free hydrogen-sulphide gas. It is not, however, a combined sulphur water. This well is at present the main source of the city water, which it supplies in the greatest abundance, filling a reservoir 250 by 160 by 5 feet in twelve hours. The log is practically the same as that of the other Clinton wells, extending into the Gasconade limestone. The main source of water is probably in the Roubidoux sandstone. This well began to flow at about 375 feet and the water was comparatively soft with but little mineral salts and hydrogen-sulphide gas. The flow gradually increased with the depth of the well with a corresponding increase of mineral constitutents. The following analysis of this water was obtained:

Analysis of water from well No. 7, Clinton, Henry County.[b]

[Analyst, J. C. Draper, June 20, 1902.]

	Parts per million.		Parts per million.
Silica (SiO_2)	6.4	Sulphate radicle (SO_4)	122
Iron (Fe)	Trace.	Chlorine (Cl)	122
Calcium (Ca)	147	Alkaline chlorides	1,562
Magnesium (Mg)	56		2,194.4
Carbonate radicle (CO_3)	179		

The Jordan well is located in sec. 19, T. 41, N., R. 25 W., about 3 miles southeast of Clinton. It flowed feebly for a number of years after it was drilled and yielded a mildly chalybeate water, which was extensively used. It is now, however, abandoned and choked up. No log was kept and no analysis was made, but the water apparently had its source in the Cherokee shales.

[a] Flow has decreased since the sinking of well No. 7.

[b] Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

ST. CLAIR COUNTY.

APPLETON.

In 1891 the Appleton City Water and Power Company put down a well 1,190 feet deep in prospecting for oil, gas, or water. It is to be regretted that the greater portion of the record of this well has been lost. It was cased for 300 feet with 8-inch casing. A strong body of water was struck between 1,000 and 1,100 feet. It was decidedly saline, and contained a large amount of sulphureted hydrogen. The mouth of the well has an altitude of 760 feet; the well starts in Cherokee shales, and water stands 40 feet from the surface. Acknowledgment is made to Mr. T. C. Brown for the use of such drill samples as have been preserved. The well cost $2,000. At 50 and 150 feet small coal seams were struck.

From the cuttings that have been preserved, Mr. Ellis gives the following incomplete log:

Partial log of well at Appleton City, St. Clair County.

	Thickness.	Depth.
	Feet.	*Feet.*
Grayish-brown compact limestone containing numerous small, well-rounded quartz grains, at		587
Compact limestone and chert, with small rounded quartz grains	21	608
Finely crystalline dark-brown limestone, with some chert and many rounded quartz grains	37	645
Thoroughly crystalline, fine-grained gray limestone, with small amounts of chert and marcasite	30	675
Compact, crystalline grayish-brown limestone, with oolitic chert and sand	65	740
Finely crystalline, light-gray limestone, with few sand grains; no chert	50	790
Rather fine-grained sandstone, nearly white, iron stained, grains well rounded	10	800
Crystalline light-gray limestone, with white chert	200	1,000
Compact light-gray limestone, with some sand grains	190	1,190

The greater part of this section is probably Gasconade limestone.

Analysis of water from artesian well at Appleton City, St. Clair County.[a]

[Analyst, Paul Schweitzer.]

	Parts per million.		Parts per million.
Silica (SiO_2)	40	Carbonate radicle (CO_3)	12
Calcium (Ca)	369	Sulphate radicle (SO_4)	272
Magnesium (Mg)	161	Chlorine (Cl)	4,939
Sodium (Na)	2,589		8,392
Lithium (Li)	10		

This water was used by the city for two years, being pumped by a small engine, but it was finally discarded because of its highly mineralized character. It is stated that the water corroded iron and tin and killed neighboring vegetation.

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

OSCEOLA.

In 1891 a well about 500 feet deep, with an 8-inch bore, was sunk in Osceola and cased 12 feet to rock. A strong vein of water was struck, which rose within 75 feet of the surface. The water is hard, and was pumped for general use. The cost of the well was $1,500.

Another well is now (summer of 1905) being drilled at Osceola for oil and gas by the Osceola Development Company on the farm of M. M. Love, 1 mile west of the Frisco Railway station, on the top of a hill having an elevation of 832 feet. The well was started in the base of the Des Moines, and the company expects to go to a depth of 1,800 feet.

VERNON COUNTY.

NEVADA.

Nevada, Vernon County, is, like Clinton, the center of a group of several flowing and nonflowing deep wells. The oil excitement in Kansas stimulated the boring of deep holes in this region, which resulted in the finding of several valuable artesian wells in this county. The most important of these are the wells at Nevada, Sheldon, Stotesbury, and Walker.

In the suburbs of Nevada, a little over a mile from the railway station, is a well owned by Harry C. Moore. Depth, 800 feet; altitude, barometrically, 900 feet; casing, 6-inch; depth, unknown; temperature of water, 63° F.; of air, 69° F.; flow, 10,000 gallons per hour; date of completion, 1887; cost, $2,500; surface formation, base of Cherokee shales. The well is situated on the side of a valley at the foot of a low ridge. The water rises through an iron pipe and flows into a basin, whence it is conveyed to two lakes covering 15 acres each. The water is strongly impregnated with sulphureted hydrogen and a deposit of white algæ, the same as that at Clinton, covers the basin and its outlet. It is to be regretted that no record of the log of this well has been preserved. An analysis made by Schweitzer in 1892[a] is here given:

Analysis of water of artesian well at Nevada, Vernon County.[b]

[Analyst, Paul Schweitzer, 1892.]

	Parts per million.		Parts per million.
Silica (SiO_2)	14	Sulphate radicle (SO_4)	53
Calcium (Ca)	80	Chlorine (Cl)	423
Magnesium (Mg)	33		1,252
Sodium (Na)	307		
Bicarbonate radicle (HCO_3)	342		

[a] Missouri Geol. Survey, vol. 3, 1892, p. 122.

[b] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

A number of deep nonflowing wells in this district have been sunk in the search for oil or gas. Among them may be mentioned the drill well of the Nevada Gas, Oil and Asphalt Company, 9 miles south of Nevada, at an elevation of 821 feet above tide. The writer is indebted to Mr. George A. Pierson for the following record:

Log of drill well of Nevada Gas, Oil and Asphalt Company, 9 miles south of Nevada, Vernon County.

	Thickness.	Depth.
	Feet.	*Feet.*
Des Moines (294 feet):		
Surface clay	4	4
Sand rock	50	54
Shale	30	84
Sand rock	50	134
Slate	6	140
Coal	3	143
Shale rock	18	161
Flint; at 180 feet strong water rose within 80 feet of top; well cased with 10-inch casing	33	194
Sand rock; at 230 feet strong water rose within 85 feet of the top	100	294
Mississippian (413 feet):		
Limestone	53	347
Shale; 8-inch casing to this point	60	407
Limestone	100	507
Water limestone	100	607
Sandy limestone	100	707
Devonian and Joachim limestone (200 feet):		
Soft sandstone (probably limestone)	100	807
Fairly hard sandstone (probably limestone)	100	907
St. Peter sandstone (100 feet):		
Fine sandstone	100	1,007
Jefferson City limestone (175 feet):		
Hard sand limestone; at 1,092 feet water thrown out of pipe 30 feet high	175	1,182
Roubidoux sandstone (60 feet):		
Hard sandstone	60	1,242
Gasconade limestone (207 feet):		
Hard limestone	8	1,250
White sand	15	1,265
Limestone	20	1,285
White sandy limestone	10	1,295
Limestone; water strong at 1,300 feet	30	1,325
White sandy, hard limestone	19	1,344
Hard white sandstone	12	1,356
Dark-brown limestone (drillers call this Trenton)	16	1,372
Sandstone, unaccounted for	75	1,447

This record has been a very difficult one to summarize. Through the courtesy of the company the writer was allowed to examine some of the samples contained in glass tubes, and he feels little doubt that some of the material described as sandstone in the log is limestone. It is very common for drillers to use the term sandstone for a siliceous limestone. The correlations, while somewhat doubtful, as stated, are believed to be approximately correct and check fairly well with other more reliable data.

This company has just started another well west of Nevada, in the NE. $\frac{1}{4}$ sec. 16, T. 35, R. 31. The altitude at the mouth of this well is 821 feet.

The water supply of Nevada is derived from 2 wells, 1,001 and 869 feet deep. The altitude of the water station, obtained barometrically, is 900 feet. The water of the deeper well is strongly impregnated with sulphureted hydrogen and deposits a white precipitate of *Begatoria alba* around the outlet. The temperature was 67° F. when

the air temperature was 69° F. The water stands 78 feet below the surface and is pumped into a large reservoir, from which it is distributed to the city. The water station is about 80 feet above the park where the flowing well previously described is located. The following log of the deeper well is furnished by Mr. J. P. Stevenson:

Log of city waterworks well, Nevada, Vernon County.

	Thickness.	Depth.
Des Moines (170 feet):	*Feet.*	*Feet.*
Drift	8	8
Sand rock	52	60
Sand shale	10	70
Trace of coal	3	73
Sand shale	48	121
Black slate	49	170
Mississippian (448 feet):		
Limestone	150	320
Sandstone	15	335
Limestone	60	395
Hard flint limestone	40	435
Lime rock	25	460
Slate	35	495
Lime rock	123	618
Devonian and Joachim limestone (157 feet):		
Gritty bastard limestone	20	638
Lime rock	22	660
Sandy bastard lime rock	35	695
Flint lime rock	40	735
Lime rock	40	775
St. Peter sandstone (43 feet):		
White sand	10	785
Lime rock	45	830
Sand	23	853
Flint	15	868
Jefferson City limestone (133 feet):		
Lime rock	32	900
Salt lime rock	30	930
Sandy lime rock	20	950
Blue lime rock	31	981
Unaccounted for	20	1,001

RICHARDS.

In the southwest corner of sec. 30, T. 36, R. 33, is a well owned by E. S. Weyand; depth, 650 feet; altitude, barometrically, 765 feet; flow, weak; casing, 6-inch; temperature of water, 62° F.; of air, 59° F.; date of completion, 1889; driller, John A. Young; surface formation, Cherokee shales. Like many others, this well was sunk during the oil excitement, and it was near enough to the Kansas oil fields to show some evidence of gas, which would burn for a short time, but which soon became exhausted. Now only a little gas comes up, intermittently, in small bubbles. There is a strong odor of sulphureted hydrogen and a thin white film is deposited around the outlet of the well. The owner informed the writer that before a rain storm the water becomes slightly milky in the trough. Washing one's hands in the water as it comes from the pipe also gives it a milky appearance—a peculiar phenomenon which may, perhaps, be explained by the breaking up of the gas bubbles. This water has a larger amount of sulphureted hydrogen than any other in the State, so far as known. It is stated that the water will rise in a pipe 15 feet above the surface.

SHELDON.

Six miles east of Sheldon, on the farm of L. C. Moore, in sec. 30, T. 34, R. 30, on the western slope of an anticlinal fold having a northeast-southwest trend, a well 17 feet deep was bored through the Graydon sandstone to the Mississippian. The water immediately rushed up, and a pipe was inserted through which it was conveyed to a tank. This is a very interesting example of the conditions favorable for artesian pressure. The limestone rocks of the Mississippian outcrop in strongly tilted ledges in the road not far away, running down the westerly slope of the anticline. The sandstone on the summit of the fold forms a catchment area through which the water penetrates to the Mississippian limestone or water table. When the reservoir is tapped low down on the fold, the water rises to the surface. The water of the Moore well is chalybeate and leaves a yellow deposit.

The anticline just referred to is one of a series of such folds that run with a northeast-southwest trend over a considerable area, and in many places the ridges outline these folds. East-west roads crossing these ridges show in the gullies the outcrops of the tilted sandstones, shales, and limestones on the slopes of the folds. The extension of these folds to the north has affected the course of the rivers, especially the Missouri.

In July, 1903, the Vernon Oil and Mining Company, of Sheldon, began drilling a well for oil and gas 4½ miles northeast of Sheldon, on the farm of Dr. C. B. Brand. This well was sunk to a depth of 1,306 feet, when work was stopped in October of the same year. The cost of drilling was about $2.25 per foot. The following is a log of this well, with correlations that are believed to be approximately correct:

Log of the Vernon Oil and Mining Company's well in the SE. ¼ SW. ¼ sec. 27, T. 34, R. 30, Vernon County.

	Thickness.	Depth.
Pleistocene (20 feet):	*Feet.*	*Feet.*
Soil	20	20
Des Moines (95 feet):		
Sandstone saturated with asphalt	25	45
Shale	30	75
Dark shale	40	115
Burlington limestone (235 feet):		
Coarse-grained crystalline limestone, some chert	210	325
Hard, compact crystalline limestone	25	350
Chouteau limestone (60 feet):		
Buff sandy limestone; water rose within 25 feet of surface	25	375
Buff sandy limestone, some flint	10	385
Buff sandy limestone	25	410
Hannibal sandstone and shale (75 feet):		
Brown sandstone, some shale	25	435
Bluish-white shale	50	485
Devonian (45 feet):		
Flint and compact limestone	45	530
St. Peter sandstone (30 feet):		
White sandstone; water came within 120 feet of top	10	540
Flint and limestone, with white rounded pebbles of sandstone	20	560
Jefferson City limestone (230 feet):		
White sandy limestone; probably siliceous limestone	230	790
Roubidoux sandstone (35 feet):		
Irregular sand grains, iron stained	35	825
Gasconade limestone (481 feet):		
Limestone, with occasional chert layers; at 1,250 feet some finely crystalline limestone, with soft gray shale	425	1,250
Record lost	56	1,306

STOTESBURY.

Just east of Stotesbury in the NE. ¼ NE. ¼ sec. 28, T. 37, R. 33, on the south bank of Osage River, a well was put down by the Missouri Oil and Development Company in August, 1901. It has flowed feebly ever since, except in very dry weather. The following log is given:

Log of well No. 1 of Missouri Oil and Development Company, near Stotesbury, Vernon County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pleistocene (9 feet):		
Soil	9	9
Des Moines (269 feet):		
"Soapstone"	20	29
Coal	3	32
"Soapstone"	13	45
"Soapstone" and blue shale	20	65
"Soapstone" and black sand	22	87
"Soapstone" and blue shale	3	90
Black sand and blue shale	30	120
Limestone	5	125
"Soapstone" and blue shale	12	137
Coal	3	140
Oil, sand, and shale	30	170
Slate and "soapstone"	35	205
Black and blue sandy shale and sandstone	20	225
"Soapstone" and shale	18	243
Limestone	2	245
Sandy shale	15	260
Fine-grained micaceous sand	5	265
Gray and black shale, with some sand	5	270
Micaceous carbonaceous shale	5	275
Carbonaceous sandy shale	3	278
Mississippian—Burlington limestone (67 feet):		
Cherty limestone	6	284
Same	1	285
Gray cherty limestone	5	290
Shaly limestone, some soapstone	5	295
Gray cherty limestone	50	345

Four miles west of Stotesbury, in a prospect hole for gas and oil, water rose and gently flowed over the surface.

WALKER.

Four miles northwest of Walker, on the farm of E. T. Litton, a well was sunk to a depth of 400 feet. The water obtained is strongly impregnated with sulphur, and the well has a rather strong flow, which has not materially decreased.

SOUTHWESTERN DISTRICT.

GENERAL ARTESIAN CONDITIONS.

The southwestern district includes an irregular area in the southwestern portion of the State, in Barry, Christian, Dent, Greene, Howell, Jasper, Laclede, Lawrence, McDonald, Newton, Ozark, Phelps, and Texas counties. The conditions in this district are in general rather unfavorable for strong artesian pressure, although there are several good wells. The country is much broken by folding, faulting, and fissuring, especially in the lead and zinc region. Several

wells are found along the slopes of the larger folds. The general dip of the rocks is toward the west and southwest. In southern Christian County the dip is to the southeast. As the richest zinc mines in the world are located in this district a great many drill holes have been made and careful records of many of them have been kept. Flowing wells are found at or near the following places: Comet and Corry, Lawrence County; Carl Junction, Jasper County; Neosho, Newton County; Tiff City, Lanagan, Noel, and Wanda, McDonald County; Ash Grove, Greene County; and in Christian County.

BARRY COUNTY.

EXETER.

Northwest of Exeter, Barry County, is a well owned by the St. Louis and San Francisco Railroad, and drilled by E. F. Stanley. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of St. Louis and San Francisco Railroad well near Exeter, Barry County.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil	65	65
Strata of lime and flint, alternating	230	295
Slate	23	318
Lime and flint	507	825
Sand rock, bearing water of a sulphur nature, but good for any purpose	44	869

CHRISTIAN COUNTY.

In Christian County, 15 miles south and east of Ozark, is a well owned by the New England Zinc Company. Depth, 225 feet; altitude, barometrically, 990 feet; casing, 10-inch; temperature of water, 58° F.; of air, 86° F.; flows feebly over a pipe 2 feet high; surface formation, near base of Jefferson City limestone. This well was sunk as a prospect hole for zinc by the New England Zinc Company and is located on the east side of the highway near Bull Creek. The water has a slight odor of sulphur, and it has deposited an iron precipitate on the pipe, which is corroded at numerous points. The rocks dip decidedly to the southwest for several miles. As far as the writer could learn this is the only flowing well in southern Missouri on the south side of the Ozarks. The water supply probably comes from some sandstone-bed in the Gasconade formation. No log could be obtained and no analysis of the water has ever been made.

DENT COUNTY.

SALEM.

Four miles southwest of Salem, Dent County, in sec. 3, T. 33, R. 6, is a well owned by Warren Bertrand and drilled by C. C. Gower. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Bertrand well near Salem, Dent County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soft sand, red	80	80
Gray lime, soft	60	140
Blue lime, medium soft	10	150
White flint, hard	2	152
Blue lime, soft	8	160

Seven miles south of Salem, in sec. 18, T. 33, R. 5, is a well owned by George Bullock and drilled by C. C. Gower. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Bullock well near Salem, Dent County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soft red clay	20	20
Soft red sandstone	75	95
Hard white lime	40	135
Hard gray flint	4	139
Rather soft white lime	18	157

West of Salem in sec. 13, T. 34, R. 6 is a well owned by W. L. Hogh and drilled by C. C. Gower. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Hogh well near Salem, Dent County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	4	4
Soft yellow clay	36	40
Blue flint, hard	5	45
Gray flint, hard	5	50
White flint, hard	5	55
Gray flint, hard	5	60
White flint, hard	9	69
Gray flint, hard	16	85

West of Salem, in sec. 13, T. 34, R. 6, is a well owned by George Stellman and drilled by C. C. Gower. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Stellman well near Salem, Dent County.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay, red	20	20
Flint rock, hard, blue	2	22
Clay, yellow	13	35
Flint rock, hard, white	1	36
Clay, yellow, soft	4	40
Flint rock, hard, white	1	41
Clay, yellow, soft	14	55
Flint rock, hard	2	57
Clay, red, soft	3	60

One mile east of Salem, in sec. 18, T. 34, R. 5, is a well owned by J. A. Murray and drilled by C. C. Gower. The following log was received from Messrs. M. L. Fuller and S. Sanford.

Log of Murray well near Salem, Dent County.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay	10	10
Yellow clay, with an occasional flint bowlder	45	55

GREENE COUNTY.

ASH GROVE.

About 1878 Judge Ralph Walker, then of Ash Grove, sunk a prospect hole 226 feet deep on the south line of sec. 28, T. 30, R. 24, on the Corum land and kept a very careful record of the strata passed through. The following log was furnished by him. This well is a particularly good one, and it is unfortunate that it was not sunk deeper.

Log of Walker drilled well, Ash Grove, Greene County.

	Thickness.	Depth.
Burlington limestone (136 feet):	*Feet.*	*Feet.*
Soil	10	10
Coarse-grained gray limestone	30	40
Buff-colored rock (Chouteau-like layer), chert, and calcite	4	44
Limestone and chert	12	56
Coarse brown limestone, known as "yellow rock"	5	61
Fine-grained limestone with ferruginous clay and calcite	6	67
Limestone	11	78
Light-drab limestone, ferruginous chert	4	82
Coarser-grained limestone, much chert and pyrite	8	90
Mostly white chert, with some argillaceous matter	12	102
White chert, shaly, drab-colored magnesian limestone	24	126
Shaly, argillaceous, impalpable powder	10	136

Log of Walker drilled well, Ash Grove, Greene County—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Chouteau limestone (43 feet):		
Greenish-yellow, coarser magnesian limestone	4	140
Buff-colored argillaceous limestone, little chert	3	143
Drab argillaceous magnesian limestone	16	159
Dark-drab magnesian limestone, much white chert	10	169
Shaly magnesian limestone, coarse grained, no chert	5	174
Gray magnesian limestone, calcite crystals, much chert	5	179
"Sac" limestone [a] (14 feet):		
Gray magnesian limestone, no chert	11	190
Bluish-gray magnesian limestone, with bluish-drab shale	3	193
"Eureka" shale [b] (23 feet):		
Blue slate with bituminous shale and chert	23	216
"King" limestone [b] (6 feet):		
Drab magnesian limestone, coarse grained, little shale, and ferruginous clay	6	222
Joachim limestone (4+feet):		
Drab magnesian limestone, marcasite crystals	2	224
Light-drab magnesian limestone, fine grained, no silica	2	226

[a] Missouri Geol. Survey, vol. 12, 1898, p. 74.
[b] Ibid., p. 67.

In 1891 the Pennsylvania Mining Company sunk a shaft near the railroad track, not far from the middle of section 28 and close to the city of Ash Grove. The following section is taken from Winslow's report on lead and zinc deposits,[a] the correlations for the summary being made by the writer, who also visited the shaft during the process of sinking. The Devonian was determined from the finding of shark's teeth, *Ptyctodus calceolus*.

Section of Pennsylvania Company's shaft at Ash Grove, Greene County.

	Thickness.	Depth.
	Feet.	*Feet.*
Burlington (180 feet):		
Surface débris	17	17
Limestone, white, crystalline, no chert; probably Burlington	23	40
Limestone, yellow, with clay pockets and perhaps some chert; close textured; an intercalated bed in the Burlington, frequently mistaken for Chouteau	40	80
Limestone, dark colored, coarsely granular	10	90
Limestone, light gray, finer textured	15	105
Limestone and chert in very thin layers, limestone fine grained and dense	75	180
Chouteau limestone (40 feet):		
Shale, drab, close textured, dense, slacks on exposure	40	220
Devonian (25 feet):		
Limestone, dark colored, coarsely granular, growing finer in texture and more arenaceous toward base, contains some pyrite	4	224
Quartzite, calamine near top, somewhat dark colored	6	230
Sandstone or quartzite, white	8	238
Shale, dark, calcareous, passing upward into the sandstone	3	241
Shale, almost black, arenaceous in lower half; much water flowed from stratum	4	245
Joachim limestone (25 feet):		
Magnesian limestone, light gray and porous; probably Silurian	5	250

In the spring of 1906 the Ash Grove White Lime Association drilled a well just northeast of their lime kilns at Ash Grove. At a depth of 260 feet a strong flow of pure water was struck, with a pressure sufficient to carry it 30 feet above the surface. No record of drillings could be obtained, but it is probable that the water came

[a] Missouri Geol. Survey, vol. 7, pt. 2, 1894, p. 628.

from the St. Peter sandstone. The well started in the Burlington. The following is the analysis of water from this well:

Analyses of water from well of Ash Grove White Lime Association, Ash Grove.

[Analyst, A. F. Shattuck, chief chemist, The Solvay Process Company, Detroit, Mich., December 5, 1905.]

Sanitary Analysis.	Parts per million.	Mineral Analysis.	Parts per million.
Total residue	181.8	Silica (SiO_2)	9.80
Loss on ignition	37.8	Oxide of iron and alumina ($Fe_2O_3+Al_2O_3$)	Traces.
Oxygen consumed	.4	Calcium (Ca)	39.16
Albuminoid ammonia	.056	Magnesium (Mg)	19.02
Free ammonia	.08	Sodium (Na)	2.87
Nitrites	0	Chlorine (Cl)	4.44
Nitrates	.09	Sulphate radicle (SO_4)	15.97
Turbidity. none.		Carbonate radicle (CO_3)	90.98
Sediment, none.			
Color, none.			
Odor, none			

The mineral constituents are probably combined as follows:

Hypothetical combination of minerals in water from well of Ash Grove White Lime Association, Ash Grove.

Silica (SiO_2)	9.80
Iron and alumina ($Fe_2O_3+Al_2O_3$)	Traces.
Calcium carbonate ($CaCO_3$)	94.64
Calcium sulphate ($CaSO_4$)	4.37
Magnesium carbonate ($MgCO_3$)	55.10
Magnesium sulphate ($MgSO_4$)	15.98
Salt (sodium chloride) (NaCl)	7.31

The water is slightly alkaline, as the analysis shows.

The carbonic acid was estimated by calculation from the remainder of the analysis, as the sample was not large enough to permit an accurate determination of it after the other determinations were completed. The carbonates are probably present as bicarbonates; that is, they are held in solution by an excess of carbonic acid over the amount necessary to form the normal carbonates.

SPRINGFIELD.

At Springfield, Greene County, there are three wells from which a record of 1,000 feet has been partially obtained. The logs of the three wells are as follows:

Log of Springfield Traction Company drill well, corner Phelps avenue and Main street Springfield, Greene County.

	Thickness.	Depth.
	Feet.	*Feet.*
Burlington (250 feet):		
Limestone, soft, cherty	50	50
Coarse-grained gray limestone, some chert	70	120
Limestone, soft, cherty, gray, and white	50	170
Limestone, dark yellowish drab, clayey	20	190
Chert, drab and white, compact and coarse (Chouteau?)	20	210
Limestone, gray and dark brown, little chert	40	250
Hannibal (30 feet):		
Shale, dark drab; plastic clay	30	280
Louisiana (20 feet):		
Limestone, very compact, dense, dark gray, small quantity white knife-blade chert	20	300
Devonian (40 feet):		
Sandstone, well cemented, fine grained, white	10	310
Limestone, compact, white or light gray, some gray chert and iron stains	10	320
Limestone, compact, bluish gray, some iron stains; probably same as last; free from chert	10	330
Same as last, but with peculiar brownish-gray tinge, apparently more magnesian	10	340
Joachim limestone (60 feet):		
Limestone, rather soft, white, earthy, free from chert, some iron stains	10	350
Limestone, cherty, yellowish, with light-gray sandstone and calcareous cement; iron stains numerous	10	360
Limestone, compact, light gray, few rounded quartz grains	10	370
Limestone, dark gray, dense, with a siliceous appearance, inclosing a few rounded grains of quartz; iron stain	10	380
Missing	20	400
St. Peter sandstone? (35 feet):		
Sandstone, light color to grayish yellow, fine grained, with calcareous cement; iron stains	20	420
Limestone, light gray, siliceous	10	430
Sandstone, fine grained, light colored	5	435

No record is available from 435 to 617 feet, where the following log begins:

Log of gas company well, Springfield, Greene County.[a]

[Record first preserved at 617 feet.]

	Thickness.	Depth.
	Feet.	*Feet.*
Limestone, light gray, with little white chert		617
Limestone, fine grained, brownish gray, crystalline, a little white chert	3	620
Limestone, compact, gray; bluish-white chert; iron stains	10	630
Limestone, compact, earthy, nearly white, free from chert; little iron stain	10	640
Limestone, dark, grayish, crystalline, with white chert	10	650
Limestone, hard, white, earthy to brownish gray, crystalline; little iron stain	10	660
Similar, with white conchoidal chert, some vein quartz, and a small quantity of pink limestone	12	672
Limestone, dark gray, compact, containing rounded grains of quartz and a little chert	8	680
Limestone, gray, crystalline, with numerous rounded quartz grains and some chert	10	690
Sandstone, yellowish gray, with some calcareous matter and iron oxide	5	695
Limestone, finely crystalline, gray, chert partly colitic, and quartz grains	5	700
Record missing	127	827

[a] Jefferson City limestone, Roubidoux sandstone, and Gasconade limestone constitute this log, but they can not be correlated.

Log of Anheuser-Busch cold-storage well, Springfield, Greene County.

[Record first preserved at 830 feet.]

	Thickness.	Depth.
	Feet.	*Feet.*
Limestone, light gray, siliceous, with small proportion of iron oxide; mainly chert, part of which is oolitic		830
Limestone, light gray, less siliceous than above, and slightly dolomitic, with iron oxide and galena; cherty portion partly oolitic	5	835
Dolomite, gray, siliceous	15	850
Limestone, dolomitic, with iron oxide	10	860
Limestone, light gray to nearly white, fine grained; no oxide	5	865
Dolomite, fine grained, gray, siliceous, with a little iron oxide	5	870
Chert, nearly pure white to light gray, with some iron-oxide stains	13	883
Limestone, light colored, finely granular, free from chert; some iron oxide	12	895
Dolomite, dark-gray, rather finely crystalline, with a compact white chert resembling Burlington chert; iron-oxide stains	15	910
Limestone, light colored, with chert and iron stains	10	920
Limestone, light colored, nearly white and comparatively pure; iron stains	10	930
Limestone, fine grained, crystalline, gray, white calcite crystals, and pink dolomite; iron stains	5	935
Limestone, compact to crystalline, with chert and some iron stains	65	1,000

The well of the Springfield Traction Company was put down in the summer of 1902 in order to supply water for the boilers of the power house. The drillings were carefully watched by the writer. A good flow was obtained from the St. Peter sandstone, but the water was apparently impregnated with other water and very hard in consequence. The 35 feet of sandstone at 400 feet is, without doubt, the St. Peter sandstone, and is made up of rounded, waterworn quartz grains, slightly iron-stained, and loosely coherent. It is greatly to be regretted that complete records of the gas company and cold-storage wells are not obtainable.

About 1870 the St. Louis and San Francisco Railroad sunk a deep well for water at the car shops, north of Commercial street and Washington avenue, in what was then North Springfield. The drill record was not made public for many years. It is probable that the "sandstone" encountered from 610 to 645 feet in this well was a siliceous limestone. The writer had no opportunity to see the drillings, which were not preserved, but so many instances have occurred in which a limestone of this character has been mistaken for sandstone by the driller that this inference seems justifiable.

The water obtained from this well was clear and fine, though hard, and the temperature at the bottom of the well was 60° F. The well is situated on the crest of the great divide or watershed of the Ozarks, water to the north flowing into Sac, Osage, and Missouri rivers, and to the south into Wilson Creek, James, White, and Mississippi rivers. For this reason the water level is deep, being 225 feet. Considerable water was encountered at a depth of 325 feet, evidently from the "Phelps" sandstone. At 406 feet, in the St. Peter sandstone, the water was tested by pumping 500 gallons per hour, which lowered it

50 feet. More water was struck at 540 feet. At 610 feet, in the Roubidoux standstone, 750 gallons per hour were pumped without lowering the level.

The following is the log of this well:

Log of well at car shops, Springfield, Greene County.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
Burlington (250 feet):				
Soil and limestone	35	.0	35	.0
Gray limestone	118	.0	153	.0
Flint and limestone	62	.0	215	.0
Limestone	35	.0	250	.0
Chouteau limestone (47 feet):				
Soft slate or soapstone	30	.0	280	.0
Gray limestone	17	.0	297	.0
Devonian ("Phelps" sandstone[a]) (4 feet):				
Sand rock	4	.0	301	.0
Devonian ("Sac" limestone[a]) (29 feet):				
Gray limestone	17	.0	318	.0
Flint, limestone with pyrites	12	.0	330	.0
Devonian ("King" limestone[a]) (6 feet):				
Light-gray limestone	6	.0	336	.0
Joachim limestone (54 feet):				
Flint and limestone	4	.0	340	.0
Gray limestone	7	.0	347	.0
White gritty limestone	25	.0	372	.0
Fine limestone	3	.0	375	.0
Coarse limestone	15	.0	390	.0
St. Peter sandstone? (16 feet):				
Porous sandstone	8	.0	398	.0
Limestone and some sand	8	.0	406	.0
Jefferson City limestone (126 feet):				
Bluish-brown limestone	29	.0	435	.0
Fine flinty limestone	77	.0	512	.0
Fine sand	10	.0	522	.0
Fine gray limestone	10	.0	532	.0
Roubidoux sandstone (55 feet):				
Very fine sand rock	55	.0	587	.0
Gasconade formation (138 feet):				
Brown limestone	5	.0	592	.0
Flinty siliceous rock	8	.0	600	.0
Very fine white sand rock	10	.0	610	.0
Finer sand	10	.0	620	.0
Sand	25	.0	645	.0
Brownish-gray limestone and flint	33	.0	678	.0
Reddish-brown limestone	12	.0	690	.0
Gray limestone and white flint	8	.0	698	.0
Fine white sand, sharp grit	22	.10	720	.10

[a] Missouri Geol. Survey, vol. 12, 1898, p. 67.

About 1888 the Frick Ice Company sunk several wells near Phelps avenue and Summit street. The water obtained was hard. The following is the log of one of the wells:

Log of well of old Frick ice factory, Springfield, Greene County.

	Thickness.	Depth.
	Feet.	*Feet.*
Coarse-grained gray limestone	100	100
White flint and gray limestone	40	140
Fine-grained limestone	40	180
Light gray argillaceous limestone	144	324
Light-gray fine limestone	16	340
Hard, fine-grained, shaly buff limestone	5	345
Fine-grained argillaceous limestone	27	372
Light-gray limestone	34	406
Fine white magnesian limestone	50	456

HOWELL COUNTY.

WEST PLAINS.

Three miles southwest of West Plains, Howell County, in sec. 35, T. 24, R. 8, is a well owned by the Frisco Ore Mining Company. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well at West Plains, Howell County.

	Thickness.	Depth.
	Feet.	*Feet.*
Red or yellow clay and chert, commonly known as Boone chert	60	60
Dolomite of irregular strata, carrying some iron ore all through from top to bottom	340	400

JASPER COUNTY.

CARL JUNCTION.

Three miles north of Carl Junction, near the Kansas City Southern Railway, in sec. 19, T. 29, R. 33, is a well on land owned by R. H. Crain, of Carthage. Three holes were drilled; the first two stopped flowing when the third was put down. These wells were sunk in 1900 to a depth of about 200 feet each. They are cased with $5\frac{5}{8}$-inch casing to bottom. They passed through alternating beds of limestone and flint all the way down. No log was kept, but the drilling was all the way in Burlington limestone.

The third well has flowed continuously since it was first put down, the water rising 3 feet above the ground and flowing over the pipe. The water is clear, cold, and hard. The drilling was done by Mr. Kilgore, of Webb City.

CARTERVILLE.

Mr. W. C. Glenn, superintendent of the American Lead and Zinc Smelting Company, furnishes the following data in regard to a well, 799 feet deep, sunk on the company's land, at Carterville, Jasper County, in 1891. The principal vein of water was found at 700 feet, in sandy rock, and the water rises within 115 feet of the surface. It is used for boiler and drinking purposes. The drilling cost $1.10 per foot. No log was kept, but the following analysis of the water was obtained:

Analysis of water from deep well of the American Lead and Zinc Smelting Company, Carterville, Jasper County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	11	Bicarbonate radicle (HCO_3)	254
Iron (Fe)	.08	Sulphate radicle (SO_4)	1.2
Aluminum (Al)	.11	Chlorine (Cl)	5
Calcium (Ca)	53		355.69
Magnesium (Mg)	7.3	Total residue on evaporation	263.5
Sodium (Na)	24		

[a] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

CARTHAGE.

One of the deepest and most important wells in the southern half of the State is that at the Harrington dairy, near Carthage, at an elevation of 955 feet. This well is owned by Charles O. Harrington, proprietor of the Harrington Hotel. It was drilled, in 1890, to a depth of 2,005 feet, with an 8-inch bore. So far as known this is one of the four wells in the State, outside of the granite area, that reaches the crystalline rocks. Water is obtained by pumping, and is used for domestic purposes and for the dairy. It is slightly hard, clear, pure, and cold. The cost of this well was $4,000, and $1,000 more was expended for pump and tanks.

Log of Harrington deep well, near Carthage, Jasper County.

	Thickness.	Depth.
	Feet.	*Feet.*
Burlington limestone (355 feet):		
Soil and clay with chert fragments	15	15
Chert, buff and bluish white, somewhat coarse grained	15	30
Limestone, gray and white, with layers of chert and with 10 to 15 per cent magnesia	135	165
Chert, compact, white and buff colored, little limestone in lower half	80	245
Chert and limestone, white and drab, two-thirds chert	110	355
Chouteau (15 feet):		
Limestone, shaly, with some chert	15	370
Hannibal (15 feet):		
Shale, light drab and yellow	15	385
Devonian (65 feet):		
Limestone, grayish-brown, siliceous, cherty and sandy (rounded grains of white quartz)	65	450
Joachim limestone (50 feet):		
Dark-gray silico-magnesian limestone, with little chert (5 per cent)	50	500
St. Peter sandstone (85 feet):		
White sandstone, small rounded grains of quartz	60	560
Sandstone, some chert and siliceous gray limestone	25	585
"Potosi" and Saratogan (910 feet):		
Dark-gray magnesian limestone, cherty	15	600
Gray limestone with chert containing small sand grains	165	765
Fine-grained crystalline white limestone	55	820
Same, with a little chert and considerable brownish-yellow material	100	920
Similar, but with more chert and limestone and less brown material	80	1,000
Magnesian limestone	675	1,675
Magnesian limestone, slate-colored, clayey	75	1,750
Archean (255 feet):		
Fine dark-reddish porphyry grains with quartz sand	200	1,950
Same, darker and coarser, with light-colored dolomitic limestone and sand	55	2,005

CHITWOOD.

Mr. H. O. Ballard furnished the accompanying log of a deep well on the United Zinc Company's land at Chitwood, near Joplin, in sec. 32, T. 28, R. 33, on lot 48. This well has a 6-inch bore and was drilled to a depth of 800 feet. Water rises within 100 feet of the surface, and pumping does not materially affect its level. The water is used for boiler and drinking purposes. The cost of drilling was $800.

Log of deep well of United Zinc Company, Chitwood, Jasper County.

	Thickness.	Depth.
	Feet.	*Feet.*
Hardpan	18	18
Blue chert	27	45
Limestone and chert	35	80
Limestone	95	175
White chert	25	200
Blue chert and limestone	40	240
Shale	10	250
Blue chert and limestone	16	266
Shale	6	272
Chert	73	345
Limestone	5	350
Green selvage	15	365
Limestone and chert	10	375
Blue chert	3	378
Limestone	22	400
Chert	8	408
Limestone	123	531
Limestone and chert	4	535
Same	70	605
Limestone	4	609
Limestone and chert	31	640
Limestone	5	645
Limestone and chert	60	705
Limestone	95	800

DUENWEG.

Two miles northwest of Duenweg, Jasper County, is a well owned by S. D. Mitchell and drilled by S. N. Smith. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Mitchell well near Duenweg, Jasper County.

	Thickness.	Depth.
	Feet.	*Feet.*
Cement	13	13
Lime and chert	32	45
Chert, jack shines	5	50
Chert and lime	140	190
Chert, jack shines	10	200
Chert and lime	150	350
Coarse gray lime	150	500
Lime, black	155	655

JOPLIN.

The Missouri Lead and Zinc Company drilled a well in Joplin near the center of the NE. ¼ SW. ¼, sec. 11, T. 27, R. 33, at an elevation of about 1,018 feet above sea level. This well was drilled by Bailey & Waugh, and the following data were furnished by Mr. H. R. Conklin:

Log of well of Missouri Lead and Zinc Company, Joplin, Jasper County.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and flint bowlers	12	12
Lime	173	185
Flint	103	288
Lime	177	465
Lime and flint with very few shines of jack	5	470
Lime	20	490
Lime, flint, and sandstone	327	817
Flint, with very few jack shines	3	820
Siliceous limestone	140	960
White sandstone	10	970
Siliceous limestone	417	1,387

At 940 feet drilling was suspended and a pump placed in well 151 feet below the surface. The water level was 107.5 feet below the surface; capacity, 39 gallons per minute, and 35.3 gallons per minute after pumping twenty-three hours.

When the drill reached a depth of 1,387 feet the pump was again started. The water then rose within 110 feet of the surface; the capacity was 96½ gallons per minute after pumping one-half hour, 68 gallons per minute after pumping nine hours, and 68 gallons per minute after pumping twenty-three hours. In both tests the pump discharged all water furnished by the well due to the head pumped off, the pump being kept on air during the test. In November, 1903, the pump was lengthened to 211 feet. The water stood at a depth of 110 feet; the pump ran to a capacity of 125 gallons per minute without any indication of going on air.

The hole was drilled 13 inches in diameter to 400 feet, and cased to that depth with 10⅝-inch (inside) casing. From 400 to 1,105 feet the hole was drilled 8¼ inches, and from 1,105 feet to 1,387 feet 6¼ inches in diameter. All ground below the first 12 feet was hard enough to stand without caving.

The following are some analyses of the water from this well:

Analyses of water from well of Missouri Lead and Zinc Company, Joplin, Jasper County.[a]

ANALYSES AT TIME OF DRILLING.

[Analyst, Cleveland & Millar Analytical Laboratory.]

First Pumping, 940 Feet.	Parts per million.	Second Pumping, 1,387 Feet.	Parts per million.
Silica (SiO_2)	14	Silica (SiO_2)	10
Iron (Fe)	.83	Iron (Fe)	.90
Calcium (Ca)	44	Alumina (Al)	.48
Magnesium (Mg)	22	Calcium (Ca)	37
Sodium (Na)	23	Magnesium (Mg)	17
Bicarbonate radicle (HCO_3)	272	Sodium (Na)	23
Sulphate radicle (SO_4)	13	Bicarbonate radicle (HCO_3)	224
Chlorine (Cl)	10	Sulphate radicle (SO_4)	14
	398.83	Chlorine (Cl)	12
Residue on evaporation	263		338.38

ANALYSIS OF WATER TAKEN DECEMBER 7, 1903, FROM A TAP AT POWER HOUSE.

[Analyst, C. V. Miller.]

	Parts per million.		Parts per million.
Silica (SiO_2)	12	Bicarbonate radicle (HCO_3)	168
Iron (Fe)	1.7	Sulphate radicle (SO_4)	16
Calcium (Ca)	34	Chlorine (Cl)	7
Magnesium (Mg)	14		260.4
Sodium (Na)	7.7		

[a] Expressed by analysts in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

ANALYSIS OF WATER TAKEN MAY, 1904.

[Analyst, J. H. Parsons Chemical Company.]

	Parts per million.		Parts per million.
Silica (SiO_2)	9.9	Chlorine (Cl)	8.8
Calcium (Ca)	41		175.7
Magnesium (Mg)	18		
Carbonate radicle (CO_3)	98		

The well pump is a Cornish-style lift pump, with barrel 7¾ inches in diameter, stroke 5 feet, operated by electric motor. Distribution system, 4-inch cast-iron pipe mains. Emergency steam pump, 14 by 8½ by 10 inches, duplex, supplied by reservoir of 1,000,000 gallons capacity, always ready for operation. Usual pressure, 40 to 80 pounds; fire pressure to be 100 pounds. In ordinary operation the well pump delivers water direct to the mains and the pressure is equalized by a pressure tank 36 by 7 feet in diameter, containing an air cushion.

The Freeman well, near Fourteenth and Joplin streets, Joplin, was drilled in 1901, to a depth of 908 feet, 400 feet being cased with 6⅝-inch casing and the remaining 508 feet with 5⅝-inch casing. Strong flows were obtained at depths of 815, 860, 875, and 900 feet. The water, which rises within 120 feet of the surface, is soft and contains a little sulphur. It is used for the boilers of the Freeman Foundry. The cost of the well was $2,000.

A strong odor of gas was noticed with the first flow of water, at 815 feet, and continued. When this depth was reached, seepage water rose in the case to 80 feet below the surface, but was easily bailed out. When the 815-foot flow was struck, the surface of the water in the well dropped to a depth of 119½ feet, where it has remained ever since. Neither compressed air nor bailing lowers this level, and the removal of 300,000 gallons in twenty-four hours has had no effect. The well is now pumped at the rate of 20,000 gallons in twenty-four hours. The temperature of the water is 65° F.

The following is an analysis of water taken from the 815-foot level:

Analysis of water from Freeman Foundry deep well, Joplin, Jasper County.[a]

[Analysts, Cleveland & Millar.]

	Parts per million.		Parts per million.
Silica (SiO_2)	7.2	Potassium (K)	Trace.
Iron and alumina oxides ($Fe_2O_3+Al_2O_3$)	.4	Bicarbonate radicle (HCO_3)	254
Calcium (Ca)	53	Sulphate radicle (SO_4)	35
Magnesium (Mg)	16	Chlorine (Cl)	7.0
Sodium (Na)	26		398.6

[a] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

The following is a more recent analysis of the same water, October, 1904:

Analysis of water from Freeman Foundry deep well, Joplin, Jasper County.[a]

[Analyst, Harrison Hale.]

	Parts per million.		Parts per million.
Silica (SiO_2)	35	Carbonate radicle (CO_3)	79
Iron and alumina oxides ($Al_2O_3+Fe_2O_3$)	9.7	Sulphate radicle (SO_4)	19
Calcium (Ca)	52	Chlorine (Cl)	5
Magnesium (Mg)	5	Organic	2.5
Sodium (Na)	3.5		210.7

Three and one-half miles southeast of Joplin, in sec. 7, T. 27, R. 32, is a well owned by the Rex Mining and Smelting Company and drilled by W. R. Burchell. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well of Rex Mining and Smelting Company near Joplin, Jasper County.[a]

	Thickness.	Depth.
	Feet.	*Feet.*
Blue and white chert	230	230
Dark shale	5	235
Gray and white lime	472½	707½

Water was struck at about 60 feet.

One-fourth mile south of Joplin is a well owned by Tim McCarty and drilled by H. W. Atherton. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of McCarty well near Joplin, Jasper County.

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay and chert	20	20
Dark lime and blue chert	35	55
Blue chert	5	60
Lime and white chert	40	100
Lime and chert; hard limy water	200	300

WEBB CITY.

At Webb City, Jasper County, the Missouri Zinc Fields Company sunk a well to the depth of 854 feet. The drilling was done by Crossman Brothers and was completed November 15, 1902. The altitude of the well is 940 feet. Strong flows of water were found at 795 and 845 feet, in limestone openings. Water rises within 100 feet of the surface. The cost of the well, piping, tanks, pumps, etc., was $2,150. The water is used for boiler and domestic purposes.

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

The accompanying analysis of water from this well was made by Waring & Son, Webb City:

Analysis of water from well of Missouri Zinc Fields Company, Webb City, Jasper County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	13	Sulphate radicle (SO_4)	4.8
Calcium (Ca)	52	Chlorine (Cl)	5.9
Magnesium (Mg)	18	Undetermined	7.7
Sodium (Na)	3.9		
Carbonate radicle (CO_3)	120		225.3

The following is the log of this well:

Log of well of Missouri Zinc Fields Company, Webb City, Jasper County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soapstone and slate sand bowlders	67	67
Limestone, shine of lead	9	76
Blue and white flint	1	77
Limestone and blue flint	45	122
Blue and white flint	24	146
Blue and white flint, zinc shines	14	160
Limestone bowlders	4	164
Blue and white flint, sand and spar ground, soft	41	205
Limestone and blue and white flint, hard	80	285
Slate and shale	1	286
Limestone and blue flint	60	346
Limestone	55	401
White sandy limestone	20	421
"Tiff" and spar	1	422
Gray limestone	68	490
Limestone and flint	12	502
Limestone and flint, dark; zinc shines	5	507
Limestone and white flint	98	605
Brown limestone and white and blue flint in strata	189	794
Opening	1	795
Sandy limestone	40	835
Blue and white limestone and "tiff"	9	844
Opening	1	845
Limestone	9	854

In a shaft, a short distance away, a stream yielding 1,000 gallons of water per minute was encountered. This water is highly charged with iron sulphate, which soon clogs the 6-inch pipe and which forms a cement binding the pebbles, etc., into a conglomerate where it flows out on the ground. The temperature is 64° F.

The Southwest Missouri Electric Railroad Company sunk a well to the depth of 826 feet, with an 8-inch bore, near its power plant at Webb City. The depth of the principal source of water is 815 feet and another vein was found at 250 feet. The water rises within 75 feet of the surface and has a temperature of 50° F. The well cost $2,000 for drilling, and an additional $500 for pumping machinery. The following analysis of the water is given, the analyst and date being unknown:

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Analysis of water from well of Southwest Missouri Electric Railroad Company, Webb City, Jasper County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	3.7	Sodium and potassium sulphates ($Na_2SO_4+K_2CO_4$)	24
Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	5.0	Sodium and potassium chlorides ($NaCl+KCl$)	5.7
Calcium (Ca)	28		
Magnesium (Mg)	14		160.2
Carbonate radicle (CO_3)	76		
Sodium and potassium carbonates ($Na_2CO_3+K_2CO_3$)	3.8		

In 1899 the Center Creek Mining Company engaged H. B. Crossman, of Joplin, to sink a deep well in sec. 18, T. 29, R. 32. This well was drilled to a depth of 827 feet 6 inches and was cased with 8-inch casing for 315 feet. The principal source of water was found at 800 feet, in a sandy formation. Another vein was found at 500 feet. The level of the water in the well is 75 feet below the surface. The water is used for boiler and drinking purposes. The cost of drilling, with casing, was $2,300, with an additional $2,000 for pumping machinery.

Mr. W. C. Stewart, to whom the writer is indebted for this information, was secretary of the company, and states that the object of drilling was to get purer water for boilers and mines, and it was found to be so much better for drinking than the city water that four teams are engaged in hauling and selling it to various consumers. The accompanying analysis, furnished by Mr. Stewart, was made in December, 1899, by George Waring:

Partial analysis of water from deep well of Center Creek Mining Company, Webb City, Jasper County.[a]

	Parts per million.		Parts per million.
Calcium (Ca)	63	Chlorine (Cl)	3.4
Sodium (Na)	2.2		
Carbonate radicle (CO_3)	86		169.6
Sulphate radicle (SO_4)	15		

LACLEDE COUNTY.

LEBANON.

At Lebanon, Laclede County, in 1887, a well was sunk to a depth of 985 feet. The elevation of Lebanon is 1,265 feet. The first water was found at a depth of 135 feet in a bed of gravel overlain by clay.

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

The force of the stream washed in the waterworn gravel and undermined the clay, thereby necessitating casing. At a depth of 427 feet the Roubidoux sandstone was reached and considerable water came in. The "Third" sandstone, or quartzite, was struck at the bottom of the well. From 500 to 600 feet the underground flow was so strong that drillings were obtained with great difficulty. From 680 to 960 feet drillings could be obtained only at a few points between openings. These cavernous openings are remarkable and indicate a strong underground current from the north. For further discussion of this subject the reader is referred to the writer's paper on the spring system of the Decaturville dome.[a] The first cavernous opening of 12 inches occurred at 615 feet; another at 633 feet; another of about 3 feet at 761 feet; another of 3 feet at 830 feet; one of 1 foot at 850 feet, and one of 1½ feet at 880 feet.

The water at present rises within 360 feet of the surface. It is very pure and is used for drinking, carbonating, and shipping, and also for boiler purposes. The well has a 6-inch bore and is cased to 135 feet. It is mainly used as a source of supply for the city of Lebanon. An analysis of the water is given on page 206. The following is the log of the well:

Log of city well at Lebanon, Laclede County.

	Thickness.	Depth.
St. Peter sandstone (10 feet):	*Feet.*	*Feet.*
Soil	5	5
Sandstone	5	10
Jefferson City limestone (417 feet):		
Bastard limestone with seams of clay and flint	155	165
Yellow cherty limestone	50	215
Bluish limestone	40	255
White flint	5	260
Brown limestone	5	265
White flint	5	270
Yellowish-brown limestone	20	290
White chert	20	310
Brown siliceous limestone	50	360
Yellow "cotton rock"	15	375
Grayish-white limestone	52	427
Roubidoux sandstone (32 feet):		
Quartzite (took twenty-four hours to cut)	2	429
Sandstone	30	459
Gasconade limestone (521 feet):		
"Cotton rock"	11	470
Coarse bluish limestone	15	485
Fine-grained brownish-yellow limestone	50	535
White flint	15	550
Compact yellowish limestone	20	570
Coarse limestone	10	580
"Cotton rock"	10	590
Clouded marble	20	610
Red ferruginous limestone	10	620
Opening	2	622
Gray and pink ferruginous limestone	50	672
Pink limestone	43	715
Coarse bluish limestone	25	740
Coarse light ferruginous limestone	10	750
"Cotton rock"	5	755
Pinkish limestone	6	761
Opening	3	764
Coarse dark limestone	35	799
Compact limestone	46	845

[a] Water-Sup. and Irr. Paper No. 110, U. S. Geol. Survey, 1905, pp. 113-125.

Log of city well at Lebanon, Laclede County—Continued.

	Thickness.	Depth.
Gasconade limestone—Continued.	*Feet.*	*Feet.*
Coarse ferruginous limestone	12	857
Hard limestone	10	867
Compact yellowish limestone	30	897
Coarse dark limestone	20	917
Compact yellowish-white limestone	8	925
"Cotton rock"	6	931
Limestone	42	973
Siliceous limestone, with pyrites	5	978
Bluish shale, possibly serpentine	2	980
Archean (5 feet):		
Quartzite	5	985

In 1890 a well 442 feet deep was sunk by the St. Louis and San Francisco Railroad at a distance of 60 feet from the city well. The following is the log of the railroad well:[a]

Log of well of St. Louis and San Francisco Railroad at Lebanon, Laclede County.

	Thickness.	Depth.
Jefferson City limestone (430 feet):	*Feet.*	*Feet.*
Soil and clay	30	30
Flint bowlders and clay	35	65
Limestone; first water at 85 feet	20	85
Limestone and chert	22	107
Limestone	24	131
Limestone and chert	19	150
Sandstone	18	168
Magnesian limestone	27	195
Chert bowlders	30	225
Limestone	5	230
Chert bowlders	20	250
Soft chert	40	290
Chert bowlders	35	325
Limestone	10	335
Limestone and chert	30	365
Limestone	22	387
Chert	20	407
Limestone	18	425
Chert	5	430
Roubidoux sandstone (12+ feet):		
Sandstone	12+	442+

LAWRENCE COUNTY.

AURORA.

At Aurora, Lawrence County, the deepest well, at present, is the drill well sunk by the Sphalerite Mining Company. This passed through an inclined ore body a part of the way, and the strata could not be correlated all the way down because of the secondary deposit of mineral. The well was put down in the summer of 1899. The following analysis was made by a Chicago chemist. The water was obtained after pumping for several hours.

[a] Acknowledgment is due to Mr. C. D. Purdon, engineer of maintenance of way of the Frisco System, for the logs of the city and railroad wells; also to Mr. M. W. Serl, of Lebanon, for many valuable notes on the city well and on the geology of Laclede County.

Analysis of water from well of Sphalerite Mining Company, Aurora, Lawrence County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	16	Carbonate radicle (CO_2)	121
Iron and alumina oxides (Fe_2O_3+ Al_2O_3)	16	Sulphate radicle (SO_4)	219
Calcium (Ca)	131	Chlorine (Cl)	21
Magnesium (Mg)	13		565
Sodium (Na)	28		

The following is the log of the well:

Log of well of Sphalerite Mining Company, Aurora, Lawrence County.

	Thickness.	Depth.
	Feet.	*Feet.*
Burlington (356 feet):		
Soil	10	10
Coarse gray limestone, some chert	115	125
Flint, lime, and small calcite crystals	35	160
Limestone and flint, with traces of marcasite, calcite, and copper and zinc ore	48	208
Coarse brecciated limestone and flint (ore body), with much zinc and calcite	6	214
Limestone and chert, with traces of calcite, marcasite, bitumen, and zinc ore	91	305
Dolomitic limestone, chert, some zinc and calcite	15	320
Shaly blue limestone	10	330
Blue limestone, some chert and calcite	12	342
Dark-gray limestone and chert, some zinc	6	348
White flint, limestone, brecciated ore body, much zinc	2	350
Gray limestone and flint	6	356
Chouteau limestone (33 feet):		
Shaly dolomitic limestone	4	360
Brecciated blue limestone, white flint, rich zinc	12	372
Mainly blue limestone, chert	17	389
Undifferentiated (107 feet):		
Shaly blue magnesian limestone	6	395
Siliceous dolomitic limestone, some calcite and zinc	2	397
Ore breccia, pink dolomite, blue limestone, and chert	8	405
Gray limestone, some chert	13	418
Gray dolomitic shaly limestone, trace of marcasite	6	424
Dark-gray limestone, chert breccia, zinc, and pink dolomite	2	426
Light-gray dolomitic limestone and chert	4	430
Light-gray limestone	2	432
Dolomitic limestone, cherty, some zinc	38	470
Dolomitic limestone, fine grained, brecciated with zinc	8	478
Dark-gray siliceous dolomitic limestone, white chert, some zinc	12	490
Same, with some oolitic limestone at bottom	6	496

COMET.

On the north bank of Sac River, just north of Comet post-office is a well owned by Clate Hargroves. Depth, 170 feet; altitude, barometrically, 890 feet; casing, $5\frac{5}{8}$-inch; flow, carries water to a height of 17 feet in a 3-inch pipe; date of completion, April, 1900; driller, M. C. Gothard, Dadeville, Mo.; cost, $170; surface formation, Burlington limestone. This well was sunk by a Clinton mining company in prospecting for mineral. A flow of water was struck in white sand at a depth of 166 feet. The log, which follows, was furnished by Mr. Gothard.

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Log of Hargroves's well, Comet, Lawrence County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	10	10
Coarse-grained gray limestone and flint	100	110
Blue shale	40	150
Devonian:		
Sac limestone[a]	10	160
Phelps sandstone[a] (water bearing)	10	170

[a] Missouri Geol. Survey, vol. 12, 1898, p. 74.

The water of this well is soft and pure.

CORRY.

Three small flowing wells are found near the Corry mines. They were shallow prospect holes for mineral. One of them is located on the farm of John Woody, 2½ miles southwest of Corry, and is 100 feet deep. Water flows feebly to the surface. The two others are located on the old Jim Boyd place, one-fourth of a mile due north of Corry, and each is about 100 feet deep.

PIERCE CITY.

Three and one-half miles northwest of Pierce City, Lawrence County, in sec. 7, T. 26, R. 28, is a well owned by J. L. Wight and drilled by Ira C. and W. P. Wight. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Wight well near Pierce City, Lawrence County.

	Thickness.	Depth.
	Feet.	*Feet.*
Flint bowlders mixed with clay	80	80
Sandstone, or rotten flint	37	117
Water	2	119
Ledge of flint	2	121
Crevice; stream of water	4	125
Solid flint	15	140

VERONA.

Five-eighths of a mile north of Verona, Lawrence County, in sec. 8, T. 26, R. 26, is a well owned by G. H. Ruggles and drilled by F. Lechner. The following log was received from Messrs. M. L. Fuller and S. Sanford.

Log of Ruggles well, Verona, Lawrence County.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface, rock, water on top of rock	43	43
Flint and lime, hard	37	80
Opening, large amount of water, some lead ore was found in drill cuttings	4	84
Flint and lime; some zinc ore appeared in cuttings	30	114
Flint, lime, and zinc	14	128
Light shale or "soapstone"	21	149
Flint and lime	4	153
Zinc ore in cuttings	14	167
Flint and lime; occasional shines of zinc ore, water very strong	41	208

M'DONALD COUNTY.

LANAGAN.

At the railway station in Lanagan, McDonald County, is a well owned by the Kansas City Southern Railway, of which the depth is about 600 feet; temperature of water, 58.1° F.; of air, 65.3° F.; flow, strong; surface formation, Burlington limestone. This is a very strong flowing well, filling the tank for locomotives and supplying a neighboring hotel. The water is probably carried 30 feet above ground. The record has been lost and the actual depth is unknown. The water is strongly charged with sulphureted hydrogen.

The Irvin Walker well is one-quarter of a mile southeast of Lanagan, on the south side of the road leading to Pineville. Its depth is 435 feet; altitude, 865 feet; casing, 5⅝-inch, 18 feet; temperature of water, 53° F.; flow, 8 to 10 gallons per minute; date of completion, December, 1901; driller, Irvin Walker; surface formation, top of Devonian shale. The following are analyses of this water:

Analysis of water from Walker well, Lanagan, McDonald County, January 17, 1903.[a]

[Analyst, J. C. Draper.]

	Parts per million.		Parts per million.
Calcium (Ca)	30	Organic matter	30
Magnesium (Mg)	8.5		240.5
Carbonate radicle (CO_3)	66		
Alkaline chlorides	106		

Analysis of water from Walker well, Lanagan, McDonald County, May 15, 1905.

[Analyst, E. E. Ellis.]

	Parts per million.		Parts per million.
Iron (Fe)	Trace.	Sulphate radicle (SO_4)	Trace.
Calcium (Ca)	77	Chlorine (Cl)	26
Carbonate radicle (CO_3)	112	Turbidity	None.
Bicarbonate radicle (HCO_3)	136	Color	None.

NOEL.

On a hill one-fifth of a mile east of Noel, in sec. 14, T. 21, R. 33, is a well owned by the Noel Improvement Company.[b] Depth, 880 feet; altitude above tide, 865 feet; casing, 5⅝-inch, 6 feet; temperature of water, 55° F.; flow; date of completion, January, 1903; driller, Irvin Walker, Lanagan; surface formation, lower part of Burlington. This well was put down by a company of Noel citizens for the purpose of supplying the town with water, and for this reason the hole was drilled on the top of a hill 90 feet above the railway station. At a

[a] Expressed by analyst in hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

[b] The writer is indebted to Mr. Irvin Walker, of Lanagan, for notes on this well and the Walker well at Lanagan, and also for the privilege, accorded to Mr. Ellis, of examining a carefully kept set of drillings from this well.

depth of 350 feet water was struck which rose rapidly under artesian pressure, escaping, according to Mr. Walker's statement, in a crevice of the rock, 16 feet below the surface. The following is the log of this well:

Log of deep well at Noel, McDonald County.

	Thickness.	Depth.
	Feet.	*Feet.*
Limestone, with layers of chert	95	95
Noncherty gray limestone	36	131
Soft brown shale, slightly carbonaceous	59	190
Compact gray limestone, with semiopaque chert	25	215
Gray and white limestone, with chert and fragments of black slate	115	330
Soft shaly gray magnesian limestone	15	345
Hard, compact gray limestone	5	350
Soft limestone	10	360
Hard compact limestone, with some earthy limestone	45	405
Similar limestone, with band of hard, black slaty shale	10	415
Hard, grayish-brown, finely crystalline limestone	5	420
Hard, compact brown shale	5	425
Gray limestone, generally earthy, with some slate	40	465
Fine-grained crystalline limestone, with much earthy limestone and no chert	177	642
Compact gray limestone, with a little chert	24	666
Fine-grained gray limestone, with hard black shale	99	765
Light-gray, finely crystalline limestone, with chert	10	775
Light-gray compact limestone	35	810
Similar limestone, with considerable semiopaque compact chert	70	880

SOUTHWEST CITY.

In Southwest City, McDonald County, is a well owned by Jacob Winters, and drilled by Sterner Brothers. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Winters well, Southwest City, McDonald County.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface and coarse rock	48	48
Blue flint and white quartz rock, with small deposits of coal at 74 and 78 feet	30	78
Light-gray rock	20	98
Dark-brown flint, with iron pyrite	12	110

Three miles west of Southwest City is a well owned and drilled by Levi Shinn. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Shinn well near Southwest City, McDonald County.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil	10	10
Red clay	5	15
No entry	5	20
Flint	30	50
No entry	10	60
Red sticky clay	10	70
Bowlders	10	80
White and black red flint	15	95
White chalk rock	30	125

All of the above record is in the upper part of the Burlington.

TIFF CITY.

Three-fourths of a mile from Tiff City, in sec. 4, T. 23, R. 34, is a well owned by John Manning. Depth, 180 feet; casing, 5-inch, to rock; flow, weak; date of completion, June, 1900; driller, T. W. Hutchinson; cost, $180; surface formation, Burlington limestone. This well is situated in a valley, 300 feet from a small stream. The principal water was struck at a depth of 150 feet in crevices which opened in the rock. The flow has not varied since drilling, and the water, which is slightly charged with sulphureted hydrogen, is used for drinking.

WANDA.

In the SE. ¼ sec. 5, T. 24, R. 30, 1 mile northeast of Wanda post-office and about 7 miles south and east of Granby, there is a well on the land of W. R. Moore. Depth, 144 feet; altitude, barometrically, 1,086 feet; casing, 5⅝-inch, 20 feet; temperature of water, 57.2° F.; of air, 66.2° F.; flow, 42 cubic feet per minute; date of completion, 1901; surface formation, base of Burlington limestone. This well was sunk as a prospect hole for mineral. The flow has been strong from the first and has not varied.

Another well, which had also a strong artesian flow, was sunk near by at the same time. The stream of water is said to have come from cavernous openings in limestone. No log was kept, but the flow was probably from the base of the Devonian. The regional dip of the rocks in this district is toward the west.

NEWTON COUNTY.

DIAMOND.

Three and one-half miles west of Diamond, Newton County, in sec. 1, T. 26, R. 32, is a well owned by W. A. Parnell. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Parnell well near Diamond, Newton County.

WELL NO. 1.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface, clay, and flint bowlders	18	18
Limestone	30	48
Blue flint	2	50
Limestone	20	70
Blue flint	2	72
Limestone	18	90
Blue flint	4	94
Limestone	25	119
Blue flint	2	121
Limestone; water plentiful at 140 feet	19	140
Limestone	60	200

In this vicinity there are four other wells. Their logs are as follows:

Log of wells near Diamond, Newton County.

WELL NO. 2.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, clay, and flint bowlders; water, running stream at 14 feet	14	14
Limestone	24	38
Blue flint	6	44
Limestone	52	96

WELL NO. 3.

Clay and flint bowlders; water, not so strong as in other wells, at 35 feet	35	35
Limestone	35	70

WELL NO. 4.

Soil, clay, hardpan	14	14
"Soapstone;" water pretty strong, soft, at 40 feet	26	40
Clean "tiff"	1	41
"Soapstone" and some black sand bowlders	54	95
"Burnt-looking limestone"	3	98
Brownish-yellow sand rock	6	104
Whitish flint rock	8	112
"Soapstone;" did not penetrate	36	148

WELL NO. 5.

Clay and hardpan	15	15
Clay and flint; water, soft	20	35
White flint	15	50
Clay and flint	45	95

The above wells are all in the Burlington limestone.

One and one-half miles north of Diamond, in sec. 31, T. 27, R. 32, is a well owned by Leathers Brothers and drilled by W. H. Leathers. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Leathers well near Diamond, Newton County.

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay and flint	45	45
Lime and flint	83	128
White flint and zinc	2	130
Lime and flint	30	160
Soft white flint or water flint	50	210
Mississippi limestone	7	217

All of the above record is in the upper part of the Burlington.

MOUNT PLEASANT MILL.

The Granby Mining Company has drilled a deep well on the north side of lot 15, in the SE. ¼ SW. ¼ sec. 31, T. 26, R. 30. The following record was furnished by Mr. Elias Gatch, president of the company:

Log of well of Granby Mining Company, near Mount Pleasant Mill, Newton County.

	Thickness.	Depth.
	Feet.	*Feet.*
Red ferruginous sandstone	21	21
Blue clay, shale, and cherty flint	6	27
Almost solid sheet of mundic, with very small vein of coal on top	6	33
Mundic	2	35
Black sand	3	38
Blue clay and black sand	4	42
Black sand	8	50
Blue clay	16	66
Gravelly flint	24	90
Blue clay	6	96
Flint	24	120
Blue shale and flint	11	131
Solid flint	7	174
Mixed flint and lime, shines of blende	[a] 13	187
Limestone	3	190
Black flint	6	196
Flint bowlders and clay	32	228
Flint, with a little clay	42	270
Opening containing mud	5	275
Flint	12	287
Lime and flint	11	298
Limestone	14	312
Siliceous magnesian limestone	28	340
Lime and flint, flint largely predominating	82	422
Limestone	8	430
Limestone, with a little flint	25	455
Limestone, with a band of white flint	99	554
Limestone and flint, with some zinc	36	590
Limestone	30	620
Blue flint	25	645
Blue flint and limestone	17	662
Limestone	8	670
Soft, shelly limestone	2	672
Blue flint and clay	18	690
Limestone	16	706
Flint and limestone	40	746
Flint and limestone	4	750
White flint	6	756
Limestone	7	763
Limestone and flint, mostly flint	21	784
Limestone, with a little flint	41	825
Limestone	40	865
Granular quartz	26	891
Limestone, with strata of white clay	12	903
Nearly pure limestone	11	914
Limestone, with quartz in crevices	35	949
Limestone, nearly pure	10	959
Blue flint	1	960
Nearly pure limestone	17	977
Limestone, some flint, and dolomite crystals	14	991
Limestone	5	996
Hard flint	19	1,015
Mainly limestone water channel; eat 1,014 feet water rose nearly to surface	14	1,029
Limestone	17	1,046
Flint and limestone	166	1,212
Limestone, with white sand	7	1,219
Limestone and sandstone	11	1,230
Granular limestone	9	1,239
Limestone and sandstone	12	1,251
Granular limestone	9	1,260
Hard blue flint	4	1,264
Granular limestone, with a little flint	23	1,287
Limestone and flint	29	1,316
Limestone	10	1,326
Limestone, with black shale and a little black flint	52	1,378
Limestone, with black shale and mundic	33	1,411
Limestone	27	1,438
Black sandstone and limestone	14	1,452
Quartzite, lime, mundic, and tallow clay	9	1,461
Nearly all limestone	13	1,474

[a] Probably error in driller's log; should be 43 feet.

Log of well of Granby Mining Company, near Mount Pleasant Mill, etc.—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Black flint (quartzite)	9	1,483
Calcium carbonate and quartzite	10	1,493
Very black limestone with odor of bitumen	38	1,531
Hard shale, denoting water channel	15	1,546
Limestone and black shale	16	1,562
Nearly all limestone	4	1,566
Limestone	8	1,574
Limestone and black shale	1	1,575
Nearly all limestone	5	1,580
Limestone and shale	21	1,601
Nearly all limestone	14	1,615
Limestone and shale	7	1,622

Hole abandoned and casing taken out.

NEOSHO.

There are several flowing wells near the city of Neosho. One is located on the east side of the railroad, two or three blocks south of the station. Depth, 300 feet; altitude, 1,018 feet; temperature of water, 58.1° F.; of air, 65.3° F.; flow, 1½ gallons per minute; date of completion, 1899; surface formation, Burlington limestone. This well was put down with the hope of obtaining mineral water, and was used for several years to supply a public bath house. The water is now used mainly for drinking purposes. It has a slight odor of sulphureted hydrogen. The following analysis was made by E. E. Ellis May 16, 1905:

Analysis of water of well at Neosho, Newton County.

	Parts per million.		Parts per million.
Iron (Fe)	Trace.	Sulphate radicle (SO_4)	35
Calcium (Ca)	80	Turbidity	None.
Bicarbonate radicle (HCO_3)	217	Color	None.

At the fish hatchery is a well put down by the United States Government. Its depth is 292 feet; altitude, 1,033 feet; casing, 5⅝-inch to 22 feet; temperature of water, 59° F.; flow, very weak, less than 1 gallon per minute; date of completion, 1899; surface formation, Burlington limestone. The following is the log of this well:

Log of fish-hatchery well, Neosho, Newton County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	10	10
Compact white and light-gray limestone, free from chert	48	58
Same, with compact white and gray chert	7	65
Dark-gray compact limestone, showing small calcite cleavage planes	8	73
Compact dark-gray chert, breaking with sharp edges, with a small mixture of compact gray and white limestone	85	158
Same, with slightly more limestone	28	186
Very hard and compact light-gray limestone, earthy-looking chert of same color	4	190
Dark brownish-black, rather hard shale, similar to that at Lanagan	22	212
Compact grayish-brown limestone, siliceous, finely crystalline	16	228
Same, with lighter and darker streaks, layers of chert in darker portion	64	292

The water has a slight odor and taste of sulphureted hydrogen, similar to that of the "Neosho" well. This well was drilled for the purpose of obtaining additional water for the fish hatchery, but work ceased when the water was found to be charged with sulphureted hydrogen, and at present the water is used only for drinking. The source of the water is probably at a depth of 150 to 160 feet, where openings were found. This well is probably all in the Burlington limestone.

OZARK COUNTY.

BAKERSFIELD.

One mile southwest of Bakersfield, Ozark County, in T. 22, R. 11, is a well owned by John Paris and drilled by W. L. Fowler. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Paris well near Bakersfield, Ozark County.

	Thickness.	Depth.
	Feet.	*Feet.*
Solid clay	10	10
"Soapstone"	125	135
"Copper"	6	141
Slate	15	156
Hard rock; "cuttings like ashes"	3	159
Black sandstone	2	161

PHELPS COUNTY.

EDGAR SPRINGS.

Two miles west of Edgar Springs, Phelps County, is a well owned by W. R. Denison and drilled by F. L. Cook. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Denison well near Edgar Springs, Phelps County.

	Thickness.	Depth.
	Feet.	*Feet.*
Dirt	40	40
Sandstone	108	148
Lime and flint	30	178

ROLLA.

The cores from a well drilled at Rolla in 1905 were furnished by Dr. George E. Ladd, director of the Missouri School of Mines, and from them the following record was obtained:

Log of well at Rolla, Phelps County.

	Thickness.	Depth.
	Feet.	*Feet.*
Jefferson City limestone (279 feet):		
Soil	25	25
Compact light-gray "cotton rock" (dolomite)	10	35
Same, trace of chert	5	40
Compact "cotton rock"	5	45
Same, with a little chert	5	50
Buff-colored fine-grained "cotton rock," some white chert	15	65
Gray splintery dolomite, some flint	20	85
Fine-grained buff-colored siliceous limestone, with white flint	5	90
Light-gray splintery limestone, some white flint	5	95
Light-gray splintery "cotton rock" (dolomite)	5	100
Fine-grained splintery siliceous magnesian limestone	5	105
Fine-grained white to gray cherty limestone	5	110
Fine-grained light-gray splintery siliceous dolomite	10	120
Fine-grained white dolomite, more compact	10	130
Fine-grained light-gray splintery dolomite	15	145
Coarser grained light-gray siliceous dolomite, granular, some chert, with little blue shale	25	170
Coarser grained gray siliceous dolomite, increase of chert and quartzite	15	185
Fine-grained dark-gray siliceous dolomite, some white chert and marcasite	20	205
Fine-grained dolomite, with some white chert and marcasite	19	224
Same, with dark-colored siliceous dolomite	5	229
Dark-gray siliceous dolomite and white chert	25	254
Mottled siliceous dolomite, some white chert and marcasite	25	279
Roubidoux sandstone (65 feet):		
Quartz sandstone, coarse, waterworn, little white chert and marcasite	20	299
Light-gray dolomite, with marcasite and white chert	10	309
Fine sandstone, with white siliceous dolomite and marcasite	5	314
Light-gray siliceous dolomite, with sandstone, white chert, and marcasite	20	334
Fine-grained white chert, with marcasite	5	339
White waterworn sand, white chert, and much marcasite	5	344
Gasconade limestone (256 feet):		
White to gray cherty quartzite, with marcasite	10	354
Gray siliceous dolomite, with some chert and marcasite	65	419
Light-gray fine-grained cherty quartzite sand, oolitic	15	434
Gray siliceous dolomite, with chert and more marcasite	39	473
Coarser blue and white chert, with some siliceous dolomite and grains of marcasite	5	478
Fine-grained gray siliceous dolomite, less white chert and marcasite	25	503
Fine-grained gray siliceous dolomite, with magnesian shale, white chert, and marcasite	10	513
Fine-grained siliceous dolomite, with cherty quartzite and some marcasite	15	528
Cherty siliceous dolomite and marcasite	65	593
Fine-grained sandy dolomite, chert, and much marcasite	5	598

Six miles southeast of Rolla, Phelps County, in sec. 28, T. 25, R. 7, is a well owned by J. W. Gower and drilled by C. C. Gower. The following log is furnished by Messrs. M. L. Fuller and S. Sanford:

Log of Gower well near Rolla, Phelps County.

	Thickness.	Depth.
	Feet.	*Feet.*
Dirt and clay	10	10
Red sand, soft	8	18
Flint rock, hard	4	22
Gray lime, soft	23	45
Blue lime, hard	10	55
White sand rock, soft	4	59
Blue lime, soft	6	65

WESTCOTT.

Two miles southeast of Westcott, Phelps County, in sec. 35, T. 33, R. 9, is a well owned and drilled by W. A. Corey. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Corey well near Westcott, Phelps County.

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	48	48
Flint mostly	32	80

TEXAS COUNTY.

PLATO.

In sec. 28, T. 33, R. 12, 3½ miles northwest of Plato, Texas County, is a well owned and drilled by F. L. Cook. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Cook well, Plato, Texas County.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	60	60
Limestone	20	80
Sand rock	30	110
Lime and flint	36	146

ST. LOUIS BASIN DISTRICT.

GENERAL ARTESIAN CONDITIONS.

The well-defined St. Louis basin district includes a small area, which is made up of St. Louis, St. Charles, the northern portion of Jefferson, and the northeastern portion of Franklin counties. It lies mainly on the slope of an anticlinal ridge which extends from Plattin, Jefferson County, through Pacific, in the northeast corner of Franklin County, and, crossing Missouri River at a point between Labadie and St. Albans on the south side and passing through Klondike on the north side, in St. Charles County, continues northeastward through Warren County. This fold is well outlined along its course by the outcropping of the St. Peter sandstone, cross sections of which are finely shown in the bluffs along the river at Klondike and at Currelbaums Rock, on the south side of the river about 1 mile south of Becker, where the crumpled and disturbed condition of the strata is well exhibited. In this locality the Missouri, meeting the soft and somewhat crumpled St. Peter sandstone elevated by this fold, was enabled,

probably, to cut its way into another channel and continue along a new route to the Mississippi. The early channel of the Missouri probably passed by Labadie and Grays Summit into the Meramec, near Pacific.

The strata dip with considerable uniformity to the northeast and continue so for some distance into Illinois. Throughout the northern part of the State a general northeasterly dip from the Ozarks is characteristic of all the rocks but the Pennsylvanian series, which seem to have been deposited in several basins more or less independent of each other. In the district under discussion, however, this general dip is slightly interrupted by the course of the anticlinal fold above described.

A number of deep wells have been sunk in the St. Louis basin district. The records of only two have been carefully preserved, but these are so remarkable in their accuracy and completeness as to compensate, in a great degree, for the loss of data regarding the others.

This artesian district lies in a cone-shaped basin. On the north side is the Cap au Grès axis (briefly outlined by A. H. Worthen[a]), which brings the St. Peter sandstone to the surface in Cap au Grès Bluff, on Mississippi River. In describing this axis, Worthen says:

> It intersects the Mississippi bluffs immediately below the high bluff of St. Peter sandstone to which the name of Cap au Grès, or sandstone headland, was given by the French voyageurs, and, with a trend of E. 10° S., it intersects the bluffs of the Illinois about 2 miles below Monterey, crosses the bluffs on the eastern side of that stream about 5 miles above its mouth, and after intersecting an elbow of the river bluff for 3 or 4 miles is finally lost in the valley of the Mississippi.

It is stated by others that this axis within a short distance turns to the east and north and continues farther into Illinois.

The St. Peter sandstone outcrops in high bluffs between McLeans Creek and Sandy Creek, and at various points along this axis, which here takes a north by west course through Lincoln, Pike, and Ralls counties, forming what is known as the Lincoln Ridge. Broadhead states that the northernmost point at which this axis is noted in Missouri is near Newark, Knox County.

The geologic map of this region (Pl. I, p. 6) indicates that St. Louis is partially surrounded on the south, west, and north by two folds which show outcroppings of St. Peter sandstone. One of these is the Cap au Grès axis already described. The other, on the south, is the Pacific axis or anticline, extending from Crystal City and Plattin Rock, on the Mississippi, south of St. Louis, through Pacific and Klondike on the Missouri, and thence northward into Warren County. Within the area inclosed by these folds the cone-shaped St. Louis basin, having conditions highly favorable for artesian pressure,

[a] Geology of Calhoun County: Geol. Survey Illinois, vol. 4, 1870, p. 2.

is located. East of St. Louis the rocks dip gently at the rate of 10 to 12 feet per mile.

There is little doubt that flowing wells might be obtained from the St. Peter sandstone along the Missouri and Mississippi valleys in the interior of this basin at an altitude not exceeding 450 feet. A summary of the thickness and depth of the St. Peter sandstone in this district is given in the following table.

Thickness and depth of St. Peter sandstone in St. Louis basin district.

Locality.	Thickness.	Depth.
	Feet.	*Feet.*
Housemans, near Brentwood		1,000
Clayton, St. Louis County		1,145
St. Charles		1,475
Insane Asylum well, St. Louis	133	1,452
Grone Brewery well, St. Louis		1,450
Belcher well, St. Louis	138	1,500
Belz Packing Company well, St. Louis		1,500
Godfrey, Monticello, Ill	100+	1,525
Granite City, Ill	125	1,645
Cahokia, near Monks Mound, Ill	125	1,975

The catchment basin for these wells is probably largely along the Pacific anticline.

FRANKLIN COUNTY.

LUEBBERING.

One hundred yards east of Luebbering, Franklin County, in sec. 29, T. 41, R. 2 E., is a well owned by F. A. Pilliod and drilled by L. Widman. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Pilliod well, Luebbering.

	Thickness.	Depth.
	Feet.	*Feet.*
Red sand	100	100
Flint	5	105
Limestone	10	115
White sand	35	150

SULLIVAN.

In sec. 34, T. 42, R. 2, W., is a well on the farm of Thomas Rutherford; depth, 1,550 feet; altitude above tide, 641 feet; casing, 10-inch to 100 feet; 8-inch to 600 feet; 6-inch to bottom; temperature of water, 63.5° F.; of air, 87.8° F.; flow, 8 gallons per minute; date of completion, 1896; surface formation, base of Jefferson City limestone. This well does not strictly belong to the district in which it is placed, as it lies on the west side of the Pacific fold and probably derives its water directly from the Ozarks. It is described here for the sake of convenience. It was sunk in a series of interbedded hard sandstones and cherty limestones, and water is said to have come from a pure white

sandstone, the principal flow being from the bottom—1,550 feet. Water rose at first, it is said, to a height of 40 feet, but the pressure has since considerably decreased. It has been impossible to obtain the log of this well. Keyes[a] states that granite is said to have been encountered 1,100 feet from the surface in Franklin County, the reference being probably to this well. The water is good and contains some sulphur.

JEFFERSON COUNTY.

KIMMSWICK.

One-fourth of a mile north of Kimmswick, Jefferson County, in sec. 6, T. 42, R. 6, is a well owned by the Columbia Excursion Company and drilled by F. J. Miller. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of well near Kimmswick, Jefferson County.

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay (earth)	38	38
Black limestone	18	56
Yellow rock, soft	14	70
Blue-black slate or soapstone	25	95
White limestone	35	130
Blue flint	11	141

MADISON COUNTY, ILL.

GRANITE CITY.

The following log of a well at Granite City, Ill., was obtained by E. E. Ellis from George S. Reed, the driller. Altitude, about 435 feet.

Log of well at Granite City, Ill.

	Thickness.	Depth.
	Feet.	*Feet.*
Soft brown sandy loam	40	40
Coarse brown quicksand	50	90
Gravel	23	113
White limestone; well full of water	382	495
Soft gray slate	60	555
Hard brown limestone; water softer	30	585
Hard to softer gray sand rock; oil smell	63	648
White limestone; filled up with sulphur water	87	735
Hard gray sandy limestone	50	785
Shale with shells	15	800
Soft red and gray shale with shells	20	820
Soft dark shale	20	840
Medium gray limestone	50	890
Soft red and gray shale with shells	30	920
Medium pink magnesian limestone	55	975
Hard gray limestone; a little water	50	1,025
Soft green and gray shale	145	1,170
Hard pink magnesian limestone	330	1,500
Soft gray limeston; water at 1,580 feet	130	1,630
Very soft gray sandy limestone	15	1,645
Light-gray to white soft sandstone; at 1,650 feet the hole filled with mineral water which flowed from top	125	1,770
Yellowish lime rock	15+	1,785

[a] Missouri Geol. Survey, vol. 8, 1895, p. 334.

The St. Peter sandstone was struck at 1,650 feet. After going through 125 feet of this sandstone the drill penetrated 15 feet farther into yellowish Jefferson City limestone. The well was cased to 500 feet, and a vein of water found between 600 and 700 feet; cased again at 800 feet, and water found between 975 and 1,025 feet. It was next cased with 8½-inch casing to 1,035 feet. At 1,770 feet several efforts were made to case the water off, but all of them failed.

ST. CHARLES COUNTY.

ST. CHARLES.

At St. Charles a 6-inch well was sunk at Charles Shibi's brewery, 5½ Clay street, to a depth of 1,475 feet. Saline water with a temperature of 56° F. rose within 80 feet of the surface. The record of this well is lost, but it is stated that water was struck in a white sandstone. The brewery is situated about 100 feet above the river. The altitude at the Wabash Railway station at St. Charles is about 490 feet, which is probably 50 feet above the lower part of the city.

ST. CLAIR COUNTY, ILL.

MONKS MOUND.

Four miles northeast of East St. Louis, Ill., in Brook's pasture, near Monks Mound, St. Clair County, is a well owned by the Cahokia Development Company, of St. Louis, Mo. It was drilled by O. S. Willson and the record was furnished by S. L. Shellenberger, of Atoka, Ind. T. Altitude, about 450 feet; diameter of well, 12 inches to depth of 150 feet; date of completion, January, 1905.

Log of Cahokia Development Company's well near Monks Mound, Ill.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, sand and silt	40	40
Fine sand	20	60
Coarse quartz sand	10	70
Coarse sand, gravel and shells	80	150
Bluish clay and marl (water at 205 feet)	55	205
Bluish limestone and marl	15	220
Fine-grained white limestone	15	235
Compact limestone	70	305
Bluish fine-grained limestone (salt water at 365 feet)	10	315
White compact fine-grained limestone	60	375
Blue and grayish compact limestone	35	410
Rusty mottled limestone	30	440
Hard blue limestone	50	490
Fine-grained chocolate-colored limestone	15	505
Coarse bluish and grayish limestone	20	525
Reddish rusty-looking limestone	10	535
Grayish limestone	183	718
Bluish clay or marl	62	780
White limestone (salt water at 825 feet)	[a]135	1,015
Reddish marl	30	1,045
Mottled limestone, clay, and marl	7	1,052
Grayish limestone	18	1,070

[a] Probably error in driller's record; should be 235 feet.

Log of Cahokia Development Company's well near Monks Mound, Ill.—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Hard, gray and red limestone	25	1,095
Clay, "slate," or marl	10	1,105
Hard clay "slate"	30	1,135
Bluish limestone	35	1,170
Chocolate-colored limestone	25	1,195
Gray limestone	15	1,210
Fine-grained reddish limestone	15	1,225
Flinty dirt-colored limestone	5	1,230
Reddish-gray limestone	25	1,255
White flinty limestone	60	1,315
Granular dirt-colored limestone	20	1,335
Blue marly-looking shale (a little oil and gas at 1,490 feet)	155	1,490
Dirty grayish limestone	40	1,530
Fine-grained limestone of varying colors	445	1,975
White sand (well flowed slightly at 2,100 feet; sulphur water)	125	2,100

The first vein of water was struck at a depth of 205 feet. Salt water was obtained at 365 and 825 feet. At 1,490 feet a little oil and gas were encountered. When the well reached a depth of 2,100 feet a small stream flowed at the surface; the water came undoubtedly from the St. Peter sandstone. This record shows a gentle dip of the strata from Missouri eastward into Illinois.

ST. LOUIS COUNTY.

BRIDGETON.

Thirteen miles northwest of St. Louis, near Bridgeton, in T. 46, R. 6, is a well owned by C. D. Garnett and drilled by H. W. Steinsick. The following log was furnished by Messrs. M. L. Fuller and S. Sanford.

Log of Garnett well near Bridgeton, St Louis County.

	Thickness.	Depth.
	Feet.	*Feet.*
Alternate sands, limestones, shale and fire clay, all inclined to cave badly	260	260
Limestone, gray, hard; thin layers of clay	45	305
Limestone, light gray, very hard	10	315
Limestone, dark, brittle, arenaceous	115	430
Sandstone, dark gray, soft	70	500
Limestone, very dark, soft	18	518

ST. LOUIS.

At the corner of Main and O'Fallon streets, St. Louis, on the bank of Mississippi River is a well owned by the Belcher Water, Bath and Hotel Company. Depth, 2,199 feet; altitude above tide, 420 feet; temperature of water, 70° F.; flow, 75 gallons per minute; date of commencement, April, 1849; of completion, March 12, 1854; cost, $10,000; surface formation, Pennsylvanian.

The following is a portion of the description of the Belcher well, as given by Litton:[a]

Carbureted hydrogen was first perceived in passing the thin shale at a depth of 457 feet, and was found to increase in penetrating the soft shales at the depth of 650 feet and the red marl beneath, to augment in passing the shale at the depth of 885 feet, and to be evolved most abundantly in passing the bituminous marl at the depth of 950 feet. This stratum of marl was found to be very bituminous and the borings when heated evolved much carbureted hydrogen, leaving a clay covered by the oxide of iron. At the depth of 1,090 feet the quantity of gas was found to diminish, and this diminution continued to the depth of 1,135 feet. At the depth of 1,183 feet it began again to increase, and became still more abundant at the depth of 1,222 feet. At the depth of 1,270 feet it diminished in quantity; but at 5 feet below it began again to increase, while at the depth of 1,301 feet its quantity was observed to diminish.

Sulphureted hydrogen was first observed at the depth of 1,510 feet, and the water was then found to be strongly impregnated with it.

At the depth of 610 feet the water was first discovered to have a saline taste, and at 849 feet this property was found to be more marked, the water at that depth, upon evaporation, leaving a residue of $1\frac{3}{8}$ per cent of solid constituents. At the depth of 1,015 feet the quantity of these was found increased to $2\frac{1}{4}$ per cent. At 1,187 feet the percentage of salts in solution was found to have diminished, 1 pound of water on evaporation leaving only 148 grams, but at the depth of 1,230 feet the percentage was found to be about 3.

* * * * * * *

The observations made during the sinking of the well showed that the main supply of water was obtained in the soft white sandstone at the depth of 1,515 feet; and from experiments since made by Mr. Holm, by passing a tube to the depth at which the main supply of water was obtained, he thinks there is no water which rises to the surface below this sandstone. This Saccharoid sandstone is very porous and is exposed in the counties to the west and south of St. Louis, at which points the general dip of the rocks is to the east and north.

* * * * * * *

The ratio of the increase of the earth's temperature as we descend, deduced from the data furnished by the artesian well at St. Louis, does not agree with that calculated from observations made at other artesian wells. The water as it flows from the well at the refinery has a constant temperature, and according to my observation, made with a thermometer graduated to one-fifth of a degree, it is 23° C.=73.4° F. The mean annual temperature of St. Louis, deduced from the observations of Doctor Engelmann, continued daily during twenty-two years, is 55.22° F.=12.9° C. Taking the depth from which the water at the well comes to be 1,515 feet, this would give an increase of 1° F. for every 83.3 feet of descent; and for an increase of 1° C., a descent of 71.8 feet; but for an increase of 1° C. requires, according to the observations at Grenelle, a descent of 104.6 feet; at Monsdorf, a descent of 97 feet; at Neusalswerk, a descent of 95.7 feet; at Pregny, near Geneva, a descent of 97.3 feet.

* * * * * * *

Five hundred grams of the water, to which had been added 1.981 grams pure carbonate of soda, were evaporated in a platinum capsule to dryness, and heated to 150° C., gave for total weight of solid constituents 4.3955, in which was found 0.0012 gram of silica.

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[a] Litton, A., Trans. St. Louis Acad. Sci., vol. 1, 1860, pp. 82-86.

Analyses of water from Belcher well, St. Louis.[a]

[Analyst, A. Litton.]

No. 1.	Parts per million.	No. 2.	Parts per million.
Silica (SiO_2)	2.4	Silica (SiO_2)	2.3
Iron (Fe)	4.5	Iron (Fe)	4.4
Calcium (Ca)	495	Calcium (Ca)	474
Magnesium (Mg)	180	Magnesium (Mg)	172
Sodium (Na)	2,472	Sodium (Na)	2,365
Potassium (K)	84	Potassium (K)	81
Carbonate radicle (CO_3)	132	Carbonate radicle (CO_3)	126
Sulphate radicle (SO_4)	576	Sulphate radicle (SO_4)	551
Chlorine (Cl)	4,706	Chlorine (Cl)	4,500
Free sulphureted hydrogen (H_2S)	14		8,275.7
Free carbon dioxide (CO_2)	55		
	8,720.9		
Residue on evaporation	8,791		

No determinations of other gaseous constituents than carbonic acid and sulphureted hydrogen were made for want of an accurate endiometer.

Log of Belcher well, St. Louis.[b]

	Thickness.	Depth.
Carboniferous (628 feet):	*Feet.*	*Feet.*
Limestone	27	27
Shale	3	30
Limestone	230	260
Cherty rock	15	275
Limestone	75	350
Shale	27	377
Limestone	78	455
Shale	3	458
Limestone	37	495
Shale	8	503
Limestone	125	628
Chemung[c] (90 feet):		
Red marl	17	645
Shale	30	675
Red marl	43	718
Hudson River, Trenton, and Black River (699 feet):		
Shale	42	760
Limestone	119	879
Shale	67	946
Bituminous marl	20	966
Shale	75	1,041
Limestone	138	1,179
Cherty rock	60	1,239
Limestone	133	1,372
Shale	18	1,390
Limestone	27	1,417
Magnesian limestone, undifferentiated (782 feet):		
Shale	47	1,464
Limestone	38	1,502
White soft sandstone	138	1,640
Sandstone with much iron	187	1,827
Sandstone with clay	192	2,019
Sandstone with lime and clay	136	2,155
Unrecorded	44	2,199

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

[b] Trans. St. Louis Acad. Sci., vol. 1, 1860, pl. 5.

[c] Probably Devonian.—E. M. S.

The company has recently built a fine large hotel and bath house at the corner of Fourth street and Lucas avenue, to which point the water from this well has been piped. The water is aperient.

About 6 miles southeast of the Belcher well is the insane-asylum well, depth, 3,843½ feet; altitude above tide, 600 feet; temperature of water (Broadhead), 105° F.; date of commencement, March 31, 1866; date of completion, August 9, 1869; surface formation, Pennsylvanian.

The following log of this well was published by G. C. Broadhead in 1878.[a] The work was superintended by Mr. C. W. Atkinson, who collected specimens every few feet and carefully arranged them in boxes, which were stored away in the asylum. He also filed with the county clerk a section and record of the work.

Log of insane-asylum well, St. Louis.

	Thickness.	Depth.
	Feet.	*Feet.*
Clays of "Bluff" [Pleistocene] (40 feet):		
Clay	40	40
Pennsylvanian (80 feet):		
Tumbled masses of limestone	4	44
Red clay	5	49
Limestone	8	57
Red clay	4	61
Coal	5	66
Fire clay	2	68
Light-colored limestone; bottom of dry well	3	71
Blue and drab clay, slightly calcareous	9	80
Cherty limestone	6	86
Dark and bluish-gray shales, slightly calcareous	21	107
Cherty limestone	4	111
Coal	1	112
Light-blue clay	8	120
Mississippian (670 feet):		
Hard cherty limestone, upper part fine grained, lower part coarse	139	259
Blue shales	3	262
Drab and gray limestone, generally hard and cherty	176	438
Alternating limestone and shales	98	536
Hard blue cherty limestone	92	628
Very hard chert, coarse bluish-gray to buff and drab cherty limestone	75	703
Sandstone, very fine grained	6	709
Mostly light gray or drab limestone; chert and limestone at 721 and 732 feet	81	790
Chouteau group (93 feet):		
Red limestone	10	800
Light-drab and gray limestone, some chert	35	835
Argillaceous limestone	5	840
Light-gray limestone, some chert	43	883
Trenton, with Black River and Birdseye (421 feet):		
Mostly a light-gray or blue clay	67	950
Dark clay	16	966
Blue clay alternating with thin limestone layers	56	1,022
Blue and drab limestone, with probably some magnesian layers at 1,139 feet; cream-colored limestone at 1,216 feet	194	1,216
Light-blue cherty limestone; salt water at 1,220 feet	9	1,225
Light-colored limestone	27	1,252
Dark limestone	52	1,304
First Magnesian limestone [Joachim] (148 feet):		
Light-drab cherty limestone	49	1,353
Yellowish-gray limestone	17	1,370
Dark limestone from 1,402 feet	78	1,448
Light-colored limestone	4	1,452
Saccharoidal sandstone [St. Peter] (133 feet):		
Mostly pure white sandstone, clear rounded grains, contains sulphur water; lower portion somewhat brown	133	1,585
Second Magnesian limestone [Jefferson City] (517 feet):		
Buff-brown and drab cherty limestone	61	1,646
Buff and drab cherty magnesian limestone	456	2,102
Second sandstone [Roubidoux] (82 feet):		
Hard and mostly pure sandstone, with some limestone beds with chert, brown or reddish-gray	82	2,184

[a] Trans. St. Louis Acad. Sci., vol. 3, No. 2, 1878, p. 216.

Log of insane-asylum well, St. Louis—Continued.

	Thickness.	Depth.
Third Magnesian limestone [Gasconade] (838 feet):		
Limestone and chert, drab, buff, and gray; chert beds probably include one-half the series	*Feet.* 487	*Feet.* 2,671
No chert from 2,671 to 2,735 feet; sand often abundant	172	2,843
Mostly sandstone with a little lime in upper part	37	2,880
Limestone, mostly free from chert and sand	142	3,022
Third sandstone (98 feet):		
Sandstone, dirty to blue and reddish-gray	98	3,120
Fourth Magnesian limestone (384 feet):		
Dark magnesian slate	13	3,133
Yellowish-drab or gray magnesian limestone, hard, with little sand; the lower 66 feet is thin bedded and dirty reddish-gray, with some sandy beds.	371	3,504
Potsdam sandstone (54 feet):		
Mostly hard, thin-bedded sandstone, dark olive-gray in color, consisting of white and black grains	41	3,545
Sand and limestone	13	3,558
Mostly granite (285½ feet):		
Brown sandstone near upper part, the lower mostly granite; the lower 40 feet is a hard red rock and is certainly powdered granite	285½	3,843½

Broadhead says:[a]

When the borings began, the water in the well stood at 40 feet below the surface; at 134 feet an 8 or 10 inch opening was struck and the water sank in the well to a depth of 128 feet. Salt water was obtained at 1,220 feet. At 1,225 and 1,262 feet from the surface a strong petroleum smell was recognized. Sulphur water was reached at 2,140 feet. At 2,256 the water in the sand pump indicated 3 per cent of salt; at 2,957, 4½ per cent; at 3,293, 2 per cent; at 3,367, less than 2 per cent; at 3,384 feet, 3 per cent, and below 3,545, 7 to 8 per cent.

Experiments with a Fahrenheit registering thermometer indicated the following:

Temperature at different depths in insane-asylum well, St. Louis.

Depth.	Temperature.	Depth.	Temperature.
Feet.	° *F.*	*Feet.*	° *F.*
3,127	106	3,604	105
3,129	107	3,641	104.5
3,264	106	3,728	105.5
3,376	106	3,800	105
3,473	105	3,837	105
3,533	105		

It is to be regretted that no tests of temperature were made above these indicated depths.

In boring to the depth of 833 feet the drill was often observed to be highly magnetized, but after passing that depth no further influence was observed.

[a] Op. cit., p. 221.

At the corner of Forest Park boulevard and Vandeventer avenue is a well owned by the Welle-Boettler Baking Company and drilled by Ed. Meloy and A. W. Dickinson. The following log was furnished by Messrs. M. L. Fuller and S. Sanford:

Log of Welle-Boettler Baking Company well, St. Louis.

	Thickness.	Depth.
	Feet.	*Feet.*
Filling	20	20
Clay, gray, soft	20	40
Sand and gravel	20	60
Shaly limestone, gray, hard, little water	20	80
Limestone, brown, soft	20	100
Limestone, gray, hard, sharp	20	120
Limestone, gray, soft	20	140
Limestone	100	240
Shale, light, soft	20	260
Limestone, gray, hard	5	265
Broken limestone and shale, gray, soft	15	280
Limestone, gray, soft	10	290
Limestone, gray, hard	55	345
Limestone, gray, soft	60	405
Limestone, gray, hard	35	440
Limestone, light, hard	20	460
Limestone, flint, gray, very hard	10	470
Limestone, light gray, hard	15	485
Shale, gray, soft[a]	5	490
Limestone, gray, hard[a]	20	510
Shale, dark red, soft, showing of oil[a]	20	530
Limestone, gray, hard[a]	35	565
Limestone and shale cave, gray, hard; hole caved badly	35	600
Shale, black, soft; little oil	20	620
Limestone, Trenton, brown, soft; little oil	30	650

[a] 490 to 565 feet probably Kinderhook.

The St. Louis Transit Company sunk six deep wells at the corner of Park and Vandeventer avenues, four in 1899 and two in 1900. These varied from 500 to 800 feet in depth.[a] No records were preserved. One well was sunk to a depth of 500 feet, and later, in December, 1904, it was continued to 700 feet, when it was "shot" with 100 pounds of dynamite in the hope of obtaining gas. The water from all these wells was strongly saline and impregnated with sulphureted hydrogen. As it corroded the boilers, the wells were abandoned. Water stands within 100 feet of the surface.

In 1895 the same company drilled a well at its station near the power house, on the corner of Jefferson street and Geyer avenue, to a depth of 1,400 feet. Strong sulphosaline water rose within 6 or 8 feet of the surface.

The following analyses were furnished by Mr. Edward D. Smith, the analyst and date being unknown.

[a] The writer is indebted to Messrs. Edward D. Smith and Charles P. Gregory for information relating to these wells.

Analyses of water from wells of St. Louis Transit Company, Park and Vandeventer avenues, St. Louis.[a]

WELL BACK OF OFFICE.

	Parts per million.		Parts per million.
Silica (SiO_2)	18	Sulphate radicle (SO_4)	163
Iron and alumina oxides ($Fe_2O_3+Al_2O_3$)	5.2	Chlorine (Cl)	39
Calcium (Ca)	134		585.2
Magnesium (Mg)	28	Residue on evaporation	670
Sodium (Na)	25	Residue on ignition	530
Carbonate radicle (CO_3)	173		

WELL SOUTH OF RAILROAD TRACK.

	Parts per million.		Parts per million.
Silica (SiO')	12	Sulphate radicle (SO_4)	113
Iron and alumina oxides ($Fe_2O_3+Al_2O_3$)	4.4	Chlorine (Cl)	28
Calcium (Ca)	104		438.4
Magnesium (Mg)	19	Residue on evaporation	490
Sodium (Na)	20	Residue on ignition	400
Carbonate radicle (CO_3)	138		

DEEP WELL SOUTH OF RAILROAD TRACK.

	Parts per million.		Parts per million.
Silica (SiO_2)	13	Sulphate radicle (SO_4)	146
Iron and alumina oxides ($Fe_2O_3+Al_2O_3$)	Trace.	Chlorine (Cl)	32
Calcium (Ca)	118		497
Magnesium (Mg)	23	Residue on evaporation	533
Sodium (Na)	20	Residue on ignition	415
Carbonate radicle (CO_3)	145	Suspended matter	210

In 1903 the St. Louis Athletic Club sunk a well to the depth of 580 feet. No record was kept, and no analysis of the water has been made. It is stated that drilling stopped in a soft yellow sandstone. The water, which is saline, is pumped into the club's large swimming pool by a Worthington pump.

Numerous other wells have been sunk in St. Louis and vicinity to depths varying from 200 to 1,800 feet. In all cases saline water was obtained, and the largest supply came from the St. Peter sandstone at a depth of about 1,500 feet.

The Anheuser-Busch Brewing Company has two wells which have been abandoned, because of the corrosive action of the water on the boilers. At the Grone brewery, Twenty-third street and Clark avenue, water was found in the St. Peter sandstone at a depth of 1,450 feet. In June, 1904, the Belz Packing Company sunk a well on its property at 3600 South Broadway, and found water in the St. Peter sandstone at a depth of 1,500 feet.

[a] Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

One and one-half miles southwest of St. Louis, in block 2136, St. Louis County, is a well owned by the Bambrick Construction Company and drilled by H. Steinsick. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Bambrick Construction Company well, near St. Louis.

	Thickness.	Depth.
	Feet.	*Feet.*
Dark-gray shaly oolitic limestone	180	180
Light-gray limestone, with much chert	80	260
Light-gray limestone, crinoid remains	44	304
Light-gray cherty limestone	71	375
Light-brown cherty limestone	23	398
Light-grayish crinoidal limestone	18	416
Gray shaly limestone	30	446
Light grayish-brown massive limestone, Kinderhook	62	508
Brown, sandy limestone, Chemung	27	52.
Black limy shale	173	708
Light brownish-gray limestone	78	786

ST. FRANCIS MOUNTAINS DISTRICT.

The St. Francis Mountains district includes the southeastern part of the State, with the exception of the swampy region. Portions of the following counties are within its borders: Jefferson, Washington, St. Francois, Ste. Genevieve, Iron, Reynolds, Madison, Perry, Cape Girardeau, Bollinger, Wayne, and Carter, The catchment area for most of the flowing wells in this district is in the St. Francis Mountains. Flowing wells are located at or near the following places: De Soto, Jefferson County; Bismarck, St. Francois County; Pilot Knob and Ironton, Iron County; Fredericktown, Madison County; Pocahontas, Cape Girardeau County, and Grandin, Carter County.

CAPE GIRARDEAU COUNTY.

BURFORDVILLE.

In Burfordville, Cape Girardeau County, in sec. 32, T. 31, R. 11, is a well owned by J. H. Estes and drilled by Henry Bresuke. The following log was received from Messrs. M. L. Fuller and S. Sanford:

Log of Estes well, Burfordville, Cape Girardeau County.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	30	30
Sand rock	3	33
Limestone; water comes in on top	10	43

POCAHONTAS.

In Pocahontas, near the center of sec. 31, T. 33, R. 13, is a well owned by Thomas D. Hope. Depth, 62 feet; casing, 6-inch; flow, weak; date of completion, May, 1903; drillers, Steimel & Reid, Jackson; cost of well, $100; surface formation, Hudson group. The water flowed from a clay opening immediately under 50 feet of solid limestone. No variation in pressure has been noted, and pumping merely stops the surface flow. The water is hard, cool, agreeable to the taste, and is used for all purposes.

CARTER COUNTY.

GRANDIN.

Four wells were drilled in Grandin on the land of the Missouri Lumber and Mining Company, in sec. 11, T. 25, R. 2 E, on low ground and near a stream. Through the courtesy of Mr. C. C. Sheppard, superintendent of the company, the writer received a set of drill samples and data from well No. 3 of this group, from which the accompanying log was obtained. One of the wells flows, and the other three stand full. Well No. 3 is 206 feet deep; altitude above tide, about 580 feet; casing, 8-inch, 18 feet to rock; date of completion, 1900; cost of well, about $400; surface formation, probably Bonneterre limestone. The principal source of water was reached between 140 and 160 feet, in a limestone rock that was much seamed and fissured. This and the other wells of the group were drilled to supply good water for boiler purposes. Each well will furnish about 50,000 gallons when pumped for twenty-four hours, and the supply is not diminished. The water is hard, pure, and cold. One of the wells was sunk to a depth of 320 feet, but the record was not preserved.

Log of well No. 3, Grandin, Carter County.

	Thickness.	Depth.
	Feet.	*Feet.*
Pink siliceous limestone (dolomite), with mammillary quartz cavities and some siliceous particles	64	64
Light pinkish-gray siliceous dolomite, increase in silica	17	81
Same, with some chert; more siliceous	20	101
Similar, but finer grained, more angular particles, with increase of white chert and silica	30	131
Similar, highly siliceous, with some white chert	10	141
Similar, some white chert, small cavities in particles	10	151
Decided change; large angular fragments of light-gray, highly siliceous dolomite; no chert	10	161
Gray, coarse siliceous dolomite, with irregular cavities that are slightly iron stained	10	171
Finer grains of highly siliceous pink dolomite merging into pink quartzite	20	191
Limpid, milky-white to pink quartzite and highly siliceous dolomite	15	206

This well is all in one formation, and probably near the base of the Bonneterre limestone or Fourth Magnesian limestone of Swallow.

IRON COUNTY.

IRONTON.

The records of two nonflowing wells at Ironton, Iron County, are as follows:

The Ironton Manufacturing Company well was drilled by T. J. Lemaster, of De Soto, in 1902, to a depth of 300 feet, with a 6-inch bore. The main source of water was found at 100 feet, but other water-bearing beds were found at 15, 75, 150, and 200 feet. The water, which contains iron and sulphur, rises within 5 feet of the surface, whence it is pumped to a feed boiler. The well cost $350.

The Clark Manufacturing Company has a well, drilled in 1900, which is situated in a valley. It has a 6-inch bore and is 305 feet deep. The main source of the water was found in the rock at 301 feet. Water rises to the surface, but does not flow. It is hard, contains a little sulphur and iron, and is used for boiler purposes. It is lowered 20 feet by pumping.

PILOT KNOB.

Several prospect holes sunk by the Iron Mountain Company near Pilot Knob with a 1¼-inch diamond drill, about 1890, have resulted in flowing wells. The first one of these is located half a mile north of Ironton, close to the west side of the St. Louis, Iron Mountain and Southern Railway. It has a feeble flow of slightly chalybeate water, with a temperature of 56° F. when the air temperature is 78° F. Another well about 1,000 feet north of this one raises the water about 2 feet above the surface, whence it is conveyed to a public watering trough. About 1,000 feet still farther north is another well that raises the water about 4 feet above the ground and also supplies a watering trough. The temperature of this water is 59° F. when the air temperature is 78° F. One-half mile west of the last-named well, and just west of the Old Fort, is another feebly flowing well of chalybeate water. A quarter of a mile northeast of this is the last well of the group. All records of depth have been lost. The rocks dip to the west from Pilot Knob.

JEFFERSON COUNTY.

DE SOTO.

The town of De Soto is situated in a valley near the head of Joachim Creek, at an altitude of 498 feet. Its main street runs parallel with the St. Louis, Iron Mountain and Southern Railway, and a number of deep wells are sunk along both sides of this street. The owners, location, and depths are as follows:

1, James Hopson, No. 1, Pratt and Second streets, 265 feet; 2, Electric Light Company, Main street, about 200 feet; 3, Sherlock's mill, East Second and Clement streets,

about 200 feet; 4, Crawford lumber yard, East Clement and East Third streets, 235 feet; 5, Hammel Lumber Company, Boyd and Second streets, 310 feet; 6, John Hopson, Main and Plattin streets, 185 feet; 7, James Hopson, No. 2, Main and Miller streets, 225 feet; 8, Packing house, East Third and Miller streets, 190 feet; 9, R. M. Booth, East Main and Pratt streets, 200 feet; 10, S. W. Crawford, Main and Easton streets, 200 feet; 11, G. Hammel, Main and Williams streets, 300 feet; 12, John L. Rouggly, Main and Stone streets, 300 feet; 13, 14, City Water Company, pump house, 300 feet; 15, W. J. Manthes, 265 feet; 16, Commercial Hotel, Main street, about 200 feet; 17, Herman Hammel, Main street between Clement and Mineral streets, about 200 feet; 18, Dr. H. E. Zorn, Main and Mineral streets, 200 feet; 19, George Mann laundry, Main and Stewart streets, 200 feet; 20, Herman brickyard, three-fourths mile north of city, about 200 feet; 21, Electric-light plant, 185 feet.

These wells are nearly all 6-inch drill wells, generally cased with 4-inch casing to a depth of about 150 feet. No. 3 has ceased to flow, the water probably wasting, as the casing is only 80 feet deep. No. 10, the Crawford well, and No. 11, the Gus Hammel well, have both ceased to flow, owing to the fact that other wells seem to have tapped their source. No. 12, the Rouggly well, supplied the drinking water for the Louisiana Purchase Exposition. Nos. 13 and 14, the City Water Company wells, flow about 70,000 gallons in twenty-four hours, and these, when pumped, cause a number of other wells in the neighborhood to stop flowing. Nos. 16, 17, 18, and 19 have all ceased to flow.

James Hopson sunk his first well in 1886, on the corner of Pratt and Second streets, in the endeavor to find soft water for the boiler at his mill. The first flow was obtained at a depth of 100 feet; the second, which raised the water 17 feet above the surface, was reached at a depth of 225 feet. The temperature was 58° F. when the air temperature was 83° F. This well and mill are now owned by Henry Lupp.

One well was sunk on a hill 97 feet above Main street to a depth of 328 feet. Water rose within about 80 feet of the surface, a level corresponding to that of the flowing wells which are situated at a lower point. The third well sunk in the city was the packing-house well. The surface at this point is about 10 feet below the general level of the town. A strong flow was struck at 115 feet, with a second flow at 190 feet. These two flows are separated by two pipes. The first comes from a sandstone, probably the Roubidoux, and the second from the Gasconade limestone. The surface formation is the Jefferson City limestone.

The flow of all the wells in this vicinity, included in a valley about a mile long and half a mile wide, is affected, in one way or another, by various causes. For example, the John Hopson well, No. 6, situated about 1,200 feet northwest of the waterworks wells, stops flowing when the latter are being pumped. As soon as the pumping is discontinued the Hopson well flows again at an abnormally rapid rate. When the Crawford well, No. 10, was sunk, it had a good flow, but

when the Gus Hammel well, No. 11, was put down, the Crawford well stopped flowing until the Hammel well was shut off, the latter being 12 feet higher than its neighbor. The wells in the southern part of the town have the strongest flow, and since so many have been sunk in this vicinity most of those to the north have ceased flowing.

The regional dip of the rocks in this district, from Bismarck to De Soto, is from the St. Francis Mountains to the northeast. This fact, together with the peculiar phenomena connected with the flowing of the wells, seems to indicate that the catchment basin for this De Soto group is in the St. Francis Mountains.

One mile up Joachim Creek from De Soto is a large spring which comes to the surface with a strong flow, bringing with it fine white sand, and it is probable that this spring is one of the natural outlets of the artesian pressure from the Roubidoux sandstone.

All the wells in the De Soto basin show signs of decreasing pressure. This is undoubtedly because of the escape of waters through crevices in the rocks, due to bad casing, and because so many wells have been sunk within the limits of so small an area. The expense of drilling in this region varies from $1.50 to $2 per foot; generally about $1 for the first 100 feet, $1.50 for the next 100, and $2 for the third 100 feet. The water is clear, cool, and pure, containing a little iron. The temperature varies from 56° to 57° F. That of the waterworks well is 56° F. when the air temperature is 80° F. The city is replacing the old waterworks plant with one more modern, to supply which two wells a few feet apart, both with a 10-inch bore, have been sunk. A pump house has been erected and a pump is being placed for the purpose of raising the water to a reservoir that is being built on a hill 220 feet above the city. This will provide De Soto with one of the best and purest water supplies in the State. No analysis of these waters has ever been made.

It is stated that at Hematite, 8 miles north of De Soto, a prospect hole drilled to a depth of 300 feet struck flowing water.

MADISON COUNTY.

FREDERICKTOWN.

On the farm of Mrs. Emma Copeland, in the NW. ¼ sec. 2, T. 33, R. 7, near Mine La Motte, is a diamond-drill well sunk about 1900 to a depth of 300 feet. The water flows feebly about 3 feet above the surface. It is clear and cold, and is used for stock purposes.

Four wells were bored on the Sheldon estate, in sec. 25, T. 34, R. 7, to a depth of about 300 feet each, by Mr. H. R. Amling, of Fredericktown. They all had a strong flow, but when the casing was pulled out they filled up and stopped flowing.

On the farm of F. M. Griffin, in the NW. ¼ sec. 14, T. 33, R. 7, a well was bored in March, 1905, to a depth of 304 feet. Water rises 5 feet above the surface. It is clear and cold, and is used for stock purposes.

In the NW. ¼ of sec. 16, T. 33, R. 7, a well was sunk by the North American Mining Company to a depth of 300 feet. It has a feeble flow.

All the wells at Fredericktown are situated on the west side of a dividing ridge of the St. Francis Mountains, and the rocks dip to the southwest.

PERRY COUNTY.

PERRYVILLE.

The Perryville Ice Company completed a well to a depth of 386 feet, with a 6-inch bore, cased to the bottom. This is located a quarter of a mile east of Perryville. Water was obtained in an opening at a depth of 60 feet, probably an underground stream. Pumping does not change the level. The water is soft, and is used for boiler purposes and in making ice. Rock was struck at a depth of 14 feet, and with the exception of the crevice opening at 60 feet, solid limestone continued to a depth of 300 feet.

ST. FRANCOIS COUNTY.

BISMARCK.

Bismarck is situated in a basin with outcroppings of porphyry on the west, south, and east. Several flowing wells are located in or near the town. The catchment basin for the group is in the porphyry hills to the west and south.

One of the Tullock wells is situated in sec. 16, T. 35, R. 4. It is 313 feet deep and flows about 3 gallons per minute. It was drilled by Ben Hoskins, of Central, in 1901, and is 120 feet below the railway station at Bismarck, according to the barometer. The water is clear, fairly soft, and has a temperature of 56° F., the air temperature being 75° F. This is a diamond-drill well, with a 1¼-inch bore, and was drilled by the Iron Mountain Company. It goes 20 feet into granite. Mr. Tullock's second well was sunk in 1891, by the same company, in sec. 17, T. 35, R. 4, to a depth of 240 feet. It is 15 feet higher than the first well, according to the barometer. The casing was drawn out of this well, and the water wastes away at the surface. The rocks in both cases dip to the west, away from the porphyry hills. Neither the logs nor the analyses of these wells have been preserved. They probably obtain water from the Bonneterre limestone.

The Stephen Fine well is situated 1½ miles west and a little north of Bismarck in a little valley close to a small branch, about 115 feet

below the town by barometric measurement. It is about 180 feet deep, and has the strongest flow of any in the group, raising the water about 12 feet above the surface. The water is clear, pure, and cold, having a temperature of 56° F., when the air temperature is 80° F. This well, like the two preceding, probably obtains water from the Bonneterre limestone. The rocks dip to the west. About 150 feet distant from this well is another which flows feebly in wet weather.

The John Neujus wells are situated in the NE. ¼ lot 2, sec. 5, T. 35, R. 4. They were drilled in 1894 and 1901 with a 1¼-inch diamond drill. Barometrically, they are at the same altitude as the town of Bismarck. They are about 250 feet deep, cased a few feet to rock, and have a feeble flow reaching only about 4 feet above the surface. The water commenced to flow at a depth of 90 feet. It is clear, pure, soft, and cold, with a temperature of 57° F., the air temperature being 80° F. The wells are sunk within a few feet of each other in a little swamp. Mr. Neujus stated that there are thirteen small springs within a radius of 13 feet of the wells. He has built a fish pond which is fed by these springs. Several other drill holes were sunk in the immediate vicinity, at a surface altitude of 6 to 8 feet higher than the wells just described. In them water stands but a few inches from the surface. The Neujus wells are all probably in the Elvins formation, and the rocks dip to the north.

A diamond-drill well, with a 1¼-inch bore, was sunk to a depth of 300 feet on the farm of William Gruner, one-eighth of a mile south of the Neujus wells. It flows only a part of the time, and then but feebly.

It is stated that two prospect holes sunk on Flat River, near Central, flowed for a time.

SOUTHEASTERN SWAMP DISTRICT.

GENERAL ARTESIAN CONDITIONS.

The most interesting artesian district in the State, that of the southeastern lowlands, includes but a portion of the true swamp district, which extends into the adjoining States of Illinois, Kentucky, Tennessee, Mississippi, and Arkansas. This Missouri portion embraces the following counties: Scott, Mississippi, New Madrid, Stoddard, Butler, Dunklin, and Pemiscot.

The only flowing wells in the embayment region in Missouri are those at Morehouse, New Madrid County, and Campbell, Dunklin County, on the north and east sides of the embayment.

Attention has been briefly called to the fact that the Missouri lowlands occupy the northwest corner of the great Mississippi embayment. Into this cone-shaped trough empties the drainage of the southeastern flanks of the Ozarks from Missouri, bringing a vast

quantity of water, not only over the surface by means of the rivers and smaller streams, but also through those porous aquifers, the Cambro-Ordovician sandstones, cherts, and porous limestones, which have a strong southeasterly dip into this basin. That these rocks are loaded with water is shown by the immense springs and underground streams that everywhere abound in this region. In fact, some of the largest springs in the world are found in close proximity to this district. From the north comes the drainage from the southern flanks of the St. Francis Mountains and southern Illinois, the volume of which is indicated by the interesting phenomena discussed in the consideration of the well at Benton, Scott County (p. 179). From the east is received the drainage from the plateau of western Kentucky and Tennessee, the rocks all dipping strongly westward from the central catchment basin of these two States.

This embayment region, which was largely eroded during later geologic time, has been gradually filled from the south by Cretaceous, Tertiary, and Quaternary deposits consisting, as is shown by the well records of this district, of alternating layers of incoherent sands and thick, tenacious clays, forming perfect water bearers separated by impervious beds. These well records and cross sections also show that the beds not only dip strongly toward the center of this basin from each side, but that they thicken and dip strongly to the south. Into these great deposits of sand a vast volume of water pours from the west, north, and east, causing an immense artesian pressure; and when it is remembered that the alternating impervious layers are not solid rock, but thick beds of flexible, tenacious clay, underlain by water-logged, incoherent sands, it is not difficult to understand why this is a district of unstable equilibrium, subject to the disturbances manifested in the frequent slight earthquake shocks which have produced numerous fissures and fault scarps throughout the entire region.

Flowing wells are confined entirely to the outer margin of the embayment, as at Cairo and Mound City, Ill.; Hickman, Ky.; Dyersburg and Memphis, Tenn.; and Campbell, Morehouse, and Grandin, Mo. Numerous deep wells near the center of the embayment do not flow. This interior region of nonflowing wells is saturated with water which is constantly coming to the surface in lakes, swamps, and streams, and which is continually renewed from a deep-seated source—a living supply, supporting the finest game fish. The escape of this volume of water through fault cracks and fissures relieves the pressure below, and thus tends to preserve an equilibrium and at the same time creates conditions unfavorable to the existence of flowing wells.

The logs given on pages 175 and 177 indicate the frequent occurrence of iron, iron pyrites, and lignite, which in decomposing produce in the water such impurities as iron, sulphur, and small amounts of gas. Chemical analyses show that water taken from wells near the edge of

the basin is, as a rule, purer than that from those farther in, for the reason that the water in the outer wells, being nearer its source, has been in contact with these substances for a shorter time, and consequently is less impregnated with impurities than the waters that are obtained farther from the catchment area.

BUTLER COUNTY.

POPLAR BLUFF.

At Poplar Bluff, Butler County, W. F. Alfrey sunk a well to a depth of 517 feet. He states that the water rose within 15 feet of the surface, and that a 12-horsepower pump could not lower it an inch. He further gives the interesting fact that in 1892, after an earthquake shock, the well was nearly ruined, there being at times hardly enough water to run the factory. It is to be regretted that no log has been preserved, either of this or of other wells at Poplar Bluff.

The ice factory has a well about 400 feet deep, the Oil Well Supply Company one about 200 feet, the Missouri Pacific Railway one about 200 feet, and the Palmer Company one about 250 feet deep.

Mr. W. S. Randall, postmaster at Poplar Bluff, who furnished the above data, also stated that in the bottoms, at a depth of less than 30 feet, the water is hard, impregnated with iron, and comes from a black to reddish quicksand. Below 30 feet good water is obtained from a white quartz sand. Most of the sand in the vicinity has well-rounded globular grains. In this surface stratum of iron-bearing sand are mounds of sand about 3 feet high and from 10 to 20 feet in diameter, which are termed "sand blows." It is claimed that pipes put down in these sand blows give a better quality of water—a significant fact. This condition is very general through the Missouri portion of the embayment district, the best water being obtained in the white sand beneath the reddish surface sand. It is the custom in this region to drive a galvanized-iron pipe with a conical strainer at the end down into this white sand, from which a good water supply may be pumped.

DUNKLIN COUNTY.

CAMPBELL.

At Campbell, Dunklin County, a well is located on the land of the Campbell Lumber Company. Depth, 960 feet; elevation above tide, about 310 feet; casing, 4-inch, to 910 feet; temperature of water, 72° F.; flow, 16 gallons per minute; date of completion, September, 1902; drillers, Johnson & Fleming, Memphis, Tenn.; cost, $3,000. The principal source of water was found at 940 feet in sand, and another water-bearing horizon was found at 145 feet. The water is somewhat soft, though rather saline, and contains sulphureted hydro-

gen. The following log of this well was furnished by Mr. Wm. B. Johnson,[a] of Memphis, Tenn.:

Log of well of Campbell Lumber Company, Campbell, Dunklin County.

	Thickness.	Depth.
Loess? (112 feet):		
Yellow clay, a little darker than that on Crowleys Ridge	*Feet.* 112	*Feet.* 112
Lafayette (43 feet):		
Orange sand and gravel; the sand has many white, loamy clay nodules mixed in it	43	155
Lagrange formation (785 feet):		
Very hard black and brown clay or marl, with numerous very hard strata from 1 to 23 inches thick, composed largely of iron pyrites. At some point between 700 and 750 feet a bed of logs 10 or 12 feet thick was penetrated. This clay differed from any other bed struck in the bottoms in containing no sand strata, and not even a trace of the "gray sand" found in other wells was noted	785	940
Ripley sands (20 feet):		
Very fine black sand, with a large percentage of mica in small grains. Water headed about 7 feet above surface and flowed 16 gallons per minute had brackish taste	20	960

The water from this well is used for boiler and drinking purposes. It is probable that the bottom of the well is not far from bed rock.

NEW MADRID COUNTY.

MOREHOUSE.

In Morehouse, New Madrid County, in sec. 31, T. 26, R. 13, is a well owned by the Himmelberger-Harrison Lumber Company. Depth, 780 feet; altitude above tide, about 330 feet; casing, 10-inch pipe at top, $6\frac{5}{8}$-inch casing at bottom; flow, 200 gallons per minute; date of completion, summer of 1902. This well was drilled through the estuary deposits to solid limestone. The pressure raises the water 18 feet above the surface, and no variation has ever been noted. Though the water is somewhat saline, it is used for drinking. The accompanying log and some samples of drillings for study were furnished by Mr. John H. Himmelberger:

Log of well at Morehouse, New Madrid County.

	Thickness.	Depth.
Loess (30 feet):		
Clay	*Feet.* 30	*Feet.* 30
Lagrange (218 feet):		
Coarse sand	110	140
Gravel	10	150
Gumbo, or brown clay	40	190
Brown quicksand	40	230
Gumbo	10	240
Cemented gravel	8	248
Porters Creek (Eocene) (218 feet):		
Gumbo	197	445
Rock	1	446
Gumbo	20	466
Ripley sands (Cretaceous) (224 feet):		
Fine white sand	224	690
Cambrian (probably Gasconade limestone) (90 feet):		
Limestone	40	730
Sandstone	15	745
Limestone, full of crevices and badly broken	35	780

[a] The writer is indebted to Mr. Johnson for many favors and much valuable information in regard to the wells of this district. The work of the geologist would be greatly facilitated if other drillers would take as much interest in preserving data as has been shown by Mr. Johnson.

The 30 feet designated as probably loess and the 110 feet of coarse sand included in the Lagrange formation are doubtfully so placed. The 90 feet of limestone and sandstone penetrated at the bottom is a light-gray, highly siliceous, shaly rock, probably the Gasconade limestone. This well record is a particularly valuable one, as it gives the thickness of the estuary deposits at this point.

Morehouse is situated in what was probably one of the early channels of Mississippi River, and the 140 feet of sand and clay at the surface may have had its origin as a river deposit. Mr. Himmelberger, in a personal letter, states that in going through the white sand above the limestone, fragments of charred and decayed wood were brought to the surface. He furnishes an analysis of the water of this well, made at the Missouri State University.

Analysis of water from well at Morehouse, New Madrid County.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	12	Sulphate radicle (SO_4)	123
Calcium (Ca)	208	Chlorine (Cl)	1,437
Magnesium (Mg)	55		2,484
Sodium (Na)	649		

The following log of this well, furnished by Mr. Otto Kochtitzky, of Cape Girardeau, varies slightly from that given by Mr. Himmelberger:

Log of well at Morehouse, New Madrid County.

	Thickness.	Depth.
	Feet.	*Feet.*
Sand and fine gravel	66	66
Coarse sand	40	106
Sand	35	141
Black soapy clay	9	150
Dark-blue clay	22	172
Blue clay and sand	65	237
Sand and clay	20	257
Sand and blue clay	22	279
Blue clay, except 1 foot of shale	148	427
Sand, except about 2 feet of gravel on limestone bed	269	696
Limestone	90	786

NEW MADRID.

A well was sunk at New Madrid by the Mississippi River Commission in 1881. About 20 borings were made in the vicinity, two of which extended to a depth of over 200 feet, but none of them resulted in flowing wells. Mr. Henry Moss, who was a member of the Commission, stated that a great many wells were sunk all along the river from Listers Island, 20 miles north of New Madrid, to Fort Pillow,

[a] Expressed in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at the United States Geological Survey.

near Osceola, 90 miles south of New Madrid. Most of these were about 200 feet deep, and none of them less than 125 feet. Whenever these drill holes penetrated through the clay layer into the deep sand, water and sand would shoot up to a height of 30 or 40 feet in the pipe, the sand clogging the pipe in the bottom. The following is the log of well No. 9,[a] at New Madrid, which was begun about 12 feet above high-water mark:

Log of well near New Madrid, New Madrid County.

	Thickness.	Depth.
Alluvium and possibly some Lafayette (64.3 feet):	*Feet.*	*Feet.*
Sand, gray above and light brown and more clayey below	4	4
Clay, blue above and sandy below	31.6	35.6
Sand, dark gray, containing particles of lignite and layers of blue clay	9.4	45
Gravel, with some sand and lumps of lignite and decayed wood	19.3	64.3
Lagrange (149.7 feet):		
Clay, blue, containing wood showing fiber	5	69.3
Sand and gravel	17.3	86.6
Sand, thin layers of clay, interstratified with some gravel	24.3	110.9
Clay	20.3	131
Sand, yellowish and reddish, interstratified with thin layers of yellowish and gravish pebbly clays	40.2	171.2
Clay, brown	10.8	182
Sand, gray	17.6	199.6
Clay, gray, with thin layers of fragments of lignite	1.4	201
Sand, gray, with few thin layers of gray clay	13	214

Another well sunk to a depth of 207 feet had a similar section. A strong body of water was found in the lowest gravel, below 192 feet.

PEMISCOT COUNTY.

CARUTHERSVILLE.

The city waterworks well at Caruthersville, Pemiscot County, is located in sec. 13, T. 18, R. 12; depth, 428 feet; altitude above tide, 280 feet; casing, 5-inch to bottom; temperature of water, 60° F.; date of completion, March, 1903; drillers, Johnson & Fleming, Memphis, Tenn.; cost, with pumping machinery, $2,500. Water was struck at 25 feet, but the principal supply was found at 268 feet, from which the water rose within 10 feet of the surface. It is pumped into a standpipe 100 feet high by two Gardner pumps and distributed by 4½ miles of 4, 6, and 8 inch mains. The pressure is 75 pounds, which may be increased to 120 pounds for fire purposes. A daily consumption of 500,000 gallons does not affect the supply. The water contains a large amount of iron and is objectionable to some on account of the yellow precipitate. The mouth of the well is 25 feet above Mississippi River, just north of the city, and the water level is influenced by the rise and fall of the river, although it is normally higher than the river level.

[a] Miss. River Comm. Rept. of Progress, 1881, p. 180.

Two analyses of the water from this well have been made. The one here given was furnished by Doctor Byers, mayor of the city, who has also supplied other valuable data in regard to this region:

Sanitary analysis of Caruthersville city water.

[Analyst, Dr. R. B. H. Gradwohl, St. Louis.]

	Parts per million.		Parts per million.
Nitrogen as free ammonia	0.06	Oxygen consumed	2.5
Nitrogen as albuminoid ammonia	.082	Chlorine	6
Nitrogen as nitrites	0	Alkalinity	100
Nitrogen as nitrates	.22	Total solids	120

The test for iron shows but a trace—about 3 parts per million. This represents a fairly good drinking water.

The amount of iron given in this analysis is manifestly incorrect. The water probably stood for some time, which allowed the iron to precipitate. Doctor Byers states that another analysis, now lost, gave over 34 parts of iron per million.

A well at the oil mill in Caruthersville, 385 feet deep, furnishes water that is apparently of the same character as that from the preceding well and is used for steam purposes.

The ice-factory well was first sunk to the depth of 715 feet. The casing was afterwards pulled up and a strainer put on at 416 feet, much better water being obtained. The log of the well given below is furnished by Mr. W. B. Johnson, who states that the formations in all the Caruthersville wells are uniform:

Log of ice-factory well, Caruthersville, Pemiscot County.

	Thickness.	Depth.
	Feet.	*Feet.*
Black sandy loam, shading to sand	19	19
Sand and gravel, practically same as river sand (gravel mostly large)	154	173
Very hard blue clay	32	205
Very soft blue clay, mixed with sand	175	380
Gray sand, mixed with lignite	335	715

Mr. Johnson states that drilling was stopped in this gray sand at 715 feet, and that as no change was found the pipe was pulled back and the strainer put on at 416 feet. The well yields 400 gallons per minute by pumping.

RIPLEY COUNTY.

NAYLOR.

A deep well is reported near Naylor, Ripley County, in sec. 33, T. 22, R. 4 E., on the property of the Doniphan Lumber Company. This was sunk to a depth of 990 feet. The log was not preserved. An abundance of water was found all the way down, and all efforts to case it off proved futile. The well was drilled for gas. When it was abandoned the water stood at the surface.

SCOTT COUNTY.

BENTON.

In the northeast corner of the public square in Benton, in sec. 13, T. 28, R. 13 E., is a well owned by the county. Depth, 1,500 feet; altitude above tide, 470 feet; casing, 6-inch, to 160 feet; temperature of water, 60° F.; of air, 80° F.; date of completion, December, 1904; driller, Charles S. Wise, St. Louis; cost, with pumping machinery, $10,000. This well was put down by the county court in order to provide water for the court-house and jail. Benton is situated more than 100 feet above the level of the swamp country—an isolated elevation that was formerly joined to Crowleys Ridge. The principal supply of water was found between 1,200 and 1,500 feet. One of the very interesting peculiarities of this well is the fact that though drilling was very hard between the limits just mentioned, not more than a quart of the cuttings could be secured. The water supply seems to come from crevices in the rock, and the last cuttings obtained were from a depth of 1,440 feet, though the well is 1,500 feet deep. Evidently a very large body of water flowing through these crevices carried off the drillings. This strong flow is from the north toward the artesian basin, as is shown by the dip of the rocks in the surrounding region—a significant fact, that is again referred to on page 173. Other water-bearing beds were found at depths of 150, 180, 480, and 600 feet. The water stands in the well at about 120 feet from the surface, and a 4-inch pump, worked continuously for three days, did not affect the level.

The writer is indebted to Mr. Albert De Reign, water commissioner of Scott County, for a carefully kept record of this well, for samples of drillings, and for much information resulting from his close observation of artesian conditions in this locality. With reference to the height of the water in this well, he states that the tubing, with a rubber packer, was first inserted at 600 feet. It was then raised and a test made at every joint, i. e., every 20 feet, resulting in no perceptible difference in the height of the water. Then 1,460 feet of 2-inch tubing was inserted in the same way. At this depth the packer was sprung and all water from above satisfactorily cut off. After about thirty minutes a test was made with a plumb line and the height of the water carefully measured, both in the interior of the 2-inch tubing and on the outside. This test showed that the water had risen 10 feet. Similar tests were then made as the tubing was raised at intervals of 20 feet. At no joint, however, did the water rise higher than at the 1,460-foot level. The present depth of water from the surface is the same as when the first test was made, viz, 120 feet. It was very difficult to control the water above 1,460 feet, from the fact that there were several perpendicular and diagonal crevices, as well as

cavities, leaving no smooth wall against which the packer at the end of the tube could find lodgment to completely shut off other water.

From samples of drillings that were carefully preserved by Mr. De Reign and sent to the writer, the following log of the well is given. It is noticeable that no sandstone occurs below 475 feet, which makes it very difficult to correlate the section. It is very probable, however, that sandstone beds may have occurred, the drillings from which were washed away in the last 300 feet, as already suggested.

Log of well at Benton, Scott County.

	Thickness.	Depth.
Tertiary (158 feet):	*Feet.*	*Feet.*
Clay, yellow		55
Gravel, hard	10	65
Iron ore, yellow bowlders, soft	30	95
Quicksand	36	131
Lithographic stone, brown, medium	9	140
Quicksand and metamorphic sandstone	18	158
"Richmond" and Kimmswick ? (272 feet):		
Limestone, gray, medium	22	180
Limestone, brown, medium; strong odors of gas	50	230
Limestone, brown-buff, medium, with sand	200	430
St. Peter sandstone (45 feet):		
Sandstone, yellow, medium	8	438
Sandstone, gray, medium	9	447
Sandstone, yellow, medium coarse	28	475
Jefferson City limestone (225 feet):		
Limestone, blue, medium	95	570
Trenton limestone, brown, medium; gas odor	30	600
Limestone, blue, medium	30	630
"Gypsum" (calcite?), white, soft; here 200 gallons of water per minute rose within 100 feet of top	20	650
Limestone, gray, hard	5	655
Shale, black, medium	45	700
Roubidoux and Gasconade (540 feet):		
Limestone, blue, gray, medium	135	835
Limestone, gray, hard	195	1,030
Limestone, blue, gray, hard	60	1,090
Limestone, gray, hard	82	1,172
Limestone, blue, gray, hard	8	1,180
Limestone, blue, hard	20	1,200
Limestone, buff, gray, hard	40	1,240
Upper Elvins or lower Gasconade (200 feet):		
Dolomite, brown, hard	80	1,320
Dolomite, gray, hard	30	1,350
Dolomite, buff, hard	15	1,365
Dolomite, brown, hard	5	1,370
Dolomite, gray, hard	50	1,420
Dolomite, brown, gray, hard	20	1,440
Elvins (60 feet):		
Dolomite, black, hard	60	1,500

The last record was taken at about 1,440 feet, no drill cuttings being obtainable during the remaining 60 feet, although the drilling was hard.

A sample of the water from the Benton well was sent to Prof. Harrison Hale, of Drury College, who made a partial analysis, which is given below. The water was taken from the well after continuous pumping for three weeks.

Partial analysis of water from well at Benton, Scott County. [a]

	Parts per million.		Parts per million.
Calcium (Ca) [b]	77	Sulphate radicle (SO_4)	0
Sodium (Na)	22		
Carbonate radicle (CO_3)	144		274
Chlorine (Cl)	31	Temporary hardness	260
Iron (Fe)	0	Permanent hardness	0

WELLS OUTSIDE OF MISSOURI.

CAIRO, ILL.

Several flowing wells have been sunk in the city of Cairo and immediate vicinity. The writer is indebted to Mr. Otto Kochtitzky for the following record of the well at the Halliday Hotel:

Log of flowing well at Halliday Hotel, Cairo, Ill.

	Thickness.	Depth.
	Feet.	*Feet.*
Alluvium (109 feet):		
Sand and clay	50	50
River sand	59	109
Lagrange (237 feet):		
Sand and gravel	10	119
White sand	176	295
Kaolin; first artesian water at 698 feet	6	301
Gravel and sand, mixed with iron	45	346
Porters Creek (187 feet):		
Yellow clay	5	351
Kaolin	27	378
Shale	155	533
Ripley sands (45 feet):		
Sand and cement gravel	45	578
Mississippian (276 feet):		
Flint rock	19	597
Sand and cement gravel	13	610
Flint rock	50	660
Sand and gravel	20	680
Gray lime rock; second artesian water at 792 feet	174	854

HICKMAN, KY.

At Hickman, Ky., is a well 917 feet deep, owned by H. A. Tyler. It is 130 feet above the railroad and 133 feet above the high-water mark on the Mississippi River gage. The following record was furnished and the correlations made by Prof. L. C. Glenn, of Nashville, Tenn.:

Log of Tyler well, Hickman, Ky.

	Thickness.	Depth.
	Feet.	*Feet.*
Loess (80 feet):		
Yellow clay	80	80
Lafayette (10 feet):		
Soft sand	10	90
Lagrange (627 feet):		
Soft blue clay	460	550
Very fine sand	6	556
Tough blue clay	144	700
Sand	17	717

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

[b] CO_3 given equals 192, calculated as all $CaCO_3$.

The section of a near-by hole, which is 850 feet deep, shows that the lowest sands mentioned in the above log extend to a depth of at least 830 feet.

DYERSBURG, TENN.

Messrs. Johnson & Fleming report the following section at Dyersburg, Tenn.:

Log of well at Dyersburg, Tenn.

	Thickness.	Depth.
Lafayette (90 feet):	*Feet.*	*Feet.*
Conglomerate, mostly wash from the hillside	42	42
Sand and gravel	48	90
Lagrange (538 feet):		
Very hard blue and brown clay	430	520
White clay, very sticky and hard to penetrate	80	600
Coarse white sand, considerably lighter in color than the Memphis sand, but similar to that in having small particles of lignite in it	28	628+

The elevation of the well mouth is 1 foot above high water in Mississippi River, 1897. The water rose to a height of 12 feet above the surface and flowed 102 gallons per minute at the surface. It was analyzed by Dr. Felix Paquin, city chemist, Memphis, and pronounced very good and practically the same as the Memphis water, though to the writer it seemed to contain more iron.

JONESBORO, ARK.

Deep wells have been reported at Jonesboro, Ark., where it is said that rock was struck at a depth of 1,200 feet, which gives the depth of the embayment deposit. It is unfortunate that the logs were not preserved.

MARKED TREE, ARK.

At Marked Tree, Ark., is a well owned by the Chicago Mill and Lumber Company, of Blytheville, Ark. The following record is furnished by Mr. W. B. Johnson:

Log of well at Marked Tree, Ark.

	Thickness.	Depth.
Alluvium and Lafayette (?) (220 feet):	*Feet.*	*Feet.*
"Buckshot," shading to sand	27	27
Orange sand and gravel	193	220
Lagrange formation (clay, 146 feet):		
Soft white clay	12	232
Very hard blue clay	63	295
Soft, sandy blue clay with thin streaks of sand	71	366
Lagrange formation (sand, 32 feet):		
Gray sand, same as at Memphis	32+	398+

This is one of three wells made by Mr. Johnson at this point, all of which had similar logs. When the gray sand was struck, water rose within 3 feet of the surface. Three gallons per minute were pumped on a test, this being the full capacity of the pump. The water has been analyzed as follows, and reported excellent, with about the same amount of iron as the Memphis water.

Analysis of water from well at Marked Tree, Ark.[a]

[Analyst, Felix Paquin.]

	Parts per million.		Parts per million.
Silica (SiO_2)	2.4	Sulphate radicle (SO_4)	4.7
Calcium (Ca)	9.4	Chlorine (Cl)	5.3
Magnesium (Mg)	.89		
Sodium (Na)	3.5		39.19
Carbonate radicle (CO_3)	13		

MEMPHIS, TENN.

At Memphis, Tenn., there are 141 artesian wells, most of them flowing, mainly connected with the city waterworks system, which is one of the best in the country. The following condensed information and log, as well as samples of drillings, were furnished by Messrs. Lanhan and Davis, engineers at the waterworks. Both the engineers state that in these wells there is a continuous flow of fine sand, brought to the surface by artesian pressure, from depths ranging from 450 to 600 feet. A brass strainer, with openings one one hundred and fiftieth of an inch in width, is placed in the bottom of each well, and these are so rapidly worn by the sand that they have to be replaced in from three to five years, and every precaution has to be taken to keep this sand from the valves and piston rods of the pumps. These wells are tapped at depths varying from 40 to 60 feet and the water conveyed by brick tunnels to a central reservoir at the pumping station. It is necessary occasionally to clean the sand out of these tunnels. Recently one was found nearly filled with it. A variation of 12 feet in the level of the water in the wells has been noted between the wet and the dry seasons. The temperature of the water varies from 60° to 62° F.

The section given below is the log of the deep well on Quinby street, near Robinson, in which the water rises within 14 feet of the surface.

[a] Expressed by analyst in hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

Log of deep well No. 109 at Memphis, Tenn.

	Thickness.	Depth.
	Feet.	*Feet.*
Loess (45.4 feet):		
Yellow clay	27	27
Hard brown clay	10	37
Slightly soft brown clay	8.4	45.4
Lafayette (18 feet):		
Gravel and sand	4	49.4
Soft brown clay and sand	14	63.4
Lagrange formation (clay, 213 feet):		
Slightly hard brown clay	12.5	75.9
Stiff blue clay	3	78.9
Soft blue clay	4.4	83.3
Stiff blue clay	2.6	85.9
Soft brown clay	1	86.9
Hard brown clay	2	88.9
Hard reddish clay	1.5	90.4
Hard blue clay	15.5	105.9
Soft blue clay	15.1	121.
Stiff blue clay	1	122
Soft brown clay	4	126
Rather hard brown clay	1.3	127.3
Stiff brown clay	1	128.3
Hard brown clay	6.7	135
Do	61	196
Rather hard blue clay	18	214
Hard blue clay	9	223
Sandy blue clay	53	276
Lagrange formation (sand, 724 feet):		
Fine sand and clay	27	303
Fine sand	35.4	338.4
Fine sand and lumps of clay	41.6	380
Coarse sand and lumps of clay	10	390
Soft blue clay	17	407
Sandy blue clay	10	417
Fine sand and clay	15	432
Sandy blue clay	42	474
Fine sand	2.6	476.6
Sandy blue clay	6.6	483.2
Fine sand	.8	484
Coarse sand and clay	6	490
Soft blue clay	2.3	492.3
Fine clay and sand	17.7	510
Very fine sand	25	535
Very fine sand and clay	38.2	573.2
Very fine sand	16.8	590
Very coarse sand	8	598
Lignite, iron pyrites, and clay	2	600
Very fine sand and lignite	195	795
Soft white clay	17	812
Very fine sand	53	865
Hard brown clay	31	896
Fine white sand	30	926
Hard brown clay	24	950
Fine sand	50	1,000
Porters Creek (Cretaceous) (147.55 feet):		
Stiff brown clay	25.6	1,025.6
Very hard substance	.5	1,026.1
Very stiff blue clay	121.4	1,147.5

This well was a failure, so far as obtaining a satisfactory flow of water was concerned, for the reason that no sand was found sufficiently coarse to be checked by the strainer. This unusual condition is sometimes encountered. Water flows more freely from coarse than from fine sand, and, furthermore, coarse sand is less likely to pass through the strainer than the fine, which seriously injures the pumping apparatus.

The Lagrange formation consists of intercalated irregular alternating lenses of sand and clay, the clay predominating above and the sand below. As a rule coarse sand is obtained in the Memphis district at depths of 350 to 560 feet. Generally the sand is finer above

and below this water-bearing layer. The water company is considering the question of sinking through the Porters Creek formation, which is mainly clay, into the Ripley below, which is a water-bearing sand. The following is a summarized section of the strata in this southern part of the embayment:

Strata in embayment region in western Tennessee.

	Thickness.
	Feet.
Loess	15- 27
Lafayette gravels	6- 40
Lagrange formation:	
Clay	150–200
Sand	800
Porters Creek clay, with supposed thin strata of limestone at bottom	250
Ripley sand	200–300
Selma clay	200–350
Eutaw sand	250

The last three members of this section belong to the Cretaceous. The Lagrange sands outcrop in the Tennessee hills east of Memphis and form the catchment basin for the greater part of this area. The main source of water in this belt is the bed near the middle or base of the Lagrange sands. The water here is very pure, while farther west and northwest it becomes less so, being impregnated with iron and, in some places, with sulphur. At Jackson, Miss., a stronger flow of still purer water was struck, which comes, it is stated, from the Ripley sands below the Lagrange. The engineers at Memphis are confident that a better quality and a stronger flow of water are characteristic of the Ripley.

It is interesting to note in the above summary the alternation of the impervious beds with the water bearers. The loess and the Lagrange, Porters Creek, and Selma clays alternate with the porous Lafayette gravel and Lagrange, Ripley, and Eutaw sands. It is stated that the water from the Eutaw is always impure. The water derived from these different formations is purer in proportion to the nearness of the well to the catchment basin.

MISSISSIPPI COUNTY, ARK.

The following analyses of water from shallow driven wells in Mississippi County, Ark., were furnished by Mr. W. B. Beckman, manager of the Chicago Mill and Lumber Company, of Blytheville, Ark. They are valuable in that they show the uniform character of the water throughout this part of the embayment region. The wells are located in sec. 9, T. 14, R. 9, at the foot of Big Lake.

Analysis of water from 30-foot well near Big Lake, Arkansas.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	40	Free ammonia	0.04
Iron and alumina oxides (Fe_2O_3+Al_2O_3)	1.5	Albuminoid ammonia	.06
Calcium (Ca)	12	Nitrogen as nitrates	Trace.
Magnesium (Mg)	3.4	Nitrogen as nitrites	0
Sodium (Na)[b]	8.2	Chlorine as chlorides	7.26
Carbonate radicle (CO_3)	17	Oxygen consumed	2
Sulphate radicle (SO_4)	24	Appearance, good.	
Chlorine (Cl)	.7	Color, none.	
Loss, etc	.8	Odor, none.	
	113.9	Appearance of residue, white; no color on heating.	

This water is considerably better than the average for use in a steam boiler. It will, of course, deposit some scale, which is prone to be quite hard, etc. There is a very slight tendency to corrosion.

From a sanitary point of view the above analysis shows this water to be of a sufficient purity to warrant its use as a drinking water.

Analysis of water from 40-foot driven well near Big Lake, Arkansas.[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	38	Free ammonia	0.04
Iron and alumina oxides (Fe_2O_3+Al_2O_3)	4.8	Albuminoid ammonia	.05
Calcium (Ca)	22	Nitrogen as nitrates	Trace.
Magnesium (Mg)	5.8	Nitrogen as nitrites	0
Sodium (Na)[b]	9	Chlorine as chlorides	7.26
Carbonate radicle (CO_3)	41	Oxygen consumed	1.8
Sulphate radicle (SO_4)	21	Appearance, slightly turbid.	
Chlorine (Cl)	7	Color, none.	
Loss, etc	1.6	Odor, none.	
	150.2	Appearance of residue, white; no color on heating.	

The action of the water when used in a steam boiler will be of the same nature as that from the 30-foot well, but the amount of scale formation will be about 38 per cent greater in quantity.

As regards the use of this sample for drinking purposes it is equally as good as the sample from the 30-foot well. While the sample is slightly turbid, it is due to a slight amount of mineral matter in suspension and in no way affects the quality. While the analysis shows a very slight difference, the two samples are virtually the same from a sanitary standpoint.

[a] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

[b] Sodium and potassium calculated as sodium.

TERRELL, ARK.

In sec. 29, T. 9, R. 8, is a well owned by the Baker Lumber Company. It was sunk in 1901 and cased with 6-inch casing to 86 feet and 4-inch casing to the bottom. The water, which is warm, rises within 12 feet of the surface. The following log was furnished by Mr. W. B. Johnson:

Log of well at Terrell, Ark.

	Thickness.	Depth.
	Feet.	*Feet.*
Alluvium and Lafayette (182 feet):		
"Buckshot," shading to sand	16	16
Orange sand and gravel, with thin clay partings	166	182
Lagrange formation (clay, 658 feet):		
Blue clay with enough fine sand to make sinking by hydraulic process easy; no water	658	840
Lagrange formation (sand, 24 feet):		
Gray sand, like that at Memphis; lignite in large quantities	24	864

When drilling in this well was stopped at 864 feet it was still in sand. The water has been analyzed and found excellent, with a little more iron than the Memphis water.

DRIFT-WELL DISTRICT.

Wells that obtain water from the drift are numerous in Iowa, Illinois, and the other Northern States, but have few representatives in Missouri, and these are almost entirely confined to the northwest corner of the State.

ATCHISON COUNTY.

TARKIO.

Tarkio is situated in the extreme northwestern part of the State, on Tarkio Creek. In May, 1890, a company was organized for the purpose of obtaining a city water supply, and later a number of wells were sunk in the district. The first one of these was put down at the edge of town, in sec. 14, T. 65, R. 40. Owner, Tarkio Water and Electric Light Company; depth, 210 feet; altitude above tide, 943 feet; casing, 8-inch; flow, strong; date of completion, May, 1890; driller, John Kain.

The following log of this well was furnished by Prof. J. C. Adair, of Tarkio College, to whom the writer is also indebted for the table of wells on page 190 and for partial water analyses, many of them made especially for this report.

Log of Tarkio Water and Electric Light Company well (No. 11), Tarkio, Atchison County.

	Thickness.	Depth.
	Feet.	*Feet.*
Black loam	30	30
Gray clay, with strata of glacial bowlders	40	70
Blue clay	100	170
Hardpan	10	180
Coarse sand	10	190
Rock	20	210

The water from this well flows in a stream from an 8-inch pipe 6 feet above the ground, and is conveyed to a reservoir 30 feet in diameter and 30 feet deep. Thence it is forced by a Dean surface pump, with a capacity of 1,000,000 gallons per day, to a standpipe 50 feet high and 12 feet in diameter, which stands on a hill 100 feet above the well. There is a normal pressure of 75 pounds from the standpipe and a fire pressure of 150 pounds. The well is also provided with a Cook deep-well pump of the same capacity. The water is hard, clear, and cold. The flow from the pipe varies a little, being not quite as strong now as it was at first. Other wells sunk at a lower level have to a slight degree lessened its head. A surface well 40 feet deep was also sunk by this company into the bowlder stratum given in the log. A feeble flow was obtained from this well, and the water is softer and better suited for boiler purposes. The population of Tarkio is 2,500, and it is estimated that the water supply is sufficient for a city of 10,000. At present the city uses about 150,000 gallons per day.

There seem to be two aquifers or water bearers in this district. The upper one varies from 7 to 10 feet in thickness and is usually found at a depth of 40 to 60 feet. It consists of either rounded bowlder material or gray, sharp, angular, coarse sand. The water from this bed is soft and is excellent for boiler use. The bed is usually overlain by 25 to 40 feet of yellow clay, forming the impervious layer.

The main water-bearing stratum and the one having the strongest pressure is a bed of 20 feet or more of sand which is made up of rounded grains and is called the "artesian sand." This is overlain by an impervious layer of dark-blue clay from 140 to 160 feet thick, the lower half of which contains small round pebbles the size of walnuts and numerous pockets of sand.

Tarkio Valley is from 2 to 3 miles wide and is inclosed by low, rounded hills which rise from 50 to 100 feet above Tarkio Creek, a rapid stream that frequently overflows its low banks. The channel has been straightened through the town, where it is confined to a deep ditch running between dikes, which partially control the floods. When visited in July, 1904, the whole valley was sodden with water

as a result of long-continued rains. The cornfields were swamps, although miles of drainage tiles had been laid through them. This condition certainly suggests that the water must rise from the first sand layer under such pressure as to keep the land unusually damp.

Fig. 6 shows the location of the wells referred to in the accompanying table. They extend for a distance of 14 miles, beginning 5 miles north of Tarkio and continuing for 9 miles south, to Fairfax. Mr. James Chambers, who has sunk some wells in this region, states that there is apparently an ancient buried channel in this valley and that the flow in this channel is from the northwest. He has noted that in sinking wells on the extreme sides of the valley only 2 or 3 feet of the "artesian sand" were passed through, while nearer the center of the valley this sand layer is 40 or more feet thick. Mr. Chambers states that in drilling these wells he uses an auger and that frequently good veins of water are found in the yellow clay. If such a vein is tapped there is no necessity of going deeper, as a shallow well of living water is thus assured. Wells bored in this way are quickly and cheaply obtained, 80 to 90 feet being the maximum day's work.

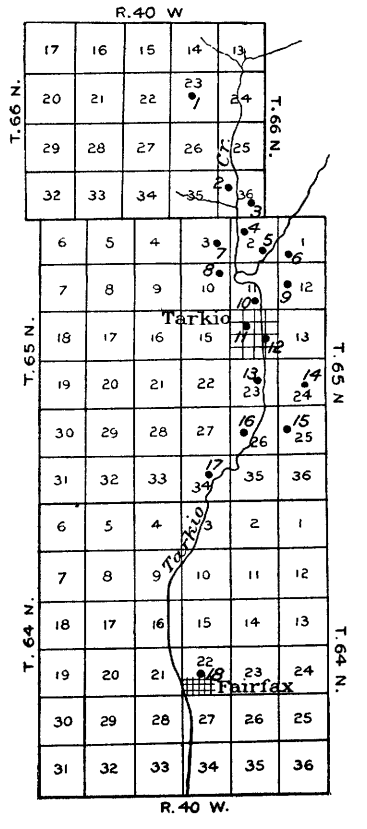

FIG. 6.—Map showing location of the Tarkio artesian wells, Atchison County.

The following is the log of well No. 17, a salt well:

Log of Rankin well (No. 17), Tarkio, Atchison County.

	Thickness.	Depth.
	Feet.	*Feet.*
Black loam	30	30
Gray clay, with occasional strata of loose bowlders	40	70
Blue clay	110	180
Hardpan, white	15	195
Gravel, water bearing	10	205
Carbonaceous shale, with considerable lignite	15	220
Rock; stopped before going through it	50	270

This well contains 5,400 parts of chlorine per million, while well No. 11, 2 miles to the north, gave only 111 parts, and Nos. 15 and 16, a little over a mile to the northeast, 128 and 120 parts, respectively. Well No. 18, at Fairfax, is also a salt well, with about 5,400 parts of chlorine per million, or about 3 ounces of salt to the gallon.

The accompanying table, prepared by Prof. J. C. Adair, gives condensed data in regard to the wells of this district:

Statistics of well in Tarkio district, Atchison County.

No. in fig. 6.	Owner of land.	Driller.	Location.			Elevation of well mouth (feet).	Date drilled.	Depth (feet).	Flow (gallons per minute).	Height of water above surface (feet).	Partial analysis (parts per million).					
			Township.	Range.	Section.						Total solids.	Chlorine.	Free ammonia.	Albuminoid ammonia.	Temporary hardness.	Permanent hardness.
1	B. J. Jones	R. C. Van Leuvan	66	40	23	933	1894									
2	D. West	do	66	40	36	925	July, 1894	130	1			106	6.2	5	243	405
3	E. Lindstrom	do	66	40	36	925										
4	D. O. Murphy	do	65	40	2	921			1							
5	R. C. Van Leuvan	do	65	40	2	920	July, 1901	140	1½			162			287	340
6	A. Smith	do	65	40	1	920		140								
7	Stevenson & McPherson.	do	65	40	3	925	1893	145	2			106			233	516
8	G. D. Gordon		65	40	10	917						152			41	455
9	A. Craig		65	40	12	915		148								
10	D. Rankin	John Kain	65	40	11	915	1891	165	1½			118	8	4	122	506
11	Tarkio Water and Electric Light Co.	do	65	40	14	943	May, 1890	210			1,442	111	8	10	259	367
12	Dr. S. R. Andes	R. C. Van Leuvan	65	40	14	913			2			118	8	5	157	501
13	D. Rankin	John Kain	65	40	23	905	May, 1891			32						
14	W. S. Wood	R. C. Van Leuvan	65	40	24	905		175								
15	P. McKenzie	Jas. Chambers	65	40	25	901		170	1½	20		128	1	1.5	203	379
16	D. Rankin	John Kain	65	40	26	900	Sept. 1890	170	1			120			202	367
17	do	—— McIntosh	65	40	34	896	Mar. 1891	220	1	40	9,753	5,400	5.2	5	298	688
18	W. P. Green		64	40	22	876	June, 1891					5,400				
19	Tarkio Water and Electric Light Co.[a]	John Kain				943		40	1½			1.6		.06	142	40

[a] Surface well; used for boiler supply, also by laundries.

The diameter of all these wells is 3 inches, with the exception of No. 11, which is 8 inches. The temperature of the water is 12° C.

Several of the wells flowed for a short time, but when others were put down they ceased to flow and are now being pumped. The depth to the "artesian sand" seems to increase to the south. In well No. 14, in the extreme eastern part of the basin, rock was reached without finding the sand. To the west the surface is much higher, and though the sand is reached the wells do not flow. Seven miles west of Tarkio, at Rockport, a well was drilled to a depth of 700 feet without finding water. It is probable that the western side of the buried channel is but a few miles west of Tarkio Creek. This ancient channel was undoubtedly cut during the extension and retreat of one of the great northern ice sheets. The vast quantity of water set free by the melting front of this ice sheet found its outlet through the valleys toward the south, in which they left their load of sand and gravel. These deposits were in turn covered by impervious clays from the moraines of subsequent ice sheets, a condition which probably occurred more than once.

Professor Adair has called attention to the large amount of ammonia, both free and albuminoid, contained in the waters of these wells. It is also interesting to note the great variation in the composition of water in wells very near to each other, a fact to which attention has already been called. A series of partial analyses made by Professor Adair shows a constant variation of ammonia in the same well during a period of years. So excessive an amount of albuminoid ammonia as is contained in some of these wells would ordinarily condemn the water at once as being subject to sewage contamination; but there could be no possibility of such contamination in this district, and it is a well-established fact that many other drift wells contain large amounts of this substance. Norton[a] mentions its occurrence in the waters of the drift wells of Iowa, and suggests several theories for its presence. One of these theories is that these artesian waters were originally storm and surface waters, which have taken ammonia from the atmosphere and soil and kept it imprisoned in these basins. Another and a more probable hypothesis is that the ammonia originated from the decomposition and breaking up of the fossil organic remains contained in these sedimentary deposits. Just as the ammonia of commerce is manufactured from the products resulting from the distillation of coal, so it is possible that the ammonia in the water may be derived from the nitrogen of the lignite and carbonaceous shales which are so often present in the drift—a view which, according to Norton, is supported by the association of the ammonia with the hydrogen sulphide of these waters.

[a] Norton, W. H., Artesian wells of Iowa: Ann. Rept. Iowa Geol. Survey, vol. 6, 1897, pp. 358-361.

A well not far from the salt well at Fairfax is highly charged with iron and sulphur.

HOLT COUNTY.

MOUND CITY.

In sec. 29, T. 62, R. 38, on the farm of James A. Vandeventer, is a shallow well flowing about 3 gallons per minute, with no apparent variation. The water is clear, cold, and soft, with some iron, and leaves a reddish coating on pipes and ground. It is derived from a sand layer under a blue clay. It is highly esteemed as a chalybeate water. An artificial lake and a grove of native forest trees render the locality of the well an attractive pleasure ground.

CITY WATER SUPPLIES.

GENERAL DISCUSSION.

SOURCE OF SUPPLY.

The tendency toward the concentration of population in cities and towns has caused a growth that has outdistanced all calculations made when most waterworks systems were originally established. Moreover, the increase in the per capita use of water has been very great and cities are everywhere forced to seek new sources of supply. Lakes, rivers, and springs have heretofore been the main dependence; but these are so generally becoming polluted by sewage, manufacturing wastes, and in other ways, that the problem of pure water is yearly more and more serious.

This problem is more difficult of solution for the larger cities because of the thickly settled districts which surround them. New York City consumes 340,000,000 gallons of water per day. An increase in population of 100,000 per year, which has been the case for the last decade, means necessarily a large addition to the water supply in order to keep pace with such tremendous growth. This city is now looking to the Catskill Mountains as apparently the only available source from which the present supply can be increased. To bring the water of this distant region to the doors of the New York consumers will entail an expenditure of $150,000,000. The present system has already cost $100,000,000.

The problem is even more serious for some foreign cities. Paris has for many years taken from the Seine water for all purposes, but now finds it suitable for street sprinkling and industrial uses only. Other cities of France have secured control of all the available mountain lakes and streams, leaving the capital to contemplate the advisability of establishing filtration plants to make possible the use of the sewage-laden river water.

Many cities, apparently ideally located so far as water supply is concerned, have difficulties to overcome. Chicago, for example, situated on a great fresh-water lake, has had to expend millions of dollars, not only in extending the intake of its water supply farther into the lake, but also in building a great drainage canal to carry into the Mississippi River the sewage that would otherwise pollute the water.

Cleveland has been compelled to go far toward the center of Lake Erie for an intake free from pollution. Philadelphia, procuring water from Delaware and Schuylkill rivers, which are badly polluted, as is shown by the epidemics of typhoid fever so common in that city, is now planning to spend $20,000,000 in the construction of a sand filtration plant for the purification of this water.

London, England, has under consideration a project for bringing from Wales water sufficiently pure for drinking purposes, and Manchester obtains its supply from the lakes of Scotland.

Many southern cities are largely dependent on cisterns for water for domestic purposes. These cisterns are open to contamination from many sources and can not be considered suitable for a permanent supply.

ARTESIAN WATER AS A SOURCE OF SUPPLY.

As a knowledge of the dangers existing in natural water supplies is more widely disseminated, the advisability of seeking in deep wells a source of city water is being more seriously considered. Some degree of uncertainty is connected with the sinking of such wells, not only as regards the quantity of water to be obtained, but also with respect to the quality. Both of these questions are geologic in their nature and can be intelligently considered only in the light of a knowledge of the structure of the rocks which underlie the region and of the nature of the water which characterizes the different geologic formations. It is one purpose of this report to show, so far as available knowledge of the stratigraphy and geologic structure of Missouri goes, the possibility of obtaining in various localities not only flowing wells, but also a sufficient quantity of wholesome water from deep, nonflowing wells.

The city of Memphis, Tenn., has solved its own water problem in a highly satisfactory manner. Formerly having one of the highest death rates in the country, and frequently visited by terrible epidemics of cholera and yellow fever, it is now one of the healthiest cities in the United States; and it is not saying too much to claim that this new sanitary condition is largely the direct result of the development of a magnificent system of artesian wells.

CHARACTERISTICS THAT AFFECT THE VALUE OF WATER FOR PUBLIC SUPPLY.

The value of water for a public supply may be discussed under two heads: (1) Its potability; (2) its suitability for domestic and manufacturing purposes.

POTABILITY.

A drinking water may be injurious from two causes—from the amount of injurious mineral constituents, and from pathogenic bacteria. A good drinking water should be clear and palatable, and should not have an excess of such mineral matter as the salts of lime and magnesia, which are claimed by many to produce or aggravate such diseases as rheumatism, urinary calculi, goiter, and cretinism. The best authorities recommend the avoidance of very hard waters by people over fifty years of age. The presence of iron gives a peculiar taste to the water, which is in such cases known as chalybeate. While this is not injurious to health, except when the iron is in excess of 1 part per million, and is often considered beneficial as a mineral water, it is objectionable for a public supply and general use both because of the taste and the fact that, on standing, a precipitate usually forms that discolors the water and the containers.

Whatever difference of opinion may exist in regard to mineral impurities, there can be no dispute concerning the danger connected with organic impurities existing as a result of contamination from sewage and many other sources. It must be made clear, however, that it is not the dead organic matter or sewage that renders the water dangerous, but the living pathogenic bacteria that can thrive only in waters containing such impurities. Typhoid fever, for example, often has its source in the use of polluted water. This is also believed to be true, to a large degree, of such diseases as cholera and dysentery. Abundant statistics could be given relating to the great decrease of these diseases in cities that have changed from a polluted to a pure water supply.

Great care should be taken of the water after it is derived from the ground, particularly in the reservoir, where it is stored to await distribution. A standpipe is far better than an open reservoir for such a purpose. The latter is liable to become infected by dust, by the intrusion of animals, and by depredations committed by thoughtless or malicious individuals. Even the standpipe is not wholly free from contamination unless properly protected. As an illustration of this, it may be stated that after an outbreak of typhoid fever in one of the cities of a neighboring State, it was discovered that while the water at its source was pure, the tap water contained typhoid bacilli. An investigation of the standpipe, which was over 100 feet high, revealed the fact that it contained an accumulation of over 2 feet of dead

English sparrows that had flown against the inner wall and had drowned. All standpipes should be covered with wire gauze to prevent similar pollution.

HARDNESS.

For domestic supply water should not be too hard—that is, it should not contain too large an amount of the salts of lime, magnesia, and iron. If such is the case, it is objectionable for cooking purposes. Very hard waters are said to affect the taste of foods cooked in them. If too much iron is present, it unites with the tannin of tea and coffee to form a black precipitate. An excess of iron is also objectionable for laundry use, as it is likely to form rust spots on clothing. But one of the most serious objections to hard water from the standpoint of domestic use is the large amount of soap that it requires to produce a lather. Turneaure and Russell,[a] quoting from Parks, state that the city of Glasgow, Scotland, saves $180,000 annually in the cost of soap used since the introduction of the soft water from Loch Katrine as a city supply. Soap is a combination of soda with some of the fatty acids. Pure water, such as rain water, dissolves soap perfectly and forms a lather at once. But water containing certain mineral salts in solution—notably the carbonates and sulphates of lime, magnesium, and iron—does not do this, because these salts form insoluble precipitates with the soap. If it takes a great deal of time to produce a lather with soap, the water is hard, and it will be seen that the amount of soap required before the water will lather gives a test of the relative amount of salts which cause the hardness of the water.

That quality of water called "hardness" is usually referred to as "total," "temporary," and "permanent," the last being, perhaps, the most important of the three, since it represents the sulphates, chlorides, and nitrates of lime and magnesia. By "total hardness" is meant the natural hardness of the water—that is, the aggregate amount of earthy salts and free carbon dioxide. The "temporary hardness" is that which disappears on boiling, and the "permanent hardness" is that which is unaffected by boiling. Clark's scale of hardness is expressed in degrees, 1° being equivalent to the hardness produced by 1 grain of calcium carbonate per gallon. In American practice the hardness is expressed in terms of parts of calcium carbonate per million. To convert degrees of hardness to parts per million, multiply by 14.3. In a general way, if a water has a total hardness of less than 85 parts per million, it is soft; at 115 parts per million it is moderately hard; at 230 parts per million it is very hard, and above that it is objectionable.

The waste of soap and extra labor entailed by the use of very hard water make the subject of hardness of very great importance. Every

[a] Turneaure, F. E., and Russell, H. L., Public Water Supplies, 1901, p. 143.

grain of carbonate of lime in water decomposes 10 grains of soap, and thus, for example, the hardening matter contained in 100 gallons of water such as is supplied to the city of London, where the water has a total hardness of 230 parts per million, will destroy 35 ounces of soap—that is, the first 35 ounces of soap added to 100 gallons of water will disappear without forming any lather or having any cleansing effect.

For manufacturing purposes, perhaps the most important use for water is in the production of steam, and here the question of hardness is of paramount importance. The term "scale" is applied to the harder matter deposited on boilers from the decomposition of certain mineral salts. The term "sludge," or "mud," is applied to the softer or loose precipitates, such as calcium and magnesium carbonates. These form the temporary hardness of water and are, as before stated, more easily removed from boilers than the scale, which represents the permanent hardness and is made up mainly of calcium and magnesium sulphates. This scale involves considerable loss of energy. It is estimated that an incrustation one-sixteenth of an inch thick, being a nonconductor of heat, causes a loss of energy of 15 to 20 per cent of the coal used. Waters that have a temporary hardness produce a friable scale that may be blown out; while those that have a high permanent hardness form a scale which can be removed only with great difficulty. This scale not only results in the loss of energy, but tends to corrode the iron and is frequently the cause of boiler explosions. Edwards[a] estimates that the extra expense due to the use of hard waters on the railway engines of the Middle and Western States amounts to about $750 per year for each engine.

At a session of the American Association of Railway Chemists at Buffalo, N. Y., in 1887, a system of rating for boiler waters was suggested, which, as slightly modified by Norton,[b] is as follows:

Ratings for boiler waters.

Rating.	Amount of incrusting solids.	
	Grains per gallon.	Parts per million.
(a) Very good	0- 8	0- 98
(b) Good	8-15	95-255
(c) Fair	15-20	255-340
(d) Poor	20-30	340-515
(e) Bad	30-40	515-685
(f) Very bad	40+	685+

[a] Practical Steam-Engine Guide, 1894, p. 120.

[b] Norton, W. H., Artesian wells of Iowa: Ann. Rept. Iowa Geol. Survey, vol. 6, 1897, p. 406.

The problem of scale is very serious and many methods of obviating this difficulty have been proposed.[a] A careful quantitative analysis must always be made to determine the nature of hard water and the treatment necessary to render it suitable for use. In some cases waters that contain a large amount of scale-forming material carry also enough alkaline salts to supply their own remedy. In Oklahoma, as reported to the writer by Mr. C. D. Purdon, engineer of maintenance of way of the Frisco System, the water used to supply one tank contains a large amount of scale-producing salts, while that of another but a few miles distant contains the remedy for them, and a mingling of the two waters produces results so good that engineers find no difficulty in their use.

The mineral salts that occur in water and that are objectionable in the manufacture of steam are described in the following paragraphs:

Calcium carbonate is the most common form in which lime occurs. It is but slightly soluble in distilled water, but when carbon dioxide is present, as is generally the case, it is easily soluble and forms lime bicarbonate. Heat decomposes this lime bicarbonate in boilers, driving off the carbon dioxide and precipitating the lime. This forms a scum on the water which prevents the free escape of steam and, if in excess, frequently causes "foaming." It is also precipitated in the form of scale, some of which is carried by the steam into the piston and cylinders, where it has a most injurious effect. The lime does not form a hard scale unless mixed with other salts which cement it to the sides and flues of the boiler.

Calcium sulphate forms the hardest scale known, sometimes almost as hard as porcelain. When the boiler pressure is at 50 pounds, this substance is almost entirely precipitated from the water.

Calcium chloride is occasionally present in water. It does not form scale, but is highly corrosive. If lime or magnesium sulphates are present, under heat and pressure an interchange of acids takes place and calcium or magnesium sulphates, which do form a scale, are produced.

The action of magnesium carbonate is similar to that of calcium carbonate, but only the magnesium bicarbonate is soluble. It is a fine nonconductor of heat, for which reason it is frequently used on the outside of boilers and pipes.

Magnesium chloride is frequently present in water and, if in considerable amounts, is very injurious. At 310° F. it is decomposed, reacting, with water, to form magnesium oxide and hydrochloric acid, which latter corrodes the boiler, especially at the water line. Allen states that certain amounts of sodium chloride may prevent

[a] An excellent article on this subject is given by Turneaure, F. E., and Russell, H. L., Public Water Supplies, 1901, p. 481.

this decomposition, the two chlorides uniting to form a stable double salt. Norton[a] says:

> In contact with boiler plates, calcium and magnesium carbonates of the scale are changed to caustic oxides by the intense heat, and, according to Lewes, if magnesium chloride is present the same result may be reached by reaction with calcium carbonate. So long as heated these oxides remain anhydrous, but are changed to hydrates by access of water on cooling.

A small amount of magnesium chloride, even a grain or two to the gallon, is considered objectionable in boiler waters.

Magnesium sulphate is one of the most soluble of all the mineral salts. In itself it does not produce scale, but when superheated in the presence of other lime salts it breaks up, and new and injurious combinations are produced.

Sodium sulphate and sodium chloride are not scale producing, but are liable to produce "foaming" when present in large amounts. The same is true of sodium carbonate. Sodium chloride is highly corrosive.

Iron bicarbonate, having a weak hold on the carbon dioxide, is easily decomposed and forms ferrous oxide, which, uniting with oxygen and water, forms the hydrated sesquioxide, the yellow precipitate commonly noticed in chalybeate waters. Iron sulphate is frequently present in waters that have their source in the Pennsylvanian rocks, and it is very corrosive in boilers.

The presence of carbon dioxide, ammonia, nitrates, and nitrites is probably objectionable, but how much so has not been fully determined. Some of these, especially the nitrates, are, without doubt, corrosive when present in large amounts.

Silica usually occurs in so small amounts as to be of little importance in this connection.

CITY WATER SUPPLIES IN MISSOURI.

STATISTICS.

The accompanying tables give a list, as complete as it has been possible to make, of the 103 cities and towns in Missouri that have a public water supply, with statistics relating to each and analyses of many of the waters. In connection with the capacity of the various systems, it is interesting to note the daily consumption in different cities and the possibilities of providing for future needs.

In preparing these tables, the writer has supplemented his own notes by reference to Baker's Manual of American Waterworks. The following table gives the per capita consumption of the largest cities in the world.

[a] Norton, W. H., Artesian wells of Iowa: Am. Rept. Iowa Geol. Survey, vol. 6, 1897, p. 402.

Daily per capita consumption of water in various cities.

	Gallons.		Gallons.
Paris	37	Brooklyn	90
London	45	New York	125
Berlin	50	Chicago	180
Kansas City	80	Philadelphia	236

In calculating the amount of water necessary for a city supply, at least 100 gallons per capita per day should be estimated. In artesian districts it is very easy to estimate either the flow or the pumping capacity of wells. Norton[a] suggests that where a number of wells are sunk, they should be aligned at right angles to the dip of the water-bearing strata, so as to tap a larger area. The distance between flowing wells should be as great as is consistent with the other factors considered in their disposition. If the flow is weak, "shooting" will frequently increase the pressure.

[a] Norton, W. H., Artesian wells of Iowa: Ann. Rept. Iowa Geol. Survey, vol. 6, 1897, p. 410.

Statistics of city waterworks in Missouri.[a]

City.	County.	Population (1900).	Source.	Date established.	Cost.	System.	Pressure.		Reservoir capacity.	Standpipe capacity.	Length of mains.	Daily consumption.	Remarks.
							Ordinary.	Fire.					
							Pounds	*Pounds*	*Gallons.*	*Galls.*	*Miles.*	*Gallons.*	
Albany	Gentry	2,025	Well			Direct pressure							
Aurora	Lawrence	6,191	Spring	1892	$79,000	Steam pumps	45	110		132,000	14¾	250,000	Analysis 1.
Bethany	Harrison	2,093	Creek	1894	30,000	Pump to standpipe				84,000	4		
Bolivar	Polk	1,869	2 springs	1894	11,267	Pump							
Bonneterre	St. Francois	4,500	Big run	1887		Direct pumping							
Booneville	Cooper	4,377	Missouri River	1883	89,500	Pump to reservoir and standpipe; gravity.	40–65	60–85	6,250,000	60,000	8	250,000	
Bowling Green	Pike	1,902	Well			Gravity							Analysis 2.
Brookfield	Linn	5,484	Open well	1890	33,500	Pump to standpipe and direct pressure.	60	100		93,000	8	40,000	Analysis 3.
Brunswick	Chariton	1,403	Grand River	1894	13,500	Pump to standpipe and direct.	70	150		29,000	1½	20,000	
Butler	Bates	3,158	Miami Creek	1891	75,000	Pump to reservoir and standpipe and direct.	40	130	2,000,000	115,000	6	30,000	
Cameron	Clinton	2,979	Pond for drainage.			Pump to standpipe							
Canton	Lewis	2,365	Artesian well			Gravity							Analysis on p. 46.
Cape Girardeau	Cape Girardeau	4,815	Mississippi River	1895		Pump to reservoir			1,200,000		7.3		
Carrollton	Carroll		Driven well	1888	30,000	Pump to standpipe and direct.	80	130		93,000	2½		Analysis 4.
Carterville.[b]													
Carthage	Jasper	9,416	Spring River	1882		Pump to standpipe and direct.	40	118		182,000	14		Analysis 5.
Caruthersville	Pemiscot	2,315	Deep well	1903	26,000	do							Analysis on p. 178.
Charleston	Mississippi	1,893	Driven well										
Chillicothe	Livingston	6,905	River and wells	1887	225,000	Pump to standpipe and direct.	65	100		126,000	13	500,000	Analysis 6.
Clarence	Shelby	1,184	Well										
Clinton	Henry	5,061	Artesian wells	1886	93,000	Pump to standpipe and direct.	75	150	2,800,000		7⅓	275,000	Analysis on p. 117.
Columbia	Boone	5,651	Ponded creek	1893		Pump direct from ponded reservoir.							
Commerce	Scott	588	Springs, wells			Windmill, tanks, and mains.							
Concordia	Lafayette	889	Well			Standpipe							
De Soto	Jefferson	5,611											
Dexter	Stoddard	1,862	Well			Windmill and direct pressure.							

Eldorado Springs	Cedar	2,137	Deep well			Pump						
Excelsior Springs	Clay	1,881	River	1892		Filter and pump to reservoir.						Analysis 7.
Farmington	St. Francois	1,778	Deep well									
Fayette	Howard	2,717	Deep well (not used.)			Pump to standpipe; system of shallow wells being developed.						
Ferguson	St. Louis	1,015	Missouri River	[c]1903								
Fulton	Callaway	4,883	Artesian wells	1889		Gravity to reservoir and direct pumping.	75	150	132,000	109,000	3.7	30,000	Analysis 8.
Gallatin	Daviess	1,780	Well			Pump to standpipe						
Glasgow	Howard	1,672	Missouri River	1895	10,000	Pump to standpipe and direct.	45	82		40,000	1	20,000	
Granby	Newton												
Grant City	Worth	1,406	Well	1896	7,500	Pump to tank	40	140		30,000	1	5,000	
Hannibal	Marion	12,780	Mississippi River	1880	172,000	Pump to reservior	25	100	17,500,000		15½		
Hermann	Gasconade	1,575											
Higbee	Randolph	1,151											
Higginsville	Lafayette	2,791	Deep well	1891	15,000	Pump to reservoir and direct.	55	125	80,000		1½	25,000	Analysis 9.
Holden	Johnson	2,126	Ponded reservoir.	1887	65,000	Pump to standpipe and direct.				75,000		50,000	
Huntsville	Randolph	1,805											
Independence	Jackson	6,974	Missouri River	1884	100,000	Pump to settling basin and thence to standpipe.	50	100	1,000,000	250,000	8½	250,000	
Jackson	Cape Girardeau	1,658	Pearl River			Standpipe and direct							
Jefferson City	Cole	9,664	Missouri River	1888	140,000	Pump to reservoir and thence to standpipe.	70	125	2,400,000	300,000	8	450,000	
Joplin	Jasper	2,623	School Creek	1880	185,000?	Pump to reservoir and direct.	30	110	3,000,000		24		Analysis 10.
Kahoka	Clark	1,818	Deep well (509)	1902 1873	3,000?	Direct pressure	40	100	75,000				Well in sandstone.
Kansas City and Westport.	Jackson	163,752	Missouri River		3,000,000?	Pump to reservoir	130	175			138.7	11,000,000	
Kirksville	Adair	5,966	Deep well (1,300 feet) and Chariton River.	1894	60,000	Pump to reservoirs and repumping direct.	40	100	145,000		4½	40,000	Analysis 11.
Kirkwood	St. Louis	2,825	Missouri River	[d]1903		Pump to standpipe							
Lamar	Barton	2,737	Creek			do							
Lebanon	Laclede	2,125	Artesian well (1,000).	1890		do				85,000			Analysis 12.
Lexington	Lafayette	4,190	Missouri River	1885	100,000?	Pump to settling tanks and thence to stand pipe.	65	120	2,000,000	350,000	7	228,000	

[a] This table has been compiled from notes obtained by the writer from Baker's Manual of American Waterworks and from Missouri Geological Survey reports.
[b] See Webb City.
[c] Incomplete.
[d] In progress.

Statistics of city waterworks in Missouri—Continued.

City.	County.	Population (1900).	Source.	Date established.	Cost.	System.	Pressure.		Reservoir capacity.	Standpipe capacity.	Length of mains.	Daily consumption.	Remarks.
							Ordinary.	Fire.					
							Pounds	*Pounds*	*Gallons.*	*Galls.*	*Miles.*	*Gallons.*	
Louisiana	Pike	5,131	Mississippi River	1888		Pump to reservoir and direct gravity.	120		2,000,000		6		
Macon	Macon	4,068	Chariton River	1891	30,000	Direct pumping from ponded reservoir.	60	125	60,000,000		3 ½		
Malden	Dunklin	1,462		a1897									
Marshall	Saline	5,086	Wells	1885	85,000	Direct pumping	65	130			5	275,000	Analysis 13.
Maryville	Nodaway	4,577	One Hundred and Two River.	1886	140,000	Pump from river to reservoir and thence to standpipe and direct gravity.	60	120	20,000,000	120,000	9 ½	287,671	
Memphis	Scotland	2,195	Well and creek		13,000	Pump to standpipe				78,000			
Meramec Highlands	St. Louis	110	Meramec River	1893		Pump to tank and direct.	30	100		16,000	1 ¾		
Mexico	Audrain	5,099	Artificial lake and deep well (1,000 feet).	1885	80,000	Pump to reservoir and direct.	50	100	50,000,000		5	400,000	Analysis on p. 73; water in sandstone at 1,000 feet.
Moberly	Randolph	8,012	Ponded creek and two deep wells (500 feet).	1885	100,000?	Pumps			250,000,000		6 ¾	410,000	Analysis 14.
Monett	Barry	3,115	Well	1892	15,000	Standpipe							Analysis 15; well supposed to intercept subterranean stream.
Montgomery City	Montgomery	2,026	Deep well			Pump to tank							
Mound City	Holt	1,681	Wells		14,000	Pump to standpipe	90			35,000	2		
Mount Vernon	Lawrence	1,206	Spring	1897	15,040	do							
Neosho	Newton	2,725	Elm Springs	1891	50,000	Gravity system	50	60			12		
Nevada	Vernon	7,461	Deep wells and Marmaton River.	1885	150,000?	Pump to reservoir and direct.	23	150	2,000,000		26	700,000	Analysis 16.
Oregon	Holt	1,032	Well		22,000	Pump to tank							Analysis 17.
Osceola	St. Clair	1,037	Osage River			Pump to tower and tank.							
Ozark	Christian	830	Spring										
Pacific	Franklin	1,213	Meramec River		b15,000				500,000				Proposed.

Palmyra	Marion	2,323	Spring	1891	50,000	Pump from reservoir and standpipe direct.	90	140	100,000	4		
Paris	Monroe	1,397	Salt River		23,000	Standpipe and direct pressure.						
Parkville	Platte	931	Missouri River									
Pierce City	Lawrence	2,151	Spring	1888	45,230	Gravity to standpipe.						
Poplar Bluff	Butler	4,321	Black River	1895	25,000	Pump to standpipe			158,000	4	60,000	
Princeton	Mercer	1,575	Well	1896	16,500	do			42,000			
Rich Hill	Bates	4,053	River	1883	130,000?	Pump from river to well and direct pumping.				10	240,000	
Richmond	Ray	3,478	Driven wells	1897	42,102	Pump to reservoir and standpipe.	60	80,000	118,000	8.4		
Rockport	Atchison	1,080	Deep well	1892	17,000	Pump to standpipe	80		39,000		10,000	
St. Charles	St. Charles	7,982	Missouri River	1881	80,000	Pump to settling tanks and thence to standpipe and direct.			250,000	7 ½		
St. Joseph	Buchanan	102,979	do	1880		Pump to reservoir	120	16,000,000		63		Analysis 18.
St. Louis	St. Louis	575,238	Mississippi River	1831	13,345,000	Reservoirs and standpipes.	5	75 65,000,000	63,000	462	55,000,000	
Sedalia	Pettis	15,231	Artesian wells	1871	578,000	Pump to standpipe and to reservoir.	56?		364,000	34	1,500,000	Analysis on p. 98.
Slater	Saline	2,502	Deep well (650 feet).		20,000							Analysis 19.
Springfield	Greene	23,267	Spring	1883	475,000	Pump to reservoir and tanks.		4,000,000	750,000	57 ½	2,500,000	Analysis 20.
Stanberry	Gentry	2,654		1893		Pump				3 ½		
Sullivan	Franklin	714	Spring			Pump to water tank			30,000			
Sweet Springs	Saline	1,080	Deep well			Tower, tank, gravity						
Tarkio	Atchison	1,901	Artesian well	1891		Pump to standpipe and direct.	70	120	42,000		50,000	Analysis 21.
Trenton	Grundy	5,396	Grand River and wells.	1886	78,200	do	60	130	317,000	7		Analysis 22.
Union	Franklin	744	Bombois River	1896	10,000	Pump to reservoir and direct.	60	100 175,000		2 ½		
Unionville	Putnam	2,050	Pond	1897	15,000	Direct pressure						
Verona	Lawrence	750	River	1894	30,000?	Pump to standpipe						
Warrensburg	Johnson	4,724	Springs	1894	150,000?	do					8,000	Analysis 23.
Washington	Franklin	3,015	Missouri River	1889	65,000	Pump to settling reservoir and thence to standpipe and direct.	70	100 125,000	105,000	4 ½	75,000	
Webb City and Carterville	Jasper	9,201 4,445	Springs	1890	150,000	Gravity to well and then pumped to standpipe.	45	75	125,000	21	500,000	Analysis 24.
Webster Grove	St. Louis	1,895	Well	1891	(c)	Pump to tank						
Westport d	Jackson			1890								
Willow Springs	Howell	1,078	Deep well		16,000	Pump to tank	20	40	67.000	3		

a Open for bids. b Estimated. c In Kansas City system. d In progress.

ANALYSES OF WATERS OF PUBLIC SUPPLIES.

ANALYSIS 1.—*Aurora city water, January 15, 1904.*[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	8.2	Residue on evaporation	100
Iron (Fe)	.86	Residue on ignition	91.8
Aluminum (Al)	.08	Free ammonia	.16
Calcium (Ca)	54	Albuminoid ammonia	.15
Magnesium (Mg)	2.5	Nitrogen as nitrates	.23
Sulphate radicle (SO_4)	26	Nitrogen as nitrites	0
Chlorine (Cl)	3.5	Oxygen consumed	3.04
		Color, very clear.	
	95.14	Odor, none.	

ANALYSIS 2.—*Bowling Green city water, January 17, 1904 (partial analysis).*

	Parts per million.		Parts per million.
Silica (SiO_2)	4	Residue on evaporation	572
Iron (Fe)	1.6	Residue on ignition	409
Aluminum (Al)	.37	Free ammonia	.08
Calcium (Ca)	114	Albuminoid ammonia	.15
Magnesium (Mg)	36	Nitrogen as nitrates	12
Sulphate radicle (SO_4)	48	Nitrogen as nitrites	Trace.
Chlorine (Cl)	49	Oxygen consumed	2
		Color, clear.	
	252.97	Odor, none.	

ANALYSIS 3.—*Brookfield city water (open well), March 12, 1904.*[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	17	Residue on evaporation	417
Iron (Fe)	1.9	Residue on ignition	396
Aluminum (Al)	.15	Free ammonia	.12
Calcium (Ca)	6.8	Albuminoid ammonia	.22
Magnesium (Mg)	14	Nitrogen as nitrates	.5
Sulphate radicle (SO_4)	59	Nitrogen as nitrites	.018
Chlorine (Cl)	17	Oxygen consumed	3.2
		Color, none.	
	115.85	Odor, none.	

ANALYSIS 4.—*Carrollton city water, April 7, 1904.*[a]

	Parts per million.		Parts per million.
Total residue after evaporation	450	Nitrogen as nitrates	0.35
Oxygen consumed	7.95	Nitrogen as nitrites	.05
Free ammonia	.24	Color, slightly amber.	
Albuminoid ammonia	.18	Odor, none.	

ANALYSIS 5.—*Carthage city water, March 7, 1904.*[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	16	Residue on evaporation	178
Iron (Fe)	2.4	Residue on ignition	166
Aluminum (Al)	.1	Free ammonia	.05
Calcium (Ca)	50	Albuminoid ammonia	.17
Magnesium (Mg)	4.2	Nitrogen as nitrates	.63
Sulphate radicle (SO_4)	25	Nitrogen as nitrites	.007
Chlorine (Cl)	4.2	Oxygen consumed	2.9
	101.9		

[a] Bull. Missouri State Board of Health, vol. 1, No. 4, 1904. Recomputed to ionic form at United States Geological Survey.

ANALYSIS 6.—*Chillicothe city water, February 6, 1904.*[a]

	Parts per million.
Silica (SiO_2)	20
Iron (Fe)	6.1
Alumina (Al)	.14
Calcium (Ca)	3.6
Magnesium (Mg)	6.8
Sulphate radicle (SO_4)	26
Chlorine (Cl)	5
	67.64

	Parts per million.
Residue on evaporation	183
Residue on ignition	166
Free ammonia	.24
Albuminoid ammonia	.33
Nitrogen as nitrates	.26
Nitrogen as nitrites	.055
Oxygen consumed	7
Color, slightly turbid.	
Odor, none.	

ANALYSIS 7.—*Excelsior Springs city water (river).*[b]

	Parts per million.
Silica (SiO_2)	22
Iron and alumina oxides (Fe_2O_3+ Al_2O_3)	3.5
Calcium (Ca)	85
Magnesium (Mg)	7.7
Sodium (Na)[c]	6.8
Carbonate radicle (CO_3)	115
Sulphate radicle (SO_4)	50
Chlorine (Cl)	11
	301

	Parts per million.
Free ammonia	.02
Albuminoid ammonia	.07
Nitrogen as nitrates	Trace.
Nitrogen as nitrites	Trace.
Chlorine as chlorides	53.05
Oxygen consumed	3.1
Color, somewhat turbid.	
Odor, none.	

This river water is filtered through a layer of coke 5 feet thick, then through 28 inches of sharp sand and 12 inches of fine gravel, after which it gathers in a large well, whence it is pumped to the reservoir.

ANALYSIS 8.—*Fulton city water.*[a]

	Parts per million.
Residue on evaporation	520
Residue on ignition	435
Free ammonia	.01
Albuminoid ammonia	.03
Nitrogen as nitrates	0
Nitrogen as nitrites	.96

	Parts per million.
Chlorine	11
Hardness	386
Color, clear.	
Odor, none.	
Reaction, alkaline.	

ANALYSIS 9.—*Higginsville city water, January 28, 1904.*[a]

	Parts per million.
Silica (SiO_2)	18
Iron (Fe)	2
Alumina (Al)	.15
Calcium (Ca)	51
Magnesium (Mg)	8
Sulphate radicle (SO_4)	27
Chlorine (Cl)	23
	129.15

	Parts per million.
Residue on evaporation	362
Residue on ignition	338
Free ammonia	.03
Albuminoid ammonia	.2
Nitrogen as nitrates	Trace.
Nitrogen as nitrites	.004
Oxygen consumed	2
Color, clear.	
Odor, none.	

[a] Bull. Missouri State Board of Health, vol. 1, No. 4, 1904; recomputed to ionic form at United States Geological Survey.

[b] Expressed by analyst in grains per gallon and hypothetical combinations; recomputed to ionic form and parts per million at United States Geological Survey.

[c] Sodium and potassium calculated as sodium.

ANALYSIS 10.—*Joplin city water.*

	Parts per million.		Parts per million.
Residue on evaporation	148	Iron	.02
Free ammonia	.005	Alkalinity	96
Albuminoid ammonia	.062	Permanent hardness	11
Nitrates	2.65	Free CO_2	1
Nitrites	.001	Bacteria per cubic centimeter, 5.	
Oxygen consumed	2	Bacillus coli communi, none.	
Chlorine	3.9		

ANALYSIS 11.—*Kirksville city water, April 4, 1904.* [a]

	Parts per million.		Parts per million.
Silica (SiO_2)	11	Residue on evaporation	188
Iron (Fe)	2.6	Residue on ignition	171
Alumina (Al)	.06	Free ammonia	.12
Calcium (Ca)	34	Albuminoid ammonia	.50
Magnesium (Mg)	8.1	Nitrogen as nitrates	.31
Sulphate radicle (SO_4)	35	Nitrogen as nitrites	0
Chlorine (Cl)	4.3	Oxygen consumed	7.6
	95.08	Color, clear.	
		Odor, none.	

ANALYSIS 12.—*Lebanon city water (artesian well, 1,000 feet).* [b]

	Parts per million.		Parts per million.
Silica (SiO_2)	11	Sulphate radicle (SO_4)	4.8
Iron (Fe)	Trace.	Chlorine (Cl)	Trace.
Aluminum (Al)	1.7	H, bicarbonate	3.4
Calcium (Ca)	33		285.9
Magnesium (Mg)	16	Free CO_2	70
Sodium (Na)	13		
Carbonate radicle (CO_3)	203		

A very fine water.

ANALYSIS 13.—*Marshall city water, January 27, 1904.* [c]

	Parts per million.		Parts per million.
Silica (SiO_2)	11	Residue on evaporation	1,202
Iron (Fe)	3.3	Residue on ignition	1,119
Aluminum (Al)	.9	Free ammonia	.342
Calcium (Ca)	156	Albuminoid ammonia	.13
Magnesium (Mg)	24	Nitrogen as nitrates	Trace.
Sulphate radicle (SO_4)	191	Nitrogen as nitrites	Trace.
Chlorine (Cl)	464	Oxygen consumed	1.95
	850.2	Color, very clear.	
		Odor, none.	

[a] Bull. Missouri State Board of Health, vol. 1, No. 4, 1904.

[b] Analysis by L. G. Eakins. Bull. U. S. Geol. Survey No. 60, p. 172.

[c] Analysis by Missouri State board of health. Recomputed to ionic form at United States Geological Survey.

ANALYSIS 14.—*Moberly city water (reservoir).* [a]

	Parts per million.	
Silica (SiO_2)	32	Odorless, tasteless.
Iron (Fe)	15	Slightly turbid, and of yellowish tint.
Calcium (Ca)	15	
Undetermined	21	
	83	

It contains the merest trace of chlorine and ammonia; no nitric acid; no albuminoid ammonia. The only life that could be determined was represented by specimens of cyclops and vesabia, appearing to the naked eye as moving specks.

ANALYSIS 15.—*Monett city water, March 2, 1904.* [b]

	Parts per million.		Parts per million.
Silica (SiO_2)	11	Residue on evaporation	237
Iron (Fe)	1.3	Residue on ignition	212
Aluminum (Al)	.05	Color, clear.	
Calcium (Ca)	.64	Odor, none.	
Magnesium (Mg)	7.5		
Sulphate radicle (SO_4)	50		
Chlorine (Cl)	8.2		
	142.05		

ANALYSIS 16.—*Nevada city water, April 4, 1904.* [c]

	Parts per million.		Parts per million.
Silica (SiO_2)	10	Residue on evaporation	1,319
Iron (Fe)	1.7	Residue on ignition	1.297
Aluminum (Al)	.1	Color, very clear.	
Calcium (Ca)	86	Odor, none.	
Magnesium (Mg)	39		
Sulphate radicle (SO_4)	86		
Chlorine (Cl)	576		
	798.8		

ANALYSIS 17.—*Oregon city water, May 25, 1899.* [c]

	Parts per million.		Parts per million.
Silica (SiO_2)	8.6	Carbonate radicle (CO_3)	235
Iron and alumina oxides (Fe_2O_3+ Al_2O_3)	16	Sulphate radicle (SO_4)	14
Calcium (Ca)	90	Chlorine (Cl)	16
Magnesium (Mg)	40		436.6
Sodium (Na)[d]	17		

[a] Analysis by Paul Schweitzer. Expressed by analyst in grains per gallon; recomputed to ionic form and parts per million at United States Geological Survey.

[b] Bull. Missouri State Board of Health, vol. 1, No. 4, 1904. Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

[c] Expressed by analyst in hypothetical combinations; recomputed to ionic form at United States Geological Survey.

[d] Sodium and potassium calculated as sodium.

ANALYSIS 18. *St. Joseph city water.*

	Parts per million.		Parts per million.
Albuminoid ammonia	0.55	Total solids	5970
Free ammonia	.04	Iron	5.1
Nitrogen as nitrates	.35	Alkalinity	104
Nitrogen as nitrites	0	Permanent hardness	60
Chlorine	11	Sulphuric acid	0
Oxygen consumed	25	Carbonic acid	8

Appearance, muddy; odor, none; color, 250 F. F. M.

ANALYSIS 19. *Slater city water, January 29, 1904.*[a]

	Parts per million.[a]		Parts per million.[a]
Silica (SiO_2)	5 2	Residue on evaporation	726
Iron (Fe)	1.7	Residue on ignition	598
Aluminum (Al)	.05		
Calcium (Ca)	83		
Magnesium (Mg)	29		
Sulphate radicle (SO_4)	67		
Chlorine (Cl)	166		
	351.95		

Color, very clear; odor, none.

ANALYSIS 20. *Springfield city water, May, 1905.*[b]

	Parts per million.		Parts per million.
Silica (SiO_2)	9.4	Oxygen consumed	0.072
Iron (Fe)	1.4	Free ammonia	.1
Aluminum (Al)	.1	Albuminoid ammonia	.124
Calcium (Ca)	57	Nitrogen as nitrates	Trace.
Magnesium (Mg)	4.2	Nitrogen as nitrites	0
Sodium (Na)	2.6	Temporary hardness	165.7
Potassium (K)	Trace.	Permanent hardness	13.6
Bicarbonate radicle (HCO_3)	191	Total hardness	179.3
Sulphate radicle (SO_4)	5.8	Total dissolved solids	214.411
Chlorine (Cl)	3.9		
	275.4		

Color, very clear; odor, none.

ANALYSIS 21. *Tarkio city water.*[c]

DEEP WELL.

	Parts per million.		Parts per million.
Chlorine	111	Temporary hardness	259
Free ammonia	8	Permanent hardness	367
Albuminoid ammonia	10	Total solids	1,442
Total hardness	626		

[a] Bull. Missouri State Board of Health, vol. 1, No. 4, 1904. Recomputed to ionic form at United States Geological Survey.

[b] Bull. Bradley Geol. Field Station, No. 11, Drury College. Chemical analysis by Miss Kate Lyman; sanitary analysis by Miss Etta Little. Recomputed to ionic form at United States Geological Survey.

[c] Analyses by Prof. J. C. Adair, of Tarkio College. See p. 191 for comments on the large amounts of albuminoid ammonia.

SURFACE WELL.

	Parts per million.		Parts per million.
Chlorine	1.6	Temporary hardness	142
Albuminoid ammonia	.06	Permanent hardness	40
Total hardness	182		

ANALYSIS 22. *Trenton city water, February 27, 1904.*[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	5.5	Residue on evaporation	202
Iron (Fe)	8.6	Residue on ignition	175
Aluminum (Al)	1.4	Oxygen consumed	10.3
Calcium (Ca)	22	Free ammonia	.8
Magnesium (Mg)	5.3	Albuminoid ammonia	.6
Sulphate radicle (SO_4)	33	Nitrogen as nitrates	.32
Chlorine (Cl)	3.1	Nitrogen as nitrites	.0714
	78.9		

Odor, none.

ANALYSIS 23. *Warrensburg city water, February 6, 1904.*[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	8.8	Residue on evaporation	168
Iron (Fe)	2.3	Oxygen consumed	3.4
Aluminum (Al)	.5	Free ammonia	.8
Calcium (Ca)	36	Albuminoid ammonia	.3
Magnesium (Mg)	8.5	Nitrogen as nitrates	.237
Sulphate radicle (SO_4)	35	Nitrogen as nitrites	0
Chlorine (Cl)	6.1		
	97.2		

Color, clear; odor, none.

ANALYSIS 24. *Webb city and Carterville city water, February 26, 1904.*[a]

	Parts per million.		Parts per million.
Silica (SiO_2)	76	Residue on evaporation	412
Iron (Fe)	2	Residue on ignition	381
Aluminum (Al)	.4	Oxygen consumed	1.15
Calcium (Ca)	95	Free ammonia	.096
Magnesium (Mg)	7.3	Albuminoid ammonia	.22
Sulphate radicle (SO_4)	202	Nitrogen as nitrates	1.56
Chlorine (Cl)	4.8	Nitrogen as nitrites	0
	387.5		

Color, clear; odor, none.

MINERAL WELLS.

The water of many wells is so highly charged with mineral salts as to be objectionable for general use, though in some of them it is extremely valuable from a medicinal standpoint. The wells at Excelsior Springs, Canton, Lagrange, St. Louis, and in other parts of the

[a] Bull. Missouri State Board of Health, vol. 1, No. 4, 1904. Recomputed to ionic form at United States Geological Survey.

State belong to this class. In regard to their value as therapeutic agents, Dr. Crook[a] makes the following statement:

> There exists among medical practitioners in the United States a wide-spread skepticism regarding the medicinal value of mineral waters. This incredulity is, no doubt, based to a considerable extent upon a somewhat justifiable prejudice; but may it not be due, in a much greater degree, to a want of correct information? We are all acquainted with the mineral springs advertising circular. * * * When the intelligent practitioner reads that a certain water is positively curative in an imposing list of diseases set forth in divers pages of testimonials from renovated statesmen, restored clergymen, and rejuvenated old ladies, and then learns from the analysis that it contains 2 or 3 grains of lime salts to the gallon, with the remaining ingredients requiring perhaps a third or fourth decimal figure to express, he can hardly be blamed for tossing the circular into his waste-basket, with an objurgation upon quacks generally, and mineral-springs quacks in particular. Yet the conservative physician will find a safe and dignified position between that of the pretentious advertisement which claims everything and that of the medical skeptic who will believe nothing.

There is no doubt that much benefit is derived from most of the health resorts connected with mineral springs or wells; and while a great deal of it is undoubtedly psychic, some is unquestionably due to the use of the waters. People who are broken down from overwork or who are troubled with many incipient diseases find at these resorts rest, which they perhaps can not get elsewhere; a change of air; a new environment; possibly a change in climate or altitude; pleasant associations; distractions from trouble; and they use, both internally and externally, perhaps a much larger amount of water than has been their custom at home; these, together with faith in the curative qualities of the water (since every wise physician recognizes faith as a helpful element in cure), form a stimulus to nature in the restoration of normal action to the functions of the body.

The following constituents are more or less common in the evaporated residue of the waters of mineral wells and springs in Missouri. They are derived from the action of percolating waters in dissolving out many of the varied substances of the rocks through which they pass:

Silica.
Alumina.
Ferrous bicarbonate.
Ferrous sulphate.
Manganous bicarbonate.
Calcium bicarbonate.
Calcium sulphate.
Calcium sulphydrate.
Calcium chloride.
Calcium phosphate.
Magnesium bicarbonate.
Magnesium sulphate.
Magnesium chloride.
Potassium bicarbonate.
Potassium sulphate.
Potassium chloride.
Potassium bromide.
Sodium carbonate.
Sodium chloride.
Sodium sulphate.
Lithium chloride.
Oxygen.
Carbon dioxide.
Hydrogen sulphide.

[a] Mineral Waters of the United States, 1899, p. 34.

The therapeutic action of the individual elements is discussed by Hessler.[a]

Sodium chloride, or common salt, is found in all mineral waters in amounts varying from a mere trace up to several thousand grains per gallon. It is present in almost every tissue of the body, and a certain amount is required to keep the organs in a healthy condition. It "regulates absorption, nutrition, and secretion." Internally, "it may produce an increase of the gastric juice, bile, pancreatic juice, and intestinal fluids, promoting the appetite and assisting digestion."[b] It has a slight aperient effect on the bowels and probably tends to prevent intestinal decomposition. Its presence in water, in a nonsaline subsoil, is ordinarily an indication of sewage contamination as the only source from which it could be derived, since practically all of the salt taken into the animal body is passed out through the secretions.

Sodium sulphate, or Glauber salts, is a common and frequently abundant constituent, derived from the Pennsylvanian rocks and the Hannibal shales in Missouri. It is unessential in the healthy body. Hessler says:[c]

> Small doses stimulate the intestinal and urinary secretions, larger doses are laxative, and still larger doses are cathartic. * * * This salt is useful in some disordered conditions of the digestive tract—gastric, hepatic, and intestinal. * * * In certain dropsical conditions, as that dependent on some forms of heart disease, it may give relief by helping to abstract the accumulated fluid. * * * In a number of diseases the use of water containing much of this salt must be avoided.

Sodium sulphate occurs in considerable quantities in the B. B. mineral spring, the Lineville well, and the Allen well, at Versailles.

Sodium carbonate is found in the human body in the blood and saliva, both of which are alkaline in character. When taken into the system, these alkaline salts neutralize the free acids, and they are considered valuable in some cases of acid dyspepsia and the treatment of gallstones. According to Hessler[d]—

> The bicarbonate is usually prescribed. It is useful in certain affections marked by acid conditions, among which may be mentioned some of the fevers, rheumatism, gout, and irritable bladder, particularly if this irritation be due to the acidity of the urine, the latter becoming alkaline under its use. In uric-acid conditions the potassium bicarbonate is to be preferred.

The presence of sodium carbonate in water may sometimes aggravate certain diseases. The excessive use of soda will almost invariably derange the digestive system.

Potassium sulphate is a rare constituent of the mineral waters of Missouri. It somewhat resembles, in its action, sodium and magnesium sulphate.

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[a] Hessler, Robert, The medicinal properties and uses of Indiana mineral waters: Twenty-sixth and twenty-seventh Ann. Repts. Indiana Dept. Geology and Nat. Res., 1903, pp. 159, et seq.

[b] Hessler, Robert, op. cit., p. 167.

[c] Op. cit., pp. 167–168.

[d] Op. cit., p. 168.

Calcium carbonate is the most common of all the mineral constituents of waters of the State, being derived from the solution of the limestone in which it is found. It is "chiefly antacid and diuretic."

Calcium sulphate is a very common constituent of hard waters. It is usually present in small amounts, as it is not readily soluble. It has no especial action on the system.

Magnesium sulphate (Epsom salts) is characteristic of the waters from the Pennsylvanian rocks and the Hannibal shale. It is milder in its action and more agreeable to the taste than sodium sulphate or Glauber salts, and has a similar effect on the human system.

Magnesium carbonate is usually found in small quantities in the waters of the magnesium limestones (dolomites) that are so common through the central and southeastern parts of the State. It is an antacid.

Iron, usually the bicarbonate, is almost always present in water, either in minute traces or in small appreciable amounts. In the latter case it forms the important constituent of chalybeate springs and wells. The importance of iron as a tonic need not here be emphasized. "In many affections, notably in alterations of the blood, iron waters may be of decided benefit."[a]

Iron sulphate is sometimes found in the waters derived from the shales of the Pennsylvanian series. It is less palatable and more astringent than the bicarbonate, and when in excess is an objectionable constituent.

Aluminum sulphate is found but rarely, and in water derived from the Pennsylvanian shales. The water from the Versailles alum well, in Morgan County, contains 1,275 parts per million. It also occurs in one of the springs of the Graydon group, in Polk County. Alum is a very strong astringent, but has no other definite therapeutic character.

Carbonic acid gas is frequently found in mineral waters in small amounts. It has a soothing effect on the mucous membrane of the stomach and tends to allay nausea.

Hydrogen sulphide is a gas having the odor of rotten eggs and is a common constituent of the so-called sulphur waters. It is doubtful if this gas, especially when the amount usually ingested with the water is considered, has any influence on the body or is of any marked benefit in diseased conditions. Used externally, it may have some influence in certain skin diseases.

Warm sulphur baths may be useful in chronic lead poisoning, as that of painters. Many of the famous sulphur waters are hot or thermal springs, and their virtues, aside from that of their accompanying constituents, are often due to the manner in which they are used.[b]

[a] Hessler, Robert, op. cit., p. 171.

[b] Op. cit., p. 172.

BLOWING WELLS.

There is a blowing well in Camden County, near Decaturville, and one of greater interest on the farm of J. B. Murphy, near Raymondville, Texas County. This well, which is on a hill, was drilled in 1899 to a depth of 187 feet. Soft water was struck at the bottom and rose 7 feet in the well. In a dry time, especially in the winter, the well becomes dry. In drilling it, a cave 3 feet high was struck at a depth of 100 feet. When the well is dry, if there is a long prevailing wind from the north, a current of air rushes from the pipe strong enough to blow the cap from the tubing. This fact illustrates the honeycombed and cavernous nature of the rocks in this region. About 10 miles to the north, in the valley of Ashley Creek, is what Schoolcraft described in the account of his trip through this region in 1818 as "the valley of caves." Here in the eroded bluffs may be seen numerous caves which testify to the great amount of underground drainage, and through which probably the prevailing winds are sucked underground and carried for long distances.

The traveler passing south from the crest of the Ozark plateau, crosses a belt throughout which sink holes prevail, a fact noticed by Schoolcraft, who refers to the locality as "the prairie of little lakes." The large amount of water that soaks into the catchment basin of the Ozark dome quickly begins its work of solution by forming underground cavernous waterways, manifested at the surface in numerous places by sink holes, many of which form ponds. The gradual evolution of valleys by the cutting out of strata and the merging of these sink holes into continuous gorges can not be fully discussed here, but it is a most interesting phase of underground drainage. In some cases a section of the barrier between two sink holes resists erosion and an arch is left which forms a natural bridge. A beautiful illustration of this kind of erosion is found on Sinking Creek, Shannon County, where the large stream runs through a tortuous gorge formed by the undermining and washing out of a chain of sink holes. In one part of its course it meets a barrier of which only the lower portion is removed, and thus is formed the unusual natural feature of a stream running under a mountain and continuing its course through an eroded gorge on the other side. The channel of this stream is 40 feet deep, and one may easily ride in a boat through its course under the mountain. The accompanying illustration (Pl. VI, *B*, p. 80) shows this underground channel.

Where normal valleys cut at right angles across the line of drainage, as in "the valley of caves," there may be had a glimpse of a cross section showing the vast amount of underdrainage along the south slopes of the Ozarks. Farther south, in Shannon and adjoining counties, are

some of the outlets of this deeper system of underground drainage, manifested in springs which are probably the largest in the world. The enormous deeper seated drainage passes underneath the embayment area and helps to form the artesian basin.

The numerous cases of cold-air drafts from caves, springs, and drill wells are easily explained when the geologic structure of the region is studied.

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CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 195.]

The publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

Most of the above publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.

2. A certain number are delivered to Senators and Representatives in Congress for distribution.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at prices slightly above cost.

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The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the one hundred and sixteenth in Series B and the sixty-ninth in Series O, the complete lists of which follow: (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper).

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