

WATER RESOURCES REPORT 26

GROUNDWATER RESOURCES OF SALINE COUNTY, MISSOURI BY JOHN C. MILLER



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OF
SALINE COUNTY, MISSOURI

By John C. Miller



Mineralized spring about 40 feet in diameter on the south side of Finney Creek (south Blue Lick group). Despite its large diameter the spring flows very slowly. Photo by Jerry D. Vineyard.

1971

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES
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AD MEMORIAM

In recognition of the pioneering and accurate geologic field investigations conducted by FIELDING BRADFORD MEEK as a geologist for the State of Missouri during the middle 1800's this report is dedicated with respect.

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ABSTRACT

Saline County straddles the transition of the fresh ground water of the Ozarks to the saline ground water of northwest Missouri.

Paleozoic sedimentary rocks in Saline County have been deformed by a series of northwest-trending anticlines and normal faults. Deformation began before Kinderhook (lowermost Mississippian) time and climaxed with the development of normal faulting parallel to the anticlines in late Mississippian or early Pennsylvanian time. These structures are partially concealed by glacial drift.

Field and laboratory investigations were directed primarily to a study of the Paleozoic rocks but groundwater occurrences in the Pleistocene and Holocene sands and gravels are also noted. The nature of sulfo-saline and saline springs and wells in Saline County was studied in some detail.

Nine water quality areas have been outlined on a water quality map of Saline County and recommendations for obtaining potable water supplies have been made where possible. High fluoride concentrations may cause "mottling" of children's teeth in certain areas.

Variations in groundwater quality are correlated with thickness of Pennsylvanian shales overlying the Paleozoic carbonate rocks, depth of wells, local geologic structure, and biochemical activity. The presence of hydrogen sulfide in the water is attributed to the activities of the sulfate-reducing bacteria, Desulfovibrio sp.

Because the chemistry of the saline water is largely controlled by the mineralogical environment it is not possible to use chemical ratios of the various ions to determine the origin of the salinity of the ground water. The saline ground water in Saline County may be best described as a connate water which probably had its origin either by entrapment of seawater by marine sediments or by shale membrane filtration of more dilute waters.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

The purpose of this investigation was to determine the geographic and stratigraphic distribution of sulfo-saline ground water in Saline County, Missouri, and to discover its origin. It was hoped that such a study might contribute to the discovery of additional potable water supplies from groundwater resources in this area. This investigation represents the hydro-geologic portion of a more complete study of the geochemistry and origin of sulfo-saline ground water in Saline County (Carpenter and Miller, 1969).

The occurrence of sulfo-saline ground water in Saline County has been known for a long time but its actual presence seemed to be rather haphazard. The waters often contain offensive amounts of hydrogen sulfide gas and range in salinity from 100 parts per million to 37,000 parts per million total dissolved solids content. The results of this report indicate that the distribution of this sulfo-saline ground water has a definite pattern controlled by geologic processes and structure.

PREVIOUS WORK

Meek (1873) conducted the first geological reconnaissance of Saline County in 1855. Woodward (1890) and Schweitzer (1892) studied the sulfo-saline springs of Saline County. The geology of the northeastern part of the county was mapped in detail by Ellis (1948). Heim and Howe (1962) and

Bretz (1965) reported the occurrence of a buried glacial valley approximately coincident with the present Salt Fork valley. Fuller (1962) and Knight (1962) have studied the general aspects of groundwater quality in Missouri.

METHOD OF STUDY

The geology of Saline County was mapped on 7½- and 15-minute quadrangle maps during the summer and fall of 1966. From September 1965 to May 1967, water samples were collected at various saline and sulfo-saline springs and wells, and analyzed. Well-

log data and water-quality data were obtained from the files of the Missouri Geological Survey and Water Resources. These data were used to prepare detailed water quality maps of Saline County and to outline areas that appear to have potable groundwater supplies.

WELL-NUMBERING SYSTEM

The U.S. Geological Survey well-numbering system has been used in this report. Wells and springs are designated by symbols that indicate their locations according to the General Land Office survey system (fig. 1). For example, well 51-22-25cbl, the first two numbers indicate the township and range,

respectively. The third number indicates the section, the letters denote the quarter-quarter section, and the final number is the serial number of the well or spring in that particular quarter-quarter section. Thus, well 51-22-25cbl is the first well listed in the NW¼ SW¼ sec. 25, T. 51 N., R. 22 W.

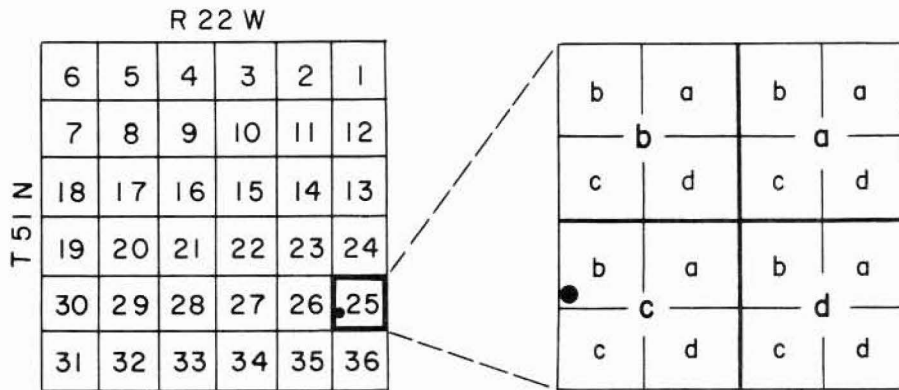


Figure 1. Location of well 51-22-25cbl according to well-numbering system used in this report.

ACKNOWLEDGMENTS

This report was prepared from a Masters thesis entitled, "Geology and Groundwater Resources of Saline County, Missouri" (Miller, 1967). The investigation was undertaken at the suggestion and under the guidance of Dr. Alden B. Carpenter. Staff members and students of the Department of Geology, University of Missouri-Columbia, provided ideas and encouragement. The chemical analyses of the waters were conducted by Dr. Edward E. Pickett, Dr. S.R. Koirtyohann, and Mrs. Jean McKinnon of the Spectrographic Laboratory, University of Missouri. Special acknowledgment is given Dale L. Fuller, geologist and chief of the Groundwater Section, Missouri Geological Survey and Water Resources, for constant guidance and encouragement throughout the study. The author would like to acknowledge the following personnel for their revision and reading of the manuscript: Dr. Wallace B. Howe, Assistant State Geologist; Jerry D. Vineyard, chief of the Publications and Information Section; Don Miller, groundwater geologist of the Missouri Geological Survey; and Edward J. Harvey, U.S. Geological Survey in Rolla.

Appreciation is extended to all citizens of Saline County who contributed water samples and otherwise assisted in this study.

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GEOGRAPHY

LOCATION AND CULTURE

Saline County covers approximately 750 square miles in central Missouri. Figure 2 shows Saline County and its relation to the occurrence of salt water and fresh water in the state. The population of Saline County (1960) was 25,148. The three large cities (1960 data) are Marshall (pop. 9,572), Slater (pop.

2,767), and Sweet Springs (pop. 1,472). The economy of Saline County is based primarily on agriculture. It is one of the more important beef-producing areas in Missouri. The quarrying of limestone for agricultural and road surfacing purposes is the county's most important mineral producing activity.

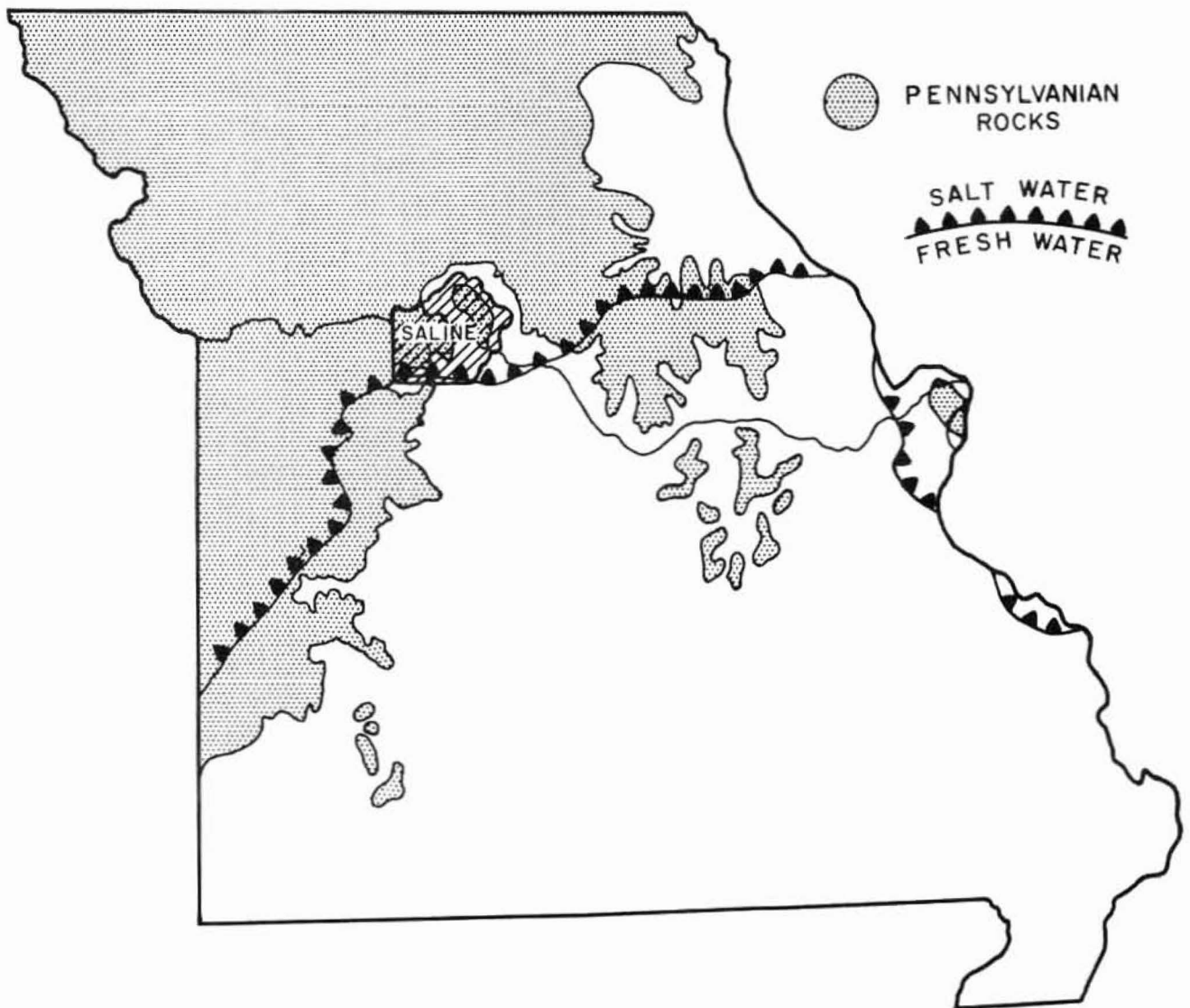


Figure 2. Map of Missouri showing Saline County in relation to the salt water-fresh water boundary and Pennsylvanian cover.

CLIMATE

Climatological data are available from two stations in Saline County – the Marshall station has been maintained since 1887 and the Sweet Springs station since 1941. The mean annual temperature at Marshall (elev. 780 feet) is 55.6 degrees F., and that at Sweet

Springs (elev. 680 feet) is 55.2 degrees F. The mean annual precipitation at Marshall is 37.37 inches with June the month of maximum precipitation. Essentially the same precipitation pattern prevails at Sweet Springs and here the mean annual precipitation is 38.66 inches.

GEOLOGY

GEOLOGIC SETTING

The geologic section in Saline County consists of approximately 1,800 feet of essentially flat-lying Paleozoic sediments resting on Precambrian basement. The sedimentary rocks may be divided into three fairly distinct lithologic groups. The Cambro-Ordovician rocks are primarily dolomite and sandstone with lesser amounts of cherty dolomite, glauconitic dolomite, and green shale. These rocks, except for a small outcrop of the St. Peter and Kimmswick formations, are not exposed in Saline County but have been logged in holes drilled for water or petroleum. The Devonian and Mississippian rocks consist largely

of limestone and cherty limestone, with minor amounts of dolomite and shale. The Pennsylvanian rocks consist primarily of thin-bedded shales and limestones, micaceous sandstones, and thin coal seams. Pleistocene sediments are represented in Saline County by Nebraskan and Kansan glacial sands, gravels, and till, as well as by loess of Illinoian age. The lithologies, thicknesses, and water-yielding characteristics of the sedimentary rocks in Saline County are summarized in table 1. Figure 3 is a geologic map of Saline County, and figure 4 shows geologic cross sections keyed to figure 3.

STRUCTURAL GEOLOGY

Rock strata in Saline County are nearly horizontal but there is a regional dip of approximately 20 ft./mile to the northwest away from the Ozark uplift. This regional dip is modified by a series of

northwest-trending anticlines and normal faults. The structures reported and named here are part of a broad structure referred to by Searight and Searight (1961) as the "Saline County arch."

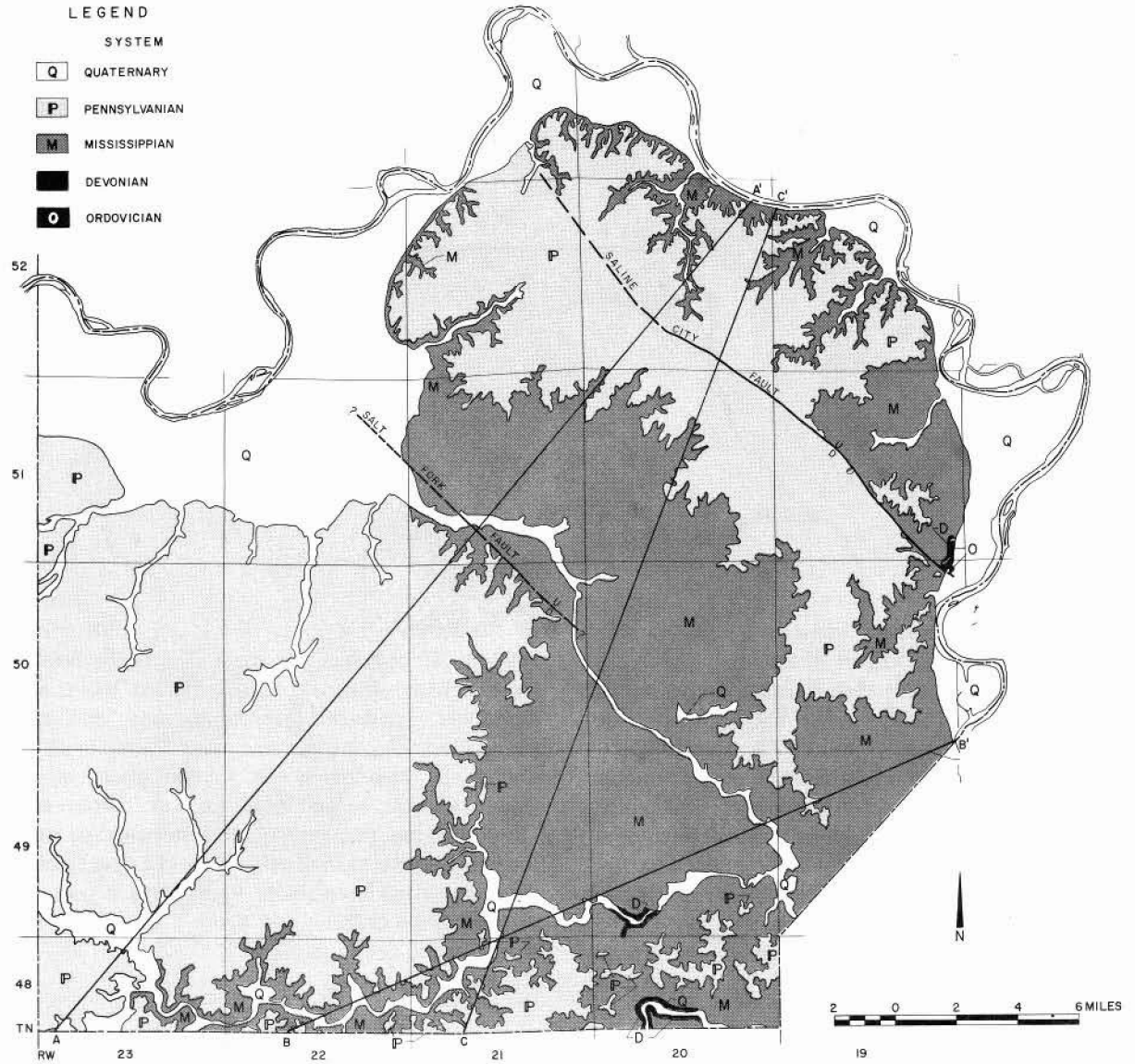


Figure 3. Generalized geologic map of Saline County (after Miller, John C., 1967).

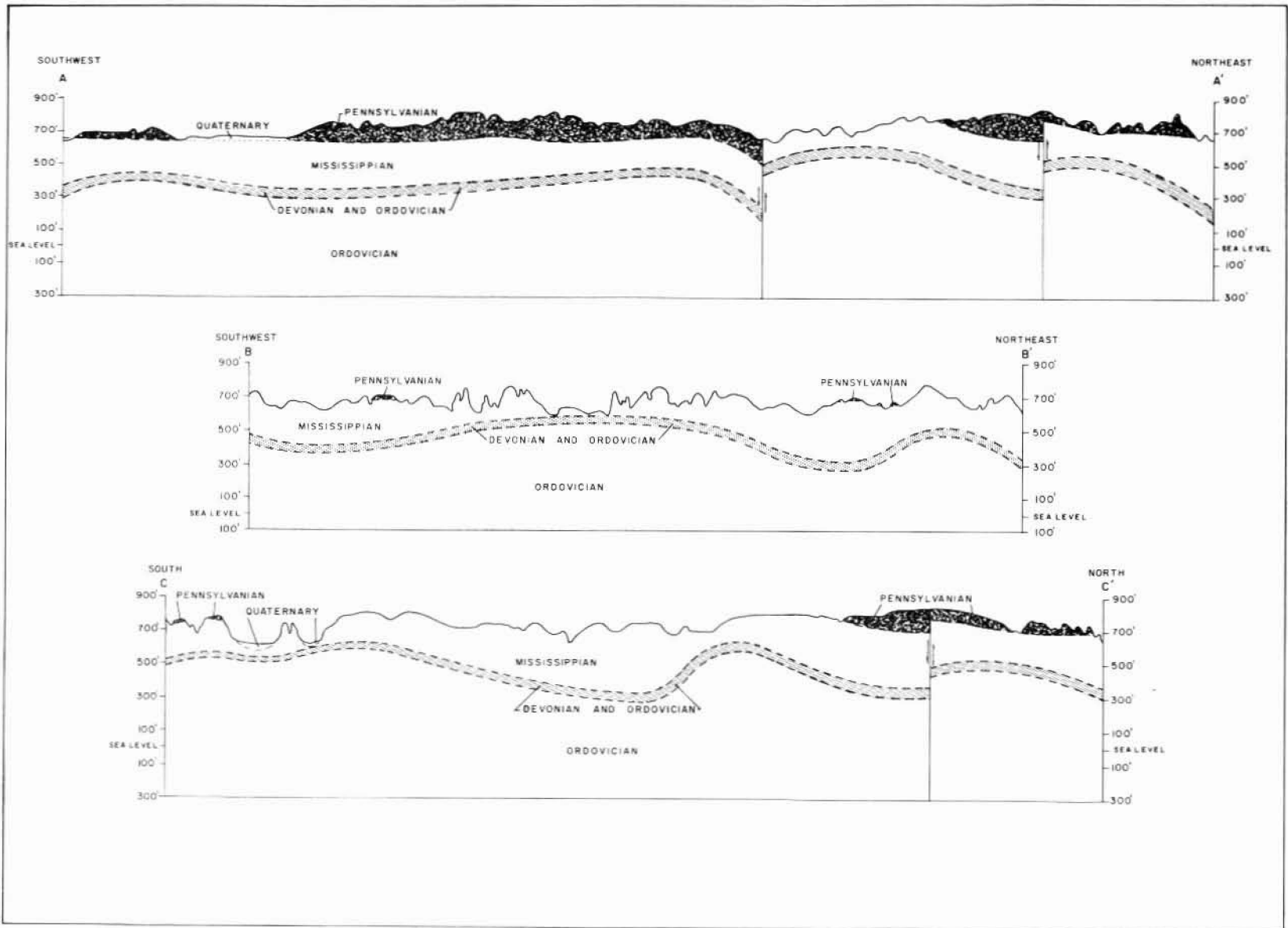


Figure 4. Generalized geologic cross sections of Saline County. See fig. 3 for lines of section.

Table 1. Stratigraphic Summary

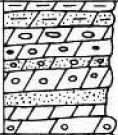
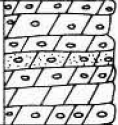
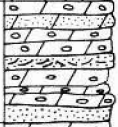
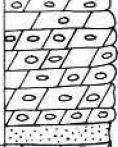
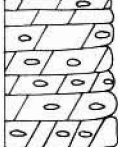
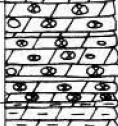


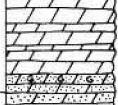
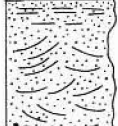

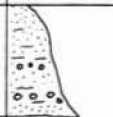



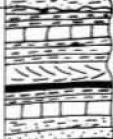
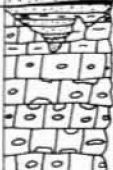


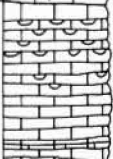

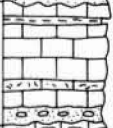
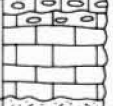

SYSTEM	SERIES	FORMATION	SECTION	THICK-NESS	LITHOLOGY	WATER - YIELDING CHARACTERISTICS	
ORDOVICIAN	CANADIAN	Cotter		70-160' (well data)	Medium to thin bedded, light gray to light brown, medium- to fine-crystalline, cherty dolomite. Thin intercalated beds of green shale and sandstone. A 15- to 20-foot thick sandstone ("Swan Creek") locally present.	1-35 GPM. Can expect 15 GPM. Greater yield if thick sandstones are present.	
		Jefferson City		130 to 190' (well data)	Thick to thin bedded, medium to fine crystalline, light brown dolomite and argillaceous dolomite. Sandstones, conglomerates, and shales are locally present. Oolitic chert.	10-75 GPM. Normally can expect 20 GPM. Yield due to solution cavities and jointing.	
		Roubidoux		80-130' 4 wells	Quartzose sandstone, dolomitic sandstone, and thin to thick bedded cherty dolomite. Sandstone composed of fine- to medium-grained quartz sand that is subrounded and frosted.	25-75 GPM. Moderately permeable. Generally saline.	
		Gasconade (includes Gunter)		245 to 300' 4 wells	Light brownish-gray, cherty dolomite. Lower dolomite is coarsely crystalline with abundant oolitic chert. Fine crystalline dolomite in upper part. 20-40' medium-grained quartzose sandstone, the Gunter, is at base.	Cumulative yields to open hole 40-500 GPM to south and east of Saline Co. Saline waters.	
CAMBRIAN	UPPER	Eminence		300 to 320' 2 wells	Medium to massive bedded, light gray, medium- to coarse-grained dolomite. Small oolitic chert nodules in upper part. Quartz druse.	No direct data.	
		Potosi		110 to 140' 2 wells	Massive, thick bedded, medium- to fine-grained dolomite. Abundance of quartz druse and associated chert.	Well # 51-22-24 cb1 bottomed in Potosi; 700 GPM. Saline.	
		ELVINS GROUP	Derby-Daerun		40-95' 2 wells	Thin- to medium-bedded, fine-grained argillaceous and silty, light brown dolomite with thin-bedded sandstones and shales. Chert. Glauconite.	No data on yield in Saline County.
			Davis		65' 2 wells	Glauconitic siltstone and fine-grain sandstone with "salt and pepper" appearance; dolomite; edgewise and "flat-pebble" limestone cong.	No data on yield in Saline County.
		Bonne Terre		50' 2 wells	Light gray, medium- to fine-grained, medium bedded dolomite. Cavities lined with dolomite rhombs. Quartz sand content increases toward base.	No data for Saline Co.	
		Lamotte		280' 1 well	Quartzose sandstone that is locally arkosic and conglomeratic. Arenaceous dolomite in upper portion. Color varies from white to brown. 60 feet of arkosic sand and granite boulders at base; overlies granite.	No data for Saline Co. To south, at Sedalia, Pettis Co., wells into or through Lamotte yield 575 GPM.	
PRECAMBRIAN		Granite		?	Granite. Well #48-23-8 aa1 penetrated 157 feet of granite encountered at depth of 1960 feet.	Nil.	

Table 1. (Continued)

SYSTEM	SERIES	FORMATION	SECTION	THICKNESS	LITHOLOGY	WATER-YIELDING CHARACTERISTICS	
QUATERNARY	HOLOCENE	Alluvium		0-120'	Unconsolidated clay, sand, and gravel.	Not investigated; 500-1000 GPM.	
		Loess (Loveland?)		0-30'	Medium- to coarse-grained, noncalcareous, dark brown silt.	Less than 1 GPM.	
	PLEISTOCENE	Glacial Valley-Fill		0-150' (well data)	Boulders, gravels, and coarse sands. Chert and igneous rock fragments.	10-20 GPM.	
		Glacial Drift		0-130' (well)	Coarse gravels and sands; clayey. Igneous rock fragments.	10-20 GPM.	
PENNSYLVANIAN	DESMOINESIAN	Undifferentiated Marmaton and Cherokee Groups		0-140' in NE 0-240' in W (well)	Thin-bedded shales; limestones; coal; crossbedded, micaceous sandstones.	0-5 GPM. A 30-foot thick sandstone (Krebs subgroup) may yield greater quantity in NE Saline County.	
MISSISSIPPIAN	OSAGEAN	Burlington-Keokuk		0-180' (well and field data)	Coarse-grained, crinoidal limestone. White to light gray, weathers light to dark tan. Abundant chert nodules and lenses. Keokuk portion consists of greenish shales and limestones with pink chert nodules. Silicified brachiopods and corals in Keokuk.	Variable. 0-25 GPM. Average 10 GPM. Yield from chert residuum, solution passages, and jointing. Low permeability if not jointed.	
		KINDERHOOKIAN	CHOUTEAU GROUP	North-view		2-4' (field data)	Coarse-grained, somewhat shaly, bluish or greenish gray siltstone. Worm markings (burrows) and "rooster tail" markings (<i>Taonurus caudagalli</i>).	Unimportant as water source. May serve as a local aquiclude.
	Sedalia				15-39' (well data) 20-25' (field data)	Medium to thick bedded, fine crystalline, dolomitic, and siliceous limestone. Bluish gray, weathers to grayish orange. Calcite-filled vugs in upper portion. Bluish-gray chert.	Generally less than 5 GPM. Yield is from joints and bedding planes. Low permeability if not jointed or fractured.
	Compton				50-75' (well data) 60-65' (field data)	Thin bedded, fine crystalline to sublithographic, light to dark gray, fine crinoidal limestone. Dark brownish green shale partings weather readily, producing "slabby" outcrops. Chert nodules in layers. Vuggy in upper portion (w/sulfide mineralization).	Less than 10 GPM. Yield from joints and bedding planes.
	Bachelor		3-8 inches	Clayey, greenish gray, quartzose sandstone w/1/4-inch dark brown layers.	Insignificant.		
DEVONIAN	MIDDLE	Callaway (Cooper facies)		15-95' (well) 7-28' (field data)	Thin to massive bedded, lithographic, olive gray to medium dark gray limestone. Thin greenish gray shale layers. Very fossiliferous horizons. Irregular calcite blebs in limestone.	Generally low yield. If jointed may yield 5-10 GPM. Greater if a local basal conglomerate is present.	
ORDOVICIAN	CHAMPLAINIAN	Kimmswick		0-30' (well data)	Coarse crystalline, white to light gray, medium bedded to massive limestone. Nodular chert in upper part.	May yield 5 GPM but is only locally present. Jointed.	
		St. Peter		10-75' (well data)	Massive, well-sorted quartzose sandstone. Grains fine to medium in size, rounded, spherical, frosted. Crossbedded and ripple-marked locally.	0-25 GPM. Average 15 GPM. Cementation may cause low yield in certain areas.	

BLUE LICK ANTICLINE

This structure was first reported by Meek (1873) who noted that the Cooper facies of the Devonian Callaway limestone was exposed on the Blackwater River and Heaths Creek in southeast Saline County where these two streams have cut through the Burlington-Keokuk formation and the Chouteau Group (fig. 5). The Blue Lick anticline

extends northwest-southeast across southeastern and west-central Saline County. It is most evident in the area between Blue Lick and Nelson on the Blackwater River and also on Heaths Creek. Northwest of Blue Lick this anticline plunges northwest where it is less pronounced and is known only from wells. Maximum closure on the anticline is 100-125 feet.

COW CREEK ANTICLINE

Meek (1873) first mentioned this structure and noted that erosion had exposed the upper portion of the Chouteau Group along creeks that cut the structure transversely. The structure is best exposed on Cow Creek and Rock Creek and on tributaries of Camp Creek northeast of Salt Fork (fig. 5). At these localities the Northview Formation and the upper

part of the Sedalia limestone are exposed. This anticline trends northwest across Saline County from the town of Arrow Rock to just north of Van Meter State Park where the Chouteau Group is exposed in a quarry. Maximum closure on this structure is about 250 feet in the Rock Creek and Cow Creek areas.

FISH CREEK ANTICLINE

A small, northwest-trending anticline, this structure is immediately north of the Saline City fault (fig. 5). In Gilliam Rock Quarry and elsewhere on

Fish Creek an almost complete sequence of the Chouteau Group is exposed. Maximum closure on the Fish Creek structure is approximately 100 feet.

SALINE CITY FAULT

This fault was first described by Ellis (1948) although Meek (1873) concluded that older rocks north of the fault had been exposed by some "uplift."

The Saline City fault extends northwest across Northern Saline County from Saline City to northeast of Miami (fig. 5). The upthrown block is on the north side of the fault. Data indicate that the fault is a high-angle normal fault that has brought strata of the Burlington-Keokuk formation against strata of the Chouteau Group, Callaway Formation, Kimmswick

Formation, and the St. Peter Sandstone. The displacement is most evident in the area north and northwest of Saline City. In the vicinity of Slater and northwest of Slater the fault is known only from wells. Ellis (1948) estimated that southeast of Slater the fault has a vertical displacement in excess of 100 feet. Well-log data used in the construction of geologic cross sections (fig. 4) and the structure contour map on the top of the Chouteau Group (fig. 5) show a vertical displacement of 125-150 feet along the fault northwest of Slater.

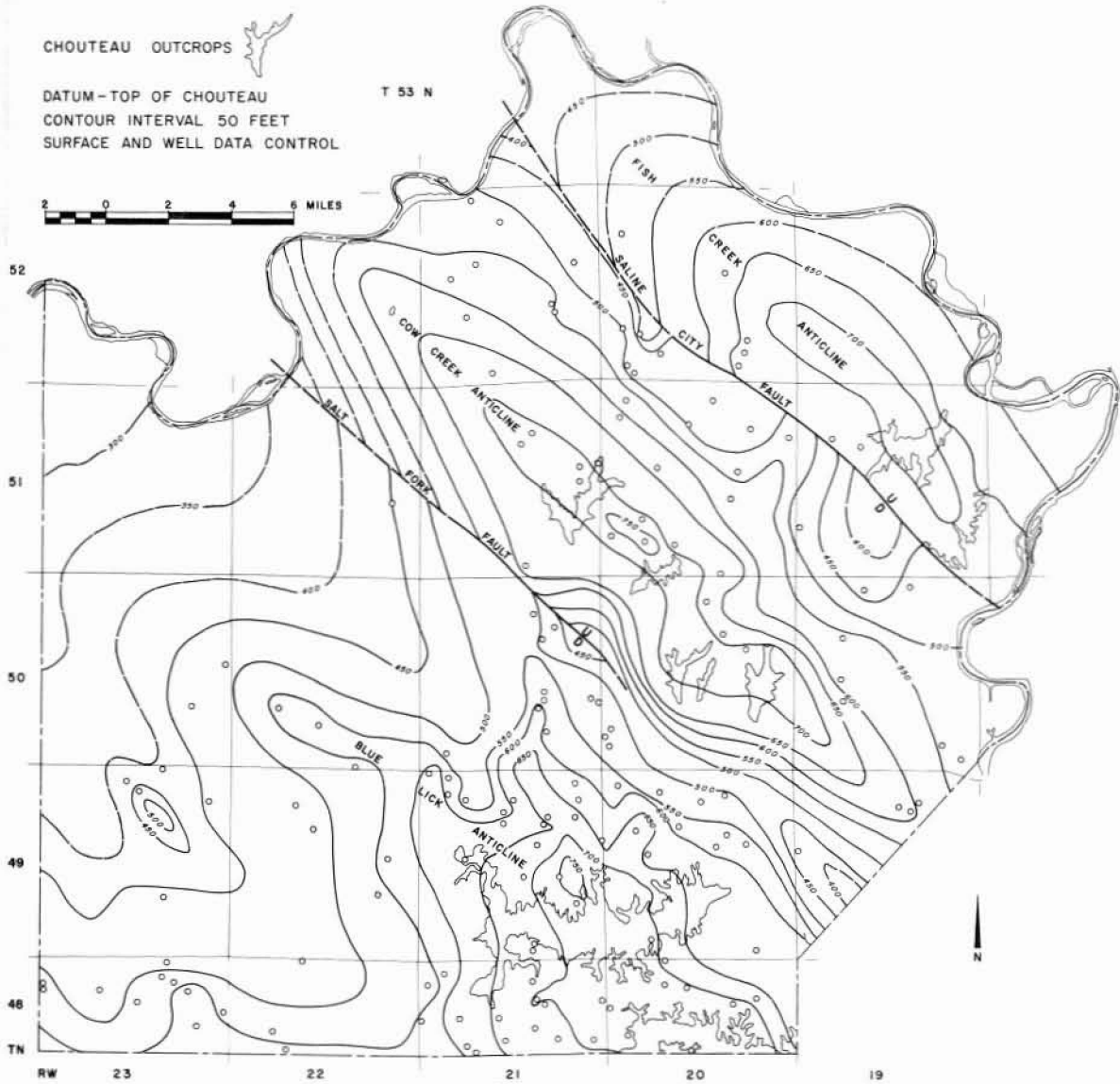


Figure 5. Structural contour map of Saline County.

SALT FORK FAULT

Strong evidence for the existence of a major fault exists in the structural map of the top of the Chouteau Group (fig. 5). This fault appears to be a high-angle normal fault of small displacement. The

vertical displacement on the fault is 200-250 feet. This fault trends in the same northwest-southeast direction as the other structures previously mentioned.

STRUCTURAL SUMMARY

Paleozoic rocks of Saline County have been folded into a sequence of broad, elongate, essentially symmetrical anticlines that are separated by small normal faults that are parallel to the folds. These northwest-trending anticlines and associated normal faults are aligned with the structural grain of Missouri (N. 40-45°W.) (Cole, 1961). Other major structures paralleling this trend are Browns Station anticline (Boone County), Mineola anticline (Montgomery County), and the Lincoln fold in northeastern Missouri.

Movement along all of these structures was related to adjustments that accompanied the Ozark uplift. Maximum deformation occurred at or near the end of the Mississippian, and may have extended into the Pennsylvanian (Allen, 1941; McQueen, Hinchey, and Aid, 1941; McQueen, 1943; Rubey, 1952;

Koenig, 1961). Ellis (1948) concluded that the major movement along the Saline City fault is post-Keokuk and pre-Pennsylvanian, with possible secondary movement in the Pennsylvanian (Cherokee). It is not possible with present data to determine when the deformation began in Saline County, although Canis (1967) believed that the "Saline County arch" of Searight and Searight (1961) served as an effective barrier to Northview sedimentation in central Missouri, thus implying that this structure existed in Kinderhook time. It is possible that the deformation in Saline County may have started at an earlier time than the Kinderhook since Rubey (1952) indicates that movements on the Lincoln fold began as early as the Silurian.

No movement is known to have occurred along the faults in Saline County since Pennsylvanian time.

GROUND WATER

INTRODUCTION

The chemical and physical characteristics of water from various wells and springs in Saline County and adjacent areas were studied in order to determine the nature and distribution of the sulfo-saline ground water of Saline County. The logs and records of 296 wells on file at the Missouri Geological Survey and Water Resources were inspected (pertinent data are summarized in tbl. 1 of the appendix). The general characteristics of 19 springs and 11 wells are presented in tables 2 and 3. Complete chemical analyses were made of water sampled from 20 springs and wells (tbl. 4). Specific conductance measurements were made on waters of 79 additional wells (tbl. 2 of the appendix). An additional 60 chemical analyses in the files of the Missouri Geological Survey and Water Resources gave further information on the quality of the ground water in Saline County (tbl. 3 of the

appendix). Gas analyses of the gases effervescing from five springs in the area are presented in table 5.

Because the interpretation of the distribution and nature of the sulfo-saline ground water in Saline County would depend in great part upon the dependability of the chemical analyses, the samples were taken according to methods described by Rainwater and Thatcher (1960). Eh was determined in the field using methods and equipment similar to that described by Back and Barnes (1961). HCO_3 and pH were determined in the field according to methods described by Barnes (1964). A complete listing of the procedures used in the chemical analysis of the groundwater samples is given in the report by Carpenter and Miller (1969).

TABLE 2
Springs in Saline County and Adjacent Areas

Name & Location	Geology	Rate of flow	Temp. OF °C	Gas evolution* and odor	Approx. TDS	Remarks
Blackwater 49-19-34ddl Cooper Co.	alluvium Burlington bedrock	less than 5 gph	**	slow sporadic large bursts H ₂ S	19,000	**tends to maintain temperature of the atmosphere because of low flow and large surface area (10' diam.). Iron sulfides. TDS variable; dilution by local water table as result of low flow.
Blue Lick North Group 49-21-21dcl	alluvium Sedalia bedrock	65 gpm	61.3 16.3	1 cu.ft./hr. H ₂ S	29,400	Main group: 16 orifices (6" to 8' diam.), native sulfur, iron sulfides, salt crust on alluvium. Smaller group to north: 2 springs rise through chert gravel.
Blue Lick South Group 49-21-28acl	alluvium Sedalia bedrock	less than 10 gpm	**	slow sporadic large bursts H ₂ S	14,600	**As above. Three orifices (4, 5 and 40' diam.). Iron sulfides.
Boonslick 50-19-31acl Howard Co.	alluvium Burlington bedrock	10 gpm	59.3 15.2	0.2 cu.ft./hr. H ₂ S	20,700	Boonslick State Park. Spring (3' diam.) and artesian well (1001' deep). Native sulfur, iron sulfides. Wood csg. at well.
Chouteau 48-18-16ddl Cooper Co.	alluvium Compton bedrock	15 gpm	62.2 16.8	.3 cu.ft./hr. H ₂ S	7,300	Four springs rising along a straight NW-SE line. Tile lined. Iron sulfides. A fifth spring is located in 48-18-16bd1.
Cow Creek 51-21-25abl	soil Sedalia bedrock	less than 2 gph	62.6 17.0	slow H ₂ S	4,000	Only one spring now - plugged spring in 51-21-24dcl. Iron sulfides. Rises in hog wallow 600 feet east of East Cow Creek.

*Approx. rates of gas evolution are: rapid, .5 cu.ft./hr.; moderate, 0.2 cu.ft./hr.; slow, 0.1 cu.ft./hr.

Table 2. Springs in Saline County and Adjacent Areas (Continued)

Name & Location	Geology	Rate of flow	Temp. OF °C	Gas evolution* and odor	Approx. TDS	Remarks
Davis Creek Group 48-23-4bd1	alluvium Burlington bedrock	very slow	59.0 15.0	slow H ₂ S	4,000	One orifice (2' diam.). Iron sulfides. Woodward (1890) mentions another spring in 49-23-ccl: Black Sulfur Spring. Other springs reported in the area.
Dennis 49-20-12bb1	alluvium Burlington bedrock	25 gph	57.4 14.1	slow no odor	3,250	Issues from 2' diam. tile.
Elk Lick 48-20-17	alluvium Callaway bedrock	100-200 gph	56.2 13.4	moderate H ₂ S	4,300	Data from Woodward (1890) and Schweitzer (1892). Iron sulfides. Not found during this study.
Grand Pass 51-23-16cc1	alluvium glacial drift	25 gph	59.0 15.0	none no odor	225	Issues from 3' diam. tile (15' deep). In use.
Great Salt Group 50-22-17dd1 50-22-20aa1	alluvium Pennsylvanian -Burlington bedrock	10,000 & 200 gph two springs	57.2 & 59.0 14.0 & 15.0	moderate H ₂ S	31,100 & 29,900	No longer flows. Reported in Woodward (1890) and Schweitzer (1892). Two large (25' diam.) springs. Iron sulfides and native sulfur.
Keithley 51-22-9dc1	Glacial drift	1 gpm	60.8 16.0	none no odor	100	Spring house.
McAllister 48-22-17aa1	alluvium Burlington bedrock	25 gpm	59.0 15.0	.25 cu.ft./hr. H ₂ S	8,900	Two springs (3' diam. tile). Originally seven springs. Iron sulfides and native sulfur. TDS variable: dilution by water table.

*Approx. rates of gas evolution are: rapid, .5 cu.ft./hr.; moderate, 0.2 cu.ft./hr.; slow, 0.1 cu.ft./hr.

Table 2. Springs in Saline County and Adjacent Areas (Continued)

Name & Location	Geology	Rate of flow	Temp. °F °C	Gas evolution* and odor	Approx. TDS	Remarks
Salt Branch (Miami) 52-21-35cal	alluvium Pennsylvanian bedrock	low	?	? H ₂ S	greater than 2,000?	Sulfo-saline spring (weak) reported in Schweitzer (1892).
Salt Branch (Napton) 50-20-28ddl	stream gravel Burlington bedrock	15 gpm	58.1 14.5	0.2 cu.ft./hr. H ₂ S	13,800	Two 2-3' diam. springs and two minor springs downstream. 5-acre plot of barren salt-encrusted ground. Iron sulfides.
Santa Fe 50-19-36acl	Burlington	5 gpm	59.0 15.0	none no odor	350	In Arrow Rock State Park.
Schanz-Stockman 48-22-7dbl	alluvium Burlington bedrock	15 gpm	59.5 15.3	slow sporadic bursts H ₂ S	11,200	10 springs along a 500' stretch of barren, salt-encrusted alluvium. Largest in 9' diam. Iron sulfides abundant.
Slough Creek 49-18-6cbl Cooper Co.	alluvium Sedalia (?) bedrock	2-3 gph	55.4 13.0	slight H ₂ S	4,100	Rises from alluvium of creek. Iron sulfides. Another similar spring can be seen in the bottom of Slough Creek when the water is low: 49-19-2acl (Saline Co.).
Sweet Spring 49-23-14bbl	Burlington	low now	59.0 15.0	slight no odor	3,200	Woodward (1890) reports flow of 1000 gph. Plugged with sediment from Blackwater River (1967). Woodward reports a sulfo-saline spring at the same locality.

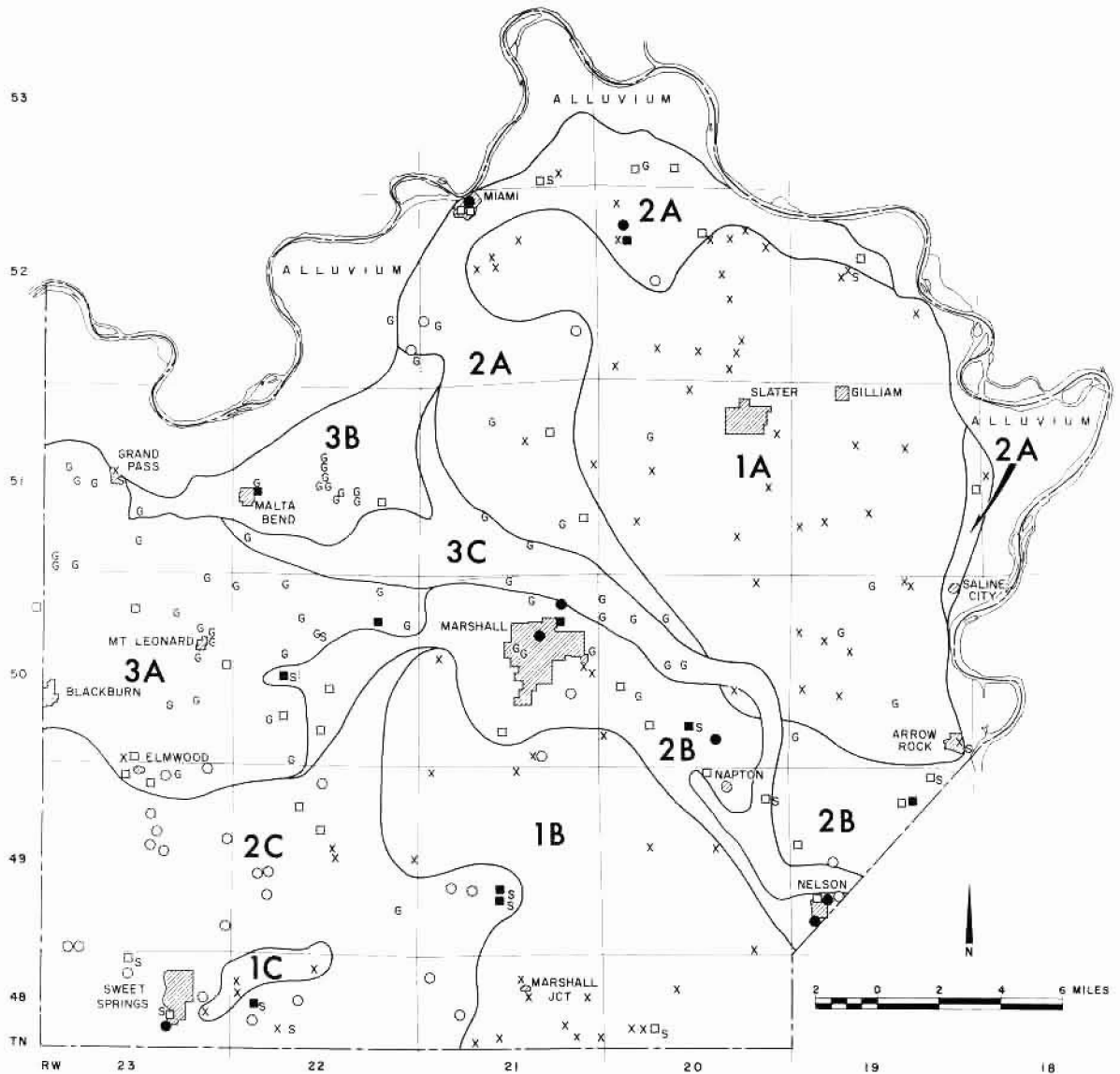
*Approx. rates of gas evolution are: rapid, .5 cu.ft./hr.; moderate, 0.2 cu.ft./hr.; slow, 0.1 cu.ft./hr.

TABLE 3
Characteristics of Sulfo-Saline Wells

Owner & Location	Depth	Aquifer	Temp. of °C	Odor	Approx. TDS	Remarks
B. Samson 48-23-4db1	150	Burlington	55.4 13.0	H ₂ S	1,120	Flowing well. 60 feet Pennsylvanian cover.
R. Sims 49-22-19ad1	300	Burlington	60.8 16.0	H ₂ S	1,830	Pennsylvanian cover exceeds 125 feet.
M. Perkins 49-22-16ab1	630	Cotter Jeff. City	62.6 17.0	H ₂ S	1,840	Well log and older chemical analyses are available. 155 feet Pennsylvanian cover.
R. Arni 49-23-3ca1	560	St. Peter	50.4 10.2	H ₂ S	1,930	Well log available. Heavy pumping loosens iron sulfides from inner surface of pipe.
C. Brown 53-20-33bd1	300	Chouteau	62.6 17.0	None	2,840	SWL 100'.
A. Finkeldei 50-24-12aa1 Lafayette Co.	600	Cotter Jeff. City	54.1 12.3	H ₂ S	4,030	Heavy pumping will loosen iron sulfides from pump and pipes. TDS variable due to dilution from upper formations.
B. Dille 51-19-24ad1	252	St. Peter	50.0 10.0	None	4,740	Quality of water extremely variable. Sp. Cond. range 1,750-8,250. Hard pumping causes increase in TDS. SWL 150'.
Sweet Springs "Gusher" 48-23-15ad1	1069	Gunter	54.5 12.5	H ₂ S	5,490	Flowing well. 130 gpm. Inside of casing coated with fine iron sulfide "slime". Oil test in 1902.
Taylor-Hamilton 52-21-5aa1	195	Burlington	65.3 18.5	None	5,630	Well log available.

Table 3. Characteristics of Sulfo-Saline Wells (Continued)

Owner & Location	Depth	Aquifer	Temp. °F °C	Odor	Approx. TDS	Remarks
R. Doty 49-19-29ccl	205	Chouteau Devonian	52.3 11.3	H ₂ S	6,550	Variable water quality - seasonal. Sp. Cond. range: 3,100 to 10,900. H ₂ S content decreases when local water table is up.
V. C. Miller 50-20-34aal	200	Burlington	60.8 16.0	H ₂ S	7,080	Iron sulfides in pipes.



GROUNDWATER QUALITY CONTROL POINTS

- x < 1000 ppm TDS
- 1000-1999 ppm TDS
- 2000-4999 ppm TDS
- 5000-10000 ppm TDS
- 10000 ppm TDS
- S Spring
- G Glacial (well)

- 1A** Burlington to Jefferson City waters - less than 600 ppm TDS. Central portion: best water.
- 1B** Southern portion - less than 500 ppm TDS to Roubidoux. Northern: Catter less than 600 ppm. Jefferson City greater than 1500 ppm.
- 1C** Unpredictable: salty water after heavy pumping. Catter 400-1000 ppm TDS
- 2A** TDS 2000-10000 ppm. North: Burlington and Chouteau saline. East: St. Peter saline. Low H_2S
- 2B** TDS depth increase to 37000 ppm in Bonneterre. Wells generally 2000-7000. Lower Burlington saline. H_2S

- 2C** Pennsylvanian cover - high H_2S . 1000-3000 ppm TDS in Burlington to Jefferson City
- 3A** Glacial drift, exceeds 100 ft thick in ss. 75-350 ppm TDS. Saline water below is extension of area 2C
- 3B** Teteseau Flats - glacial ponded sediments - 150 ft thick. 300-550 ppm TDS. Saline in bedrock
- 3C** Buried glacial stream valley - 100 ft thick. 300-550 ppm TDS. Saline water contamination from bedrock in some areas

Figure 6. Groundwater quality map of Saline County.

GENERAL NATURE OF THE GROUND WATER

An inspection of the chemical analyses reported in table 4 of the text and table 3 of the appendix indicates that there are two basic types of ground water in Saline County: sodium-chloride waters and calcium-bicarbonate waters. The sodium-chloride ground water, often with associated hydrogen sulfide gas, becomes dominant when the total dissolved solids (TDS) content exceeds about 1,000 parts per million (ppm). The calcium-bicarbonate ground water is dominant when the TDS content is less than about 650 ppm. The calcium-bicarbonate ground water appears to be separated from the sodium-chloride ground water by a transitional sodium-bicarbonate ground water.

For the purposes of this report, based on the above groundwater types, the value of 1,000 parts per million total dissolved solids content is taken as the boundary between fresh water and salt water. The U.S. Public Health Service (1962) considers 500

ppm total dissolved solids as the maximum acceptable for public water supplies when potable water is available. However, it is quite evident that this level is not strictly applicable to all areas of the United States, particularly where there are shortages of water of low mineral content. It is pointed out in this same U.S. Public Health Service report that more than 100 public water supplies in the United States provide water with more than 2,000 ppm dissolved solids. Because a good portion of Saline County is covered by Pennsylvanian shales which inhibit the free recharge of meteoric waters to the aquifers and because the author does not want to transmit the idea that these marginal waters of 500 to 1,000 ppm dissolved solids content are not usable, it seems reasonable to accept 1,000 ppm dissolved solids as the fresh-salt water boundary. These terms are quite dependent upon whether sources of better quality water are available or not.

NATURE OF THE EVOLVED GASES

A great number of the saline springs and wells of Saline County produce a gas containing hydrogen sulfide. In order to determine the composition of this gas, which effervesces freely from the mouths of the springs, five samples were taken for analysis (tbl. 5). Contrary to prior belief the dominant gas was not the odorous hydrogen sulfide. The high concentrations of nitrogen and argon seem attributable to some mechanism which has removed the original oxygen. It seems most likely that the nitrogen and

argon have their origin as gases dissolved in the waters of the original sediments before lithification or as gases in groundwater. As no oxygen was detected, and as the waters are often quite reducing, it seems that the low totals (generally less than 95 percent) for the analyses are probably the result of inaccuracy in the nitrogen determinations. The nature of the gas as a whole seems to be related to the very processes which have caused these sulfo-saline ground waters.

GROUNDWATER QUALITY DISTRIBUTION

Interpretation of the groundwater quality data obtained during the course of the study resulted in

the production of a groundwater-quality map (fig. 6). This map outlines nine water-quality areas.

TABLE 4
Results of Field Study and Laboratory Analyses

The various ions are reported as mg/l

Location	48-23-4db1	49-22-19ad1	49-22-16ab1	49-23-3ca1	53-20-33bd1	49-20-12bb1	51-21-25ab1	50-24-12aa1	51-19-24ad1	48-23-15ad1
Collection date	3-23-67	7-24-66	7-24-66	3-22-67	6-13-66	6-13-66	7-24-66	3-22-66	3-2-67	3-1-67
Temperature (F) (C)	55.4 13.0	60.8 16.0	62.6 17.0	50.4 10.2	62.6 17.0	57.2 14.0	62.6 17.0	54.1 12.3	50.0 10.0	54.5 12.5
Iron (Fe++)	.80	.21	.13	.18	2.7	.93	.42	.52	.....	.....
Iron (Fe+++)	.05	.03	.08	.02	0	0	.10	.03	.....	.....
Iron (Fe), total	.85	.24	.21	.20	2.7	.93	.52	.55	.29	1.0
Manganese (Mn)	.....	.03	.01	.....	.03	.03	.12	.....	.....	.....
Nickel (Ni)	.....	.0	.0	.....	.0	.0	.0	.....	.....	.....
Copper (Cu)	.....	.00	.00	.....	.00	.00	.00	.....	.....	.....
Lead (Pb)	.....	.00	.00	.....	.00	.00	.00	.....	.....	.....
Zinc (Zn)	.09	.25	.11	.....	2.2	.09	.09	.47	.77	.09
Calcium (Ca)	95	60	82	57	183	186	195	128	366	373
Magnesium (Mg)	50	33	38	31	80	65	70	62	99	162
Strontium (Sr)	.....	4.8	2.2	.....	4.2	2.7	5.8	.....	.....	.....
Barium (Ba)	.....	.0	.0	.....	<.1	<.1	<.1	.....	.....	.....
Sodium (Na)	256	578	560	628	760	885	1,070	1,310	1,280	1,480
Potassium (K)	13	19	17	18	15	19	26	36	24	24
Lithium (Li)	.2	.4	.3	.....	.4	.5	.6	.3	.7	.4
Rubidium (Rb)	.03	.02	.02	.03	.02	.04	.05	.05	.05	.07
Bicarbonate (HCO ₃)	285	335	360	372	324	290	.....	332	337	266
Sulfate (SO ₄)	57	90	93	59	222	209	254	132	341	188
Chloride (Cl)	510	872	865	946	1,410	1,600	1,890	2,180	2,450	3,120
Bromide (Br)	1.1	2.2	2.0	2.2	2.4	2.6	4.5	4.5	8.8	6.5
Iodide (I)	.1	.1	.0	.3	.1	.1	.2	.3	.2	.3
Phosphorus (P)	.....	.....	.....	.....	.....	.....	.....	.....	.55	.60
Boron (B)	0.67	1.4	1.5	1.3	1.1	1.2	1.2	1.5	0.51	0.58
Sulfide (S--)	1.1	2.2	4.3	8.8	0	0	1.2	11	.0	7.8
Calculated dissolved solids	1,120	1,830	1,840	1,930	2,840	3,110	.....	4,030	4,740	5,490
Residue on evaporation at 110C.	1,240	1,790	1,850	1,920	2,920	3,330	3,980	4,170	5,120	6,120
Specific conductance (micromhos/cm at 25° C.)	1,800	3,300	3,200	3,450	4,800	5,600	6,250	7,000	.....	.....
pH	7.33	7.38	7.42	7.64	7.27	7.18	.....	7.23	6.83	7.13
Eh (volts at 25° C.)	-0.0017	-0.0907	-0.0363	-0.0618	+0.1997	+0.2086	.....	-0.0982	+0.3073	-0.0909
Odor	H ₂ S	H ₂ S	H ₂ S	H ₂ S	None	None	H ₂ S	H ₂ S	None	H ₂ S

Table 4. Results of Field Study and Laboratory Analyses (Continued)

Location	52-21-5aa1	49-19-29cc1	50-20-34aa1	48-18-16dd1	48-22-17aa1	48-22-7db1	50-20-28dd1	49-19-34dd1	50-17-31ac1	49-21-21dc1
Collection date	6-13-66	3-23-67	3-3-66	7-24-66	3-1-67	3-3-66	3-3-66	3-3-66	7-24-66	3-3-66
Temperature (F) (C)	65.3 18.3	52.3 11.3	60.8 16.0	62.6 17.0	59.4 15.2	59.0 15.0	57.2 14.0	55.4 13.0	59.9 15.5	60.8 16.0
Iron (Fe++)	1.3	2.03	1.58	.03	.....	3.19	0	.55	.03	.....
Iron (Fe+++)	0	.02	.08	0	.....	.10	.02	.06	0	.....
Iron (Fe), total	1.3	2.05	1.66	.03	.01	3.29	.02	.61	.03	.....
Manganese (Mn)	.05	.....	.06	.07	.....	.14	.12	.17	.22	.22
Nickel (Ni)	.0	.....	.0	0	.....	<.1	<.1	<.2	<.2	<.3
Copper (Cu)	.03	.....	.08	.00	.....	.03	0	.02	.00	.00
Lead (Pb)	.00	.....	.00	.00	.....	.00	.00	.01	.00	.00
Zinc (Zn)	.48	.....	.55	.09	.09	.17	.07	.13	.09	.06
Calcium (Ca)	314	308	410	389	378	618	701	927	1,090	1,430
Magnesium (Mg)	133	135	148	149	188	244	250	358	409	526
Strontium (Sr)	8.6	.....	8.6	11	.....	13	16	35	59	36
Barium (Ba)	<.1	.....	<.1	<.2	.....	<.2	<.3	<.4	<.4	<.6
Sodium (Na)	1,600	1,910	1,990	2,080	2,530	3,160	4,030	5,700	5,950	8,650
Potassium (K)	35	42	37	36	41	49	67	102	115	134
Lithium (Li)	.9	.....	1	1	1.4	1.7	2.1	2.8	3.1	4.4
Rubidium (Rb)	.05	.09	.07	.09	.08	.09	.17	.26	.35	.35
Bicarbonate (HCO ₃)	328	380	306	331	317	289	309	.295	266	303
Sulfate (SO ₄)	433	390	436	370	319	394	717	1,160	1,320	1,360
Chloride (Cl)	2,930	3,560	3,880	3,960	5,010	6,480	7,700	10,500	11,600	17,000
Bromide (Br)	6.8	7.8	14	10	8.8	28	27	38	28	50
Iodide (I)	.2	.2	.8	.3	.2	.9	.4	.9	.9	.....
Phosphorus (P)	.....	.....	.....	.....	.9	.....	.....	.....	.....	.....
Boron (B)	1.7	2.3	1.8	1.5	1.4	1.3	3.7	5.6	5.7	6.0
Sulfide (S--)	0	2.6	0	3.1	18	.3	1.5	.0	12	3.9
Calculated dissolved solids	5,630	6,550	7,080	7,170	8,650	11,100	13,700	19,000	20,700	29,300
Residue on evaporation at 110C.	5,940	7,300	7,250	7,510	9,470	12,200	14,600	19,700	22,400	30,100
Specific conductance (micromhos/cm at 25° C.)	9,100	10,900	11,700	10,100	.....	18,000	21,000	28,000	28,100	40,500
pH	7.05	6.89	6.89	7.05	6.93	6.93	6.77	7.05	6.73	6.74
Eh (volts at 25° C.)	+0.1577	-0.0286	+0.0713	-0.0610	-0.0681	-0.0573	-0.0840	-0.1089	-0.0949	-0.0728
Odor	None	H ₂ S	H ₂ S	H ₂ S	H ₂ S	H ₂ S	H ₂ S	H ₂ S	H ₂ S	H ₂ S

TABLE 5
Gas Analyses From Springs*

Location	Rate of Discharge (cu. ft./h)	N ₂ (vol.%)	A ₂ (vol. %)	H ₂ O ^{**} (vol.%)	CO ₂ (vol.%)	H ₂ S (ppm)
Blue Lick 49-21-21dcl	1.0	86.0	1.72	1.7	0.30	430
Boonslick 50-17-31acl	0.2	85.1	1.72	1.7	0.10	80
Chouteau Spr. 48-18-16ddl	0.3	92.9	2.56	1.7	0.03	8
Salt Branch (Napton) 50-20-28ddl	0.2	86.8	2.14	1.7	0.10	140
McAllister Spr. 48-22-17aal	0.25	90.3	1.72	1.7	0.12	95

* Collection and analysis date: 9-6-66. Analyses by St. Louis Testing Laboratories. N₂ and A₂ determined by gas chromatography; CO₂ and H₂S determined by Drager gas detector. O₂ not detectable (gas chromatograph); hydrocarbons less than 1%, CO less than 10ppm (gas detector).

** Calculated.

AREA 1A

This area yields the least mineralized ground water from bedrock aquifers. The total dissolved solids content (TDS) of the ground water in the Burlington-Keokuk formation down to the Jefferson City Dolomite is usually less than 600 ppm (parts per

million). The central portion produces the best quality water; border areas are unpredictable. The high quality of the water is attributable to local recharge on a structural and topographic high (Cow Creek anticline) where Pennsylvanian cover is absent.

AREA 1B

This area also coincides with a structural and topographic high (Blue Lick anticline) which lacks a Pennsylvanian cover. In the southernmost portion strata as deep as the Roubidoux Formation produce water with less than 500 ppm TDS. In the northernmost portion, south of the town of Marshall, the TDS

content in water from the Jefferson City Dolomite exceeds 1,500 ppm, but water in the Cotter formation is generally less than 600 ppm TDS. In the central portion of the area some hydrogen sulfide gas is present in the ground water, particularly along the Blackwater River toward the town of Nelson.

AREA 1C

This is a very unpredictable area; wells tend to produce saltier water after heavy pumping. Strata as

deep as the Cotter Dolomite can produce relatively unmineralized water (400-1,000 ppm TDS).

AREA 2A

Like area 1C water quality in this area is very unpredictable. Wells, originally fresh, can become very saline upon heavy pumping. Generally the TDS content is not much greater than 2,000 ppm, but some wells produce waters of up to 10,000 ppm TDS (well 52-20-7da1). In the northern portion of the area Burlington formation water locally has a TDS content as high as 6,000 ppm, and Chouteau waters

are locally as high as 10,000 ppm. In the eastern portion, north of Saline City, the St. Peter water exceeds 5,000 ppm TDS content. The southwestern portion is the least saline (less than 2,000 ppm TDS). A characteristic of these waters is that even though they can be quite saline they contain little hydrogen sulfide.

AREA 2B

This long, belt-shaped area contains sulfo-saline ground water and extends from beneath the glacial sediments of area 3B and 3C to the town of Nelson. A number of sulfo-saline springs occur along this belt. The TDS content, increasing with depth, ranges from 2,000 to 37,000 ppm. The TDS content in the Bonneterre Formation is 37,000 ppm

(well 50-21-11acl) and that of the St. Peter is 19,000 ppm (well 49-19-2ccl). Many wells bottoming in the lower Burlington are sulfo-saline. Shallow wells in the upper Burlington-Keokuk and wells in the Burlington-Keokuk residuum, glacial drift and alluvium offer meager supplies of fresh water.

AREA 2C

Wells in this area are not so saline as to be completely unusable, but there is a high concentration of hydrogen sulfide in the water. In order to obtain sufficient volume for farm use, wells must be drilled to the St. Peter, Cotter, and Jefferson City formations (1,000 to 3,000 ppm TDS). Shallow wells

in the Pennsylvanian rocks and scattered glacial drift yield small volumes of relatively unmineralized water. This area extends beneath the glacial sediments of area 3A. Numerous sulfo-saline springs and seeps occur along the Blackwater River in the southern portion.

AREA 3A

The aquifer in this area consists of a large tongue of glacial drift overlying the Pennsylvanian strata and extending southward from Grand Pass to Elmwood. Thicknesses in excess of 100 feet are common, but the drift may be absent locally. The

TDS content ranges from 75 to 350 ppm, and expected production is 10-25 gallons per minute. City wells for the towns of Blackburn and Mount Leonard are in this area. The sulfo-saline waters of area 2C extend beneath this area.

AREA 3B

This area is known as Teteseau Flats. The aquifer consists of coarse sands and gravels up to 150 feet in thickness. This material has been attributed to glacial ponding of the Missouri River (Bretz, 1965). The expected TDS content is 300 to 500

ppm. The city of Marshall has seven wells in this area, producing from 550 to 1,000 gallons per minute each. Waters in the bedrock beneath the glacial sediments are sulfo-saline, an extension of area 2B.

AREA 3C

The outlines of this area are defined by the channel of a buried glacial stream valley. The sediments are finer grained than in area 3B. Generally the depth of the channel exceeds 100 feet; well 51-21-34aa1 encountered Burlington-Keokuk bedrock at 145 feet. The channel has been covered by loess and locally much of the fill has been removed by

erosion. Expected TDS content in this area is 300 to 550 ppm; expected production should be greater than 50 gallons per minute. The underlying Burlington-Keokuk formation contains salt water which contaminates the water in the lower portions of the channel (4,000 ppm TDS content in the above-mentioned well).

EVALUATION OF GROUNDWATER RESOURCES BY USE

PUBLIC WATER SUPPLIES

Dependable sources of potable water in sufficient volume are obtainable from the glacio-fluvial sediments of areas 3A and 3B, from the Missouri River alluvium and the Blackwater River alluvium.

These waters have a low mineral content and can be obtained in large volumes. Bedrock sources in Saline County are either too mineralized or have a low yield.

DOMESTIC AND FARM USE

In area 1A-B-C and 3A-B-C there is little difficulty with salinity, hardness being the major problem. In these areas the use of water softeners is recommended. In areas 2A-B-C the presence of sulfo-saline ground water poses a problem for domestic use. Water softeners are not effective in removing the "salty" taste. Submersible pumps have a short life expectancy due to the corrosive action of the waters. Iron is present in amounts that cause staining of

laundry, utensils, and home equipment. The amount of fluoride in the water is appreciably higher than the recommended maximum (1.2 milligrams per liter) for Saline County (U.S. Public Health Service, 1962). The effect of the excess fluoride is noticeable; i.e., mottling of children's teeth (particularly in area 2C). The water is likely to be suitable for livestock although it may be necessary that feed given to these animals (particularly dairy herds) have reduced quantities of added salts.

IRRIGATION USE

The sulfo-saline waters of Saline County would be detrimental to many crops as a result of high boron content, high chlorinity, and a high sodium-adsorption-ratio. During extended dry periods saline spring water has been known to raise the salinity

of the Blackwater River to such an extent that it becomes unusable for irrigation (U.S. Geological Survey Water-Supply Paper 1949, p.360, 1966). A sufficient volume of water suitable for irrigation might be obtained from the glacio-fluvial sediments of area 3B or from the Missouri River alluvium.

STRATIGRAPHIC VARIATIONS IN GROUNDWATER QUALITY

One of the factors controlling groundwater quality in Saline County is the thickness of the overlying Pennsylvanian strata. The high concentration of sulfide in the ground water of southwestern and western Saline County is related to the presence of a relatively thick section of Pennsylvanian rocks. In the northeastern part of the county, where thicknesses of the Pennsylvanian rocks are generally less than 140 feet, the ground water can be saline and yet have little trace of sulfide. The sulfide contents of the ground water in these two areas are compared in table 6.

Depth is a second factor controlling groundwater quality in Saline County. A well drilled at the Missouri State School in Marshall during the period from July 1937 to the spring of 1939 shows a definite increase in salinity with depth. Samples were taken from open holes by bailers as the drilling progressed, hence samples represent a mixture. The total dissolved solids content in successive samples from this well, 50-21-11a₁, are plotted against the depth at which each sample was taken (fig. 7); The reason for the decrease in total dissolved solids at the 665-1,245 foot level is unknown.

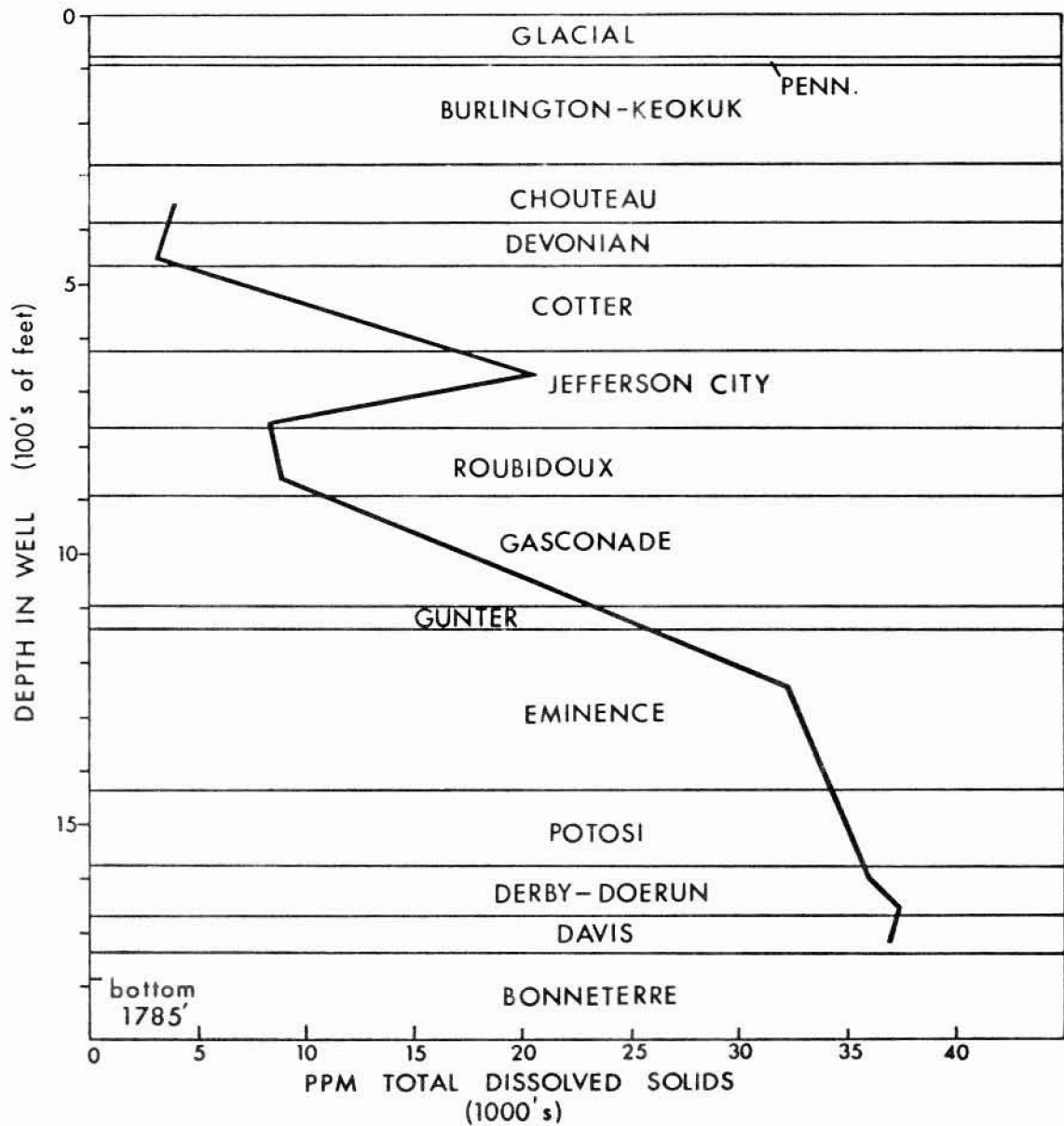


Figure 7. Salinity gradient well 50-21-11ac1, elevation 737 feet.

STRUCTURAL CONTROLS OF GROUNDWATER QUALITY

Saline water (greater than 1,000 ppm TDS) occurs in the troughs between anticlinal structures in Saline County and fresh water (less than 1,000 ppm TDS) occurs along the crests and flanks of these structures. Saline water occurs along the valley of the Salt Fork where fractures associated with the Salt Fork fault allow saline water to reach the surface. The ground water on the north side of the

Saline City fault is freshened as deeply as the St. Peter sandstone by fresher water moving across the fault from the Chouteau and Burlington-Keokuk strata that receive recharge from their outcrop area on Cow Creek anticline (figs. 3 and 8). The ground water on the north flank of Fish Creek anticline is saline. Fresh water occurs along the crest of the Blue Lick anticline except in western Saline County where it plunges beneath the Pennsylvanian rocks.

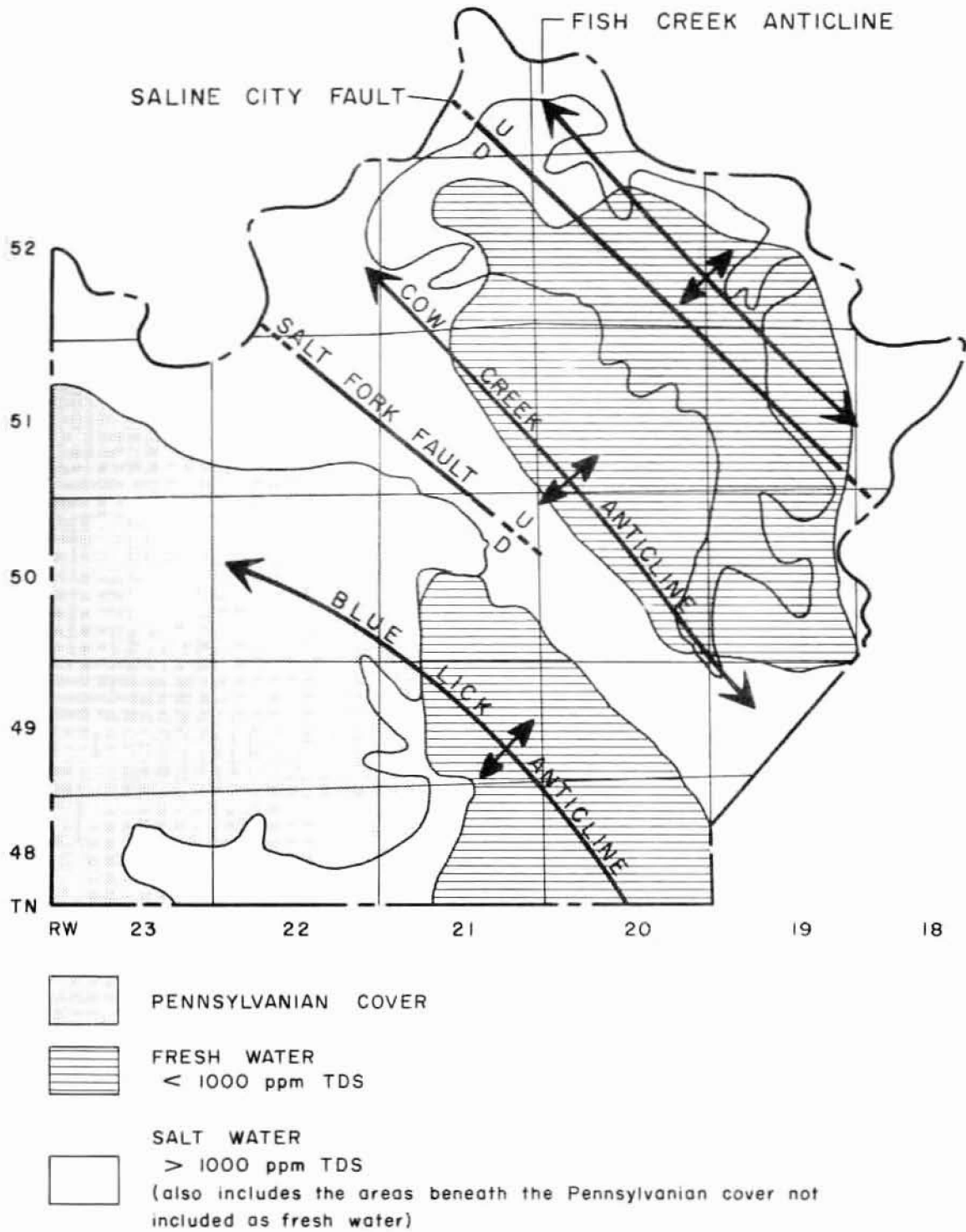


Figure 8. Stratigraphic and structural controls on bedrock groundwater quality in Saline County.

TABLE 6

Relation of Sulfide Content of Ground Water to Thickness of Pennsylvanian in Two Areas of Saline County.

SE and W Saline County				
Location	Pennsylvanian cover (feet)	TDS (mg/l)	S ⁼ (mg/l)	Eh (volts at 25°C)
48-23-4dbl	60	1,120	1.1	-0.0017
49-22-16abl	155	1,840	4.3	-0.0363
49-22-19adl	100	1,830	2.2	-0.0907
49-23-3cal	185	1,930	8.8	-0.0618
50-24-12aal	225	4,030	11	-0.0982
NE Saline County				
Location	Pennsylvanian cover (feet)	TDS (mg/l)	S ⁼ (mg/l)	Eh (volts at 25°C)
51-19-24adl	0	4,740	0	+0.3073
*52-20-7dal	70	10,200	0.8	+0.1862
52-21-5aal	47	5,630	0	+0.1577
52-20-33bdl	35	2,840	0	+0.1997

* An incomplete analysis from a well bottoming in the Chouteau Group on Fish Creek anticline.

TABLE 7
Relation of the Hydrogen Sulfide Content to the SO_4/Cl Ratio of the Ground Water

Location	SO_4/Cl	$\text{S}^{=}$ (mg/l)
Ocean water	0.14	. . . . .
53-20-33bd1	0.16	0
52-21-5aal	0.15	0
51-19-24ad1	0.14	.0
49-20-12bb1	0.13	1.2
51-21-25abl	0.13	0
50-20-34aal *	0.11	0
49-19-34dd1	0.11	.0 ***
48-23-4db1	0.11	1.1
49-19-29cc1	0.11	2.6
49-22-16abl	0.11	4.3
50-17-31acl **	0.11	12
49-22-19ad1	0.10	2.2
50-20-28dd1 **	0.093	1.5
48-18-16dd1	0.093	3.1
49-21-21dc1 *	0.080	3.9
48-22-17aal	0.064	18
49-23-3cal *	0.062	8.8
48-22-7db1	0.061	0.3 ***
50-24-12aal *	0.061	11
48-23-15ad1 *	0.060	7.8

* sulfate-reducing bacteria (Jackson, 1966)

** no sulfate-reducing bacteria (Jackson, 1966)

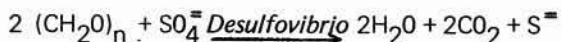
*** slow-flowing springs, much $\text{S}^{=}$ may have been lost to the atmosphere.

BIOCHEMICAL FACTORS CONTROLLING GROUNDWATER QUALITY

The presence of abundant hydrogen sulfide in many of the wells and springs of Saline County appears to be the result of sulfate reduction by anaerobic bacteria. Togwell A. Jackson, Department of Geology, University of Missouri-Columbia, isolated sulfate-reducing bacteria from the waters of deep wells within the area. Jackson (1966) concludes that:

“The H₂S-bearing groundwater of central Missouri seems to contain a dilute suspension of Gram negative and Gram positive bacteria. The Gram negative organisms include *Desulfovibrio* sp. and one or more species of non-sulfate-reducing straight rods. The presence of sulfate-reducing Gram negative straight rods such as *Desulforistella* is a possibility but has not been verified as yet. The Gram positive organisms consist predominantly of non-sulfate-reducing spore-bearing rods presumed to be *Clostridium* sp. Since the organisms were isolated from water samples taken from several deep wells in which the water flowed from the aquifer to the surface through pipes without passing through any surficial soil or sediment which might introduce contaminants, and since the wells have been in operation for a number of years — long enough to have flushed out (we presume) any contaminants introduced initially by the drilling operation, it is concluded that a population of sulfate-reducing bacteria does exist in the water.”

The biochemical reaction involved in the reduction of sulfate by sulfate-reducing bacteria such as *desulfovibrio* is:



In this type of anaerobic respiration the sulfur atom serves as the electron acceptor for the oxidation of organic substrates. The anaerobic oxidation of organic substrates by *Desulfovibrio* are characteristically incomplete and lead to the accumulation of acetic acid as a metabolic end product.

Further evidence of the action of sulfate-reducing bacteria is the lowering of the SO₄/Cl ratio. Where the hydrogen sulfide content (analyzed as sulfide, S²⁻) of the ground water is high the SO₄/Cl ratio is low (tbl. 7).

The pre-Pennsylvanian rocks apparently contain enough organic matter for the biochemical reaction to take place. This is indicated by the occurrence of H₂S-bearing waters in areas lacking Pennsylvanian rocks (stations 49-19-29ccl, 50-17-31acl, 50-20-28ddl, 48-18-16ddl, 49-21-21dcl, 48-22-17aal, 48-22-7dbl, 48-23-15adl are such cases). Well 48-23-15adl, bottoming at 1,069 feet in the Gunter sandstone, is an H₂S-bearing artesian well flowing at the rate of 130 gpm in 1967.

The difference in sulfide content of the groundwater in the southwestern and western portions of Saline County and in the northeastern portion is controlled by the Eh of the water (tbl. 6). In northeastern Saline County recharge by meteoric waters has raised the Eh such that sulfides generated by sulfate-reducing bacteria at depth are oxidized upon rising to the surface. This oxidizing environment is not favorable for sulfate-reducing bacteria which might otherwise be active in the upper formations. It cannot be estimated at this time what effect organic substances in the Pennsylvanian rocks might have on sulfate-reducing bacteria in the strata underlying these rocks (i.e., a mixing of waters within the Pennsylvanian rocks with the waters of underlying strata).

ORIGIN OF THE SULFO-SALINE GROUND WATER

Although the primary purpose of this investigation was to determine the distribution of the various types of ground water in Saline County, it was also thought to be of both academic and practical importance that the origin of the sulfo-saline ground water be determined.

In general, most geologists who have noted the saline ground water of north-central Missouri would say that these waters are simply connate waters. Connate or fossil water was originally defined by Lane (1927) and Lane and Alter (1941) as water that has remained since burial with the specific rocks

in which it occurs without change in chemical composition. Such water almost certainly does not exist. There is overwhelming evidence that changes in the chemical composition of interstitial water in sediments begin almost immediately and that any original water is never preserved unchanged. White (1965) defined connate water as water that has been out of contact with the atmosphere for at least an appreciable part of a geologic period. Most connate waters are probably marine in origin and are associated with marine rocks. It seems most likely that the sulfosaline ground waters of Saline County and north-central Missouri are connate waters which have derived their chemical composition through various physical, chemical, and biological mechanisms.

The manner in which sulfate-reducing bacteria such as *Desulfovibrio* sp. have changed the chemical composition of the ground water has been explained previously in the text. The author believes that these chemical changes resulting from biological activity resulted after the ground water had already been modified by physical and chemical mechanisms.

In 1965 White proposed certain chemical ratios of ions as being characteristic of various types of waters. A comparison of saline water taken from two of the saltier springs (Blue Lick, 49-21-21dcl and Salt Branch, 50-20-28ddl) with some of these "characteristic" ratios of waters of different origins is presented in table 8. It can also be seen from this table that the present saline ground water differs quite a bit from ocean water. There is very little similarity to magmatic, metamorphic, or evaporite-derived waters.

White (1965) has divided connate waters with an original marine origin into two types based upon which side of a shale membrane they occur. These two types of shale membrane waters are formed by the "salt-sieving" action of semipermeable membranes in shale that permit water molecules to pass through but retain more or less of the dissolved salts. This mechanism is most effective in explaining the changes in salinity of interstitial waters. "Membrane-filtered connate water" applies to connate water on the output side of an effective shale membrane and "membrane-concentrated connate water" applies to the more saline water retained behind the membrane.

Many of the chemical ratios of the saline water of Saline County are quite similar to the chemical ratios indicated for membrane-concentrated water (tbl. 8), but the same may be said in relation to the membrane-filtered water.

However, it appears that because the chemistry of the saline water is largely controlled at the present time by the mineralogical environment the chemical ratios used by White cannot be used to determine the origin of the salinity of the Saline County ground water. Carpenter and Miller (1969) have shown that lithium, sodium, potassium, and bromide all react with materials in the country rock to some extent. They also conclude that ion activity ratios such as K^+/H^+ , Ca^{++}/Mg^{++} , and SR^{++}/Ba^{++} appear to be controlled by reactions with specific minerals. The ion ratios used by White are not of use in determining the origin of the saline water since it is clear that there has been ample opportunity to change its composition substantially. Considering these results it seems most reasonable to postpone attributing the origin to a definite mechanism since chemical interaction between the saline waters and the country rock has effectively masked the original chemical ratios.

We can say that the saline water in north-central Missouri may be best described as a connate water which probably had its origin either by the entrapment of sea water by marine sediments or by shale membrane filtration of more dilute waters.

Certainly a detailed study of the hydrologic conditions which exist regionally will aid in a more definite answer. The existence of artesian conditions in the deeper strata as a result of heads established at the apparent recharge areas may either serve to flush out the saline waters with more dilute waters or may even serve as a mechanism for active shale-membrane filtration by providing the driving force as has been proposed by Bredehoeft, et al. (1963). The problem can only be solved by a regional study, which was beyond the knowledge available at the time of this investigation.

TABLE 8
Chemical Characteristics of Various Waters as Compared to Saline County Ground Water

Ratios by weight	Blue Lick 49-21-21dcl	Salt Branch 50-20-28ddl	Ocean water [#]	Connate		Magma- tic ⁺	Meta- morphic [@]	Evaporite ^{**}
				membrane [%] conc.	membrane ^{&} filt.			
Ca/Cl	0.084	0.091	0.021	*0.11	*0.033	. . .	. . . . .	0.069
Mg/Cl	0.031	0.032	0.067	0.021	0.012	. . .	. . . . .	0.0062
Sr/Cl	0.0021	0.0021	0.00070	0.0018	0.0012	. . .	. . . . .	. . . . .
Na/Cl	0.51	0.52	0.53	0.47	0.62	. . .	*0.98-8.85	0.54
K/Cl	0.0079	0.0087	0.020	0.0036	0.014	. . .	. . . . .	0.0036
Li/Cl	0.00026	0.00027	0.00001	0.00029	0.00049	. . .	. . . . .	0.00024
HCO ₃ /Cl	0.018	0.040	0.0074	*0.00080	*0.067	0.1	*5.	0.0024
SO ₄ /Cl	0.080	0.093	0.14	*0.011	*0.00041	0.1	0.05	0.0077
Br/Cl	0.0029	0.0035	0.0034	0.0038	0.0035	*0.0015	0.002	*0.00056
I/Cl	. . . . .	0.00005	0.000003	*0.00019	*0.0020	*0.0000	*0.002	0.00014
B/Cl	0.00035	0.00047	0.00024	*0.00004	*0.014	*0.02	*0.1	0.00042
Mg/Ca	0.37	0.36	3.2	0.19	0.38	*0.06	0.6	0.089
Ca/Na	0.16	0.17	0.038	0.24	0.053	*0.03	0.05	0.13
K/Na	0.0154	0.0166	0.036	0.0077	0.022	0.10	*0.02	0.0066
Li/Na	0.0005	0.0005	0.000009	0.00062	0.00079	*0.006	*0.002	0.00044

* Considered to be particularly characteristic of this type of water (White, 1963 and 1965).

Rankama and Sahama (1950)

% White (1965, Table I): brine from Ste. Genevieve limestone (Mississippian), Saline Co., Ill., depth 2,900 feet.

& White (1965, Table I): brine from Phacoides sandstone (Miocene), Kern Co., Calif., depth 3000'

+ White (1963, Table 29): median ratios, by weight, geyser waters presumed to contain magmatic (volcanic) waters.

@ White (1963, Table 29): median ratios, by weight, springs that may contain metamorphic water.

** White (1965, Table I): brine from Yegua sandstone (nonmarine, Middle Eocene), Fort Bend Co., Texas, depth 6,850 feet.

CONCLUSIONS

GEOLOGY

Paleozoic sedimentary rocks in Saline County, Missouri have been deformed by a series of northwest-southeast trending anticlines and normal faults. Displacement on the faults is less than 200 feet, and closure on the anticlinal structures does not exceed 250 feet. Rocks as old as the St. Peter Sandstone (Ordovician) have been exposed as a result of the faulting. Dissection of the anticlines by stream ero-

sion has exposed formations as old as the Callaway (Devonian). Deformation of the strata began before Kinderhook time and climaxed with the development of normal faulting parallel to the anticlines in late Mississippian or early Pennsylvanian time. These structures are partially concealed by glacial deposits. Glacio-fluvial sediments are present as drift, glacially-ponded sediments, and glacial stream valley fill.

GROUND WATER

Nine water quality areas have been outlined on a water quality map of Saline County and recommendations for obtaining better water supplies have been made where possible. A detailed study of the glacial deposits would probably result in the discovery of useful water sources in certain areas. "Mottling" of children's teeth in southwestern and western Saline County seems to be a result of a high fluoride content in ground water.

The distribution of sulfo-saline, saline, and "fresh" water in Saline County is influenced by four major factors: Pennsylvanian shale cover, depth, local structure, and biochemical activity. Pennsylvanian shale cover inhibits the "freshening" of saline waters by meteoric waters and favors the accumulation of hydrogen sulfide beneath the shales. The ground

water becomes progressively more saline with depth and tends to be more saline on the flanks of the anticlines and in the faulted troughs. It is fresher on the crests of the anticlines which are also topographic highs. The presence of sulfate-reducing bacteria (*Desulfovibrio* sp.) has resulted in a lowering of the SO_4/Cl ratio and produced high concentrations of hydrogen sulfide in the ground water.

It appears that because the chemistry of the saline water is largely controlled at present by the mineralogical environment it is not possible to use chemical ratios to determine the origin of the salinity of the groundwater in Saline County. The saline water in Saline County may be best described as a connate water which probably had its origin either by the entrapment of seawater by marine sediments or by shale membrane filtration of more dilute waters.

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APPENDIX

Table 1	Record of Wells
Table 2	Specific Conductance
Table 3	Additional Chemical Analyses

TABLE 1
Records of Wells

Well: see text for description of system.

MGS No.: Refers to log number as recorded at the Missouri Geological Survey.

Owner: Owner or occupant of property.

Yr.: Year well was drilled.

Dr.: Driller ---- AB, Allen & Brown; AM, A. Moore; AW, A. Weston; CB, Cullum & Brown; CC, C. Calhoun; CR, C. Robb; EH, E. Hammer; ET, E. Thompson; FA, F. Allen; GB, G. Bradford; JC, J. Calhoun; JH, J. Hume; JL, J. Lockney; JT, J. Thompson; LW, Layne-Western; ME, Maib Eng.; OM, O. Monsees; PD, Petroleum Drill Co.; RR, Robb & Riggs; RT, R. Thompson; SF, S. Fulkerson; ST, W. Steffens; SW, Sewell Well Co.; WS, W. Schnell; WT, W. Thompson; WW, W. Walten.

Elev.: Elevation of well (MGS checked w/Paulin altimeter)

Diam.: Diameter of well (inches)

Csg.: Depth of casing (feet) from surface.

Prod. gpm: Production in gallons/minute

Aquifer (depth): Water-bearing horizons and depth encountered. BR, Burlington residuum; B, Burlingt. BT, Bonnetterre; Ch, Chouteau Group; C, Cotter; Cn, Compton; D, Davis; Dv, Devonian (Callaway); E, Eminence; G, Gasconade; GD, Glacial Drift, Gu, Gunter; DD, Derby-Doerun; JC, Jefferson City; K, Kimmswick; L, Lamotte; N, Northview; P, Pennsylvanian; Po, Potosi; PC, Precambrian; R, Roubidoux; S, Sedalia; SP, St. Peter.

Penetr. basal form.: Basal formation and amount of penetration (abbreviations as above).

SWL (date): Level of water from surface and date of measurement.

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 48 N., R. 20 W.

2cb1	10349	F. Treece	47	RT	801	86	6	75	45	BR 50	B 86	25 1947	
4dc1	23260	R. Thomas	..	WS	778	410	6	313	..	JC (?)	JC 55	poor sampling
5aa1	10340	W. Simmons	..	RT	790	180	6	52	0.5	B 60	Ch 45	50	
5dd1	6060	J. Hopkins	39	OM	790	175	6	43	1	S 80	Ch 98	.... 45 1939	can bail dry drawdown 55 ft.
6cc1	22369	C. Seifkas	63	WS	806	435	6	189	50	JC (?)	JC 105	180 1963	
7cb1	11762	J. Marshall	50	WS	802	414	6	85	..	JC (?)	JC 54	....

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 48 N., R. 20 W. - continued

9ba1	7696	E. Holt	41	WS	805	450	6	75	20	JC 440	JC 95	140 1941	fresh water
9ba2	17026	W. Marshall	57	WS	803	590	..	...	..	JC-R (?)	R 80	....	samples may be mixed
10aa1	18176	J. Jones	59	RT	818	110	6	95	15	B 70, 90, 105	B 40	47½ 1959	
11bc1	10348	J. Jones	47	RT	792	120	6	67	18	B 58	S 35	32 1947	
11bc2	22364	Stuckey's	63	..	796	480	6	217	50	JC (?)	JC 115	180 1963	
11ad1	6218	W. Southard	40	WW	781	470	6	147	15	Ch 140, 180- 210 C 260- 295 JC 450, 470	JC 78	130 1940	at 210 feet 25 gpm w/100 feet drawdown at 470 feet 15 gpm w/30 feet drawdown. JC main supply
16dc1	12737	R. Jenkins	54	WS	759	480	6	158	..	JC (?)	JC 165	....
18ac1	17030	Schanz Sisters	58	WS	792	544	..	...	..	JC-R (?)	R 79	....	sp. cond.

T. 48 N., R. 21 W.

3dc1	11761	Viola Baptist Camp	51	WS	742	483	6	93	..	JC (?)	JC 123	100 1951	
5bc1	7379	Wm. Jewell	41	CC	722	500	..	...	..	JC (?)	JC 110	....	110 ft. drawdown
6db1	6530	C. Kemper	40	JC	710	420	..	...	15	Dv-C (?)	C 95	30 1940	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form	SWL (date)	Remarks
T. 48 N., R. 21 W. - continued													
6cal	22210	Jr. Copas	63	CR	729	730	8	612	25	JC-R (?)	R 100	100 1963	
7cd1	15988	J. Mullins	57	WS	728	475	6	108	40	JC (?)	JC 120	60 1957	35 ft. drawdown
8cd1	4204	C. Phillips	36	OM	747	308	6	64	1	B 58	C 71	....	chem. anal.
9cd1	6147	Forest Grove Sch. Dtr. 109	40	WS	750	411	6	85	..	Dv 180 JC (?)	JC 91	84 1940	
10ab1	6989	P. Igoe	41	WW	788	230	6	52	8	B-S (?)	Dv 10	50 1941	
10bb1	4297	H. Hauley	37	CC	767	407	6	140	..	JC (?)	JC 107	....
10ad1	11457	Texaco	50	WS	791	485	6	100	..	JC (?)	JC 165	130 1950	drawdown 150 feet
12ac1	13049	Blackwater 100 School	54	..	820	580	6	316	25	JC-R (?)	R 75	....	drawdown 12 feet sp. cond.
13cb1	6156	N.W. Mutual Life Insur.	40	WS	792	513	6	125	..	JC (?)	JC 53	125 1940	fresh water
14ca1	18415	J. Ezell, Jr.	59	WS	800	500	6	160	20	JC (?)	JC 100	....	poor samples
15ac1	21626	Producers	63	WS	819	586	6	320	75	JC-R (?)	R 66	....	poor samples
15ac2	22390	Producers	63	WS	821	654	6	317	75	JC-R (?)	R 124	180 1963	poor samples
15cb1	18829	W. Tooker	59	WS	785	485	..	...	20	JC (?)	JC 125	140 1959	
16db1	11588	N. Wright	51	WS	758	437	..	...	..	JC (?)	JC 137	....	no drawdown. sp. cond.
17dd1	11049	R. Mitchell	47	RT	769	250	8-6	120	1.5	B 40	Dv 5	25 1947	
17dd2	15293	Mrs. Mitchel	56	WS	775	818	6	103	...	JC-R (?)	R 43	....	sp. cond.

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 48 N., R. 22 W.

4bal	9637	Trinidad Asphalt	46	FA	734	470	C 5	
17dal	7399	A. Urton	41	CC	710	150	B-Ch (?)	Ch 45	drawdown 80 feet
18acl	18823	H. Vogelsmeier	59	..	660	410	6	173	20	C (?)	C 110	flows 1959	

T. 48 N., R. 23 W.

2ca	23226	Mo. Hwy. Dept.	..	WS	693	440	...	...	...	C (?)	C 75	.....
2cc1	2290	Sweet Spr.	30	SW	721	567	10	121	50	JC (?)	JC 92	.....	drawdown 250 feet
2cc2	2379	Sweet Spr.	38	SW	729	570	10	111	75	JC (?)	JC 90	40 1938	
3dal	14451	N. Britt, Jr.	55	WS	700	405	...	...	...	C (?)	C 75	.....	drawdown 80 feet drawdown 173 feet JC-R main supply
6cc1	8231	Emma Cream.	43	JC	755	610	6	185	25	JC (?)	JC 95	.....
7bb1	11400	Emma Cream.	50	AB	745	750	10	189	75	P 21,112 B 175, 225 JC 580, 670 R 730	R 60	77 1950	
8aal	12328	C. Heafer (Butcher Br)	53	PD	704	2117	...	...	...	.....	PC 157	.....	oil test to granite
10cb1	10498	H. Muller	48	RT	665	229	10	79	1	S 180	Ch 99	50 1948	
11acl	11651	G. Hall	51	WS	680	392	6	43	...	C (?)	C 137	flows 1951	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 48 N., R. 23 W. - continued

12dd1	23241	J. Vogelsmeier	..	WS	699	400	6	162	...	C (?)	C 50	
13bb1	18491	L. Wing	59	RR	704	417	6	59	5.2	C 122	45	
15ad1	.....	Sweet Spr. "Gusher"	02	JH	670	1069	...	...	840 in 1902 130 in 1967	.....	Gu (?)	flows 1967	sulfo-saline chem. anal. flow less now oil test (?)

T. 49 N., R. 19 W.

2db1	.....	A.&H. Hogge	..	WS	684	95	6	40	low	B (?)	S 10	.....
2cc1	6310	A.&H. Hogge	40	WS	731	268	8-6	79	...	S (?)	SP 16	.....	saline chem. anal.
3dd1	12980	E. Townsend	53	WT	766	257	6	53	low	S 140 SP 257	SP 7	76	sl. saline in St. Peter
10ba1	13288	Dr. Lawrence	54	WT	670	90	6	40	7-8	B 80-85	B 50	70	
16bb1	12982	F. Wilkerson	54	WT	655	172	6	10	1	B 160	B 172	1954	
18bd1	6531	Vandyke Co.	40	WS	690	617	6	110	...	C 575	JC 17	1954	saline - Cotter

T. 49 N., R. 20 W.

2cb1	13759	C. Shannon	55	RT	670	205	6	22	low	B 126	Ch 40	.....
3ba1	16395	J. Cornell	57	RT	667	210	6	65	2½	B 100, 198	B 170	40	sulfurous at 198 feet

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 49 N., R. 20 W. - continued													
3ccl	21621	H. Stouffer	62	WS	690	332	6	245	...	.....	Dv 74	.....
3ddl	7360	S. Abney	41	WT	645	95	6	68	40	B 85	B 95	35	
												1941	
5aal	11312	R. Field	47	WT	695	137	6	39	30	B (?)	B 102	37	
5dcl	21630	J. Clark	62	WS	719	300	6	297	...	.....	Dv 35	.....
6abl	5059	Thorp Sch.	38	WS	710	111	...	...	...	B (?)	B 91	.....
6cal	6934	Mrs. Fisher	41	WT	726	165	6	42	...	.....	Ch 30	.....
9ccl	18001	Smith Chapel	..	WS	707	180	...	...	...	.....	Ch 70	.....
11abl	14289	C. Smith	55	RT	655	140	...	...	dry	.....	B 90	.....
14acl	10137	C. Clough	48	RT	685	405	6	45	32	B 64-65 C 390-405	C 70	35	
												1948	
15aal	10133	R. Harvey	48	RT	724	196	8-6	196	4	B 55 S 136	Ch 61	25	
												1948	
15dbl	3704	P. Rose	36	WT	725	407	6-5	...	7	SP-C (?)	C 77	.....	fresh water chem. anal.
17cdl	19465	C. Duncan	56	JT	790	575	6-5	...	180	SP-C (?)	C 225	100	lower Cotter
												1956	probably JC
												105	no drawdown
18aal	5851	Wm. Davis	39	WS	767	566	6	148	25	JC (?)	JC 171	1939	
29acl	17785	E. Yeagle	58	WS	759	440	6	273	25	JC (?)	JC 75	105	
												1958	
29dbl	15048	J. Ellis	56	RT	689	215	6	26	3.3	Dv 155 C 205-210	C 55	4	oil on water
												1956	driller's note
32cal	10536	J. McCoy	48	RT	771	240	6	65	10	B 10 SP 230	SP 20	90	
												1948	
35ddl	7697	E. W. Reed	41	WS	669	344	6	40	10	JC 335	JC 54	30	fresh water
												1941	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 49 N., R. 21 W.													
1cb1	23257	W. Hinton	64	WS	724	520	6-5	292	....	JC (?)	JC 100	.....	poor samples fresh water
3ba1	11175	J. Buck	49	WT	791	335	6	62	3	SP 300	SP 45	80 1949	
4dd1	11308	W. Ballard	47	WT	742	180	6	47	....	.....	Ch 40	.....
5bc1	19471	G. Sandidge	57	JT	759	435	6	93	12	C 425- 440	C 85	.....
5cc1	23244	G. Marsh	..	WS	732	506	6-5	167	....	JC (?)	JC 46	.....	chemical analysis
6ba1	5550	E. Barr	39	CC	764	315	6	148	25	Dv (?)	Dv 40	90 1939	
6bb1	9236	R. Barton	46	GB	715	362	6	79	4	.....	Dv 77	.....
8ab1	21659	M. Reynolds	63	WS	720	400	6	120	....	C (?)	C 55	.....
9aa1	21980	J. Vardiman	63	WS	735	324	6	69	....	Dv-SP(?)	SP 44	.....
9ac1	23242	Mrs. Kloeppel	..	WS	729	449	6	13	2	Dv-C (?)	C 139	40	
9db1	9813	J. Hummel	46	JT	758	300	8-6	300	11	S 170	Dv 60	77 1946	
11cb1	5743	E. Shannon	39	WT	802	500	6	94	....	B 100 C 310 JC 455, 490	JC 60	94 1939	4.5 gpm at 180 feet 5 gpm at 200 feet 1 gpm at 100 feet w/SWL 42 feet 3 gpm at 310 feet w/SWL 52 feet
11cc1	8192	W. Lacy	42	WT	794	390	6	105	3	.....	C 70	.....
12bb1	16929	M. Yeagle	57	WS	779	530	6	168	10	JC (?)	JC 90	125 1957	
12cb1	23256	C. Stouffer	64	WS	769	520	6-5	175	50	JC (?)	JC 90	140 1964	top of casing at 204 feet
13bd1	22329	J. Davis	63	CR	799	510	6-5	248	....	B 140	JC 135	210 1963	chemical analysis
15ad1	4115	O. Woodsmall	36	WS	775	350	6	66	....	SP (?)	C 10	100 1936	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod.	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 49 N., R. 21 W. - continued

17cd1	2815	W. George	34	WT	715	150	6	52	0.5	S 114 Ch 121	Ch 58	40 1934	
22ad1	9810	E. Kephart	46	WT	784	320	6	43	9	.....	C 115	112	
23dd1	22024	Mrs. Pointer	63	CR	810	490	6	305	15	JC (?)	JC 165	180 1963	
25bc1	9814	F. Spreitzer	46	WT	787	302	6-4	119	5	C 230, 240 JC 270- 295	JC 42	123 1946	
25cc1	9815	J. Landreth	45	WT	712	283	6-5	40	24	C 165 JC 225- 230 240-283	JC 83	43 1945	
27ad1	2816	J. Leimkueh- ler	34	WT	690	101	...	...	dry	.....	Dv 41	.....	well caved
34da1	23101	Mo. Hwy. Dept.	..	..	754	421	6	306	...	C-JC (?)	JC 71	164	
34db1	13287	W. Norman	54	WT	743	360	4	280	15	C-JC (?)	JC 35	80 1954	80 feet drawdown at 170 feet
34db2	22385	K. Mitchell	63	WS	759	390	6-5	244	...	.....	C-JC 140	.....

T. 49 N., R. 22 W.

2bb1	9958	W. Barr	47	RT	772	504	6	138	...	Dv-C (?)	C 79	130 1947	21 gpm at 350 feet
9bc1	17154	A. Simms	58	RR	798	490	5	353	5	SP 480- 490	SP 25	155 1958	sl. saline sp. cond.
13cc1	16932	K. Scott	57	WS	762	400	6	155	1.5	.....	C 75	115 1957	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 49 N., R. 22 W. - continued													
13dd1	5174	C. Kemper	38	JC	762	285	....	155	....	B (?)	B 115	....	chemical analysis
15cb1	10347	H. Langewisch	47	RT	770	62	6	57	low	P 40	P 62	....
16ab1	5426	M. Perkins	39	JC	789	630	6-5	221	20	B 280 C 560	JC 45	135 1939	15 feet drawdown 3 chemical analyses
16cb1	10107	H. Pittman	47	RT	760	130	....	134	2	P (?)	P 75	56 1947	
17ca1	10116	L. Norvell	47	RT	768	100	6	104	1	P 70	P 75	40 1947	
25bd1	12179	P. Dennis	52	RT	744	39	6	34	7.5	GD (?)	GD 39	27 1952	
26aa1	18010	L. Roscher	59	WS	756	596	6	242	....	Dv-C-JC (?)	JC 81	45 1959	screen at 390-435 feet
T. 49 N., R. 23 W.													
3aa1	11169	W. Weisenberger	46	ST	772	570	6	208	10	Dv-SP (?)	SP 35	110 1946	sp. cond.
3ca1	15308	R. Arni	56	WS	775	560	6	238	....	Dv-SP (?)	SP 30	....	sulfo-saline chemical analysis
4ac1	20277	USAF	61	CB	805	585	....	...	....	Dv-SP (?)	SP 20	....	1220 ppm chloride 96 ppm sulfate poor samples
12bd1	6009	C. Houchen	40	JL	754	515	6-4	222	4	Dv-C (?)	C 30	100 1940	
27aa1	12739	R. Knipmeier	54	WS	702	440	6	177	....	.....	SP 25	100 1954	pump at 200 feet

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 50 N., R. 19 W.													
3ad1	22384	C. Blumhorst	63	WS	762	315	6	217	3	B (?)	S 15	90 1966	sp. cond. pump at 300 feet
4bd1	22379	J. Blumhorst	63	WS	740	325	6-5	298	40	B-Ch (?)	Ch 30	110 1963	
4ad1	16765	R. Borgmann	57	RT	722	45	6	40	20	GD (?)	GD 45	27 1957	well screen is casing
8dd1	4117	Mrs. Deane Liemkuehler	36	WS	728	265	...	...	...	.....	Ch 90	20 1936	chemical analysis
8dd2	12924	F. & R. Leimkuehler	54	RT	746	69	6	58	8	GD 38	GD 52	33 1954	no drawdown well screen
17bal	12129	R. Leimkuehler	52	RT	782	463	6	127	8	.....	SP 73	90 1952	old well drilled to 271 feet in 1914
20aal	5833	Wm. Davis	40	WT	770	385	6-5	213	...	Ch 255 B 175, 200	SP 70	130 1940	6 gpm at 175 feet in Burl. 12 gpm at 200 feet Burl. 50 feet drawdown
20dd1	5740	Hardeman Sch.	39	WT	760	296	6	96	14	.....	SP 41	98 1939	
22cal	14783	E. Kammeyer	55	RT	755	161	6	26	15	B 135- 145	B 146	67 1955	15 gpm at 140 feet
26acl	14784	R. Thompson	55	RT	737	195	6	43	12	B 180 35-40	B 160	52 1955	12 gpm at 180 feet
27abl	14785	C. Rinne	55	RT	779	86	6	86	30	GD 70-80	GD 86	64 1955	
31bal	18797	S. O'Dell	..	RT	...	85	...	...	...	GD (?)	GD 85	....
36bal	12983	Evangelical Reform Ch.	54	..	704	163	6	42	4	B 130- 163	B 163	78 1954	
36bb1	22386	T. Williams	63	WS	721	230	6	81	30	B-Ch (?)	Ch 30	90 1963	
36bc1	15295	Arzubright	56	WS	723	214	6	97	...	B (?)	S 9	....

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 50 N., R. 19 W. - continued

36ac1	22377	E. Green	..	WS	737	211	6	97	5-6	B (?)	S 5	90 19??	
36ad1	Arrow Rock State Park	65	74	30	52	150	alluvium	B 1	8 1965	3 feet 10 inches draw-down after 6 hours screen

T. 50 N., R. 20 W.

2aal	12431	P. Borgman	53	RT	819	225	6	75	6-8	B 180-185	B 160	80 1953	fresh water sp. cond.
3cd1	22375	J. Morrow	63	WS	790	207	6	98	30	B-Ch (?)	Ch 72	50 1963	
3dc1	19888	D. Myers	61	WS	785	220	6	82	4	B-Ch (?)	Ch 40	50 1961	
6cc1	15585	H. Gibson	56	RT	724	77	...	..	12	GD 69	GD 77	68 1956	
7cb1	15638	A. Granneman	56	RT	754	115	...	..	12	GD (?)	GD 115	....
8cb1	12410	W. Mallman	53	RT	749	135	...	..	10	GD 120	GD 85	120 1953	50 feet loess cover
9cb1	12881	E. Murphy	54	RT	756	135	...	..	dry	.....	GD 105	....	30 feet loess cover
9cb2	12882	E. Murphy	54	RT	753	126	...	..	4	GD 105	GD 96	96 1954	30 feet loess cover
10dd1	11313	Miss Alice Drumett	47	WT	770	200	6	40	10	B 55	Dv 25	18 1947	150 feet from 9 cb1 10 gpm at 180-200 feet
14ab1	9811	J. Benedic	46	JT	776	100	6	31	6	B 60 S 100	S 35	20 1946	
16cc1	4819	Mrs. J. S. Lewis	38	WT	723	76	...	...	...	GD (?)	GD (?)	39 1938	loess cover (?)

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 50 N., R. 20 W. - continued

18dc1	10134	M. Wade	48	WT	746	90	6	86	8	GD (?)	GD 90	87 1948	well screen
19ac1	12984	Toffelmeyer	52	RT	710	126	...	...	...	B 126	B 66	....	saline - abandoned
20cc1	12127	J. W. Miller	51	RT	711	120	6	79	24	GD (?)	GD 120	47 1951	
29db1	11303	A. Bishop	47	..	701	230	...	...	...	B (?)	B 115	....	saline
30ca1	8181	T. Bakin	42	..	697	300	...	...	3	.....	Dv 30	....
30cc1	18011	E. Clough	59	..	701	260	...	...	...	B-Ch (?)	Ch 95	....
31bb1	18009	F. Clough	59	..	704	410	...	...	...	.....	C 98	....	chemical analysis Cotter ?

T. 50 N., R. 21 W.

1ca1	16381	G. Hoyes	57	WS	708	400	6	89	6	.....	Dv 55	64 1957	
2dd1	4034	J. R. Black	36	AM	756	373	6	238	15	B 235, 373, 346	B 136	....	SWL at 187 feet was 70 feet. SWL at 346 feet was 140 feet chemical analyses
3bb1	12576	M. Schanz	53	RT	753	97	...	no	12	GD 80	GD (?)	....	loess cover. boulders from 67 feet to bottom
3dd1	14290	N. T. Hord	55	RT	757	116	...	...	8	GD (?)	GD 116	95 1955	
10aa1	23258	J & H Carp Lake	..	WS	747	501	6-4	363	...	SP-C (?)	C 74	....
10dd1	10132	Marshall Ice	48	RT	779	130	10	116	0.5	GD 22	GD 130	107 1948	14 feet screen chemical analysis

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 50 N., R. 21 W. - continued													
11db1	11801	Missouri State Sch.	51	RT	749	101	...	...	60	GD 82	GD 101	82 1951	some loess cover
11ac1	5816	Missouri State Sch.	37	AM	737	1785	15	105	50	.....	BT 50	65 1939	20 feet drawdown series of chemical analyses
11cc1	.....	Rea & Page Milling Co.	13	ET	748	452	...	...	5.5	SP 422	SP 30	60 1913	sulfo-saline chemical analyses
13ad1	15583	W. N. Ruff	56	RT	747	100	...	...	...	GD 95	GD 100	....	abandoned
13dc1	5725	G. Mooney	39	WT	746	123	6	87	8	B 110	B 43	90 1939	fresh water
15ca1	5924	Mun. Util. Co.	40	WT	770	133	...	...	...	GD 113- 131	GD 133	....	abandoned
15ca2	6308	Mun. Util. Co.	40	WT	770	125	...	...	...	GD 98	GD 125	....	60 feet south of 15ca1
18da1	3469	Marshall Elm Grove Sch. Dtr. 61	35	WT	752	260	8-6	116	8.5	B 190, 248	B 150	70 1935	fresh water
23cc1	14782	E. Eberhart	55	WT	758	215	6	87	5-6	B 75, 185	S 15	83 1955	ZnS in the Sedalia
24aa1	12520	R. Bowler	53	WT	725	220	6	75	1.5	B (?)	B 175	57 1953	fresh water
24ca1	18759	F. Kennedy	60	RT	732	405	6	112	0.75	B 155 C 385- 390	C 50	68 1960	
24cb1	6191	McQuistin	..	WT	708	225	...	...	4	B-Ch (?)	Ch 30	....	chemical analysis
26bb1	13046	Rasse	54	WS	769	449	8-6	113	...	.....	C 51	120 1954	
26cc1	11307	H. Mueller	47	WT	768	188	8-6	98	1.5	B 65, 150	B ?	114 1947	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 50 N., R. 21 W. - continued													
26cc2	10558	H. Mueller	48	WT	768	463	8-6	208	5	Ch 280 Dv 355	C 83	105 1958	5 gpm at 280 feet
26cc3	10557	H. Mueller	48	WT	772	450	6	178	3.5	C 380, 410 C 425- 450	C 70	115 1948	3.5 gpm at 280 feet
27aa1	11647	L. Turner	51	WS	775	475	6	126	...	Ch 280 C (?)	C 80	....
28dd1	.....	J. Carroll	99	ET	790	465	...	...	5	Sand 115 Miss 250 Shale 455	Miss ?	310 1899	sulfo-saline abandoned saline at 455 feet
28dd2	2838	H. W. Winn	34	WT	715	300	6	65	0.7	.....	Dv 10	30 1934	
29da1	19475	E. Bales	57	JT	781	212	6	165	0.4	B (?)	B 65	50 1957	
32cb1	12488	M. Shull	53	WT	758	435	6	124	...	B 162- 180 C 411- 435	C 35	85 1953	
35cb1	5744	R. Nicholas	39	WT	778	547	6	102	15	B 150 C 395 JC 450- 547 Increase in water in JC	JC 52	118 1939	78 feet drawdown 12 gpm at 150 feet SWL 128 feet at 395 feet SWL 118 feet at 450 feet chemical analyses

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 50 N., R. 22 W.													
2dbl	12408	W. Harrison	53	RT	759	105	2.5	...	12	GD 90	GD 75	....	loess cover
3cc1	10140	F. Klinge	48	RT	731	70	...	...	...	P (?)	P ?	....
5ac1	11806	M. Branson	51	RT	760	99	...	...	good	GD 83	GD 99	83	sand point well
												1951	
6bc1	10136	L. Houston	..	RT	770	55	6	55	...	GD (?)	GD 55	....
12dbl	16665	Ch. Ash	57	RT	723	50	2.5	...	5	GD 45	P 1	38	sand point well
												1957	
22bc1	13686	Rowe Sisters	55	RT	757	175	...	...	...	.....	B 70	....	abandoned
22cb1	13526	Rowe Sisters	55	RT	747	200	...	...	0.33	B 140- 155 192.5	B 110	100	sulfurous water at 192.5 feet
												1955	
25cb1	10178	T. Barr and Sisters	47	RT	778	410	6-4	374	1	B 264	Dv 55	145	
												1947	
28dd1	10528	E. E. Elsea	48	RT	794	425	...	...	33.5	P 30 SP 423	SP 20	....	sulfurous water at 423 feet well capped
29aa1	12577	A. H. Elsea	54	RT	730	100	6	70	low	.....	B 30	18	only water in loess at 32 feet
												1954	
29ac1	5736	Fulkerson School	39	RT	718	305	...	...	...	P 35 Dv 305	Dv 43	....	sulfo-saline at 305 feet. Plugged at 112 feet.
29cb1	.....	P. Fulkerson	14	SF	760	510	...	...	20	SP 460- 510	SP 50	40	chemical analysis only record is 460-510 feet
												1914	
32dd1	4223	Archie Van Anglin	36	RT	754	197	2.5	122	...	P 110- 122	P ?	110	quicksand 100- 197 feet
												1936	
32dd2	13474	Archie Van Anglin	55	RT	773	122	...	...	6	GD (?)	GD 122	100	
												1955	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 50 N., R. 23 W.													
9aa1	9878	E. Nightwine	48	RT	730	460	6	153	....	B 385 Ch 410, 440, 445	Ch 50	....	3 gpm at 325 feet saline water in Chouteau
10da1	.....	J. Robertson	..	..	750	480	...	...	....	SP 470	SP ?	....	chemical analysis log only 470-480 feet
11bc1	11357	M. Robertson	50	RT	798	89	2.5	...	15	GD 80	GD 89	....	loess cover
11dd1	15586	G. Thompson	56	RT	777	90	...	...	12	GD (?)	GD 90	77 1956	
13bb1	6476	G. Wright	40	RT	777	89	...	...	....	GD (?)	GD 89	....
13dd1	6122	M. Robertson	40	RT	815	515	6-4	305	....	Ch 350 SP 465	SP 55	....	at 350 feet slightly saline
26aa1	21647 22294	Mo. Hwy. Dept.	63 64	..	810	425	...	...	0.5	P or GD 150	Ch 70	....	well deepened then plugged to use upper water. sp. cond.
33dd1	.....	E. G. Leurhs	57	CH	770	519	...	...	...	SP 500	SP 19	....	Chemical analysis sulfo-saline
T. 51 N., R. 19 W.													
8cc1	22393	C. H. Kruse	63	WS	787	310	6	87	25	SP (?)	SP 60	150 1963	
16bb1	16092	Richardson	57	WS	787	300	6	128	...	SP (?)	SP 25	....	fresh water
19ab1	10350	Fizer Bros.	47	RT	802	380	...	...	3	B 370	B 80	75 1947	
29bc1	.....	J. Stafford	13	EH	835	490	6-4	...	....	SP 485	SP 5	75 1913	fresh water chemical analysis
30bc1	7520	L. C. Bridges	41	WT	821	356	6	212	25	B 290, 335-350	S 1	130 1941	220 feet drawdown fresh water

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 51 N., R. 20 W.													
3ca1	10560	J. G. Lyne	48	WT	862	510	6-4	287	....	P 175-200 Ch 475-480	Dv 20	110 1948	15 gpm at 200 feet 11 gpm at 175 feet
6da1	5832	Rhodes	40	RT	786	440	...	...	....	B 165 SP (?)	SP 90	100 1940	4 gpm at 165 feet
7ab1	9235	H. Bailey	46	GB	791	215	8-6	124	2.5	B 109, 185	CH 25	....	1 gpm at 109 feet
8dc1	9959	Mrs. O'Rear	47	RT	803	95	6	80	10	GD 50	P 30	25 1947	
9ac1	20056	R. Pollock	60	WS	840	585	6	204	15	.....	SP 50	250 1960	
11ac1	3900	City of Slater	11 12	..	861	889	...	...	35	S 375-400 SP 615 R 876	R 28	....	Roubidoux is salty poor samples
12db1	12738	D. McMallen	54	WS	840	550	6	150	....	SP (?)	SP 35	....	sp. cond. H ₂ S odor
14cd1	10561	Dr. Grimes	48	WT	780	435	6-4	247	....	B 200-218 Dv-SP 418-435	SP 10	110 1948	15 gpm at 200 feet
17da1	10626	S. F. Giger	47	RT	765	200	6	49	2	B 120 Ch 181	Ch 75	....
17dc1	4047	G. Hackley	36	WT	770	168	6	37	1.25	B 73, 134 S 148	Ch 33	48 1936	chemical analysis

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 51 N., R. 20 W. - continued

22ac1	7518	E. Hardin	42	WT	841	308	8-6	305	P 100, 215 220-225 B 225- 308	B 83	45 1942	30 gpm at 100 feet 55 feet drawdown
23ba1	11179	W. L. Boyd	49	WS	776	307	...	...	....	B-Ch (?)	Ch 42	....
23cb1	11311	T. Mitchell	48	WT	772	260	6	64	25	B-Ch (?)	Ch 45	90 1948	
29bc1	7519	J. S. Wall	41	WT	804	232	6-4	66	3.5	B 48 Dv 213	Dv 20	25 1941	fresh water
29cd1	19474	Mrs. Laura McCoy	57	JT	773	255	6-5	...	....	Ch 50 SP 250	SP ?	70 1957	20 gpm at 200 feet poor log
30cd1	10559	H. Wood	48	WT	748	180	6	43	30	SP 160- 180 Dv 120	SP 20	72 1948	30 gpm at 120 feet
33ba1	17276	C. Mitchell	58	WS	784	543	6-5	191	25	C-JC (?)	JC 23	....
33db1	9812	C. Merchant	46	WT	745	241	6	42	3.5	SP 155- 240	SP 85	74 1946	
34dd1	5304	M. Averbek	38	WT	820	400	6	80	...	B 116 Ch 200 SP 337 C 393	C 60	116 1938	

T. 51 N., R. 21 W.

9ab1	12679	P. Brooks	53	RT	773	110	2.5	...	12	GD 85	GD 90	67 1953	tubular well
10da1	21988	Hahn-Phillip Grease Co.	63	WS	759	393	6-4	260	30	SP-C (?)	C 83	100 1963	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 51 N., R. 21 W. - continued

10dc1	4046	Odell Heirs	36	WT	782	226	6	81	10	SP 206-226	SP 21	70 1936	fresh water chemical analysis
11cc1	23232	J. W. Cook	65	WS	749	395	6-5	133	30	SP-C (?)	C 135	160 1965	
13da1	9971	E. Huff	46	WS	750	288	6	65	10	SP 240-288	SP 48	70 1946	fresh water
13ca1	16356	C. Little	57	WS	769	245	6	64	3	.....	SP 25	103 1957	
24ba1	16380	W. H. Kunze	57	WS	760	220	6	68	...	.....	SP 15	....
26ad1	16357	R. Riley	57	WS	728	100	...	74	4	GD (?)	GD ?	65 1957	
28ba1	14499	H. Conrad	56	RT	710	125	2.5	...	12	GD (?)	GD 125	80 1956	tubular well
34aa1	.....	L. Heilman	66	LW	680	146	6	141	25	GD (?)	B 1	54 1966	chemical analysis 15 feet drawdown saline
34db1	11174	H. Wright	49	WT	760	410	6	63	...	Ch 180 SP-C 390-410	C 5	80 1949	5 gpm at 180 feet

T. 51 N., R. 22 W.

16ad1	.....	Marshall City Water	63	LW	694	126	18	...	1016 max.	GD (?)	GD 126	53 1963	partial chemical analysis. Well #7 see text
16da1	.....	Marshall City Water	63	LW	692	12?	18	...	1012 max.	GD (?)	GD 12?	63 1963	p. chemical analysis Well #6 text
19ad1	304	Saline Oil & Develop. Co.	03	..	690	1250	...	...	320	R-G-Gu (?)	E 77	flows 1903	oil test sulfo-saline chemical analysis

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 51 N., R. 22 W. - continued

21aa1	Marshall City Water	46	LW	690	126	18	...	888 max.	GD (?)	GD 126'	32 1946	see text Well #1
21aa2	.....	Marshall City Water	46	LW	690	126	18	...	837 max.	GD (?)	GD 126'	31 1946	chemical analysis Well #2 text
21aa3	.....	Marshall City Water	46	LW	690	126	18	...	748 max.	GD (?)	GD 126'	38 1946	chemical analysis Well #3 text
22bc1	.....	Marshall City Water	52	LW	685	126	18	...	759 max.	GD (?)	GD 126'	36 1952	chemical analysis Well #4 text
22bc2	.....	Marshall City Water	54	LW	685	120	18	...	795 max.	GD (?)	Limest. at 120'	43 1954	no analysis Well #5
24cb1	3095	Blosser et al.	27	..	660	1425	...	...	700	B 134 S 220 SP 469 Po 1295	Po 280	flows 1935	700 gpm Potosi oil test chemical analysis plugged 1935. Some misplaced samples
30cd1	17213	E. Brownfield	58	RT	747	101	2	...	10	GD (?)	GD 101	40 1958	tubular well

T. 51 N., R. 23 W.

18db1	6475	H. K. Thomas	40	RT	805	109	...	...	...	GD or P (?)	form.?	....
19aa1	11804	Dr. Calloway	..	RT	762	85	2	...	10	GD (?)	GD 85	64	tubular well
20ba1	4817	Mrs. Utland	38	RT	805	119	...	...	...	GD (?)	GD 119	....
28aa1	16369	O. Wehmeyer	57	RT	685	86	...	...	2	GD (?)	GD 86	....
31cc1	.....	Blackburn City Water	62	ME	772	78	6	78	...	GD (?)	GD 78	70 1967	31cc1 & 31cc2 produce 20-35 thousand gpd
31cc2	.....	Blackburn City Water	62	ME	772	79	6	79	...	GD (?)	GD 79	68 1967	chemical analysis. #1

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 51 N., R. 23 W. - continued

33aal	5793	Dr. Lowe	39	WT	773	100	GD (?)	GD 100	
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T. 52 N., R. 19 W.

16ba1	7693	W. VanBuren	41	WS	707	242	6	90	...	B 230	B 132	100 1941	salty - no use plugged 1949 6.25 gpm at 200 feet
20ab1	10102	J. L. Gordon	47	RT	775	259	6-4	167	2	B 145	B 149	55 1947	
22dd1	13275	Ch. Jaeger	54	..	687	253	6	...	15	B 200, 230-253	B 158 plus	55 1954	
23cc1	14778	Caroll Harvey	55	JT	711	280	...	...	...	B 145, 250, 282	B 200 plus	....
28cd1	14779	H. D. Powell	55	WT	732	250	6	161	10	B 200- 245	B 185	70 1955	

T. 52 N., R. 20 W.

2bc1	11358	W. E. Clement	50	RT	697	69	6	69	5	B 62	B 19	30 1950	loess cover
2cb1	12265	E. Johnston	53	RT	693	90	3	47	7	B (?)	B 25	28 1953	loess cover
4ab1	10710	F. Herman	47	RT	689	65	6	65	12	B 58	B 30	45 1947	loess cover
7da1	9449	H. Deibel, Sr.	46	RT	730	250	6	71	..	B 180 to well bot tom in Ch.	Ch 30	....	saline, no H ₂ S chemical analysis poor anion-cation balance
9ab1	10707	J. Thomas	47	..	712	120	6	67	3	B (?)	B 55	48 1947	

Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 52 N., R. 20 W. - continued

15dd1	12747	Central R-2 School	54	WS	807	331	...	152	...	B-Ch-Dv	Dv 36	39 1954	sp. cond.
17ba1	11161	Hugo Crass	49	RT	784	115	6-4	117	5	P 80, 90 95, 105	P 75	47 1949	
24ca1	9877	P. M. Jeter	46	..	705	90	6	40	3	B (?)	B 70	15 1946	
26dc1	9450	R. E. Garnett	46	RT	845	405	6	133	30	SP 385- 405	SP 40	70 1946	sp. cond.
29cb1	2944	S. H. Black	34	SW	776	606	8-6	190	12	B 227 SP (?)	SP 11	135 1934	
30ac1	16938	Dr. McBurney	57	AW	800	550	6	170	20	form? 100 SP (?)	SP 35	260 1957	
31db1	7907	S. Black	42	WS	795	400	...	168	...	B-Ch (?)	Ch 100	....	fresh water
31dd1	2943	S. L. Black	34	SW	744	349	8-6	177	27	P 55 B 140, 190, 220	Ch 64	100 1934	
32aa1	3553	R. E. Garnett	35	WS	843	645	6	180	...	SP-C (?)	C 25	130 1935	chemical analysis sp. cond.
35ba1	4127	Wm. Garnett	36	WS	843	535	6	110	...	SP-C (?)	C 80	100 1936	chemical analysis
35ba2	17818	Wm. Garnett	58	WS	837	535	6-5	170	15	.....	C 85	185 1958	no water in St. Peter
35cb1	5850	Wm. Garnett	39	..	860	595	6-4	195	25	.....	C 185	160 1939	fresh water

T. 52 N., R. 21 W.

5aa1	20708	Taylor Hamilton	61	ST	756	195	6	110	7.5	B 165, 195	B 103	chemical analysis 0.5 gpm at 165 feet 7 gpm at 195 feet
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Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Dept.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
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T. 52 N., R. 21 W. - continued

5ad1	12484	R. Lightfoot	52	WT	752	394	6	96	...	B 190-195 Dv 394	Dv 74	saline water
5ad2	12483	R. Lightfoot	52	WT	752	208	6	96	...	B (?)	B 113	....	saline water
5ddl	12126	J. W. Roe	50	..	764	244	6	110	3.5	B 230	B 139	56 1950	
9aal	12133	H. E. Stonner	52	WS	774	295	6	167	...	.....	Ch 25	....
10dbl	4222	A. R. Vashe	..	RT	816	282	6	176	...	B 275	B ?	68	sulfo-saline at first - no taste later. TDS 452 Cl 3.6 SO ₄ 10.1
13bc1	5592	Miss Doane	39	WS	750	414	6	145	...	.....	Dv 24	....
16bc1	11571	Miami Sch.	51	WS	807	288	6	150	15	B-Ch (?)	Ch 58	180 1951	drawdown to 250 feet sp. cond.
17cb1	10541	B. Huston	48	WT	717	220	6	57	1	B 105, 110	Ch 95	74 1948	
20dc1	21625	F. R. Anglen	63	WS	720	180	6-5	157	...	.....	Ch 70	....
23dc1	5082	R. Mac Smith	38	WS	765	406	6	163	...	Dv-K (?)	K 6	140 1938	chemical analysis est. top of St. Peter 430 feet
23dc2	16360	Dr. W. Smith	57	WS	755	465	6	145	15	.....	SP 65	92 1957	
30aal	16666	Ch. Gross	57	RT	725	46	6	47	3	GD 35, 46	GD 46	27 1957	
33db1	12409	G. Waters	53	RT	785	185	6	63	1.5	B 85	Ch 80	40 1953	

T. 52 N., R. 22 W.

24cc1	2965	Van Meter State Park	100	GD 45,55 B 65	B 38	35 19??	
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Table 1. Records of Wells (Continued)

Well	MGS No.	Owner	Yr.	Dr.	Elev.	Depth.	Diam.	Csg.	Prod. gpm	Aquifer (depth)	Penetr. basal form.	SWL (date)	Remarks
T. 52 N., R. 22 W. - continued													
25db1	3102	Van Meter State Park	34	WW	634	180	...	...	...	GD (?) Dv 180	Dv 40	....	chemical analysis saline at 180 feet
T. 53 N., R. 20 W.													
31dc1	9960	J. H. Audsley	47	RT	747	95	6	54	2	BR 40 B 76	B 40	55 1947	saline water
32aa1	13479	E. White	55	RT	718	230	6	82	6	B 160, 222	B 170	83 1955	
32bd1	9881	R. Mayfield	..	RT	732	215	...	...	2	B 200- 205	B 120	....
32bd2	9882	Clyde Leimkuehler	..	RT	734	91	6	91	48	GD (?)	P ?	....
33bb1	12246	J. Franklin	52	RT	732	196	6	85	4	B 95, 116	B 131	42 1952	
33ca1	9880	B. Kitchen	..	RT	730	90	6	86	...	B (?)	B 50	....
T. 53 N., R. 21 W.													
35da1	.....	J. Clements	63	CB	734	105	6	93	3.5	B (?)	B 40	40 1963	C1 85.0 NO ₃ 53.4 HCO ₃ 237.9 SO ₄ ²⁻ low alk. 195.0

TABLE 2
Specific Conductance*

Well	Owner	Year	Dr.	Date of meas.	Temp. (F)	Sp. Cond. (micromhos/cm) at 25°C.	TDS (est. ppm)	Remarks
T. 48 N., R. 20 W.								
17bd1	C. Seifkas	....	...	7-21-66	62.6	475	250	depth 200' Jefferson City
18ac1	Schanz Sisters	1958	WS	7-21-66	60.8	600	300	See table 1. Jeff. City-Roub.
T. 48 N., R. 21 W.								
3cd1	DX Station	....	RR	7-21-66	....	800	425	SWL 80' 529' deep Jeff. City
6ca2	Skelly Sta.	....	...	7-21-66	62.6	3800	2400	Jeff. City
10ac1	Cramer MFA	....	...	7-21-66	....	700	350	depth 875' (?)
12ac1	Blackwater 100 School	1954	WS	7-21-66	....	550	275	See table 1.
13da1	P. Evans	....	...	7-21-66	57.2	750	375	depth 87' Burl. Resid.
16db1	N. Wright	1951	WS	7-21-66	60.8	475	250	See table 1.
17dd2	Mrs. Mitchell	1956	WS	7-21-66	66.2	1100	600	See table 1.

*Specific conductance data is not available for all wells and springs. Specific conductance of wells and springs for which new chemical analyses were performed is included as part of these analyses. Abbreviations used are the same as in Table 1. Where temperature is not reported: indicates that water temperature was not the true ground water temperature (sample taken from tap).

Table 2. Specific Conductance (Continued)

Well	Owner	Year	Dr.	Date of meas.	Temp. (F)	Sp. Cond. (micromhos/cm at 25°C.	TDS (est. ppm)	Remarks
T. 48 N., R. 22 W.								
4ac1	Harry Hull	....	...	7-20-66	....	1500	900	550' deep Cotter-J.C.
6cc1	Harry Langewisch	....	...	7-20-66	62.6	1300	800	534' deep Cotter-J.C.
7bb1	L. Stockman	....	...	7-20-66	59.9	1300	800	Cotter-J.C.
17ab1	Mrs. H. Benson	....	...	7-20-66	....	1200	700	Spring-Burl.
18ab1	A. Vogelmeier	....	...	7-20-66	68.0	2200	1400	434' deep Cotter. Flowed
T. 48 N., R. 23 W.								
12bc1	E.L. Eckhoff	1929	AM	7-20-66	60.8	2100	1300	530' deep. H ₂ S Jeff. City
12cc1	Harley Wing	1957	RR	7-20-66	62.6	1700	1000	345' deep St. Peter
T. 49 N., R. 21 W.								
20cd1	R.O. Peterson	....	...	7-12-66	64.4	1800	1100	380' deep Devonian
20dd1	Rooks	....	...	7-12-66	57.2	1800	1100	as above
T. 49 N., R. 22 W.								
4da1	H. Egan	....	...	7-22-66	63.5	3400	2200	300' deep Chouteau
9bc1	Albert Sims	1958	RR	7-22-66	....	4000	2500	See table 1.
15cb2	Herb Langewisch	....	RR	7-20-66	64.4	750	425	305' deep Chouteau
15cc1	Herb Langewisch	....	...	7-20-66	54.5	500	250	22' deep. Penn.
16cb1	Dewey Sims	....	...	7-22-66	62.6	2400	1500	340' deep. H ₂ S Chouteau

Table 2. Specific Conductance (Continued)

Well	Owner	Year	Dr.	Date of meas.	Temp. (F)	Sp. Cond. (micromhos/cm) at 25°C	TDS (est. ppm)	Remarks
T. 49 N., R. 22 W.								
20bb1	L. Hutcherson	....	...	7-22-77	68.0	3100	1900	500' deep. H ₂ S Cotter
T. 49 N., R. 23 W.								
2bc1	G. Meyers	....	...	7-22-66	62.6	625	325	250' deep. Burl.
3aa1	W. Weisenburger	1946	ST	7-22-66	64.4	3200	2000	See table 1.
10ca1	D. Vogelsmeier	....	...	7-22-66	....	2900	1800	680' deep. J.C.
13ad1	H. Hollrah	....	...	7-22-66	66.2	2900	1800	352' deep. Ch.
15ab1	J. Vogelsmeier	....	...	7-22-66	62.6	2600	1600	640' deep. J.C.
15ca1	Dr. F. Long	....	RR	7-22-66	62.6	1750	900	535' deep. C. SWL 85' 20gpm
15dd1	H. Winfrey	1963	RR	7-22-66	62.6	1800	1100	501' deep. C. SWL 100'
31dd1	K. Klussman	1957	...	7-20-66	....	1800	1100	235' deep. Burl. flowed
32cc1	F. Mackey	....	...	7-20-66	60.8	1700	1000	205' deep. Burl. flowed
36ac1	Dewey Sims	1956	RR	7-22-66	62.6	2100	1300	505' deep. J.C. H ₂ S
T. 50 N., R. 19 W.								
2bc1	A. Borgman	1963	...	7-13-66	62.6	800	400	335' deep. Ch. SWL 135' 10gpm
3ad1	C. Blumhorst	....	WS	7-13-66	62.6	750	400	See table 1.
T. 50 N., R. 20 W.								
2aa1	P. Borgman	1953	RT	7-13-66	....	600	225	See table 1
T. 50 N., R. 22 W.								
9bc1	Montgomery Br.	....	RT	7-12-66	60.8	150	75	60' deep. GD.
9dc1	Keithley Sprg.	....	...	7-12-66	60.8	150	75	spring in drift

Table 2. Specific Conductance (Continued)

Well	Owner	Year	Dr.	Date of meas.	Temp. (F)	Sp. Cond. (micromhos/cm) at 25°C.	TDS (est. ppm)	Remarks
T. 50 N., R. 23 W.								
1bb1	H. Burfeind	....	RT	7-7-66	59.0	350	150	83' deep. GD.
13bb2	Mt. Leonard	....	...	7-8-66	....	300	150	103' deep. GD. Fluoride 2.3ppm
14dd1	H. Stallings	....	...	7-8-66	....	200	100	35' deep. GD.
26aa1	Mo. Hwy. Dept.	1963	...	7-22-66	....	700	350	See table 1.
27ad1	L. Bargfrede	....	...	7-22-66	68.0	500	250	50' deep. GD.
33cd1	A. Dieckmann	....	...	2-24-66	63.5	800	425	730' deep ?
33dd1	E. Luehrs	1957	CH	2-24-66	62.6	4100	2600	See table 1.
T. 51 N., R. 18 W.								
19bb1	A. Robinson	....	...	7-13-66	....	700	350	140' deep. Ch.
T. 51 N., R. 19 W.								
15ab1	Gilliam Rock	....	...	7-13-66	....	750	400	25' deep. Ch.
26ba1	N. Heuman	1952	WS	7-13-66	....	475	250	210' deep. Ch. 200 GPD
T. 51 N., R. 20 W.								
4ad1	R. Kitchen	....	...	7-13-66	66.2	750	375	Source ?
12db1	D. McMallen	1954	WS	7-13-66	59.0	600	275	See table 1.
24bd1	W. Gilliam	....	...	7-13-66	62.6	1000	600	Source ?
T. 51 N., R. 22 W.								
19ab1	Alma Coop	....	...	7-8-66	....	1000	600	GD
24ad1	A. Gauldin	....	AG	7-7-66	61.7	800	425	63' deep. GD.
T. 51 N., R. 23 W.								
16cc1	Grand Pass "Town Spring"	....	...	7-8-66	59.0	450	225	Penn or GD
31dd1	E. Lageman	....	ST	7-14-66	63.5	600	300	Penn or GD. 130'
32cc1	E. Lageman	....	ST	7-14-66	....	800	450	400' deep. Burl.

Table 2. Specific Conductance (Continued)

Well	Owner	Year	Dr.	Date of meas.	Temp. (F)	Sp. Cond. (micromhos/cm) at 25°C.	TDS (est. ppm)	Remarks
T. 52 N., R. 19 W.								
17da1	Spring	....	...	7-11-66	....	250	125	Penn. sandstone
17db1	R. Gilliam	....	...	7-11-66	65.3	600	325	258' deep. Burl.
23cc1	C. Harvey	....	RT	7-11-66	59.9	1100	700	See table 1.
T. 52 N., R. 20 W.								
6db1	J. H. Audsley	....	...	7-9-66	....	450	225	395' deep. SP ?
7aa1	J. Thompson	....	...	7-9-66	....	9400	6000	433' deep. SP.
7da1	H. Deibel Sr.	1946	RT	7-9-66	....	13800	8900	See table 1.
7da2	H. Deibel Sr.	....	...	7-9-66	64.4	500	250	100' deep. Burl.
10bd1	George Wise	....	...	7-11-66	....	3900	2500	175' deep. Burl.
10ca1	F. Bonar	....	...	7-11-66	59.0	900	425	67' deep. Burl.
11ac1	J. Murdock	....	...	7-9-66	64.4	700	350	Source ?
11cb1	F. Murdock	....	...	7-11-66	59.0	900	425	86' deep. Burl.
12cd1	Ch. Stafford	....	...	7-9-66	64.4	950	450	Source ?
15dd1	Central R-2 School	1954	WS	7-11-66	....	125	75	See table 1.
23cb1	K. Lewellen	....	...	7-11-66	58.1	500	250	330' deep. SP.
26dc1	R. E. Garnett	1946	RT	7-11-66	59.9	525	250	See table 1.
32aa1	L. Lewellen R. E. Garnett	1935	WS	7-11-66	60.8	800	425	See table 1.
T. 52 N., R. 21 W.								
16ab1	C. Peterman	....	...	7-9-66	60.8	900	450	80' deep. Penn.
16bc1	Miami School	1951	WS	7-9-66	....	650	325	See table 1.
16ad1	D. Peterman	1966	ST	7-9-66	....	700	350	260' deep. Burl.
19cc1	R. Bray	....	...	7-7-66	65.3	2100	1300	Source ?
25bd1	R. E. James	1917	...	7-9-66	....	2000	1200	451' deep. SP.
T. 52 N., R. 22 W.								
36aa1	Rbt. Hisle	....	IW	7-7-66	59.0	500	250	91' deep. GD.

TABLE 3
Additional Chemical Analyses
(Missouri Geological Survey and Others)

Location	48-21-6ca2	48-21-8cd1	48-22-9bc1	48-23-14bb1	49-19-2cc1	49-19-17dd1	49-19-29aa1
Anal. No.	5733	2547	1400	4174	3378	1790	1397
SiO ₂	.....	11.2	6.8	6.0	4.8	6.8	10.4
Fe (total)	.....	.20	.10	.13	.....	.....	.10
Mn	.....	.05	.....	.0	.....	.....	.04
Ca	.....	257.7	102.6	212.7	823.4	45.5	104.0
Mg	.....	14.0	37.5	100.5	339.0	19.0	16.2
Na+K	.....	59.3	128.7	609.0	5054.4	272.7	283.2
HCO ₃	267.2	387.7	280.6	262.3	271.4	424.0	345.0
CO ₃	24.0	.0	.0	.0	11.1	27.3	.0
SO ₄	.....	163.2	110.7	119.3	1146.0	66.5	92.2
Cl	835.0	112.1	230.4	1460.0	8990.9	234.9	396.8
F	.....	.0	.8	.....	1.6	.....	.9
NO ₃	tr	196.8	36.90	.1	.....	.24	1.14
TDS	.....	1334.0	1067.0	3232.0	18982.0	939.5	1171.0
Source	Roubidoux	Burlington	Miss. Ls.	Burlington (Spring)	Chouteau	St. Peter	Miss. Ls.

Table 3. Additional Chemical Analyses (Continued)

Location	49-19-29ba1	49-19-29bb1	49-20-15db1	49-21-6ba1	49-21-15ad1	49-22-13dd1	49-22-16ab1
Anal. No.	1404	1398	2231	3192	2552	3193	3194
SiO ₂	9.6	11.6	10.0	12.8	7.6	15.2	8.8
Fe (total)	.35	.15	.08	.....	.30	.....	.....
Mn	.12	.....	.02	.5	.01	.4	.....
Ca	215.9	161.4	42.1	30.5	260.6	85.6	8.0
Mg	101.8	74.3	19.9	29.4	26.5	23.1	5.9
Na+K	1428.0	1392.6	14.2	51.6	44.1	38.2	473.0
HCO ₃	362.8	386.1	219.9	233.4	239.8	458.4	738.2
CO ₃	.0	.0	2.7	2.8	2.8	.....	11.1
SO ₄	274.1	244.2	13.8	58.6	518.5	6.6	226.5
Cl	2354.0	2146.6	5.5	30.1	36.0	15.3	127.7
F	1.3	2.8	.0	.8	.9	.55	2.55
NO ₃	.0	.0	10.5	.....	55.35	.....	.....
TDS	5286.0	4721.0	258.0	366.0	1342.0	401.0	1120.0
Source	St. Peter	St. Peter	St. P-Cotter	Cooper	St. Peter	Burlington	Burlington*

*280' level (See 49-22-16ab1 next page) Sample taken at different level in same well 560'.

Table 3. Additional Chemical Analyses (Continued)

Location	49-22-16ab1 (560' lev)	49-23-1bb1	50-19-7cd1	50-19-8dd1	50-19-16cb1	50-19-17ba2	50-19-19db1
Anal. No.	3195	1391	1385	2582	1388	1384	1392
SiO ₂	15.6	4.4	5.2	8.4	5.2	8.4	9.6
Fe (total)	.....	.20	.10	.23	.10	.30	.35
Mn	.....	.....	.02	.28	.04	.03	.03
Ca	81.9	46.6	82.5	87.8	71.0	73.2	61.7
Mg	43.1	30.6	17.0	14.2	21.4	30.6	31.6
Na+K	581.4	535.0	17.0	28.5	23.6	37.1	20.6
HCO ₃	361.3	313.5	331.3	367.6	342.3	357.3	353.2
CO ₃	.0	.0	.0	.0	.0	.0	.0
SO ₄	101.0	59.3	16.7	12.1	27.8	55.8	23.2
Cl	846.9	712.5	3.2	6.6	3.2	6.3	3.6
F	3.1	2.6	.7	.2	.4	.6	.6
NO ₃	.....	.49	.87	5.02	2.21	6.71	1.39
TDS	1925.0	1641.0	340.0	388.0	373.0	451.0	451.0
Source	Cotter	Miss. Ls. or St. P.	Miss. Ls.	Chouteau	Miss. Ls.	Miss. Ls.	Miss. Ls. or Penn.

Table 3. Additional Chemical Analyses (Continued)

Location	50-19-20dd2	50-19-36ac1	50-20-23ca1	50-20-31bb1	50-21-2dd1 (346' lev.)	50-21-2dd2 (373' lev.)	50-21-10dd1
Anal. No.	1383	5604	1394	4566	2342	2289	1372
SiO ₂	8.8	8.0	21.2	.....	6.0	12.8	24.0
Fe (total)	.07	.07	.30	.88	.12	.50	2.0
Mn	.01	.0	.80	.....	.....	.28	.....
Ca	82.5	85.4	76.8	111.7	297.0	322.7	114.5
Mg	28.8	20.5	18.5	25.9	123.0	134.5	24.2
Na+K	68.3	13.4	44.8	.....	2228.6	2299.4	289.4
HCO ₃	332.7	342.8	361.4	423.3	267.1	306.2	309.1
CO ₃	8.1	.0	.0	21.6	.0	.0	.0
SO ₄	41.6	15.2	19.1	.....	516.2	495.2	116.7
Cl	80.3	9.0	28.9	10.0	3624.5	3810.1	487.2
F	.6	.2	.35	.....	.....	2.2	.....
NO ₃	8.66	9.1	.0	.....	.0	.0	.13
TDS	567.0	340.0	440.0	476.0	7520.0	8223.0	1308.0
Source	Miss. Ls.	Burlington (flow)	Miss. Ls.	?	Burlington	Burlington	drift

Table 3. Additional Chemical Analyses (Continued)

Location	50-21-11ac1 (350' lev.)	50-21-11ac1 (450' lev.)	50-21-11ac1 (665' lev.)	50-21-11ac1 (760' lev.)	50-21-11ac1 (860' lev.)	50-21-11ac1 (1245' lev.)	50-21-11ac1 (1600' lev.)
Anal. No.	2850	2851	2852	2896	2897	3074	3425
SiO ₂	3.2	5.2	11.6	2.4	4.8	1.2	4.8
Fe (total)	.18	.14	.40	.07	.09	.....	.....
Mn	.....	.....	.....	.....	.....	.....	.....
Ca	365.1	374.8	793.5	534.1	517.4	1040.4	1023.9
Mg	99.0	89.2	463.6	196.3	209.8	555.1	894.9
Na+K	708.1	466.2	5790.8	2028.0	2279.8	7222.8	9908.2
HCO ₃	165.5	155.4	294.8	106.0	79.9	223.6	211.5
CO ₃	.0	.0	.0	.0	.0	.0	.0
SO ₄	923.2	1020.3	1395.2	1070.5	1073.2	1480.2	1550.5
Cl	1314.0	846.0	10332.0	3704.8	3999.7	14174.1	17687.5
F	.....	.....	.....	.....	.....	.....	.....
NO ₃	.44	3.69	.0	.91	.69	.....	.....
TDS	3864.0	3113.0	20712.0	8205.0	8746.0	31151.0	36073.0
Source	Chouteau	Devonian	Jeff. City	Jeff. City	Roubidoux	Eminence	Derb.-Doe.

Table 3. Additional Chemical Analyses (Continued)

Location	50-21-11ac1 (1650' lev.)	50-21-11ac1 (1715' lev.)	50-21-11cc1	50-21-24cb1	50-21-34da1	50-21-35cb1 (400' lev.)	50-21-35cb1 (547' lev.)
Anal. No.	3426	3427	K.C. Testing Lab.	3347	1390	3237	3238
SiO ₂	2.8	7.6	13.5	6.0	1.6	5.6	8.0
Fe (total)	.....	.....	2.9	.....	.35	.....	.....
Mn	.....	.....	.....	.....	.03	.....	.....
Ca	1204.9	1482.5	180.7	124.3	84.6	66.0	57.9
Mg	801.3	610.4	75.9	54.3	38.0	50.1	44.3
Na+K	10112.0	10223.7	2301.0	195.1	73.8	72.7	503.6
HCO ₃	200.1	172.9	386.7	289.6	512.0	499.9	479.4
CO ₃	.0	.0	.0	.0	6.7	.0	.0
SO ₄	1554.0	1619.9	579.0	41.2	51.4	93.4	91.1
Cl	17953.5	17815.9	3420.0	464.3	19.8	27.2	737.6
F	.....	.....	.....	.....	1.5	.....	.....
NO ₃	.....	.....	.0	.....	.98	.....	.....
TDS	37439.0	37158.0	6960.7	1385.0	614.0	593.0	1806.0
Source	Derb.-Doe.	Davis	St. Peter	Burlington- Chouteau?	Miss. Ls.	Cotter	Jeff. City

Table 3. Additional Chemical Analyses (Continued)

Location	50-22-11ac1	50-22-29cb1	51-19-29bc1	51-20-17dc1	51-20-26cd1	51-21-10dc1	51-21-11
Anal. No.	1466	1387	820	2581	819	2553	826
SiO ₂	16.8	8.8	6.8	3.2	5.6	8.8	6.4
Fe (total)	.45	.30	.45	.28	.30	.....	.30
Mn	.07	.01	.....	.01	.....	.29	.....
Ca	349.4	25.8	76.1	79.2	94.0	78.5	80.4
Mg	190.3	12.3	31.4	13.3	20.0	30.6	39.0
Na+K	3709.3	179.2	51.3	15.4	27.9	184.9	705.0
HCO ₃	244.8	462.7	399.8	298.7	303.4	413.6	375.3
CO ₃	.0	4.0	30.3	1.4	17.0	1.4	34.0
SO ₄	641.5	42.4	40.1	20.8	61.3	65.2	191.6
Cl	6142.1	19.4	6.7	5.3	12.1	224.2	875.1
F	1.2	.75	.....	.45	.....	1.9	.....
NO ₃	.0	27.68	.57	3.16	2.46	.0	.18
TDS	12192.0	627.0	501.0	335.0	442.0	888.0	2283.0
Source	Miss. Ls. or St. P.	St. Peter	St. Peter	Burlington Chouteau	Miss.(?)	St. Peter	St. Peter

Table 3. Additional Chemical Analyses (Continued)

Location	51-21-34aal	51-22-19ad1	51-22-24cb1	51-23-31cc1	52-20-17dd1	52-20-23cc1	52-20-34bb1
Anal. No.	5969	1389	1405	8303	1465	1399	1386
SiO ₂	20.3	8.8	10.8	26.0	8.4	9.2	6.0
Fe (total)	6.41	.25	.80	.6	.10	.12	.15
Mn	.50	.14	.....	.....	.....	.06	.06
Ca	252.1	773.3	152.1	21.6	30.1	53.1	101.9
Mg	87.3	288.4	78.1	8.3	37.8	35.6	19.7
Na+K	1155.1	5102.4	1125.1	16.2	471.3	51.6	37.5
HCO ₃	252.5	328.6	479.2	129.2	211.8	336.8	442.2
CO ₃	16.8	.0	.0	.0	1.4	6.7	.0
SO ₄	288.1	1468.2	.0(?)	5.8	86.6	59.3	47.5
Cl	2227.5	8505.1	1903.1	5.6	755.8	22.1	3.6
F	1.2	3.0	.65	.2	.....	.85	1.0
NO ₃	.6	.0	.0	.17	.82	.23	.25
TDS	4556.0	18267.0	4287.0	146.0	1626.0	503.0	470.0
Source	drift	Roub.-Gasc.	Potosi	drift or Penn.	St. Peter	Miss. Ls.	Jeff. City

Table 3. Additional Chemical Analyses (Continued)

Location	52-20-32aal	52-20-35bal	52-22-25db1	51-22-16ad1
Anal. No.	2546	2545	1234	K.C. Testing Lab
SiO ₂	5.6	5.2	14.8	33.5
Fe (total)	.28	.14	.10	3.6
Mn	.02	.03	.....	.....
Ca	82.1	77.8	268.4	63.4
Mg	38.5	23.7	81.4	11.4
Na+K	70.5	35.2	700.3	61.3
HCO ₃	436.5	407.8	388.6	320.8
CO ₃	.0	.0	.0	.0
SO ₄	127.8	25.3	185.4	.0
Cl	14.2	3.1	1433.2	57.0
F	1.4	.75	.....	.25
NO ₃	.0	.0	.0	.0
TDS	618.0	399.0	3427.0	557.1
Source	St. P.-J.C.	St. P., Cotter	Callaway	drift