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Ground water investigation in the southern half of Franklin County, Missouri

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GROUND WATER INVESTIGATION IN THE SOUTHERN HALF OF FRANKLIN COUNTY, MISSOURI

BY

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A

THESIS

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ABSTRACT

Increasing population and industrialization in Franklin County, Missouri, has led to increased demand for water. Much of this demand will be satisfied from ground water resources. Although the general geology of Franklin County has been mentioned in several publications, no detailed study of structure and ground water geology had been done. This thesis consists of study of stratigraphy, lithology, and geologic structure, and analysis of well log data to determine occurrence and availability of ground water, in the southern half of Franklin County.

Stratigraphy and lithology is compiled from previous literature, modified to agree with well log data. Structural geology is determined from correlation of well logs and field mapping of the central 38 square miles of the area. Structural data, shown on contour maps of the tops of two major aquifers, the Gasconade and Eminence formations, on isopach map of the Gasconade, and three cross-sections, reveal four major and several minor northeasterly plunging folds. No evidence was found for some possible faults shown on previously published maps. Outcrops examined are indicated on a detailed geologic map of the field area.

Relation of number of wells drilled in various formations to expanding population is shown graphically. Depth to static and dynamic water levels, drawdown, and production rates are described for several formations. Specific capacities of the major aquifers are computed. Variations in chemical quality of ground water are illustrated by representative analyses within the area. Appendices list surface elevation, total depth, production and specific capacity of all wells studied.

TABLE OF CONTENTS

L I S T O F T A B L E S

LIST OF ILLUSTRATIONS

I. INTRODUCTION

The development of ground water resources is becoming increasingly important as the industrial complex of the nation expands. Industry and commerce require a plentiful supply of clean, chemically suitable or potable water for their processes and personnel. For this reason comprehensive investigation of ground water resources is needed in many areas.

Franklin County, Missouri, located only forty miles west of St. Louis, is an area of rapidly growing population and industry, with a foreseeable demand for large quantities of water. Although Franklin County has many surface streams, an increasing percentage of domestic, municipal and industrial supplies are being developed from ground water resources. The problem of investigating and evaluating ground water conditions in Franklin County was suggested to the author in January, 1961, by Dr. J. C. Maxwell of the Missouri School of Mines and Metallurgy, and by geologists of the Missouri Division of Geological Survey and Water Resources.

The objectives of this thesis were to describe the geology of the southern half of Franklin County with particular reference to the factors which control the occurrence and availability of ground water, and to analyze the occurrence and production of ground water in this area. The results reported here are based on a review of previous investigations, analysis of well data, field geologic mapping, and interviews with well owners and drillers. The well data were obtained from geologic well logs in the files of the Missouri Division of Geological Survey and Water Resources. The field work was done in part of the area during September and October,

1961. Personal contacts were made with some water well drillers and owners in the area to gain information about drilling problems.

The results of the investigation are described in succeeding chapters. The stratigraphy and lithology were compiled from existing literature and modified as necessary to agree with information obtained from the well logs. The structural geology is based primarily on the two hundred and five well logs studied. In a central area of approximately thirty-eight square miles, where reconnaissance mapping by previous workers had indicated the possible presence of unusual faults, detailed field mapping was done. The well logs and field mapping showed that most of the faults probably do not exist, confirmed the existence of one major fault, and revealed a previously unsuspected series of nearly parallel, plunging folds. Analysis of the well data showed an increase in the ground water production paralleling the increase in population. The amount of ground water produced from wells completed in each of the aquifers is analyzed graphically, and the availability of water in these formations is described. The chemical quality of the ground water, determined from previous analyses, is briefly described.

II. ACKNOWLEDGEMENTS

The writer wishes to express his appreciation to Dr. J. C. Maxwell, who was the advisor on this investigation. He supervised and criticized all work in this study. The writer also wishes to express his thanks to Dr. T. R. Beveridge, State Geologist, and his staff of the Missouri Division of Geological Survey and Water Resources. James H. Williams, Geologist of the Missouri Geological Survey, visited the writer in the field several times and discussed the geology of the area. Ground water conditions in the thesis area were discussed with Dale Fuller, Geologist in the Missouri Geological Survey. Dr. A. C. Spreng of the Missouri School of Mines worked with the writer one day in the field. The author's field expenses for this study were paid by the Missouri Geological Survey and Water Resources. Part of the thesis expenses were paid by a grant from the V. H. McNutt Memorial Fund.

III. DESCRIPTION OF AREA

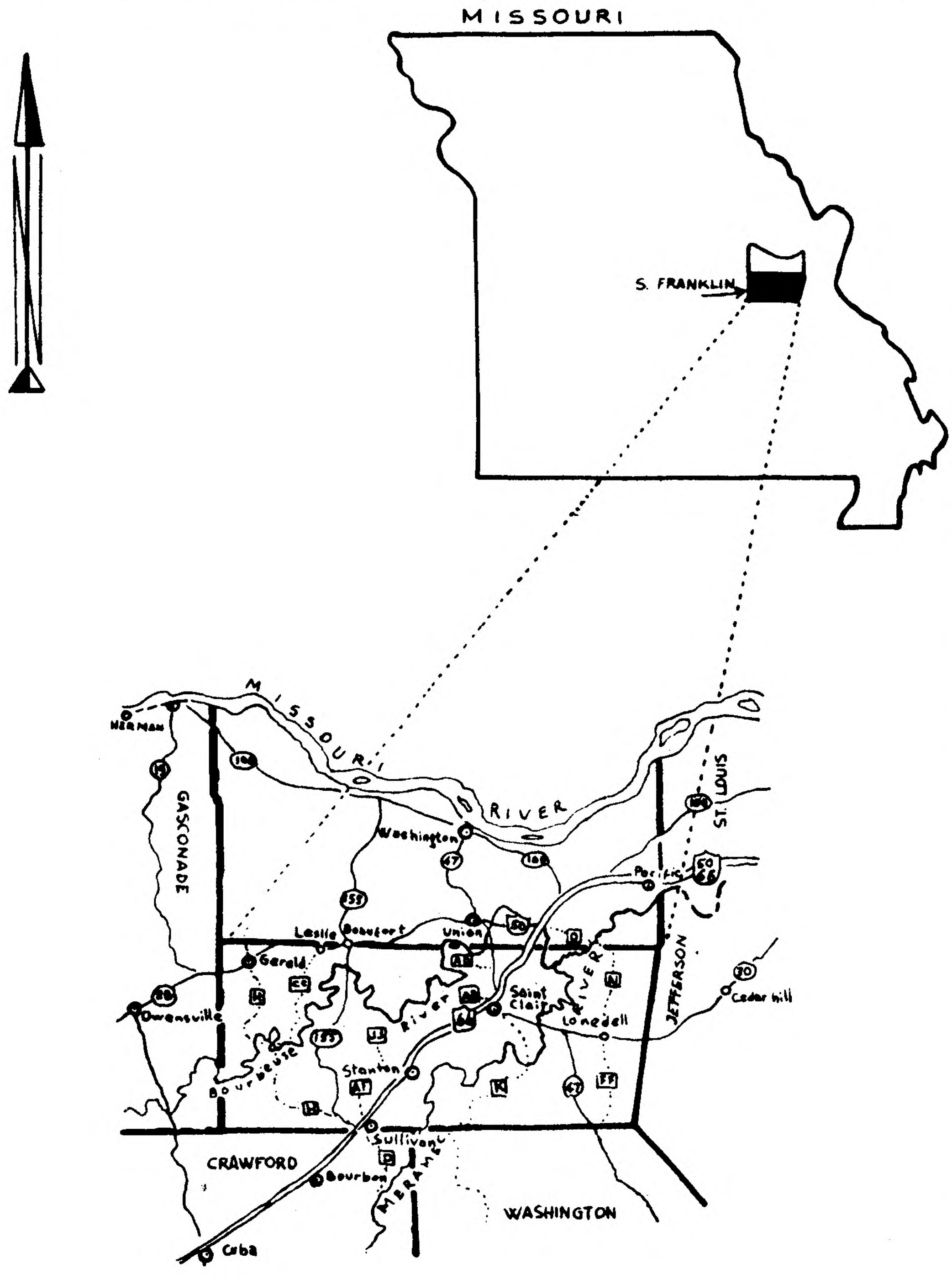
A. Geography of southern Franklin County

1. Location and size:

The area of this study is in the southern half of Franklin County, Missouri. This thesis area, shown in figure 1, is bounded on the east by Jefferson County, on the west by Gasconade County, on the south by Crawford and Washington Counties. The longitudinal limits for the study area are 90° 43' 20" and 91° 22' 00" west. Latitudinal limits are 38° 25' North, and 38° 12" North. The area studied comprises approximately 470 square miles. Greatest length from west to east is 33 miles, and greatest north-south width is nearly 14 miles.

2. Culture:

The area is approximately 40 miles southwest of St. Louis. Federal Highway 66 crosses the county in a southwest-northeast direction. State highway and supplementary routes connect the communities within the county. Some cities in the southern half of Franklin County are served by the St. Louis-San Francisco Railroad which is approximately parallel to Highway 66. The southern half of the county had a 1961 population of approximately 12,097, which is 25 persons to the square mile. It has two small cities, several towns and some smaller communities with populations as listed below.



LOCATION MAP OF STUDIED AREA

Figure 1

Sullivan	4,098	Leslie	104
St. Clair	2,711	Lonedell	25
Gerald	474	Communities	4,300(approx.)
Stanton	250	Total	12,097(approx.)
Anaconda	135(approx.)		

The area is mostly covered by forests. Some places in the floodplains of the two largest rivers, the Meramec and the Bourbeuse which flow northeastward across the county, are cultivated. The main crops are corn and hay. Wheat, oats, potatoes, sorghum and, recently, soybeans are also grown.

3. Climate:

Climate in the studied area is temperate sub-humid. The maximum average temperature is 85.5° F, and minimum average temperature is 63.4° F for the summer season. The maximum average temperature in January and February is 43.5° F, and the minimum average temperature is 24° F. Average relative humidity is 67.1 percent for the months of July and August. The precipitation in the southern half of Franklin County is about 40 inches per year. Seasonal evaporation value for April-October is 34.9 inches. This seasonal evaporation value has been calculated from the period of 1946-1955 at the station at Washington University, St. Louis, Missouri.[1]

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[1] U. S. Department of Commerce, Weather Bureau, Technical Paper No. 37., Evaporation maps for the United States, Washington D. C., 1959.

B. Physiography

1. Regional Setting:

As shown in figure 2, the State of Missouri lies within three major physiographic provinces. They are:

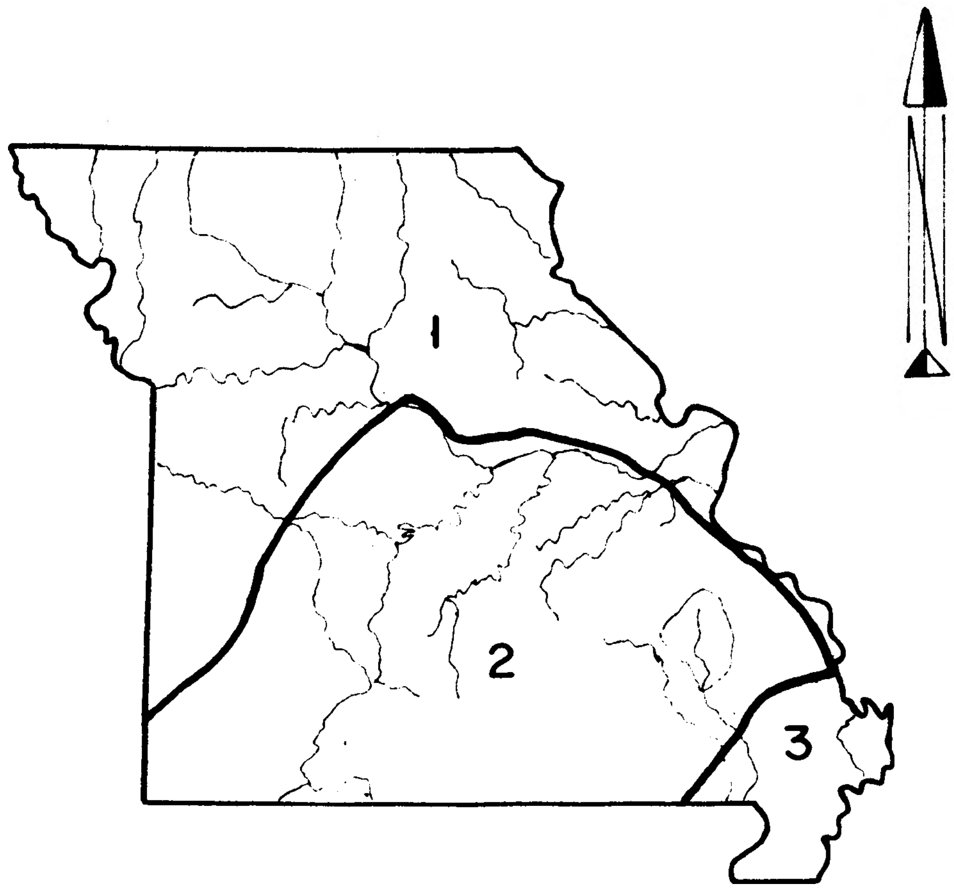
a. the Ozark Plateau Province, of which the two major sections are the Salem Plateau in the center and the Springfield Plateau on the west.

b. the Central Lowland Province, of which one section is the Dissected Till Plains on the northern border of the Ozark Plateau, and another is the Osage Plains on the western border of the Ozark Plateau.

c. the Coastal Plain Province, which is divided into many sections, one of which is the Mississippi Alluvial Plain Section that lies southeast of the Ozark Plateau.

Franklin County is located approximately on the northern border of the Ozark Plateau Province. That plateau, with its asymmetric domal structure centering in the St. Francois Mountains, extends southward from the Missouri River to the White River in northwestern Arkansas. Its elongate structural dome trends in an east-west direction from the St. Francois Mountains on the east, through Dent and Greene Counties in Missouri, and then curves through Barry County into northwestern Arkansas.

The Ozark Plateau may have passed through several successive cycles of erosion similar to those recorded in the Appalachian Plateau Province. Its inclined strata seem to be cuestas on the flank of the dome. On the east, cuesta slopes are so steep they cannot be used as evidence of an erosion surface. On the west,



THE MAJOR
PHYSIOGRAPHIC DIVISIONS OF
MISSOURI

1-CENTRAL LOWLAND PROVINCE
2-OZARK PLATEAU PROVINCE
3-COASTAL PLAINS PROVINCE

Figure 2

slopes are plateau-like and their surfaces truncate several strata. Such conditions indicate old age erosion surfaces.[1]

The Ozark Plateau has undergone several cycles of uplift. The most recent uplift took place in the late Pliocene and its effects continued through the beginning of the Quaternary.[2] During this process many joints and fractures formed.

The predominant bedrock of the Ozark Plateau is dolomite and magnesian limestone which contain chert and sand in various amounts. These Cambrian and Ordovician rocks lie upon a Precambrian complex of ancient rocks which are mostly granite and porphyry. These Precambrian rock types outcrop at numerous places in the St. Francois Mountains, and in Reynolds, Shannon, and Carter Counties.

Surface elevations of the Ozark Plateau range from 400 to 1770 feet above sea level. The higher altitudes are reached in Iron and Reynolds Counties, in the St. Francois Mountains, southeastern Missosuri; and in Wright, Douglas, and Webster Counties, south-central Missouri. Lower elevations occur in valleys cut by major rivers, such as the Black, Current, Eleven Point, Gasconade, Meramec, Niangua, North Fork, St. Francis, and Bourbeuse Rivers.

2. Topography and Drainage:

The topography is not smooth in the southern half of Franklin County. It presents a rugged surface. Within the area, narrow valleys, floodplains, and ridges are the main features of topo-

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[1]Wallace W. Atwood, The Physiographic Provinces of North America, p. 241, 1940.
[2]Fenneman, N. M., Physiography of the Eastern United States, p. 661, 1938.

graphy. The narrow valleys are not wider than 0.2 miles, and their floors are usually gravelled. Floodplains occur along the Bourbeuse and Meramec Rivers. Their widths range between 0.5 and 0.7 miles. The general trends of ridges are northwest - southeast.

The northeast corner of the south half of Franklin County is lower in elevation than other parts of the studied area. Average elevations rise gradually from that corner toward the south, southwest, and northwest. The relief in the northeast region varies from 100 to 250 feet.

The lowest point in the southern half of Franklin County is at an elevation of 476 feet on the Meramec floodplain in Section 10, dbb, Township 42 North, Range 1 East. The lowest reference elevation is a 493 foot bench mark along the St. Louis-San Francisco Railroad, near Moselle, in Section 15 ab, Township 42 North, Range 1 East. The highest point in the southern half of Franklin County is at 994 feet on a hill in Section 3, acd, Township 40 North, Range 3 West. The highest reference elevation is a 973 foot bench mark in Section 34, cdb, Township 41 North, Range 3 West. The highest city in the studied area is Sullivan, which has an elevation of about 990 feet.

The Bourbeuse and Meramec Rivers cross the southern half of Franklin County. These two rivers come together before leaving the county in Section 11 aca, Township 42 North, Range 1 East. The Bourbeuse River flows 72 miles through the studied area, and it has an average gradient of about 0.36 feet per mile.

The Meramec River within the southern half of Franklin County is shorter than the Bourbeuse River. The Meramec River flows 48 miles in the same area, and its average gradient is approximately 0.48 feet per mile. The Bourbeuse and Meramec Rivers have many tributaries in the southern half of Franklin County. Most of these are intermittent creeks or branches. Redoak Creek, Big Creek, Little Bourbeuse River, Boone Creek, Spring Creek, and Dry Creek, in the thesis area, are the major tributaries of the Bourbeuse River. The main tributaries of the Meramec River in the same area are Hoosier Creek, Indian Creek, Little Meramec River, and Calvey Brady Creek.

It is not possible to evaluate Franklin County as a single drainage basin. It lies on several drainage basins (See figure 3). The western part of the southern half of Franklin County is in the Bourbeuse drainage basin. This basin is a secondary division of the Meramec drainage basin. Its total size is 808 square miles, and about 255 square miles of it is in the southern half of Franklin County. The area of the Meramec drainage basin is 3980 square miles; about 215 square miles of this basin lie in the southern half of Franklin County.[1]

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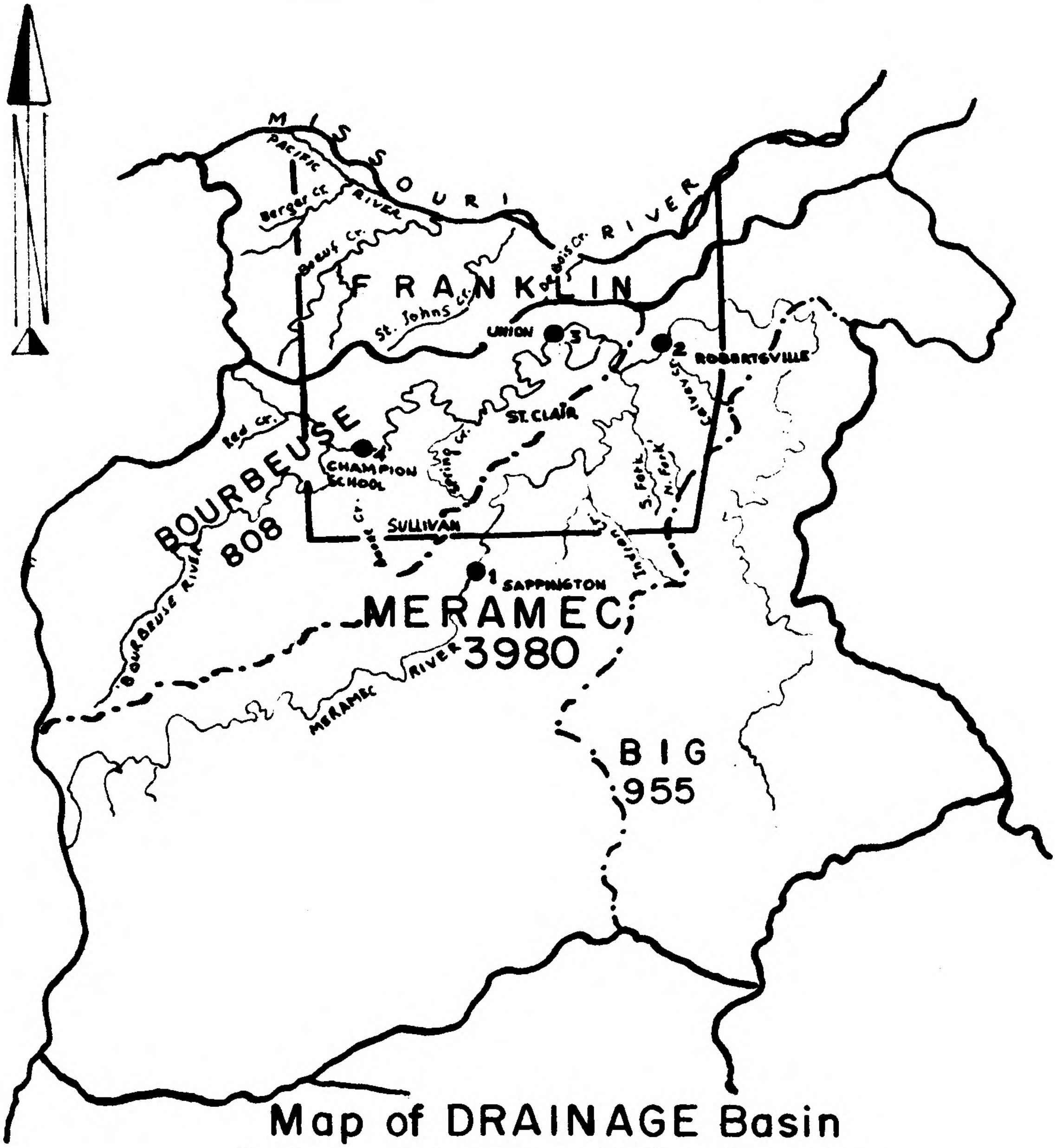
[1] Harry C. Bolon, Surface Waters of Missouri, Missouri Geological Survey and Water Resources, Volume XXXIV, Second Series, Plate I, 1952.



Map of DRAINAGE Basin Related to Franklin County

(After Harry C. Bolon)

SCALE: 1/1,000,000

LEGEND

444 FIGURES BELOW NAME GIVE TOTAL AREA OF DRAINAGE BASIN

●8 STREAM FLOW MEASURING STATION

—— BOUNDARY OF PRIMARY DRAINAGE BASIN

—·— BOUNDARY OF SECONDARY DRAINAGE BASIN

Figure 3

IV. PREVIOUS WORK

Detailed underground water investigations in Franklin County have not been done previously although the subject has been mentioned in other geologic studies. In contrast, the general geology of Franklin County has been described in papers by several authors since 1854.

Dr. A. Litton (1854), in "A Preliminary Report on Some of the Principal Mines in Franklin, Jefferson, Washington, St. Francois, and Madison Counties, Missouri" briefly mentioned the geology in the vicinity of some lead mines of Franklin County. According to Litton (page 11-30), some of the hills, knobs, and ridges are composed of Magnesian limestones. Sandstones in some places overlie the Magnesian limestones.

Dr. B. F. Shumard (1855, p. 158) in the Missouri Geological Survey's Second Annual Report, said:

> "all the rocks in Franklin County, beneath the soil and Quarternary deposits, belong to the lower Silurian system. They represent the inferior part of this system, and are equivalent in age to the Trenton and Black River limestones, and Calciferous sand-rock of the New York series."

Arthur Winslow wrote "Lead and Zinc Deposits of Missouri," published by the Missouri Geological Survey in 1894, (vol. VII, section 2). On pages 693-699, he states that the Magnesian limestones contain "greater or less quantities of chert," and "sandstones are also found associated with the limestones" in Franklin County.

H. A. Buehler's "Lime and Cement Resources of Missouri," published by the Missouri Bureau of Geology and Mines in 1907, describes most counties in Missouri from the standpoint of cement and lime resources. Rock types of Franklin County are mentioned on pages 128-129. Buehler said that with the exception of a small area in the northwestern portion of Franklin County, Gasconade and Franklin Counties are underlain with sandstone and dolomite belonging to the Cambro-Ordovician series.

Edward M. Shepard (1907) mentioned the artesian conditions, city water supplies, analyses of water public supplies, mineral wells, and blowing wells in Missouri.

The sand and gravel resources of Missouri were studied by C. L. Dake (Missouri Bureau of Geology and Mines, second series, vol. XV, 1918). In this work distribution of sand and gravel by geological formations and districts was described. This study included Franklin County.

In May, 1920 C. L. Dake mapped the Roubidoux formation in the west portion of Franklin County. This was an unpublished reconnaissance study of the area, (Missouri Bureau of Geology and Mines field notebook).

E. B. Branson (1944), in "The Geology of Missouri," summarized the stratigraphy and geology of Missouri. Some references were made to Franklin County.

In 1944 a report on "The Large Springs of Missouri" was written by H. C. Beckman and N. S. Hinchey, and was published by the Missouri Geological Survey and Water Resources in Second Series, vol. XXIX. In this report information was given about the source of springs, geology of the springs region, flow characteristics of springs, and quality of spring water in Missouri. Four springs in Franklin County were mentioned.

Under the title of "Geology of St. Clair Mining District, Franklin and Washington Counties, Missouri," unpublished Master's thesis, Missouri School of Mines and Metallurgy, mines and quarries and their geology in Franklin County were described by Robert F. Burke in 1951.

Carl Robert Burchart (1952) wrote the "Geology of the Northwest portion of the Richwoods Quadrangle, Missouri," unpublished Master's Thesis, University of Iowa. A part of this area lies in Franklin County.

The report of "Surface Waters of Missouri," prepared by H. C. Bolon in 1952, contains all stream flow records, stream flow measuring stations, and a drainage map of Missouri.

In 1952, "Stratigraphy and Structure of the Northeast Quarter of the Richwoods Quadrangle, Missouri," unpublished Master's Thesis, University of Iowa, was prepared by Robert G. Warfield. In this Master's Thesis the exposed formations and geologic structure were discussed.

In "The Structure and Magnetic Surveys of the Sullivan-Bourbon area, Missouri," the relationship of surface geologic structures to areas of high magnetic intensity in part of southwestern Franklin County have been determined by Thomas K. Searight, James H. Williams, and James S. Hendrix in 1954.

V. GEOLOGY OF THE AREA

The geology of the southern half of Franklin County is described in this chapter. An area of approximately 38 square miles in the vicinity of St. Clair and Anaconda, between the Bourbeuse and Meramec Rivers, in the southern half of Franklin County was studied and geologically mapped in detail by the author (plate II).

The formations which are exposed in the study area were formed during the Pennsylvanian, Ordovician, and Cambrian periods of the Paleozoic era. The Cherokee Group and the Cotter, Jefferson City, Roubidoux, Gasconade (which includes the Gunter Member), and Eminence formations are exposed in the study area. The Potosi, Derby-Doerun, Davis, Bonneterre, and Lamotte formations are not exposed but they were encountered in the deep water wells.

A. Stratigraphy and Lithology

A generalized geological columnar section is shown in figure 4. The name, distribution, lithology, thickness, age and correlation of the formations studied in the southern half of Franklin County are described in normal sequence in this section.

1. Cambrian System

a. Lamotte Sandstone:

The oldest sedimentary formation in Franklin County is the Lamotte Sandstone of Upper Cambrian age. It was encountered in a deep well in Section 36, abb, Township 42 North, Range 1 West. Lamotte Sandstone crops out in Iron, Madison, Ste. Genevieve and St. Francois Counties in Missouri. The name of the formation was proposed by Winslow (1894) and was derived from Mine Lamotte, St.

	SYSTEM		SECTION	NAME	THICKNESS IN FEET	DESCRIPTION
PALEOZOIC	Pennsylvanian			Cheltenham Fm.	0 – 200	Mainly sh., several ls., and ss. beds Fire Clay.
	ORDOVICIAN	CANADIAN (Ulrich)		Cotter Fm.	0 – 250	White to brownish, gray thin bedded dol., medium grained, white ss., argillaceous sh.
				Jefferson City Fm.	130-200	Yellowish, thin bedded dol., sandy ch.
				Roubidoux Fm.	95-165	White to reddish ss.; cross-bedded, ripple-marked, oolitic ch.
		OZARKIAN (Ulrich)		Gasconade and Van Buren Fm. (Gunter Member)	180-290	Light gray crystalline dol., quartzose oolitic ch., cryptozoan ch. Fine-grained ss.
	CAMBRIAN			Eminence Fm.	185-290	Gray to white dol. "finger tip" ch.
				Potosi Fm.	70-300	Bluish, gray, crystalline dolomite more drusy quartz, and ch.
		CAMBRIAN (Upper) (Ulrich)		Derby–Doerun Fm.	125-150	Dense, porous dol. glauconitic sand
				Davis Fm.	200-225	Bluish, brown sh., granular glauconitic dol.
				Bonneterre Fm.	320-330	Light, gray, yellow, sandy dol.
				Lamotte Fm.	0-400	Gray to brown ss; cross bedded.

LEGEND

Dolomite	Druzy dol.	Shale
Cherty dol.	Sandstone	Cryptozoan chert
Sandy dol.	Cross-bedded Ss.	Oolitic chert

GENERALIZED GEOLOGICAL COLUMNAR SECTION

Figure 4

Francois County.[1]

> According to C. L. Dake, "The base of the formation is conglomeratic and highly feldspathic. The mid-portion is finer grained and purer. The upper portion contains dolomite beds. The sandstone is usually yellow or brown on weathered outcrop." [2]

> According to E. B. Branson, "the Lamotte is made up largely of quartz grains varying in color through light, reddish brown, red, green and shades of yellow. Shale layers a few inches thick are common throughout the formation. The sandstone is well bedded and cross-bedding is fairly common. The sand is medium grained." [3]

The Lamotte sandstone in the deep water well at St. Clair was logged as white sand at the top, pink sand toward the bottom of the well. The bottom of the Lamotte formation was not found in this well.

The thickness of this formation varies from zero to 250 feet.[4] Thickness of the Lamotte Formation in the generalized columnar section of H. C. Beckman and N. S. Hinchey was shown as 0-400 feet.[5] According to Harold Edward Mueller, thickness of the Lamotte Formation to the west, in Phelps County is variable, from zero to 300 feet.[6]

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1 E. B. Branson, "The Geology of Missouri," The University of Missouri studies, No. 3, vol. XIX., p. 16., 1944.

2 C. L. Dake, "The Sand and Gravel Resources of Missouri, Missouri Bureau of Geology and Mines, vol. XV, 2nd Series, p. 89-90., 1918.

3 Branson (1944), <u>Op</u>. <u>cit</u>., p. 16.

4 Wallace Lee, "The Geology of the Rolla Quadrangle," Missouri Bureau of Geology and Mines, vol. XII, 2nd Series, p. 9., 1913.

5 H. C. Beckman and N. S. Hinchey, "The Large Springs of Missouri," Missouri Geological Survey and Water Resources, Vol. XXIX, 2nd Series, p. 23, 1944.

6 Harold E. Mueller, "Geology of the North Half of the Meramec Spring Quadrangle," Missouri, Thesis, Missouri School of Mines and Metallurgy, p. 34, 1951.

b. Bonneterre Dolomite:

Nason (1901) assigned the name Bonneterre to a dolomite near Bonneterre, Missouri. It appears in St. Francois, Ste. Genevive, Iron and Madison Counties. This formation was encountered in two deep water wells in the southern half of Franklin County. One of the wells is located in Section 32, cac, Township 42 North, Range 1 West, and the other is the well at St. Clair, in Section 36, abb, Township 42 North, Range 1 West.

Wallace Lee described the formation as "dark and light gray, crystalline dolomite,..the lower part is in places sandy and argillaceous. The upper part also is often argillaceous." [1] The Bonneterre Formation is described by H. S. McQueen (1943) as "gray, finely crystalline, non-cherty dolomite. Green shale is locally present, and sand is an important constituent in the basal beds." [2]

> According to John G. Grohskopf and Earl McCracken (1949), "The residue content of the upper portion is generally small and consists in the main of pyrite, clay, and shale. In the lower portion residue content increases, with shale and sand becoming the predominant residue material." [3]

The Bonneterre in two water wells in the southern half of Franklin County shows green banded silty shale at the top, and glauconitic sandy shale toward the bottom of the well.

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1 Wallace Lee (1913), <u>Op</u>. <u>cit</u>., p. 9.

2 H. S. McQueen, "Geology of the Fire Clay Districts of East Central Missouri," Missouri Geological Survey and Water Resources, Vol. XXVIII, 2nd Series, p. 127, 1943.

3 John G. Grohskop and Earl McCracken, "Insoluble Residues of Some Paleozoic Formations of Missouri, Their Preparation, Characteristics and Application," Missouri Geological Survey and Water Resources, Report of Investigations No. 10, p. 31, 1949.

The following thicknesses of the Bonneterre Formation were given by various writers for adjacent areas:

Wallace Lee (1913): 360 feet [1]
H. S. McQueen (1943): 300 feet [2]
Harold E. Mueller (1951): 200-350 feet [3]

In two water wells in the studied area the thickness was measured as 320 to 330 feet.

c. Davis Formation:

This formation was found in Davis Creek, a tributary of Flat River and was named by Buckley. As described by H. S. McQueen (1943), the "Davis Formation consists of greenish gray shale interbedded with dolomite, sandy dolomite, and locally sandstone." [4] Insoluble residues from the upper portion of the Davis are fine sand and fine glauconite; the residue resembles salt and pepper.[5]

This formation was encountered in two deep water wells in the southern half of Franklin County. Upper portions of these two wells showed rounded and frosted glauconitic sand, and gray shale. Dolomite decreases toward the bottom of the wells. According to well logs, thickness of the Davis Formation in the studied area varies from 200 to 225 feet.

d. Derby-Doerun Formation:

> "the Derby formation was named by Buckley for Derby Mine, near Eldon, St. Francois County. He called it a member of the Elvins formation. Buckley used the term Doe Run with the Derby and recently it has become a custom to include the two as the Derby-Doerun Formation." [6]

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1 Wallace Lee (1913), Op. cit., p. 9.
2 H. S. McQueen (1943), Op. cit., p. 127.
3 Harold E. Mueller (1951), Op. cit., p. 34.
4 H. S. McQueen (1943), Op. cit., p. 127.
5 John G. Grohskopf and Earl McCracken (1949), Op. cit., p. 31.
6 Branson (1944), Op. cit., p. 27.

According to E. B. Branson the formation is dominantly gray to buff dolomite, with no chert. The formation was found in some deep water wells in the studied area. According to well logs the upper portion of the formation shows gray shale, and a little brown sand and silt. Sand and brown dolomitic quartzose chert increase toward the base. Dense, soft, porous dolomite is predominant in this formation. Water well logs show that the thickness of the Derby-Doerun in the thesis area varies from 125 to 150 feet.

2. Cambrian System

a. Potosi Formation:

The Potosi was first named the "Fourth Magnesian limestone" by Swallow in 1855. In 1894 Winslow first proposed the name "Potosi." The formation is best developed in Washington County. [1]

The formation was encountered in some water wells in the studied area. According to well logs the Potosi is bluish, gray crystalline dolomitic chert with a little shale. Quartzose, drusy dolomitic chert is characteristic of this formation. Water well logs in the studied area show that thickness of the Potosi formation varies from 70 to 300 feet. H. S. McQueen said, "The thickness of the Potosi dolomite, as determined from the records of deep wells drilled in the southern district (of Missouri), is 250 to 300 feet." [2]

b. Eminence Formation:

The name Eminence was first used by Buckley in 1908, for outcrops near Eminence in Shannon County. The formation crops out in

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[1] Branson (1944), _Op. cit._, p. 30.
[2] H. S. McQueen (1943), _Op. cit._, p. 127.

the bed of Little Indian Creek, and in Section 20 c, Township 41 North, Range 1 West, at the point 108, plate II, in the southern part of the study area. The formation is usually fine-grained, crystalline dolomite. Color varies from white to gray to blue. Several types of chert are common in this formation.[1] The Eminence dolomite in the Ozark province consists of "light colored medium to coarsely crystalline dolomite which may be somewhat siliceous." [2]

Well logs of the formation in most of the water wells in the thesis area show bluish to gray crystalline dolomite. Light colored quartzose chert is found in the upper portion of the formation. Toward the middle of the formation thin sandy beds and chert are present. Gray, tan, finely quartzose chert appears at the base of the formation. Carl Burchart has mentioned that "the majority of the chert that was found consisted of the finger type variety white or brown nodules on the surface of the rock." [3]

According to well records, in the southern half of Franklin County thickness of the Eminence Formation ranges from 185 to 290 feet. Contact of the Eminence and the Gasconade formations was observed at an elevation of 615 feet at the outcrop point 108, plate II, in the southern part of the mapped area. This formation

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1 C. L. Dake (1918), Op. cit., p. 128.

2 John G. Grohskopf, "Surface Geology of the Mississippi Embayment of Southeast Missouri," Missouri Geological Survey and Water Resources, Vol. XXXVII, 2nd Series, p. 16, 1955.

3 Carl Robert Burchart, "Geology of the Northwest Portion of the Richwoods Quadrangle, Missouri," University of Iowa, Master's Thesis, p. 22, 1952.

is the youngest in the Cambrian system in this area.

3. Ordovician System

Gasconade-Van Buren Formation and Gunter Member:

"The name Gasconade was proposed by Nason (1892) for outcrops on the Gasconade River in central Missouri. Swallow (1855) was the first to mention the formation in the literature and he called it the 4th Magnesian Limestone from the outcrops along the Niangua River in Camden County." [1]

"The name, Van Buren, was used by Dake, Bridge, and McQueen in 1930 and 1931. The Gunter sandstone is the basal member of the Van Buren. It was named by Ball and Smith from outcrops in Miller County and it was considered a member of the Gasconade." [2]

"The Gunter member, Van Buren, and Gasconade (restricted) formations were mapped as one formation because the silicious oolite bed, used by Bridge as the top of the Van Buren, could not be located. McQueen has been able to separate the Van Buren from the Gasconade on the basis of the cherty insoluble residue, but according to James (1948), other members of the Missouri Geological Survey and Water Resources have found that the exact contact between the Van Buren and Gasconade is indeterminable." [3]

The name Gasconade is used by the author to describe the Gasconade and Van Buren formations together. The lower Gasconade in most well records includes the Van Buren without any separation. The Gasconade and Van Buren formations outcrop in the center of the studied area. Gunter Sandstone was found at the outcrop point 98, plate II, in Section 20, Township 41 North, Range 1 West, in the mapped area.

The Gasconade is coarsely crystalline dolomite. Light brown and green quartzose chert are found in the upper Gasconade. The

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[1] Branson (1944), Op. cit., p. 41.
[2] Branson (1944), Op. cit., p. 35.
[3] Harold E. Mueller (1951), Op. cit., p. 37,38.

percentage of these types of chert in the upper Gasconade is not more than 15. Tan, white, smooth quartzose oolitic chert and white clusters of oolitic chert (not common) are recorded in the lower Gasconade. Toward the bottom of the formation white quartz, quartz druse and some sand grains are found. According to well records the Gunter Member contains dolomite, rounded and frosted, thin bedded sand, and white to gray smooth oolites. A cryptozoan chert bed was found in some places in the upper portion of the Gasconade Formation and was used as a key horizon to find the contact between the Roubidoux and Gasconade formations. The common form of the cryptozoan chert is parallel arched lamellae ½ to 1 inch thick forming a roughly spherical colony about one to six feet in diameter.

The writer has made an isopach map of the Gasconade Formation in the study area. In this map, the Van Buren Formation and the Gunter Member have been included in the Gasconade Formation. Data for this map were derived from the well logs and were available for approximately the central part of the study area. According to the map, the thickness of the Gasconade Formation (including the Van Buren) ranges from 180 to 270 feet (plate VIII). Most of the wells in the western part of the study area did not completely penetrate the Gasconade Formation. Therefore, the thickness of the Gasconade in this area is poorly known. In one well, in Section 11, bdb, Township 42 North, Range 4 West, a thickness of 290 feet of Gasconade formation was found. The top of the cryptozoan chert is generally found 40-60 feet below the top of the Gasconade Formation. Its thickness varies between two and twelve feet. According to well records, the thickness of the Gunter Member of the Gasconade Formation ranges from 5 to 45 feet. Its average thickness in the thesis area is 20 feet.

The Gasconade is the only formation of the Ozarkian division of the Ordovician system. According to Branson (1944),

> "some of the Species of the Gasconade faunas have been found in the Oneote dolomite of Wisconsin and some in the Chepultec dolomite of the southern end of the Appalachian Trough, particularly in Alabama and Tennessee. Ulrich (1940), believes that the Gasconade is the partial equivalent of the Mons formation of Alberta." 1

4. Ordoviciann System

a. Roubidoux Formation:

Nason (1892) named the Roubidoux formation from outcrops on Roubidoux Creek in Texas and Pulaski Counties. Winslow (1894) incorrectly used the name Roubidoux for the St. Peter in his correlation table.[2] The Roubidoux Formation is exposed on the surface in many places in the study area. It is also found in the wells in the western and northeast parts of the area.

Well records show that the Roubidoux formation consists of yellowish, pinkish, red-brown, rounded and frosted (mostly) sand, dark brown quartzose oolitic chert, and interbedded dolomite. The Roubidoux formation as exposed on the surface in the study area appears to be fine to medium grained, reddish, sparkling, friable sandstone, and dark quartzose, smooth oolitic chert. Outcrops of the Roubidoux Formation are characteristically blocky. This block type outcrop of the Roubidoux Formation is shown in figure 5, taken at outcrop point 87 (plate II) in Section 17, ba, Township 41 North,

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[1] Branson (1944), Op. cit., p. 47.
[2] Branson (1944), Op. cit., p. 47.

Range 1 West. The weathered surface of this rock is brown; fresh samples are light redish-pink in color. The beds shown in the figure consist of medium to fine grained sand; the beds are separated by one-to-12-inch thick, gray or yellowish chert. This photograph of the formation clearly shows the character of the lower part of the Roubidoux. Current ripple marks are common; current directions determined from them are shown on Plate II. According to well logs the thickness of the Roubidoux formation in the southern half of Franklin County ranges from 95 to 165 feet. Its average thickness is 125 feet.

The Roubidoux occupies the lower part of the Canadian Series of the Ordovician System. Beds of equivalent age are widespread in the Appalachian Mountains where the lithology is usually a carbonate.

Figure 5

Outcrop of the Roubidoux Formation, in railroad cut in Section 17, ba, Township 41 North, Range 1 West.

b. Jefferson City Formation:

The Jefferson City Formation was named by Winslow (1894) from outcrops near Jefferson City, Missouri.[1] Meek (1873) named these beds the Second Magnesian limestone for outcrops in Miller County, 30 miles southeast of Jefferson City.

> According to Martin: "Ulrich (1911, 1915) redefined the limits of the Jefferson City and proposed a division into three formations; the Jefferson City (restricted) (lower) the Cotter and the Powell (upper)." [2]

The formation is exposed over much of the study area but has been eroded from the central and south central parts.

> According to Mueller: "The Jefferson City formation is predominantly dolomite. Argillaceous dolomite, siliceous dolomite, sandy dolomite, dolomitic sandstone, sandstone lenses, shale, chert and siliceous oolite occur in the formation." [3]

According to well log records the formation is mainly yellowish thin bedded dolomite. It contains about 10-15 percent smooth, oolitic chert and 5-10 percent sand (mostly rounded and frosted). Thickness is given as 170 feet in eastern Missouri by John G. Grohskopf and Earl McCracken.[4] Well logs show that the thickness of the Jefferson City Formation varies between 130 and 200 feet in the study area. The average thickness of the formation in the southern half of Franklin County is 160 feet.

The formation is placed in the upper part of the lower Ordovician (Canadian Series).

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[1] Branson (1944), Op. cit., p. 50.

[2] James A. Martin, "Geology of the Northwest Quarter of the Washington Quadrangle, Missouri," Master's Thesis of the Missouri School of Mines and Metallurgy, p. 16, 1956.

[3] Harold E. Mueller (1951), Op. cit., p. 72.

[4] John G. Grohskopf and Earl McCraken (1949), Op. cit., p. 29.

c. Cotter Formation:

> "In 1913, Ulrich divided what he called the Cotter, which previously had been considered upper Jefferson City, from the Jefferson City, and Purdue and Miser (1916) used the name and described the formation in the Eureka Spring, Arkansas district. [1]

The Cotter Formation is exposed on the northeastern and western parts of the southern half of Franklin County.

The formation consists of dolomite, sandstone, chert, and oolite. Well log records show that 70-85 percent of the formation is light gray, thin-bedded dolomite. Shale with quartz, some oolitic chert, and medium-grained sandstone are found in the formation. Thickness ranges from zero to 250 feet.[2] Its total thickness, below the overlying Cherokee, was recorded as 70 feet on a well log in the southern half of Franklin County. This formation is the youngest lower Ordovician unit in this area.

5. Pennsylvanian System

Cheltenham Fire Clay:

The Cheltenham fire clay is exposed in the west part of the study area. The Cheltenham fire clay was named by Wheeler (1896) from exposures in the south part of St. Louis City.[3]

McQueen (1943) divided the Cheltenham formation into three members. The lower member is of dark brown, black, or gray flint and semi-flint fire clay which is hard, fine grained and smooth. The middle member of the Cheltenham consists of semi-plastic light gray clay. Light to dark gray plastic clay characterizes the upper

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1 Branson (1944), Op. cit., p. 55.
2 H. C. Beckman and N. S. Hinchey (1944), Op. cit., p. 23.
3 Branson (1944), Op. cit., p. 274.

member. The fire clay ranges from zero about to 15 feet in thickness. The formation fills shallow sink holes. It is absent in some areas. Because of this it is difficult to give an average thickness for it. According to Martin "stratigraphic position indicates that the Cheltenham is Post-Graydon, and the formation is generally referred to the Cherokee."[2] According to the Missouri Geological Survey, the Cheltenham fire clay is currently placed in the Atokan series beneath the Cherokee Group.

6. Quaternary System

Alluvium:

Boulders, gravel, and silt are found in the beds of creeks in the study area. Chert is the most common rock in the creek beds. Because sand and silt are the dominant sediments in the floodplains of the Meramec and Bourbeuse Rivers, cultivation is possible in these valleys. The alluvial materials originate from stream erosion of the surface formations.

B. Structure

1. Regional Structure

The strata of the Ozark Province generally dip slightly away from the St. Francois Mountains. Dips are eastward from a center in Iron, Reynolds and Madison Counties; dips are northeastward in St. Francois, Franklin and Jefferson Counties; dips of 10 to 20 feet per mile northward and northwestward occur along the Missouri River as far west as Benton County. [2] Low folds occur in most places in the Ozark Province. They are not recognizable by direct

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[1] James A. Martin (1956), Op. cit., p. 75.
[2] Branson (1944), Op. cit., p. 358.

observations. In addition to the major folds there are many minor folds in the same province. Their trends are northeast or northwest.

> According to Branson (1944), "In Ste. Genevieve County there is an peculiar zone of faulting where many grabens were formed. The main fault lines are nearly parallel, but cross faults between the main lines run in various directions. The fault zone starts in eastern Perry County and the last trace of it is in Franklin County, about 100 miles northwest. The fault planes of the fault are nearly vertical." 1

2. Local Structure

Two structure contour maps, based on the tops of the Gasconade and the Eminence formations, are shown in plates VI and VII. The structure contour map of the Gasconade Formation shows the entire southern half of Franklin County. Data for the top of the Eminence Formation were available for less than two-thirds of the study area. Well logs and outcrops were used as sources of data for these maps.

These structure contour maps revealed four major and several minor folds whose axes are approximately parallel to each other. Some seem to be asymmetrical folds. The general direction of plunge of the anticlines and synclines is to the northeast. One of the major fold axes extends from the northeastern corner of the study area southwestward following the Meramec River to the vicinity of Meramec State Park. This northeastern plunging fold is here called the Meramec River Syncline. Its axial length is about 20 miles from southwest to northeast. Flanks of the fold in the south are wider than in the north. It ranges from 0.5 to 3.5 miles wide. A second major fold axis starts from the northwest corner of

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1 Branson (1944), Op. cit., p. 360.

the Meramec State Park, extends through Anaconda and ends approximately one mile north of St. Clair. The name Anaconda Anticline is here given to this fold. Its axial length is nearly 12 miles. Flank width of this anticline is between 1.5 and 3.0 miles. A third major fold called the Stanton Syncline was found to the west of the Anaconda Anticline. The axial length of the Stanton Syncline is about 15 miles. The fourth fold, called the Sullivan Anticline, starts from a point west of Sullivan City and ends in Section I, bb, Township 41 North, Range 2 West. Axial length of this fold is about 10 miles. A double plunging anticline found in the southwestern part of the study area is shown on plate VI. This anticline trends northeast and southwest, and has an axial length of 7.5 miles between the last closures of the fold.

Two faults were interpreted from well logs and a cross-section in the study area. One of these faults extends from the north-northwest to the south-southeast, in Sections 10, 14, 23, 16, 35, Township 42 North, Range 2 West, a distance of about 5.25 miles (plates III, VI, VII). The top of the Gasconade Formation in a well in Section 14, bb, Township 42 North, Range 2 West, (plate VI) and the top of the Eminence Formation in a well, Section 18, add, Township 42 North, Range 1 West, (plate VII) are higher than in several wells to the west of these two wells. Only these two wells provide evidence of the fault line. The other fault is found in Sections 7, 8, 9, 10, Township 40 North, Range 2 East, trending northwest to southeast. This fault is probably the northwest extention of a Ste. Genevieve County fault zone described by Branson.

in the above section on Regional Structure. Tops of the Gasconade and Eminence Formations in the wells north of the fault are lower than in the wells south of the fault. This is the only evidence found for the fault.

It is not certain whether the well in section 7, dbd, Township 40 North, Range 2 East is north or south of the fault. Because of this the part of cross-section A-B near the fault is uncertain.

The geologic maps of Missouri (1939, 1961) show several unusual intersecting possible faults between St. Clair and Anaconda. The presence and locations of these faults were based on reconnaissance surface mapping by Dake in 1920. Obtaining more information about these faults was one of the principal objectives of the field work done in the St. Clair-Anaconda area. Cross-sections C-D and E-F (plates IV and V), which cross these supposed faults, show that no conclusive evidence was found, either in the field or in well logs, for the existence of these faults.

Both the Gasconade and Roubidoux formations show some joint patterns. In the Roubidoux Formation it is possible to find well-developed joint systems. Joints in the Roubidoux Formation are predominately vertical. Strike directions of the two sets of joints in the Roubidoux Formation are approximately northwest and northeast. This type joint pattern in the Roubidoux Formation is exposed at outcrop points 22, 33, 57, 64, 87, 88, 89, 91, 93, 105, 109, and 110.

VI. HYDROLOGY

A. Surface Waters

1. Streams:

Three major rivers, the Missouri, Bourbeuse, and Meramec, flow in Franklin County. There are three stream-flow recording stations in Franklin County. Two of these are located on the Bourbeuse River and one on the Meramec River. Another station on the Meramec River is located 4 miles southeast of Sullivan, in Crawford County. These four flow recording stations are shown in figure 3. This figure also shows drainage basins related to Franklin County. Flow records of the Bourbeuse and Meramec Rivers have been collected systematically by the Missouri Geological Survey since 1921. The flows of the Bourbeuse and Meramec Rivers are not uniform. They vary day to day, and year to year depending on the character and amount of precipitation, and the amount of the total runoff from this precipitation. River flow records at the three Franklin County stations are given in tables 1, 2, and 3. These tables have been prepared according to water years instead of calender years. Table 1 is based on a five year record; Tables 2 and 3 are based on 10 year records.[1] Maximum and minimum discharge rates listed in the tables are highest and lowest daily discharge rate. The "mean" in table 3 is the mean of monthly averages. The highest discharges occurred in the water year of 1944-45.

The average discharge rate of the Meramec River at station

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[1] After Bolon (1932), Op. cit., p. 565-612.

number 1, for years 1922-33 and 1944-49 (17 years), as 1,282 second-feet. Maximum daily discharge rate was 77,300 second-feet on June 9, 1945, and the minimum daily discharge rates were 160 second-feet on September 22 to 30, and October 2 and 3, 1932.

Average discharge rate at station number 2, located on the Meramec River, was 2,303 second-feet for a 10 year periods. The maximum discharge rate was 10,200 second-feet June 10, 1945, and the minimum discharge rate was 256 second-feet on August 23 and 24, 1941.

The average discharge rate from 1921 to 1949 at station number 3, on the Bourbeuse River was 668 second-feet. The maximum discharge rate was 38,500 second-feet in June, 1945, and the minimum discharge rate was 14 second-feet on August 31 and September 1, 1936.

At station number 4, located on the Bourbeuse River, discharge records are available for flows greater than 1,000 second-feet. This station's minimum discharge value was recorded several times from September 1939 to November 1943. The maximum discharge rate at this station was 33,000 second-feet on April 26, 1947.

Table 1
Discharge table of Meramec
River Near Sullivan Station

Water Years	Discharge Rate in Second-Feet Max.	Min.	Mean	P.S.Mile	Runoff Inches	Acre-Feet
1944-45	70,600	273	2,414	1.64	22.24	1,748,000
1945-46	22,600	308	1,191	.87	10.96	862,000
1946-47	36,000	290	1,437	.974	13.23	1,040.000
1947-48	11,000	271	1,091	.740	10.06	792,200
1948-49	22,300	297	1,404	.952	12.92	1,016,000

Table 2
Discharge Table of Meramec
River at Robertsville Station

Water Years	Discharge rate in second-feet Max.	Min.	Mean	P.S.Mile	Runoff Inches	Acre-Feet
1939-40	10,400	288	1,098	.407	5.55	790,700
1940-41	34,400	264	1,194	.447	6.07	864,600
1941-42	60,800	362	3,113	1.16	15.83	2,254,000
1943-44	17,700	289	1,675	.627	8.54	1,216,000
1944-45	97,200	330	4,010	1.50	20.35	2,903,000
1946-47	32,400	405	1,039	.725	9.84	1,404,000
1947-48	16,800	356	1,932	.732	9.85	1,403,000
1948-49	30,800	368	2,400	.898	12,19	1,738,000

Table 3
Discharge Table of Bourbeuse
River at Union Station

Water Years	Discharge rate in second-feet Max.	Min.	Mean	P.S. Mile	Runoff Inches	Acre-Feet
1939-40	3,280	24	204	.256	3.48	148,100
1940-41	16,100	42	1,018	1.28	17.31	119,600
1941-42	19,500	20	317	.397	5.34	736,800
1942-43	10,400	36	613	.768	10.46	445,000
1944-45	27,700	26	1,124	1.41	19.14	813,000
1945-46	8,970	30	487	.610	8.28	352,300
1946-47	22,600	28	784	.982	13.35	567,700
1947-48	8,520	37	751	.941	12.80	545,600
1948-49	9,610	45	635	.786	10.67	459,500

2. Springs:

a. General Descriptions:

Most of Franklin County's large springs rise in the southern half of the county. Three of them, Elm Spring, Falling Spring, and La Jolla Spring, are located in Meramec State Park. Two others, Twin Spring, number 8 in Table 4, and Roaring Spring, number 7, are located one mile west of McCallister Ford.

These five springs form a group located within an area of five and a half miles diameter. Three other large springs rise in individual places in the southern half of Franklin County. They are Cove Spring, Kratz Spring, and Roaring Spring, number 6 in Table 4. The locations of the above springs are listed in Table 4. Most of the springs issue from the massive Orodovisian rocks.

Table 4

Location of the large springs in the southern half of Franklin County.

Number	Spring	Location
1	Cove	T.42 N., R. 1 W., Sec. 21, cda
2	Elm	T.40 N., R. 2 W., Sec. 11, caa
3	Falling	T.40 N., R. 2 W., Sec. 13, aac
4	Kratz	T.41 N., R. 2 W., Sec. 19
5	La Jolla	T.40 N., R. 2 W., Sec. 1, bab
6	Roaring	T.42 N., R. 3 W., Sec. 26, bdd
7	Roaring	T.41 N., R. 1 W., Sec. 19, d
8	Twin	T.41 N., R. 1 W., Sec. 19, d

Some of them rise from gravel beds. Most of them appear to be fed by subsurface streams flowing in solution cavities.

b. Detailed Descriptions

The flow measurements for the following springs are given in Table 5. Elm Spring is located in Meramec State Park, about two miles east of Sullivan, on State Highway 114. The discharge empties into the Meramec River, approximately two miles to the east of the spring.

Falling Spring is located in Meramec State Park, on State Highway 114, about three miles east of Sullivan and 6,600 feet east of Elm Spring. Falling Spring rises on a hill-side and discharges over a waterfall into Elm Spring Branch. Falling Spring is a source of water supple for visitors to Meramec State Park.

Roaring Spring and Twin Springs are located two miles east of Stanton. Roaring Spring issues from a cave, on the outer, north bank of a meander of the Meramec River and empties into this river approximately 30 feet away. Twin Springs rises on the outer, south bank of the same meander, and empties into the Meramec River. The straight line distance from Roaring Spring to Twin Springs is about 2,800 feet.[1]

Table 5

Discharge of some springs in the southern half of Franklin County

Spring Number	Second-Feet	Gallons Per Day	Date
2	1.36	800.000	May 25, 1937
3	0.08	50.000	May 25, 1937
4	6.8	4.390.000	September 3, 1927
	10.0	6.460.000	September 4, 1936
7	1.0	650.000	September 3, 1925
	2.36	1.530.000	September 4, 1936

(See Table 4 for names of Springs).

Chemical analyses of Kratz Spring, Roaring Spring (number 7), and Twin Springs were made by the Missouri Geological Survey, and are given here in Table 6. According to these analyses the spring

[1] N. C. Beckman and N. S. Hinchey, Op. cit., p. 74, 87, 108

waters in the southern half of Franklin County have medium hardness. Total hardness has been taken as calcium carbonate content. Mineral content in these three springs is moderate.

Table 6

Chemical analyses of three springs in the southern half of Franklin County

Spring Number	4	7	8
Turbidity		20	4
Tot. Susp. Matter	19.0	1.3	0.0
Tot. Hard.	118.0	165.3	201.2
Alkal.	118.0	165.3	195.5
Bicarb.	137.0	201.6	231.2
Carb.	3.3	0.0	3.6
Chlor.	2.7	6.6	2.3
Nitr.	0.98	1.06	1.00
Date	July 19,1925 [1]	Sept.3, 1925[2]	March 12, 1954[3]

B. Water Wells

1. Well Drilling Practices

Drillers in the southern half of Franklin County use the percussion method of drilling. The method is also known as the standard or cable tool method. This method gives good results in consolidated rock materials. The equipment for this method consists of a standard well drill, a "string" of percussion tools, and a bailer. The drilling rig for the cable tool method consists of a mast, a multiline hoist, a walking beam, and an engine. A string of percussion tools, named in order from top to bottom, consists of a rope socket, a set of jars, a drill stem, and a drilling bit. The bailer consists of a section of pipe with a valve at the bottom and

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1 H. C. Beckman and N. S. Hinchey, Op. cit., p. 49

2 H. C. Beckman and N. S. Hinchey, Op. cit., p. 41

3 After the Missouri G. S. and Water Resources files of chemical analyses of water sample.

a ring at the top. [1]

Water well drillers in the thesis area have cooperated with the Missouri Geological Survey and Water Resources. They save the rock cuttings which are removed from the wells by a bailer. Sample sacks and drillers' log books are supplied to the drillers by the Missouri Geological Survey. Rock cuttings are placed in sample sacks by the drillers and are shipped to the Geological Survey for evaluation. In filling out the log book, drillers indicate the depth of the rock, the kind of rock drilled, the size of hole, and the size of the casing and liners. They also record the static water level, water production, and depths at which water is encountered.

Interviews with the water well drillers in the studied area have shown that they follow the guides of water well construction and development which were framed by the Department of Public Health and Welfare, Missouri Division of Health. In addition, they have gained experience and have developed special well completion methods, such as screening, and plugging off undesired water in the wells. Because of competition some water well drillers are reluctant to give more information concerning their experience or business. Most of the water well drillers give complete data to the public through the Missouri Geological Survey.

Diameters of wells drilled in the southern half of Franklin County range from 3 to 15 inches. The diameter of a well is usually larger at the top than at the bottom. Water drillers use a protec-

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[1] David Keith Todd, "Ground Water Hydrology," Chapter 5, Water Wells, p. 123, 129, 1959

tive casing in the upper part of the wells to prevent entrance of possibly contaminated surface water. The length of the protective casings in most wells is not less than 10 feet. The depth to which public wells must be cased is given to drillers by the Missouri Geological Survey. Well drillers want to drill and complete a well as quickly as possible. A well, 250 feet in depth, within Ordovician rocks, in the southern half of Franklin County is drilled in approximately 15 days. Drillers generally do not drill cores unless required to do so. Bailing intervals desired by the Missouri Geological Survey are 5 feet. Most drillers follow this bailing standard and bail the wells at 5-foot intervals. The water production in most of the wells in the studied area is measured by a bailer.

During personal interviews with the author, some well owners wanted to learn the effects of nuclear tests on ground water from springs and water wells. The author has expressed the opinion that nuclear test fallout contaminates surface waters, such as rivers, ponds or lakes, which are open to air, but does not directly effect the deep water wells. Radioactive contaminants tend to be absorbed and precipitated by suspended and colloidal matter invariably present in surface waters. Because of the adsorptive properties of soil, ground water which has slowly percolated through soil is generally safe. This opinion is based on the book "The Effects of Atomic Weapons."[1]

[1] The effects of Atomic Weapons, The United States Department of Defense and The United States Atomic Energy Commission, under the direction of the Los Alamos Scientific Laboratory, p. 331, 332, 1950

2. Analysis of Well Data

a. Relation to Population:

The well logs of water wells drilled and completed in the southern half of Franklin County were obtained for study from the files of the Missouri Division of Geological Survey and Water Resources. Study of 205 water well logs has shown that 52 water wells were drilled and completed in the Roubidoux formation from 1930 to 1962. Thirty eight of these water wells were completed after 1950. Ten water wells in the same formation were completed between 1940 and 1950. Less than five water wells ending in the Roubidoux Formation were completed before 1940. Ninety-five of the studied water wells were drilled and completed in the Gasconade Formation. Sixty-six wells in the Gasconade Formation were completed between the 1950 and 1962 years. Twenty-one wells in the same formation were drilled and completed from 1940 to 1950. Less than ten water wells in the Gasconade Formation were drilled and completed before 1940. Forty-eight of 205 water wells studied were drilled and completed in the Eminence Formation. Twenty-one of these water wells were completed after 1950. Seventeen water wells in the Eminence Formation were completed between 1940 and 1950. Ten of these 48 water wells were drilled and completed before 1940. A total of ten water wells were drilled and completed below the Eminence Formation. The formations penetrated are the Potosi, Derby-Doerun, Bonneterre, and Lamotte.

From the above information it can be seen that most of the water wells in the southern half of Franklin County were drilled and completed in recent years. The main reason for this is the population increase in the studied area. Relation of population to the water wells in the thesis area are shown in Figure 6, (the census figures for 1940, 1950, 1960 are for the entire Franklin County. The number of water wells are from only the southern half of Franklin County). As shown in Figure 6, the population was 33,868 in 1949; the total completed water wells was 22. When the population increased to 36,046 in 1950; the number of water wells was about 48. The census figure for 1960 was 44,566 and the number of water wells was 135.

b. Water Level Fluctuations:

The water level in two water wells in Franklin County has been automatically recorded since 1956 by the Missouri Geological Survey and Water Resources. One of these wells is located in the northern half of Franklin County near the city of Washington, in Section 21, dd, Township 44 North, Range 1 West. Owner of this well is Everet Marquart. The well was drilled as an oil test well by Dome Oil and Gas Company in 1931. The second observation well is located in the southern half of Franklin County at the city of St. Clair on State Highway Department property in Section 26, d, Township 42, Range 1 West. The well was drilled and completed in the Gasconade Formation at a total depth of 295 feet in April 1956. Owner of this observation well is the Missouri Geological Survey and Water Resources. Water level fluctuations in these two wells are continuously measured by Stevens Water Level Recorders.

Relation of precipitation to the water level fluctuations in the observation well at St. Clair is shown in Figures 7 and 8. Average precipitation for a 5 year period is about 39.6 inches. The high value is 58.31 inches in 1957. Low value is 29.73 inches in 1960, (records missing for March and April). Static water level ranges from 72.7 to

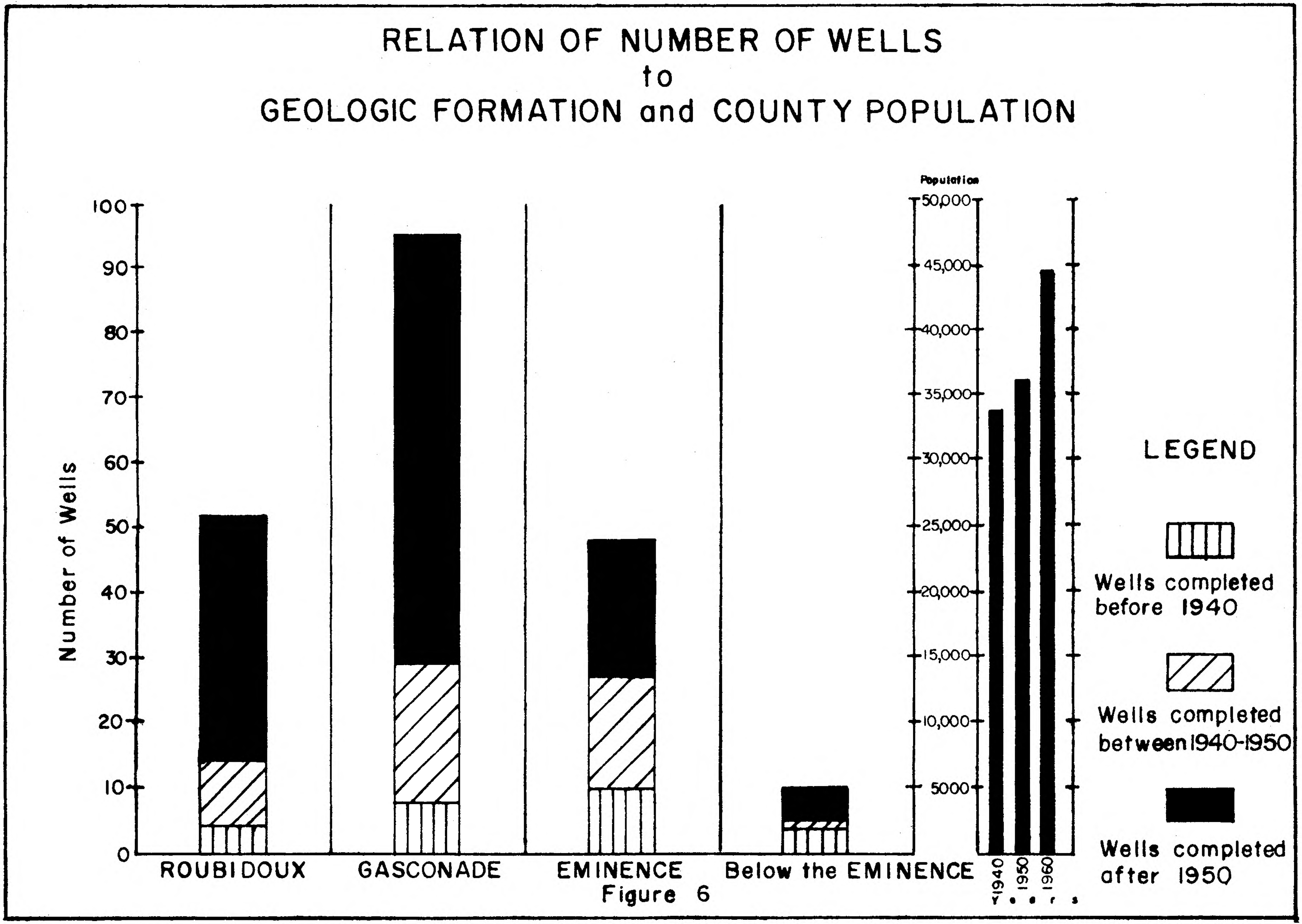
RELATION OF NUMBER OF WELLS
to
GEOLOGIC FORMATION and COUNTY POPULATION
Number of Wells
0
10
20
30
40
50
60
70
80
90
100
ROUBIDOUX
GASCONADE
EMINENCE
Below the EMINENCE
Population
5000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
1940
1950
1960
Years
LEGEND
Wells completed before 1940
Wells completed between 1940-1950
Wells completed after 1950

Figure 6

66.7 feet depth for the same 5 year period. Difference between the maximum and minimum static water level is approximately 6 feet. Static water level depth at the beginning of 1956 was 72.7 feet. Within a few months static water level rose to a depth of 68.7 feet, and reached the minimum depth, 66.7 feet, in 1957. The static water level after 1957 declined and was at the depth of 69.2 feet in 1960. Comparison of these figures show that precipitation is an accurate indicator of the static water level changes in the Missouri Geological Survey and Water Resources' observation well at St. Clair.

c. Drawdown, Specific Capacity, and Production:

Complete water well data are listed in Appendices I, II, III, and IV. These Appendices have been arranged according to the formations in which the wells were completed. The first column in these tables shows the location of the wells. The first number in this column refers to Township, the second number refers to Range, third shows the Section, and small letters shows the Quarters in the Section (see abbreviations, Appendix). The second column is the surface elevation. The third column lists the static water level in the wells, which as been defined by C. F. Tolman as:

> "The water level in a non-pumping well outside the area of influence of any pumping well. This level registers one point on the water table in a water table well or one point on the pressure surface in a confined water well." [1]

The fourth column represents the draw-down in pumped wells. The draw-down is the difference between the static water level and the

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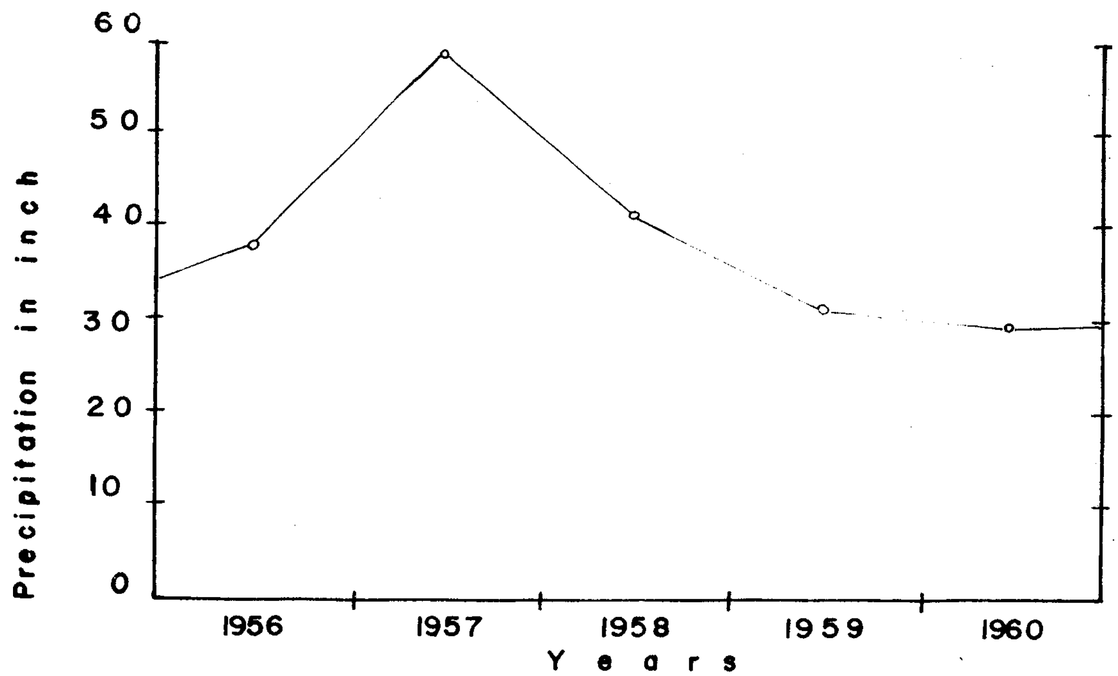
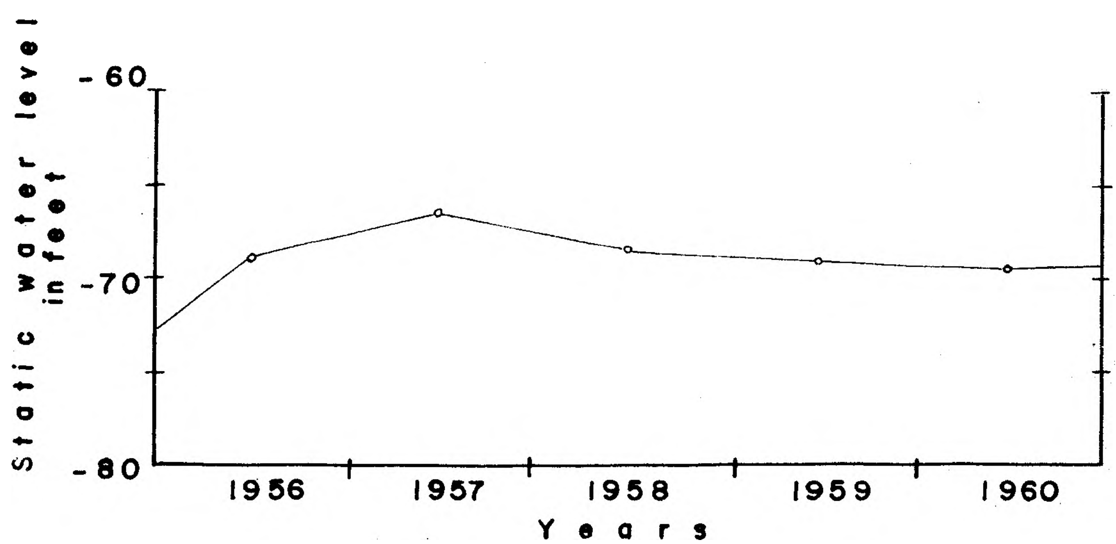
[1] C. F. Tolman, "Ground Water," Glossary, p. 563, 1937.



ANNUAL PRECIPITATION AT UNION, MISSOURI

FIGURE 7



WATER LEVEL FLUCTUATION IN THE OBSERVATION WELL AT ST. CLAIR

FIGURE 8

lower dynamic water level when the well is pumped. The fifth column shows the water production of water wells, the amount of water produced by a pumping well in gallons per minute.

The sixth column lists the specific capacity of the wells. This was calculated from the formula:

$$\text{Specific Capacity} = \frac{Q}{Dr.Da.} = \frac{Q}{D.W.L.-S.W.L.} \text{(Gpm/ft)}.$$

Q = Discharge from a pumping well, (Gpm).
Dr. Da. = Draw-down, (Ft).
D.W.L. = Dynamic Water level, (Ft).
S.W.L. = Static water level, (Ft).

The specific capacity is related to two factors, the permeability of the water bearing formation and the frictional resistance at the entrance to the well.[1]

The seventh column records the total depth of the water wells in feet. The eighth column contains the date when the water wells were drilled. The ninth column shows the level at which water was first encountered, results of pumping test, and addtional information about locations.

According to these tables the average depth to static water level in the southern half of Franklin County is 131 feet. Maximum depth to static water level is 365 feet in the well in Section 13, a, T. 41 N., R. 2 W. This well was completed in the Eminence Formation. Minimum depth to static water level is 10 feet in the well in Section 36, dda, T. 42 N., R. 1 W. This well was completed in the Roubidoux Formation. First water in this well was encountered at a depth of 90 feet.

Maximum draw-down is 195 feet in the well in Section 35, cba,

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[1] C. F. Tolman (1937), Op. cit., p. 382

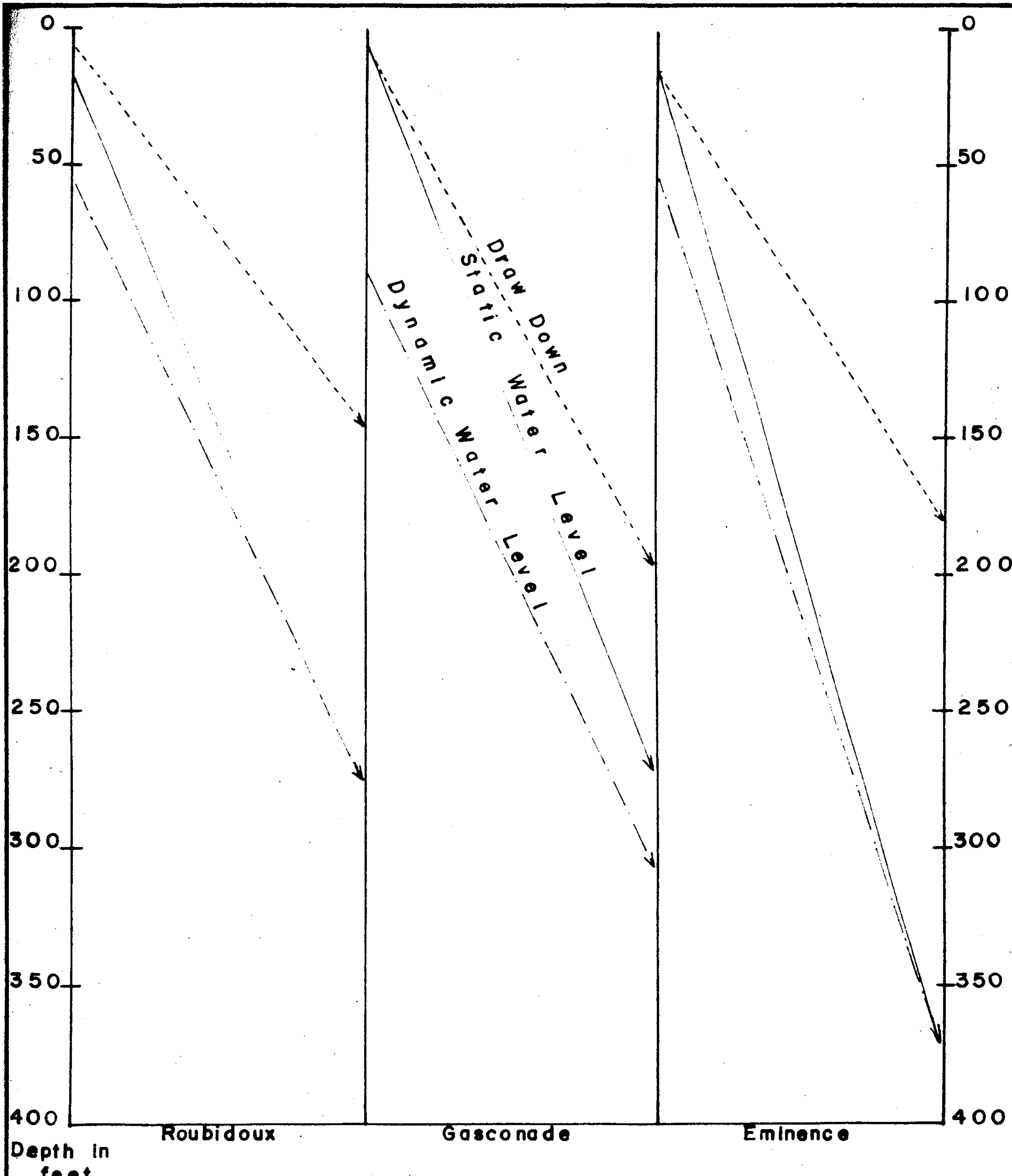
T. 42 N., R. 1 W. First water was found at 200 feet, depth. Static water level in this well is 70 feet. Dynamic water level for this well is 265 feet when water production is 13 gallon per minute. This well was completed in the Gasconade Formation.

Maximum dynamic water level in the well in Section 25, add, T. 42 N., R. 1 W, is 398 feet. Water production from this well is 36 gallon per minute. This well was completed in the Derby-Doerun Formation. Static water level and draw-down in the same well are 180 and 218 feet respectively.

Maximum and minimum values of static water level, dynamic water level and draw-down in the wells completed in the Roubidoux, Gasconade and Eminence formations within the southern half of Franklin County are represented by a graph in Figure 9.

Water production from the wells studied is between one and 375 gallon per minute. The average production from 179 water wells in the southern half of Franklin County is 17 gallon per minute. Maximum water production is from a city well at Sullivan in Section 9, add, T. 40 N, R. 2 W. This well was completed in the Derby-Doerun Formation at a depth of 905 feet in 1954. Minimum water production, from the well in Section 26, aab, T. 42 N, R. 1 E., is one gallon per minute. This well was completed in the Gasconade formation in 1936. Maximum water production from the wells completed in the Roubidoux, Gasconade, and Eminence formations within the southern half of Franklin County are shown in Figure 10.

Maximum specific capacity in the area studied was 3.00 gallon per minute per foot for the well in Section 3, bcd, T. 42 N., R. 2 E.



GRAPHIC REPRESENTATION OF MAXIMUM AND MINIMUM VALUES OF S.W.L., D.W.L., AND DR.DA. IN THE WELLS COMPLETED IN THE RB., GC., EM. FORMATIONS

FIGURE 9

This well was completed in the Gasconade Formation at a depth of 503 feet in 1957. Maximum specific capacity in the water wells completed in the Roubidoux, Gasconade, and Eminence formations within the southern half of Franklin County is represented by a graph in Figure 11.

The deepest water well in the thesis area is in Section 36, abb, T. 42 N., R. 1 W. This well was completed in 1931, in the Lamotte Formatioh, at a depth of 1540 feet. The static water level in this well is 60 feet, and first water was encountered at 170 feet. The water production from this well is 100 gallon per minute.

3. Water Bearing Formations!

Most of the Cambrian and Ordovician rocks in the southern half of Franklin County are water-bearing formations. These formations from bottom to the top are the Lamotte, Bonneterre, Davis, Derby-Doerun, Potosi, Eminence, Gunter (member of the Gasconade), Gasconade, and Roubidoux. Ground water in the study area is produced from all these formations except the Davis.

a. Lamotte Sandstone:

The sand in the Lamotteeis generally medium-grained. Approximately 50% of it passes through a 28 mesh (0.589 mm.) sieve, and for most samples the 150 mesh (0.104 mm.) sieve retains all.[1] According to David K. Todd's porosity [2] table,[3] the porosity of the

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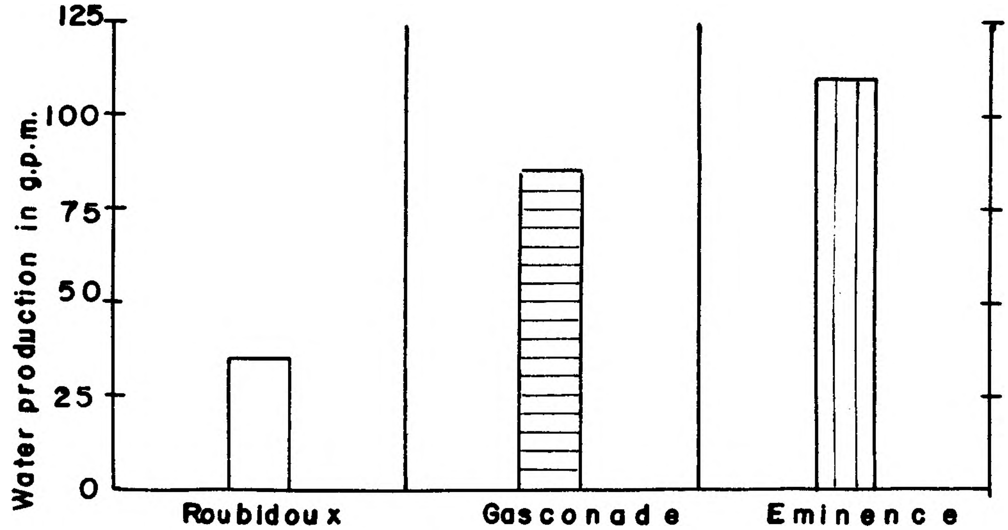
[1] Branson (1944), Op. cit., p. 16

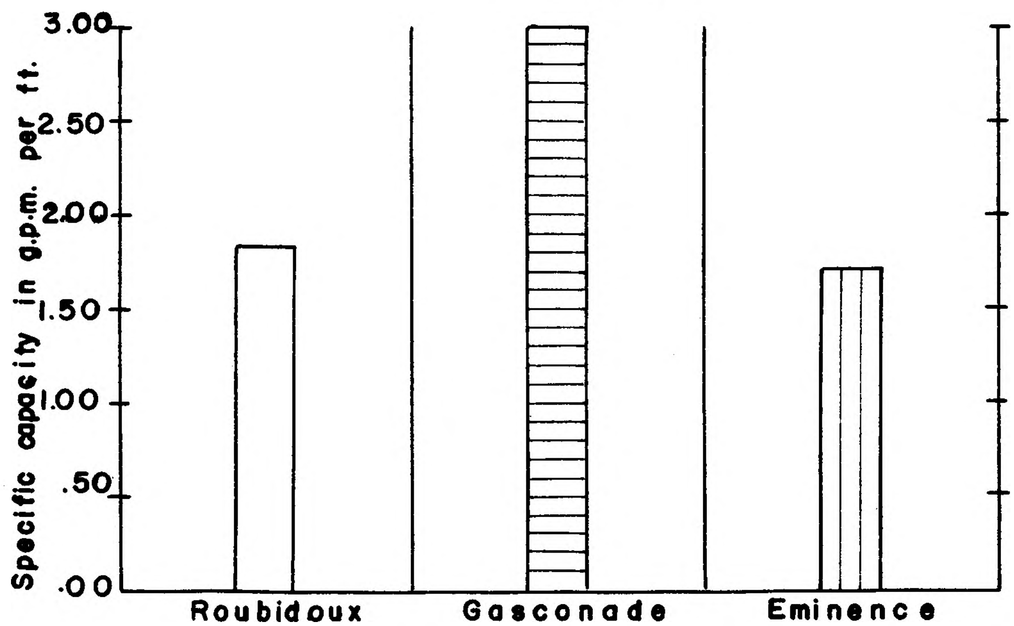
[2] The porosity is the percentage of void space to the total volume of formation, or in saturated formations, it is the percentage of the total volume of the rock which is filled by water.

[3] Todd (1959), Op. cit., p. 16



MAXIMUM WATER PRODUCTION FROM THE WELLS COMPLETED IN THE RB., GC., AND EM. FORMATIONS

Figure 10



MAXIMUM SPECIFIC CAPACITY IN THE WELLS COMPLETED IN THE RB., GC., AND EM. FM.

Figure 11

Lamotte Sandstone is estimated to be between 10 and 20 percent. This percentage is high for consolidated rocks. Ground water in the Lamotte Sandstone occurs on bedding surfaces, in fractures, and in voids between the sand grains. Only one water well in the study area at St. Clair, reaches to the Lamotte Formation. Water in this well was found at a depth of 170 feet. After completing the well in the Lamotte Sandstone the static water level rose to 60 feet depth. One hundred gallon per minute of water is produced from this well. It appears that the Lamotte Sandstone in the study area is a good yielding formation.

b. Bonneterre Dolomite

This formation is generally pervious. Some thin shale beds in the Bonneterre Formation decrease the perviousness. Sufficient water in this formation occurs in interstices of the dolomite. Water is also found in the shaly beds, but this water is fixed in the shale. It does not flow by gravity and cannot be removed by pumping.

c. Davis Formation

This formation generally occurs as shale beds with some interbedded dolomite. Some glauconitic dolomites appear at the base. A very little coarse sand is found at the base and in the middle portion of the formation. This is the only impervious formation in the Cambrian System. Although the Davis Formation is porous and has water in it, transmission of the water is not fast enough to supply a spring or well. This type of formation is known as an aquiclude for the ground water.[1]

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[1]Aquiclude is derived from Latin. Water in this type of formation is fixed. It does not percolate and water does not leave the bed.

d. Derby-Doerun Formation

This formation is known to be soft porous dolomite which permits free percolation of water. The ground water in the formation occurs along joints, bedding surfaces, and especially in cavities. Several water wells in the study area were drilled and completed in this formation. One of these is in Section 25, add, T. 42 N., R. 1 W. Water production in this well was 36 gallon per minute; after fracturing, production increased to 125 gallon per minute. This indicates that the Derby-Doerun Dolomite in the southern half of Franklin County is a good aquifer.[1]

e. Potosi Formation

This dolomite formation, from the water-carrying point of view, resembles the Derby-Doerun dolomite. The only difference between the Potosi and the Derby-Doerun dolomites is the shale content. The Potosi dolomite has very thin, but not continuous, shale beds. These may cause local imperviousness. A total of 44 gallon per minute water is produced from three wells in the Potosi Formation in the study area.

f. Eminence Formation

This formation is composed of dolomite. A few thin shale and sandstone beds are also found in the dolomite. The sandstone and especially the dolomite are very porous. Irregular solution channels in the Eminence Dolomite are the principal reservoirs for the ground water. Forty-one wells in the study area produce a total of 732.8 gallon per minute from the Eminence Formation.

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1 Aquifer's comes from Latin, meaning water-bearer. This type of formation permits the water to flow to a well or a spring, and water in this bed percolates easily.

g. Gasconade Formation

The Guner Sandstone (member of the Gasconade) at the bottom of the Gasconade, and the Gasconade dolomites above, are the main aquifers in the area. The sands in the Gunter are fine to medium grained. Its porosity may be 10 to 15 percent.[1] Although the Gunter Sandstone in the study area is not quick thick (average 20 feet), several wells in the thesis area are supplied from this sandstone. Total water production of 8 water wells in the Gunter Sandstone in the study area is 95 gallons per minute. Ground water in the Gasconade Dolomite in the thesis area occurs in joint systems, bedding planes, solution channels, pores of cryptozoan chert, and at the contact of the Roubidoux and Gasconade formations. Many water wells in the thesis area were completed in the Gasconade Dolomite. The total water production from it in the southern half of Franklin County is 1162 gallons per minute from 76 water wells.

h. Roubidoux Formation

Medium size, smooth, rounded, loosely cemented grains of quartz composes the Sandstone in the Roubidoux Formation in the study area cause large pore voids which transmit the ground water. Joint systems in the Roubidoux Sandstones in the southern half of Franklin County are well-developed. These mainly vertical joints are the best reservoir for the ground water. The total water production from this formation is 773.5 g.p.m.

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[1] Todd (1959), Op. cit., p. 16.

4. Artesian [1] Conditions

It is possible to divide artesian wells into two categories, flowing and non-flowing artesian wells. When a well reaches confined ground water, the water level in this well will rise toward the surface under pressure. If this water reaches the surface and flows, the well is a flowing artesian well. Otherwise it may be called a non-flowing artesian well. According to the above definitions the static water level in flowing and non-flowing artesian wells lies above the water table of free water. The Lamotte Sand-' stone in the studied area may contain artesian water. The Lamotte Formation overlies impervious metamorphic rock of Precambrian age. The Bonneterre Formation, 400 feet maximum thickness, overlies the Lamotte sandstone. Some shale beds in the Bonneterre dolomite may cause vertical imperviousness. In this case ground water in the Lamotte sandstone may move up under pressure. Static water level in a well in the Lamotte sandstone has risen to a 60 foot depth from its initial depth of 170 feet. This artesian well was non-flowing . The intake area for the Lamotte sandstone is not in the study area. It is exposed in the southern part of Washington County. Elevations (900=1000 feet) in this supply area are higher

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[1] The origin of the word artesian is derived from Artoes in France. According to C. F. Tolman (1937) its definition is " a well tapping a confined or artesian aquifer in which the static water level stands above the water table. The term is sometimes used to include all wells tapping coduit, in which case these wells with the water level above the water table are said to have <u>positive artesian head</u> (pressure) and those with water level below the water table, <u>negative artesian head.</u>"

than in the vicinity of this artesian well (650-750 feet). This difference in elevation probably provides the artesian pressure. Because of friction losses in the aquifer the static water level in the well cannot rise to the elevation of the outcrop of the confined strata.

Static water level in some wells in several of the formations in the study area rises a few feet above that at which water is first encountered. Water in the joint systems and solution cavities in these formations probably causes the water level to rise in the wells.

C. Quality of Ground Water

Since 1932 well water samples have been collected and analyzed by the Missouri Geological Survey and Water Resources from different localities in Franklin County. Qualitative analyses of these ground water samples include bacterial, physical, and chemical analyses.

The bacteria are mostly of the coliform group. Bacterial activity in deep well water, in Franklin County is not a problem

Physical analysis of waters is made for turbidity, odor, or taste especially for domestic purposes or for the food industry.[1] Turbidity is 0.1 parts per million or less, and odor is not objectionable for most well waters in the southern half of Franklin County. For industrial uses and irrigation, physical constituents of ground water do not play an important role compared to the chemical constituents. Therefore they can be neglected.

The results of chemical analysis of water samples which were

1 ASTM Committe D-19, On Industrial Water, Manual on Industrial Water, Amer. Soc., Test. Materials Spec. Tech. Publ. 148-A, Chapter 3, 1954.

taken from six water wells within the investigation area are shown in Table 7. The results for a given area and its vicinity were approximately the same. Figure 12 shows the locations of six wells. Each of these is closely representative of other wells in its vicinity.

According to chemical analysis of ground water samples in the St. Clair area the amount of chloride, in general, ranges between 3.0 parts per million and 5.6 parts per million. In some water wells in the same area, the amount of chloride increases to 80.0 parts per million. This high amount of chloride depends on the depth of the wells and the character of the formations in which the wells were drilled and completed. This high amount of chloride, according to prepared water standard tables, is not excessive, and is permissible for domestic, municipal, and industrial uses. In most of the water wells in the St. Clair area, the amount of sulphate varies from 10.9 to 20.6 parts per million. One well had 106.6 parts per million of sulphate present. One important reason for this high sulphate amount is the greater than average depth of the well, 702 feet. Alkalinity ($CaCO_3$) is between 154.0 and 189.0 parts per million. Amount of bicarbonate and total dissolved solids are between 190.5 and 229.9 parts per million and between 215.0 and 323.0 parts per million, respectively, in St. Clair and its vicinity. Amount of total hardness has very little variation, between 160.1 and 180.0 parts per million in the same area.

The amount of chlorides in the well waters of Sullivan is generally constant, between 3.9 and 7.6 parts per million. The

Table 7

Physical and Chemical Analyses of Some Well Waters in the Southern Half of Franklin County

Location	Well #3 St.Clair	T.41N.,2W. S.23,Stanton	T.40N.,2W. Meramec S.P.
Date	11-17-1961	12-21-1932	3-6-1934
Constituents	In Parts Per Million		
Turbidity	.1	Clear	Turbid
Odor	-	None	Musty
PH	7.6	-	-
Alkalinity	154.0	181.0	257.4
Carbonates	0.0	9.8	23.1
Bicarbonates	190.5	220.7	313.9
Silica	6.0	7.2	10.3
Calcium	32.8	40.2	58.7
Magnesium	21.4	27.1	36.3
Sodium and Potassium	1.6	0.8	3.0
Total Iron	0.03	0.12	0.2
Sulfates	12.1	11.7	4.5
Chlorides	3.2	0.98	5.4
Nitrates	0.0	0.98	0.67
Total Suspended Matter	-	260.0	66.2
Total Dissolved Solids	215.0	124.0	319.0
Total Hardness	170.0	211.0	295.6

Table 7 (Continued)
Physical and Chemical Analyses of Some Well Waters in the Southern Half of Franklin County

Location	Well #2 Sullivan	Well #2 Gerald	T.41N.,4W. S.I.
Date	1-31-1961	6-21-1961	6-8-1961
Constituents	In Parts Per Million		
Turbidity	0.1	0.1	Tan Colored
Odor	-	-	None
PH	7.7	7.4	7.75
Alkalinity	160.0	303.0	210.5
Carbonates	0.0	0.0	10.8
Bicarbonates	194.7	368.5	234.9
Silica	10.0	12.0	-
Calcium	31.2	52.8	-
Magnesium	20.4	45.2	-
Sodium and Potassium	2.2	4.1	-
Total Iron	0.01	0.01	2.78
Sulphates	20.4	10.9	22.2
Chlorides	7.6	4.5	3.5
Nitrates	0.25	0.13	0.0
Total Suspended Matter	-	-	-
Total Dissolved Solids	192.0	382.0	256.0
Total Hardness	162.0	318.0	-

amounts of alkalinity and sulphate in the Sullivan area are approximately the same as in the St. Clair area, 154.0 to 160.0 parts per million and 7.6 to 20.6 parts per million respectively. The low and high limits for bicarbonate are 168.0 and 194.7 parts per million in the concerned area. The amount of total dissolved solids in wells at Sullivan is generally lower than in the wells at St. Clair. It ranges between 178.0 and 226.0 parts per million. Total hardness is nearly constant for most of five water wells in the Sullivan area. Its values range from 162.0 to 166.0 parts per million.

The chemical analyses of ground water samples from Gerald show that the alkalinity, bicarbonate, total hardness, and total dissolved solids are greater than in well waters from St. Clair and Sullivan. For example, the amount of alkalinity in water samples from Gerald is between 303.0 and 313.0 parts per million. The maximum values in Sullivan and in St. Clair were 160.0 and 189.0 parts per million respectively. Ranges of sulphate are 10.9 to 13.3 parts per million in Gerald's water wells. The chloride limits are 4.5 and 7.3 parts per million. Amount of bicarbonate and hardness are 368.5 to 381.4 parts per million and 316.0 to 322.0 parts per million respectively in the same area. Total dissolved solids is between 347.0 and 382.0 parts per million in the water wells from Gerald.

Figure 12 shows the location of the water wells whose quality was studied in this paper. Chemical analyses of ground water from representative single wells in St. Clair, Stanton, Meramec State

Park, Sullivan, Gerald, and location number five are shown graphically in Figure 13. In this graph the amounts of alkalinity, bicarbonates, total dissolved solids, and total hardness are represented for each well. Chemical analyses of Kratz Spring, Roaring Spring, and Twin Springs in the southern half of Franklin County are shown in Table 7.

It can be seen that the quality of ground water in the southern half of Franklin County is in most cases acceptable for domestic and most industrial uses. According to prepared water standards given in Table 8, below, the values of chemical constituents of ground water are low in the southern half of Franklin County.

Table 8

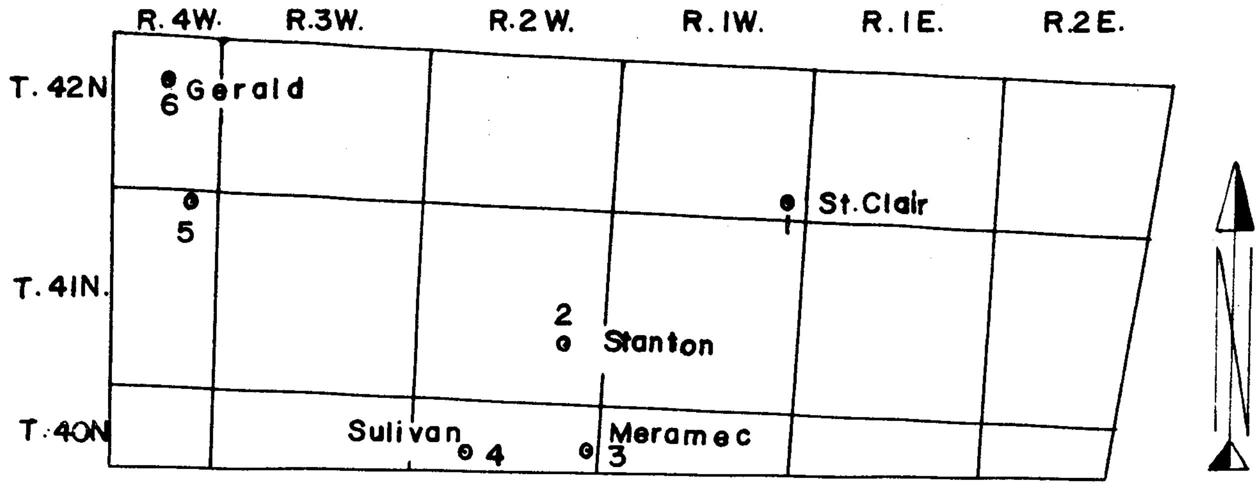
Standards of chemical analyses of ground water.[1]

Drinking Water Standards	
Chemical Constituents	Upper Limit (PPM)
Chloride (Cl)	250.0
Sulphate (So4)	250.0
Magnesium (Mg)	125.0
Iron (Fe) and Manganese (Mn) Together	0.3
Total Solids, Desirable	500.0
Total Solids, Permitted	1000.0

Tolerances for Industrial Uses

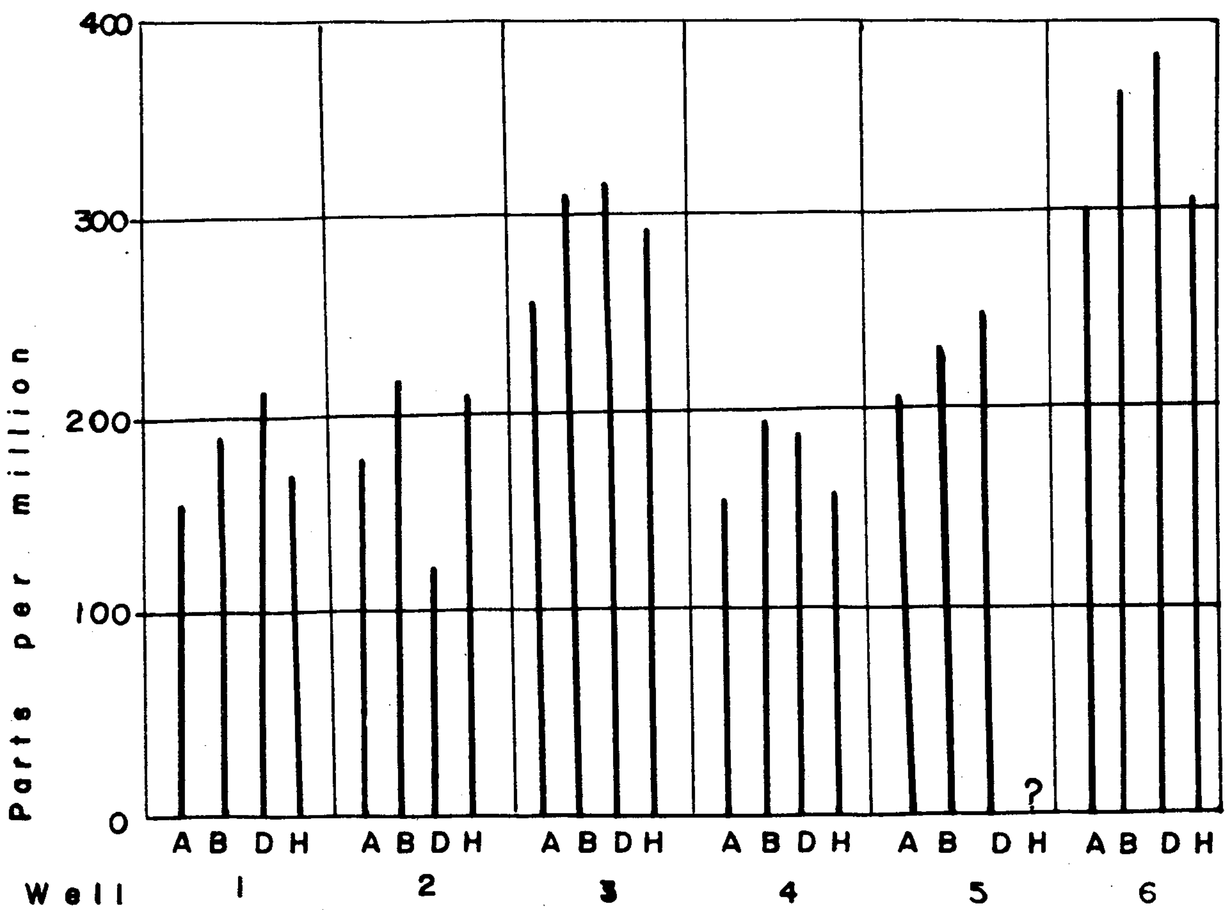
Industry or Use	Brewing & Distilling (PPM)	Food General (PPM)	Rayon(Viscose) Pulp Production (PPM)	Textiles, General (PPM)
Turbidity	10.0	10.0	5.0	5.0
Iron	0.1	0.2	0.05	0.25
Total Solids	500-1000	-	100.0	-
Hardness($CaCO_3$)	-	-	8.0	-
Alkalinity($CaCO_3$)	150.0	-	50.0	-
PH	7.0	-	-	-

[1] After Todd (1959), Op. cit., p. 185-187



LOCATION MAP OF WELL WATER SAMPLES IN THE SOUTHERN HALF OF FRANKLIN CO.

Figure 12



A Alkalinity
B Bicarbonate
D Total dissolved solids
H Total hardness

GRAPHIC REPRESENTATION OF FOUR CHEMICAL COMPOSITION OF WELL WATERS AS SHOWN IN FIG.12

Figure 13

VII. CONCLUSIONS

1. The stratigraphy and structure in the southern half of Franklin County, Missouri were described. Detailed field study of approximately 38 square miles surrounding St. Clair and Anaconda, Missouri, in the central part of the study area, was combined with well log data in a geologic map.

2. Based on the study of 205 well logs and field study, three cross-sections were drawn; two indefinite faults and four major and many minor folds were found. Structure contour maps of the top of the Gasconade and the top of the Eminence formations were made. These show that the general direction of plunge of the anticlines and synclines is to the northeast. An isopach map of the Gasconade Formation was made and thickness of the formation was found to be between 180 and 270 feet.

3. Analysis of well data showed the most of the wells in the southern half of Franklin County were drilled in the past ten years, as the population increased in the area. The water level in observation wells was found to vary with variations in rainfall. Specific capacity was found to be as large as three gallons per minute per foot.

4. Occurrence of ground water in the study area was evaluated. The Lamotte, Bonneterre, Derby-Doerun, Potosi, Eminence, Gunter, (member of the Gasconade), Gasconade and Roubidoux formations were found to be water bearing formations.

5. Artesian conditions were studied; available non-flowing artesian conditons in the thesis area were found in the Lamotte sandstone.

6. Quality of ground water in the southern half of Franklin County was studied, and was found in most cases to be acceptable for domestic and most industrial uses.

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IX. V I T A

Kemal Piskin was born on May 2, 1929, in Maras, Turkey. After completing his primary and high school education in Turkish Public Schools, he did his military service as a supply officer in the Turkish Army during 1951-1952. He entered the University of Istanbul in Istanbul, Turkey, in 1953. He received his Bachelor of Science Degree in the field of Geology in 1957. He received a scholarship from the State Water Works to attend the Institute of Hydrogeology of the Technical University in Istanbul, Turkey, and received a Special Certificate in 1958. He worked two years for the Turkish State Water Works in the Ground Water Division. In June, 1960 he came to the United States and enrolled at the Missouri School of Mines and Metallurgy for graduate study in hydrogeology. He received the degree of Master of Science in Geology in June, 1962.

A P P E N D I C E S

APPENDIX I
WELLS COMPLETED IN THE ROUBIDOUX FORMATION

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.40N, R.1E, Sec. 11, abd	734	131	Unk.	Unk.	Unk.	195	Unk.	On highway 47, 6 miles E. of St. Clair
T.40N, R.2E, Sec. 4, bb	683	24	Unk.	25	Unk.	145	1942	On mail route, 8 miles N. of Lonedell
T.40N, R.3W, Sec. 5, ccb	832	80	Unk.	10	Unk.	150	1957	Water at 120'
T.40N, R.3W, Sec. 8, da	877	125	Unk.	15	Unk.	200	1947	Water at 150'
T.40N, R.3W, Sec. 8, dbb	853	70	Unk.	10	Unk.	150	1958	Water at 80'
T.40N, R.3W, Sec. 10, cab	914	160	Unk.	20	Unk.	210	1944	Water at 50'
T.40N, R.4W, Sec. 10, ccb	805	60	Unk.	7	Unk.	115	1955	-----
T.40N, R.4W, Sec. 10, ccc	820	65	Unk.	12	Unk.	144	1956	-----
T.41N, R.2E, Sec. 5	798	Unk.	Unk.	3	Unk.	210	1948	On Robertsville Road
T.41N, R.2E, Sec. 5, bbd	763	197	38	20	0.52	220	1955	Prod. is 8 gpm at 225'

APPENDIX I (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41N, R.2E, Sec. 6, dbc	735	158	Unk.	9	Unk.	182	1936	Water at 270'
T.41N, R.2E, Sec. 8, aad	573	24	No Dr. Da.	20	Unk.	84	1943	In Lonedell
T.41N, R.3W, Sec. 16, dd	821	103	Unk.	Unk.	Unk.	225	1951	In Dutch Hill Church
T.41N, R.3W, Sec. 18, ba	795	135	Unk.	12	Unk.	225	1948	0.25 mile NE. of Strain
T.41N, R.3W, Sec. 22, ddd	776	40	Unk.	Unk.	Unk.	120	1938	Water at 110'
T.41N, R.4W, Sec. 1, bd	740	75	25	15	0.60	225	1961	0.8 mile Se. of Walbert School
T.41N, R.4W, Sec. 2, cca	757	75	30	18	0.60	180	1958	0.5 mile N. of Penticost Church
T.41N, R.4W, Sec. 10	860	160	33	15	0.45	270	1960	Approx. 6 miles S. of Gerald
T.42N, R.2E, Sec. 1, Ca	728	80	116	52	0.44	680	1958	Stained mud, ZnS, Fe_2O_3 at 360', 525', 555'
T.42N, R.2E, Sec. 4, aac	535	35	20	17	0.85	157	1950	Sand increases toward bottom of the well, Water at 60'

APPENDIX I (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.2E, Sec. 6, daa	661	190	25	17	0.68	320	1959	Water at 330', 320'
T.42N, R.2E, Sec. 7, dab	765	230	Unk.	12.5	Unk.	404	1950	FeS_2 at bottom
T.42N, R.2E, Sec. 8, bbb	714	220	20	18	0.90	350	1957	Water at 330', 350'
T.42N, R.2E, Sec. 9, ada	593	90	Unk.	3	Unk.	159	1955	Water at 150', 159'
T.42N, R.2E, Sec. 15, baa	511	25	110	40	0.36	136	1959	Water at 100'. 136'
T. 42N, R.2E, Sec. 17, aac	735	240	Unk.	17	Unk.	308	1950	2 miles S. of Roberts-ville Water at 285'
T.42N, R.2E, Sec. 20, ac	618	80	50	19	0.38	168	1956	3 miles S. of Roberts-ville, water at 150', 168'
T.42N, R.2E, Sec. 22, cad	676	55	45	7.5	0.16	163	1946	Water at 80'
T.42N, R.2E, Sec. 23, bbd	553	25	Unk.	8	Unk.	134	1952	1 mile NE. of Mt. Pleasant School
T.42N, R.2E, Sec. 26, cbd	737	195	15	20	1.33	325	1957	5 miles S. of Catawissa, Water at 330', 325'

APPENDIX I (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.2E, Sec. 27, cc	659	95	35	13	0.34	170	1957	1.5 miles SW. of Mt. Pleasant School
T.42N, R.2E, Sec. 29, ba	644	195	Unk.	5	Unk.	227	1946	5 miles S. of Robertsville, Water at 195'
T.42N, R.2E, Sec. 32, dac	619	60	40	13	0.32	150	1957	2 miles E. of Lonedell Camp
T.42N, R. 1E, Sec. 7, ada	607	55	40	7.5	0.18	140	1947	Water at 55'
T.42N, R. 1E, Sec. 10, baa	556	100	Unk.	6	Unk.	160	1939	On the N. side of Bourbeuse River
T.42N, R. 1E, Sec. 13, ddd	573	90	26	30	1.15	159	1956	Water at 135', 159'
T.42N, R. 1E, Sec. 19, bab	741	140	20	9	0.45	200	1953	2 miles E. of St.Clair on Old Spring Field Road
T. 42N, R. 1W, Sec. 13, ba	695	123	10	7	0.70	175	1936	0.8 mile N. of St. Clair
T.42N, R.1W, Sec. 24, bda	676	55	65	16	0.24	120	1957	1.5 miles N. of St. Clair
T.42N, R.1W, Sec. 36, dda	740	90	10	11	1.10	178	1951	On highway 30, Water at 90'

APPENDIX I (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.2W, Sec. 5,bb	841	255	6	11	1.83	294	1953	Water at 280'
T.42N, R.2W, Sec. 19, cd	758	140	25	34	1.36	165	1952	1.2 mile NE. of Evergreen Church
T.42N, R.2W, Sec. 31, dc	842	275	Unk.	10	Unk.	335	1960	Water at 330', 335'
T.42N, R.3W, Sec. 2, acb	829	230	40	15	0.37	340	1959	In Leslie
T. 42N,R.3W, Sec. 6, ab	870	250	25	15	0.60	402	1960	0.5 mile NE. of St. Paul Cemetery
T.42N, R.3W, Sec. 22, da	760	116	23	15	0.65	190	1959	1 mile SE. of Antioch Church
T.42N, R.3W, Sec. 30	860	235	35	15	0.42	380	1960	3/2 mile E. of Gerald
T.42 N, R.3W, Sec. 33, bb	757	87	30	15	0.50	172	1959	0.6 mile SE. of Old Grove School
T.42N, R.4W, Sec. 12	862	200	25	15	0.60	340	1960	0.5 mile SE. of Gerald
T.42N, R.4W, Sec. 14 acb	887	145	145	9	0.06	346	1959	1 mile SW. of Gerald
T.42 N,R.4W, Sec. 15, ccc	868	162	38	15	0.39	331	1960	2 miles SW. of Gerald

APPENDIX I (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.4W, Sec. 24	890	160	90	15	0.16	353	1960	3 miles S. of Gerald on route H

APPENDIX II
WELLS COMPLETED IN THE GASCONADE FORMATION

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.40N, R.2E, Sec. 4, dbd	721	11	139	11	0.07	150	1953	-----
T.40N, R.2E, Sec. 5, abd	731	Unk.	Unk.	Unk.	Unk.	135	1948	6 miles S. of Lone-dell
T.40N, R.2E, Sec. 6, dab	836	98	Unk.	8	Unk.	224	1941	0.25 mile W. of Elm-wood Church
T.40N, R.2E, Sec. 8, bbd	892	140	Unk.	Unk.	Unk.	250	1952	0.25 mile SW. of Bench Mark
T.40N, R.2E, Sec. 10, aaa	875	130	Unk.	13	Unk.	232	1936	Water at 175',220'
T.40N, R.1E, Sec. 17, ab	755	225	Unk.	Unk.	Unk.	350	---	-----
T.40N, R.1W, Sec. 2, bba	831	95	155	5	0.03	250	1958	4 gpm at 200
T.40N, R.2W, Sec. 4, bca	919	Unk.	Unk.	10	Unk.	235	1957	In St. Anthony Cemeter
T.40N, R.3W, Sec. 2, a	817	96	Unk.	7	Unk.	205	1949	0.5 mile NE. of Pilot Grove Church
T.40N, R.3W, Sec. 3, ada	982	235	Unk.	12	Unk.	320	1959	0.3 mile NW. of Pilot Grove Church

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.40N, R.3W, Sec. 6, aab	890	180	40	17.5	0.42	301	1960	-----
T.40N, R.3W, Sec. 6, bb	898	140	Unk.	9	Unk.	275	1947	Water at 125'
T.40N, R.3W, Sec. 8, cb	836	80	Unk.	15	Unk.	200	1944	Water at 120'
T.40N, R.4W, Sec. 3, cbd	811	130	Unk.	Unk.	Unk.	170	1956	-----
T.41N, R.2E, Sec. 9, bdd	672	70	60	20	0.33	150	1959	19 gpm at 120'
T.41N, R.2E, Sec. 10, acc	719	100	85	13	0.15	185	1958	On highway 30
T.41N, R.2E, Sec. 17, dbd	750	137	33	25	0.75	300	1958	0.4 mile SE. of Woodcock Cemetary
T.41 N, R.2E, Sec. 19, cc	684	Unk.	Unk.	Unk.	Unk.	200	1943	-----
T.41N, R.2E, Sec. 23, cc	795	155.5	Unk.	Unk.	Unk.	254	1940	1 mile NE. of Diamond School
T.41 N, R.2E, Sec. 28, aaa	769	113	22	20	0.90	170	1958	-----
T.41N, R.2E, Sec. 29, db	755	90	60	20	0.33	270	1958	1 mile S. of Luebbe-ring

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41N, R.2E, Sec. 33,acd	804	118	Unk.	13	Unk.	165	1941	-----
T.41N, R.1E, Sec. 2, cab	711	165	35	20	0.57	250	1955	7 gpm at 175'
T.41N, R.1E, Sec. 3, bda	694	135	Unk.	7.5	Unk.	220	1952	-----
T.41N, R.1E, Sec. 6, cb	760	140	60	14	0.23	280	1954	On Route K
T.41N, R.1E, Sec. 6, cbb	693	150	100	11	0.11	250	1959	-----
T.41N, R.1E, Sec. 7, bba	729	168	57	20	0.35	285	1952	3 miles S. of St. Clair on Route K Water at 230'
T.41N, R.1E, Sec. 8, aad	698	138	117	15	0.12	255	1955	Water at 175',200'
T.41N, R.1E, Sec. 8, cbc	725	205	100	13,3	0.13	305	1959	-----
T.41N, R.1E, Sec. 8, cbd	752	Unk.	Unk.	16	Unk.	315	1957	On Route K.
T.41N, R.1E, Sec. 8, abb	716	135	160	11	0.18	295	1954	9 gpm at 200'
T.41N, R.1E, Sec. 12, ccd	690	110	90	10	0.11	275	1955	6 gpm at 110'

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41N, R.1E, Sec. 13, bbd	600	47	103	16	0.15	150	1954	10 gpm at 100'
T.41N, R.1E, Sec. 13, aa	691	75	Unk.	10	Unk.	165	1948	-----
T.41N, R. 1E, Sec. 15, bcc	687	115	120	9 2/3	0.05	235	---	5 5/6 gpm at 175'
T.41N, R.1E, Sec. 16, aaa	760	Unk.	Unk.	7	Unk.	300	1955	4 miles S. of St. Clair on Virginia Mines Road
T.41N, R. 1E, Sec. 16, adc	597	52	48	25	0.52	150	---	------
T.41N, R.1E, Sec. 17, cb	691	125	125	10	0.04	260	1954	3 miles S. of St. Clair on Route K.
T.41N, R. 1E, Sec. 17, aba	755	170	Unk.	7	Unk.	350	1957	-----
T.41N, R.1E, Sec. 28, aad	695	100	Unk	2.5	Unk.	250	1956	0.2 mile S. of Luebbering
T.41N, R.1E, Sec. 31, Ada	733	90	Unk.	22	Unk.	275	1958	-----
T.41N, R. 1E, Sec. 35, cbc	787	85	Unk.	10	Unk.	165	1948	9 miles SE. of St. Clair

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41N, R.1W, Sec. 1, aaa	718	60	40	15	0.37	140	1958	----
T.41N, R.1W, Sec. 1, dad	711	80	120	83,3	0.69	200	---	6 gpm at 150'
T.41N, R.1W, Sec. 2, cdd	680	90	Unk.	10	Unk.	227	1935	-----
T.41N, R.1W, Sec. 3, aba	854	185	Unk.	15	Unk.	350	1948	Water at 150'
T.41N, R. 1W, Sec. 8, d	821	235	Unk.	Unk.	Unk.	205	1940	-----
T.41N, R.1W, Sec. 15, cbc	805	114	Unk.	Unk.	Unk.	215	1955	Water at 168'
T.41N, R. 1W, Sec. 22, daa	761	80	Unk.	10	Unk.	188	1959	Water at 80'
T.41N, R. 2W, Sec. 9, aa	809	140	110	21	0.19	250	1959	10gpm at 175'
T.41N, R.2W, Sec. 27, cc	918	158	Unk.	18	Unk.	250	1948	Water at 170'
T.41N, R.2W, Sec. 28, bc	835	Unk.	Unk.	Unk.	Unk.	100	1945	-----

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41, R.2W, Sec. 32, dc	948	200	Unk.	10	Unk.	275	1944	Water at 75'
T.41N, R.3W, Sec. 10	747	115	18	15	0.83	210	1961	3/4 mile E. of Champion City
T.41N, R.3W, Sec. 11, cca	850	200	10	15	1.50	294	1958	-----
T.41N, R.3W, Sec. 14, ca	948	270	Unk.	15	Unk.	365	1957	Water at 260'
T.41N, R.3W, Sec. 23, dbb	898	185	Unk.	Unk.	Unk.	250	1938	Water at 220', 240'
T.41N, R.3W, Sec. 30, bbc	853	165	Unk.	Unk.	Unk.	310	1958	-----
T.41N, R.3W, Sec. 31, ad	913	215	10	15	1.50	316	1959	1 mile SE. of Japan School
T.41N, R.3W, Sec. 34, add	928	60	Unk.	10	Unk.	265	1955	-----
T.41N, R.3W, Sec. 36, dda	971	220	Unk.	10	Unk.	300	1958	Water at 80'
T.42N, R.2E, Sec. 3, bcd	618	150	10	30	3.00	503	1957	Water at 400', 500'
T.42N, R.2E, Sec. 18,baa	602	145	Unk.	12	Unk.	360	1956	1 1/2 miles SW. of Robertsville, Water at 355'

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.2E, Sec. 33, cac	732	176	101	20	0.19	382	1955	Water at 360'
T.42N, R.1E, Sec. 4, ca	635	115	105	8	0.07	220	1953	4 miles S. of St. Clair, on highway 66
T.42N, R.1E, Sec. 8, ddd	715	160	90	16	0.17	250	1956	7 gpm at 200'
T.42N, R.1E, Sec. 15, dcd	638	165	Unk.	16.5	Unk.	245	1956	Water at 230', 245'
T.42N, R. 1E, Sec. 16, abb	700	168	110	20	0.18	278	1956	5 1/2 gpm at 200'
T.42N, R.1E, Sec. 17, bcb	710	120	Unk.	9	Unk.	205	1960	Water at 170'
T.42N, R.1E, Sec. 23, caa	684	Unk.	Unk.	15	Unk.	290	1957	D.W.L. is 250'
T.42N, R.1E, Sec. 26, aab	620	202	Unk.	1	Unk.	260	1936	-----
T.42N, R.1E, Sec. 31, ccd	742	125	Unk.	20	Unk.	255	1954	Water at 240'
T.42N, R.1E, Sec. 36, bbd	624	13	87	17	0.17	100	1956	10 gpm at 160'

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.1W, Sec. 2, d	678	180	Unk.	25	Unk.	300	1945	Water at 120'
T.42N, R.1W, Sec. 15, bb	587	60	30	16	0.53	170	1957	-----
T.42N, R.1W, Sec. 22, dd	729	90	85	15	0.17	175	1958	-----
T.42N, R.1W, Sec. 23, dad	670	60	110	15	0.14	170	1959	12 gpm at 125'
T.42N, R.1W, Sec. 25, aab	727	91	119	20	0.16	300	1956	-----
T.42N, R.1W, Sec. 26, d	739	72.7	31	40	1.29	255	1956	In St. Clair, on state highway department property
T.42N, R.1W, Sec. 27, ddd	755	67	63	4.9	0.07	155	1953	-----
T.42N, R.1W, Sec. 29, bca	818	130	Unk.	9	Unk.	285	1954	0.25 mile NW. of Duly School
T.42N, R.1W, Sec. 33, bcd	782	98	Unk.	2/3	Unk.	240	1955	-----
T.42N, R.1W, Sec. 34, baa	817	120	130	6.5	0.05	250	1954	5.5 gpm at 200'

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.1W, Sec. 34, cbd	838	130	Unk.	10	Unk.	275	1944	-----
T.42N, R.1W, Sec. 35, cba	762	70	195	13	0.05	205	1954	10 gpm at 200
T.42N, R.1W, Sec. 36, dab	744	80	120	7.5	0.06	200	1954	6 gpm at 150'
T.42N, R.1W, Sec. 36	715	100	75	6	0.08	200	1956	S. edge of St. Clair
T.42N, R.2W, Sec. 14, bb	850	90	Unk.	12	Unk.	240	1949	Water at 90'
T.42N, R.2W, Sec. 26, cdd	667	50	Unk.	19	Unk.	190	1959	Water 160',185'
T.42N, R.2W, Sec. 28, bcd	702	115	15	12	1.36	203	1939	Water at 180',190'
T.42N, R.2W, Sec. 34, cbc	725	126	Unk.	11	Unk.	225	1951	Water at 100'
T.42N, R.3W, Sec. 1, cba	712	125	23	30	1.30	481	1940	-----
T.42N, R.3W, Sec. 23,	---	129	36	15	0.41	245	1960	Approx. 5.5 miles SE. of Gerald

APPENDIX II (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.42N, R.4W, Sec. 11, bcb	889	220	little	65	Unk.	550	1951	-----
T.42N, R.4W, Sec. 11, bdb	896	224	5	14	2.80	542	1937	In Gerald

APPENDIX III
WELLS COMPLETED IN THE EMINENCE FORMATION

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.40N, R.2E, Sec. 7, dbd	857	60	140	9	0.06	200	1958	7 gpm at 140'
T.40N, R.2E, Sec. 8, ddb	727	Unk.	Unk.	20	Unk.	95	1959	13 gpm at 60'
T.40N, R.2E, Sec. 16, aaa	775	20	80	23	0.28	100	1955	-----
T.40N, R.2E, Sec. 18, bad	967	160	Unk.	10	Unk.	240	1956	-----
T.40N, R.1E, Sec. 12, bab	805	50	Unk.	8.3	Unk.	190	1955	Water at 70'
T.40N, R.1E, Sec. 13, bda	795	15	90	30	0.33	105	1958	12 gpm at 50'
T.40N, R.1W, Sec. 5, dc	635	18	Unk.	Unk.	Unk.	185	1936	In Meramec State Park
T.40N, R.1W, Sec. 6, ccc	595	18	Unk.	Unk.	Unk.	120	1931	In Meramec State Park at Fisher Cave
T.40N, R.1W, Sec. 7, baa	737	Unk.	Unk.	Unk.	Unk.	220	1938	-----
T.40N, R.2W, Sec. 5, add	935	165	Unk.	11	Unk.	330	1935	20 gpm by bailer

APPENDIX III (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr. Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.40N, R.2W, Sec. 7, cdc	997	100	Unk.	15	Unk.	250	1958	-----
T.40N, R.2W, Sec. 10, bcc	909	150	110	5.5	0.05	260	1959	Water at 170', 240'
T.40N, R.3W, Sec. 1, baa	905	175	Unk.	15	Unk.	300	1943	-----
T.40N, R.3W, Sec. 11, de '	930	120	Unk.	10	Unk.	250	1941	-----
T.40N, R.3W, Sec. 12, da	980	133	Unk.	10	Unk.	225	1949	Water at 92'
T.41 Nr, R.1E, Sec. 17, aad	694	200	Unk.	9	Unk.	375	1940	-----
T.41N, R.1E, Sec. 17, abb	723	175	Unk.	12	Unk.	370	1958	-----
T.41N, R.1E, Sec. 25, adb	753	100	65	11	0.16	165	1957	7 gpm at 125'
T.41N, R.1E,' Sec. 28, abb	564	18	32	16	0.50	128	1953	8 gpm at 25'
T.41N, R.1W, Sec. 6 bc	783	210	Unk.	5	Unk.	275	1955	-----

APPENDIX III (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41N, R.1W, Sec. 7, dda	833	290	Unk.	12	Unk.	360	1948	-----
T.41N, R.1W, Sec. 7, cc	895	260	Unk.	4	Unk.	340	1939	Water at 300'
T.41N, R.1W, Sec. 8, cab	774	140	Unk.	30	Unk.	240	1958	-----
T.41N, R.1W, Sec. 13, ccb	705	300	Unk.	14	Unk.	375	1949	Water at 305'
T.41N, R.1W, Sec. 18,bba	847	285	Unk.	15	Unk.	350	1947	-----
T.41N, R.1W, Sec. 20, daa	601	15	Unk.	10	Unk.	130	1948	Water at 125'
T.41N, R. 1W, Sec. 30, baa	644	80	Unk.	25	Unk.	125	1952	Water at 80'
T.41N, R.2W, Sec. 4, db	728	Unk.	25	15	Unk.	400	1938	-----
T.41N, R.2W, Sec. 11, bcd	858	235	Unk.	10	Unk.	307	1948	Water at 235'
T.41N, R.2W, Sec. 13, bb	875	300	Unk.	5	Unk.	475	1946	-----

APPENDIX III (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41N, R.2W, Sec. 13, a	884	365	Unk.	20	Unk.	465	1947	-----
T.41N, R.2W, Sec. 15, cb	826	175	Unk.	10	Unk.	280	1946	-----
T.41N, R.2W, Sec. 15, ad	832	Unk.	Unk.	Unk.	Unk.	270	1947	0.2 mile NW. of Miller School
T.41N, R.2W, Sec. 23, dd	868	255	15	12	0.80	329	1951	-----
T.41N, R.2W, Sec. 24, aa	874	270	10	17	1.70	376	1957	Water at 350', 376'
T.41N, R.2W, Sec. 26 bb	872	Unk.	Unk.	Unk.	Unk.	360	1946	-----
T.41N, R.2W, Sec. 31, cc	891	160	Unk.	Unk.	Unk.	270	1957	0.75 mile SW. of Stivers School
T.41N, R.2W, Sec. 31, bd	904	Unk.	Unk.	12	Unk.	330	1943	Water at 90'
T.41N, R.2W, Sec. 32, aa	887	157	Unk.	12	Unk.	225	1948	-----
T.41N, R.2W, Sec. 34, bb	882	265	Unk.	5	Unk.	350	1944	Water at 60'

APPENDIX III (Continued)

Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.41N, R.3W, Sec. 25, cda	909	200	Unk.	14	Unk.	313	1959	-----
T.42N, R.1W, Sec. 18, add	753	160	168	10	0.05	410	1959	-----
T.42N, R.1W, Sec. 29, adb	728	185	180	15	0.08	405	1954	0.15 mile N. of Duly School
T.42N, R.1W, Sec. 31, acc	739	100	Unk.	25	Unk.	250	1938	-----
T.42N, R.1W, Sec. 32, baa	819	145	Unk.	6	Unk.	370	1947	0.6 mile S. of Duly School.
T.42N, R.1W, Sec. 33, dbb	863	Unk.	Unk.	Unk.	Unk.	320	1936	-----
T.42N, R.3W, Sec. 2, a	829	220	80	104	1.30	902	1945	In Leslie
T.42N, R.4W, Sec. 11, bdb	887	227	67	110	1.64	803	1960	-----

APPENDIX IV
WELLS COMPLETED IN FORMATIONS BELOW THE EMINENCE

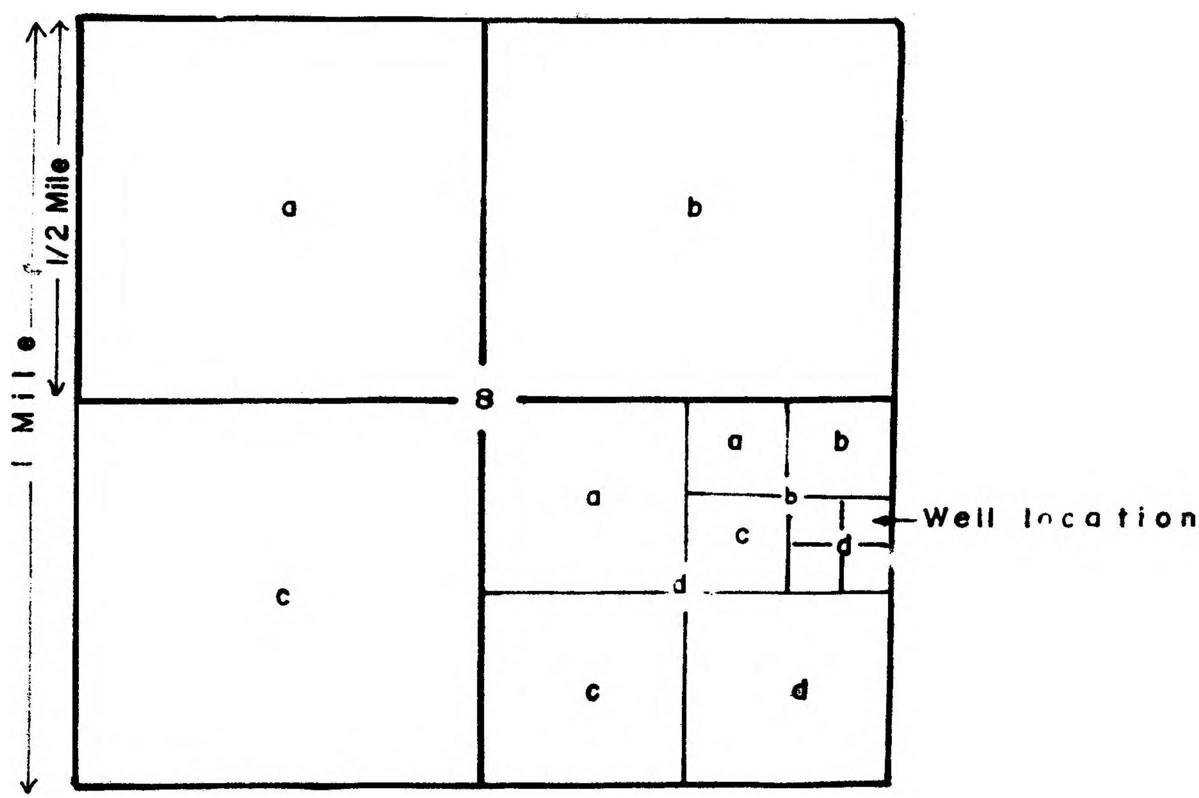
Location	S.EL. (ft)	S.W.L. (ft)	Dr.Da. (ft)	Prod. (gpm)	S.C. (gpm/pft)	Tot.De. (ft)	Date Drilled	Remarks
T.40N, R.1W, Sec. 18, aab	817	230	No Dr. Da.	25	Unk.	605	1934	Completed in Pt., water at 240',419',474'
T.40N, R.2W, Sec. 9, add	990	225	Unk.	375	Unk.	905	1954	Completed in D.D.fm.
T.41N, R.1E, Sec. 4, dab	531	Unk.	Unk.	Unk.	Unk.	434	1947	Completed in Pt.fm.
T.41N, R.1E, Sec. 18, bcb	520	25	Unk.	7	Unk.	350	1937	Completed in Pt.fm.
T.41N, R.2W, Sec. 26, bca	864	235	7	12	1.71	440	1957	Completed in Pt.fm. Water at 430', 440'
T.41N, R.2W, Sec. 27, aa	875	170	Unk.	Unk.	Unk.	585	1932	Completed in Pt.fm.
T.42N, R.1W, Sec. 25, add	796	180	218	36	0.16	838	1955	Completed in D.D., After fracturing prod. is 125 gpm.
T.42N, R.1W, Sec. 32, cac	778	200	Unk.	Unk.	Unk.	1272	1952	Completed in Bt. water at 150'
T.42N, R.1W, Sec. 32 aca	723	Unk.	Unk.	Unk.	Unk.	495	1952	Completed in Pt.fm. Water at 90'
T.42N, R.1W, Sec. 36 abb	697	60	Unk.	100	Unk.	1540	1931	Completed in Lm.fm. Water at 170'

APPENDIX V

DESIGNATION OF WELL LOCATIONS

The following system was used to describe the well locations. Each section is divided into quarters designated a, b, c, and d. These quarters are similarly divided into smaller quarters as illustrated below.

If a well is located in SE$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$, Section 8, its location is designated as Sec. 8, dbd.



A P P E N D I X VI

ABBREVIATIONS

Abbreviations used in this thesis are as follows:

Alkal.	Alkalinity
Approx.	Approximately
Bicarb.	Bicarbonate
Bt.	Bonneterre
Ch.	Chert
Chlor.	Chloride
Crys.	Crystalline
D-D.	Derby-Doerun
Dv.	Davis
Dol.	Dolomite
Dr.Da.	Draw-down
D.W.L.	Dynamic Water Level
E.	East
Em.	Eminence
Ft.	Foot or Feet
Fm.	Formation
Gpm.	Gallon Per Minute
Gpm/ft	Gallon Per Minute Per Foot
Gc.	Gasconade
Glau.	Glauconite
Gp.	Group
Gt.	Gunter
Hard.	Hardness
J. C.	Jefferson City
Lm.	Lamottee
Ls.	Limestone
L.	Lower
Max.	Maximum
Min.	Minimum
Nitr.	Nitrate
N.	North
Ppm.	Parts Per Million
P.S. Mile	Per Square Mile
Pt.	Potosi
Prod.	Production
Quz.	Quartzose
R.	Range
Rb.	Roubidoux
Ss.	Sandstone
Sh.	Shale
S.	South
S.C.	Specific Capacity
S.EL.	Surface Elevation
Susp.	Suspended
S.W.L.	Static Water Level
Tot.	Total

ABBREVIATIONS(Continued)

Tot.De.	Total Depth	U.	Upper
T.	Township	V.B.	Van Buren
Unk.	Unknown	W.	West

LEGEND

- Well completed in the Roubidoux formation
- " " " " Gasconade "
- " " " " Eminence "
- " " " " Potosi "
- " " " " Derby-Doerun "
- " " " " Bonneterre "
- " " " " Lamotte "

LOCATION OF WATER WELLS AND CROSS-SECTIONS IN THE SOUTHERN HALF OF FRANKLIN COUNTY

PLATE I

SCALE

1 1/2 0 1 2 Miles

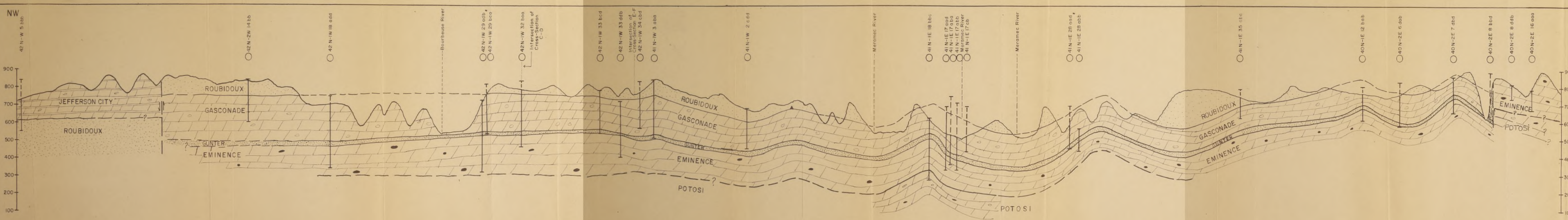
Contour interval 20 feet

GEOLOGIC MAP OF THE ST. CLAIR-ANACONDA AREA

LEGEND

QUATERNARY	Qal	Alluvium	▲44 or ⬭88	Outcrop point
ORDOVICIAN	Or	Roubidoux Sandstone	200 Rb/Gc	Contact of formations
	Og	Gasconade Dolomite	→	Ripple mark with direction
CAMBRIAN	Ce	Eminence Dolomite		Cryptozoan chert

PLATE II



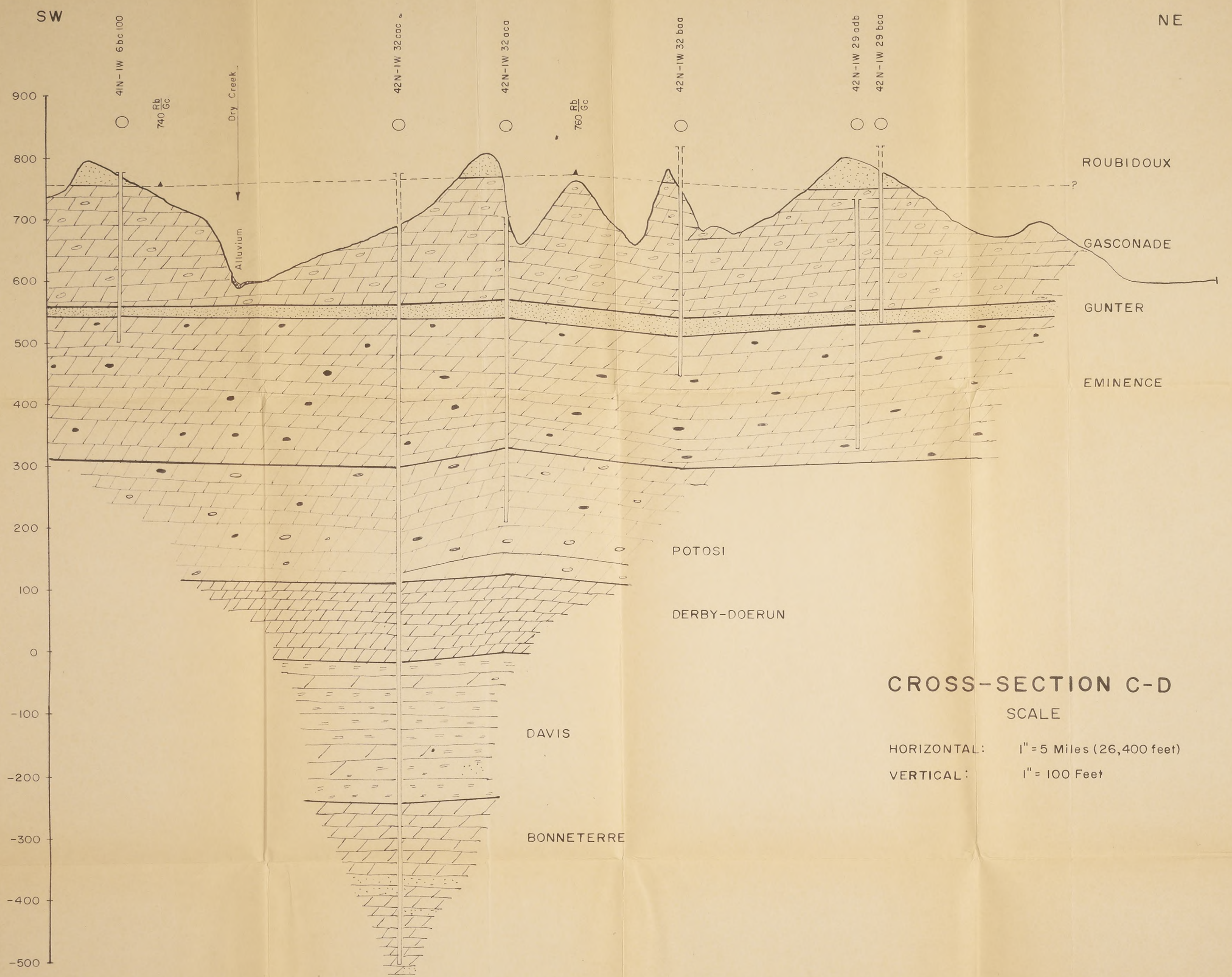
CROSS-SECTION A-B

SCALE

HORIZONTAL: 1" = 2 Miles (10,560 feet)

VERTICAL: 1" = 200 Feet

PLATE III



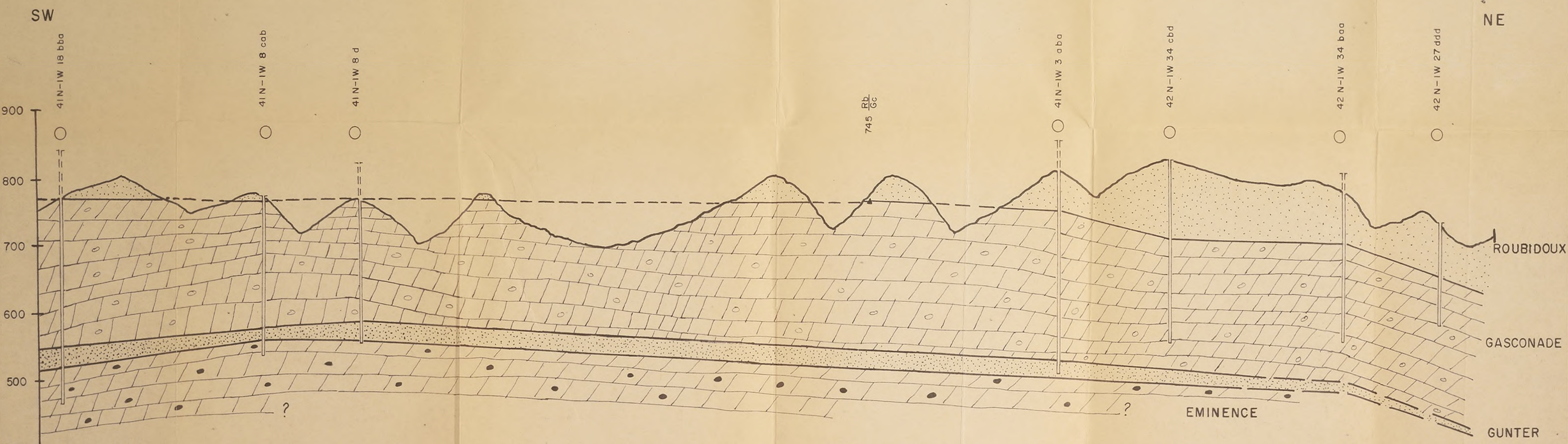
CROSS-SECTION C-D

SCALE

HORIZONTAL: 1" = 5 Miles (26,400 feet)

VERTICAL: 1" = 100 Feet

PLATE IV



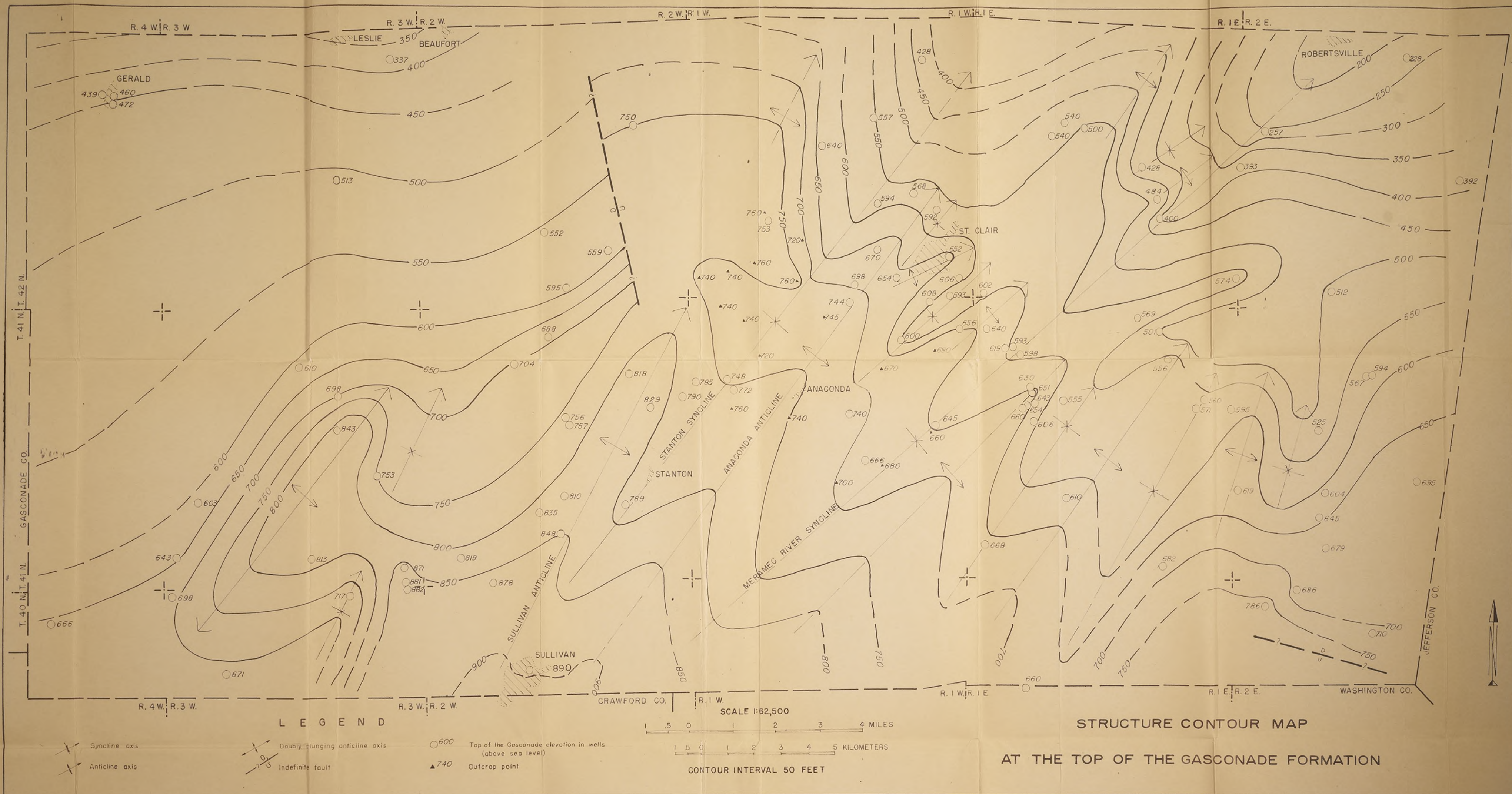
CROSS-SECTION E-F

SCALE

HORIZONTAL 1" = 5 Miles (26,400)

VERTICAL 1" = 100 Feet

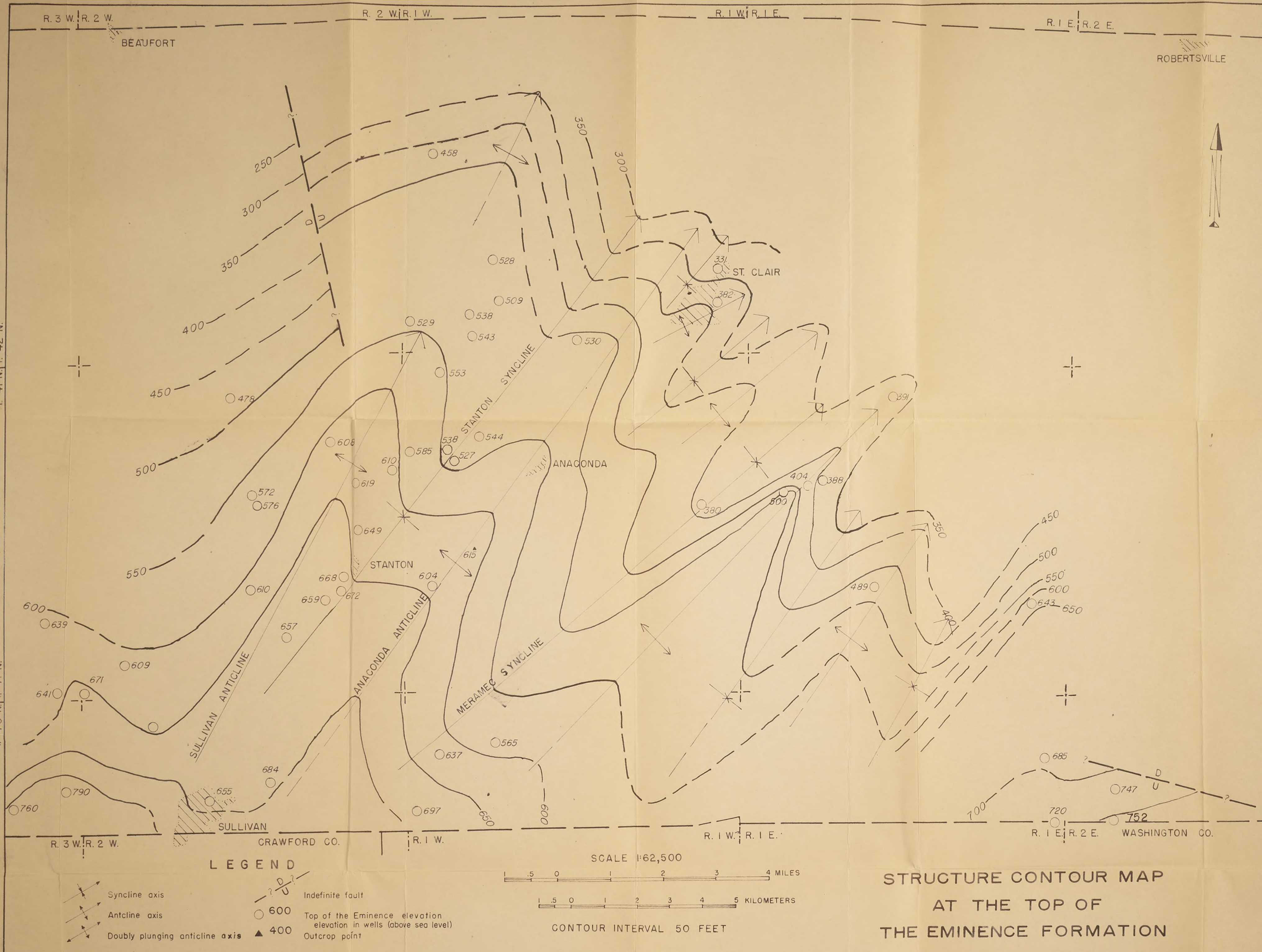
PLATE V



STRUCTURE CONTOUR MAP

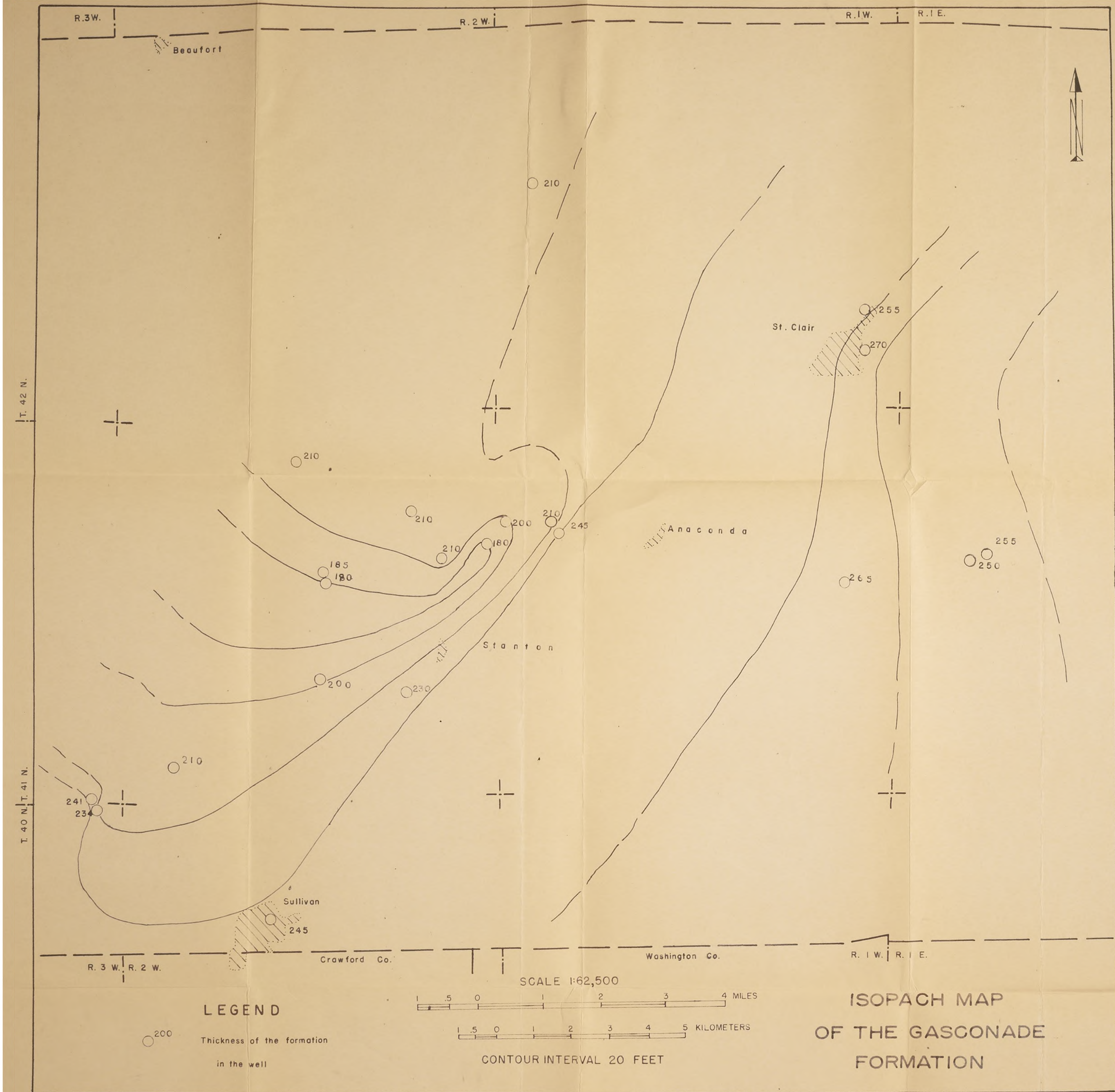
AT THE TOP OF THE GASCONADE FORMATION

PLATE VI



STRUCTURE CONTOUR MAP AT THE TOP OF THE EMINENCE FORMATION

PLATE VII



ISOPACH MAP OF THE GASCONADE FORMATION

PLATE VIII