1951

Geology of the north half of the Meramec Spring Quadrangle, Missouri

Harold Edward Mueller

Follow this and additional works at: http://scholarsmine.mst.edu/masters_theses

Recommended Citation

This Thesis - Open Access is brought to you for free and open access by the Student Research & Creative Works at Scholars' Mine. It has been accepted for inclusion in Masters' Theses by an authorized administrator of Scholars' Mine. For more information, please contact weaverjr@mst.edu.
GEOLOGY OF THE NORTH HALF OF THE
MERAMEC SPRING QUADRANGLE, MISSOURI

BY

WILLIAM EDWARD MUELLER

A

Thesis

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the
Degree of

MASTER OF SCIENCE, GEOLOGY MAJOR

Rolla, Missouri

1951

Approved by

Professor of Geology

79617
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents</td>
<td>11</td>
</tr>
<tr>
<td>List of illustrations</td>
<td>vii</td>
</tr>
<tr>
<td>List of plates</td>
<td>viii</td>
</tr>
<tr>
<td>List of tables</td>
<td>ix</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Purpose and scope of report</td>
<td>1</td>
</tr>
<tr>
<td>Previous work</td>
<td>1</td>
</tr>
<tr>
<td>Present work</td>
<td>6</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>6</td>
</tr>
<tr>
<td>Geography and physiography</td>
<td>7</td>
</tr>
<tr>
<td>Location and size of area</td>
<td>7</td>
</tr>
<tr>
<td>History and settlement</td>
<td>8</td>
</tr>
<tr>
<td>Meramec Iron Works</td>
<td>9</td>
</tr>
<tr>
<td>Population</td>
<td>14</td>
</tr>
<tr>
<td>Towns</td>
<td>14</td>
</tr>
<tr>
<td>Industry</td>
<td>15</td>
</tr>
<tr>
<td>Transportation</td>
<td>16</td>
</tr>
<tr>
<td>Railroads</td>
<td>16</td>
</tr>
<tr>
<td>Roads</td>
<td>16</td>
</tr>
<tr>
<td>Road log of State Highway No. 8</td>
<td>19</td>
</tr>
<tr>
<td>Airport</td>
<td>23</td>
</tr>
<tr>
<td>Canal</td>
<td>23</td>
</tr>
<tr>
<td>Climate</td>
<td>22</td>
</tr>
<tr>
<td>Relief</td>
<td>23</td>
</tr>
</tbody>
</table>
Drainage............................................. 23
Caves................................................. 26
Natural bridge....................................... 26
Natural tunnel....................................... 29
Scenic attractions.................................. 29
Wildlife............................................... 30
Descriptive geology.................................. 33
Stratigraphy.......................................... 33
Introduction.......................................... 33
Pre-Cambrian rocks.................................. 33
Paleozoic sedimentary rocks.......................... 34
Cambrian system...................................... 34
  Lamotte formation.................................. 34
  Donnaterre formation................................ 34
  Davis formation..................................... 34
  Derby-Doe Run formation............................ 35
  Potosi formation.................................... 35
  Eminence formation.................................. 35
Ordovician system.................................... 37
  Gasconade formation................................ 37
    Introduction...................................... 37
    History.......................................... 38
    Distribution.................................... 39
    Thickness........................................ 40
    Lithologic character.............................. 41
    Weathering....................................... 50
Topographic expression........... 30
Stratigraphic relations.......... 51
Paleontology....................... 52
Correlation......................... 52
Roubidoux formation.............. 54
Introduction....................... 54
History.................................. 54
Distribution......................... 55
Thickness............................. 55
Lithologic character.............. 55
Source of the sand................. 61
Cross-bedding, ripple marks,
and sun cracks...................... 62
Weathering......................... 63
Topographic expression.......... 63
Stratigraphic relations.......... 63
Paleontology......................... 66
Correlation......................... 67
Jefferson City formation.......... 69
Introduction....................... 69
History.................................. 69
Distribution.......................... 71
Thickness............................. 71
Lithologic character.............. 72
Weathering......................... 79
Topographic expression.......... 72
Stratigraphic relations............. 80
Paleontology.......................... 81
Correlation......................... 83
Silurian system....................... 85
Devonian system........................ 85
Mississippian system................... 86
Introduction.......................... 86
Lithologic character................... 86
Paleontology.......................... 87
Age and correlation................... 88
Pennsylvanian system................... 89
Distribution.......................... 89
Thickness.............................. 89
Lithologic character................... 90
Topographic expression................ 92
Stratigraphic relations.............. 92
Paleontology.......................... 93
Age and correlation................... 93
Quaternary system....................... 94
Alluvium.............................. 94
Structure.............................. 95
Regional............................... 95
Foldes................................. 95
Faults................................. 96
Joints................................. 98
Sink structures........................ 98
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic geology</td>
<td>102</td>
</tr>
<tr>
<td>Building stone</td>
<td>102</td>
</tr>
<tr>
<td>Clay</td>
<td>102</td>
</tr>
<tr>
<td>Coal</td>
<td>104</td>
</tr>
<tr>
<td>Copper</td>
<td>104</td>
</tr>
<tr>
<td>Iron</td>
<td>105</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>107</td>
</tr>
<tr>
<td>Water resources</td>
<td>107</td>
</tr>
<tr>
<td>Ponds</td>
<td>107</td>
</tr>
<tr>
<td>Springs</td>
<td>108</td>
</tr>
<tr>
<td>Meramec Spring</td>
<td>109</td>
</tr>
<tr>
<td>Brook Spring</td>
<td>111</td>
</tr>
<tr>
<td>Streams</td>
<td>111</td>
</tr>
<tr>
<td>Wells</td>
<td>113</td>
</tr>
<tr>
<td>Water well and prospect hole logs</td>
<td>112</td>
</tr>
<tr>
<td>Geologic history</td>
<td>114</td>
</tr>
<tr>
<td>Conclusions and summary</td>
<td>119</td>
</tr>
<tr>
<td>Bibliography</td>
<td>120</td>
</tr>
<tr>
<td>Vita</td>
<td>124</td>
</tr>
</tbody>
</table>
## LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Location of the north half of the Meramec Spring Quadrangle</td>
<td>7</td>
</tr>
<tr>
<td>2. View looking northwest at Meramec Iron Works, December, 1876</td>
<td>11</td>
</tr>
<tr>
<td>3. View looking northwest at Meramec Iron Works, December, 1871</td>
<td>12</td>
</tr>
<tr>
<td>4. View looking southwest of natural bridge</td>
<td>27</td>
</tr>
<tr>
<td>5. Remains of Meramec Iron Works and picnic grounds at Meramec Spring</td>
<td>29</td>
</tr>
<tr>
<td>6. Massive sandstone member of the Rou'blidoux formation</td>
<td>64</td>
</tr>
<tr>
<td>7. Quarry ledge of the Jefferson City formation</td>
<td>73</td>
</tr>
<tr>
<td>8. Rolling uplands and gentle slopes developed on the Jefferson City formation</td>
<td>80</td>
</tr>
<tr>
<td>9. Cryptozoan colony in the Jefferson City formation</td>
<td>81</td>
</tr>
<tr>
<td>10. Pennsylvanian sediments in a sink structure</td>
<td>90</td>
</tr>
<tr>
<td>11. Fault</td>
<td>97</td>
</tr>
<tr>
<td>12. Meramec Spring</td>
<td>110</td>
</tr>
</tbody>
</table>
## LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Meramec Iron Works about 1870....</td>
<td>following page 9</td>
</tr>
<tr>
<td>II. Fig. 1. Former course of Dry Fork and Norman Creek.......</td>
<td>following page 25</td>
</tr>
<tr>
<td>Fig. 2. Present course of Dry Fork and Norman Creek.......</td>
<td>following page 25</td>
</tr>
<tr>
<td>III. Structure sections to accompany geologic map.........................</td>
<td>In pocket</td>
</tr>
<tr>
<td>IV. Geologic map.........................</td>
<td>In pocket</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Water well and prospect hole logs</td>
<td>In pocket</td>
</tr>
</tbody>
</table>
INTRODUCTION

Purpose and scope of report

The Ozark region is visited by many persons each year, and one of its popular tourist attractions is Meramec Spring. In recent years, with the advent of better roads and swifter means of transportation, visitors are coming to this beautiful spring in increasing numbers. For those who are geologists, this work will serve as a handy guide; for those who are laymen, this work may give a better understanding of the geologic events which have made this part of the Ozarks a place of scenic beauty. Mapping of the Meramec Spring Quadrangle will complete a program of geologic mapping of a strip of quadrangles across the Ozark Uplift from Rolla to the Mississippi River. All but the Meramec Spring Quadrangle have been mapped under the auspices of the Missouri Geological Survey and Water Resources.

Previous work

Certain geologic features of the Meramec Spring Quadrangle have been described in publications and theses. Shumard(1) mentions the


presence of the Third Magnesian Limestone (Gasconade), Second Sandstone (Roubidoux), and Second Magnesian Limestone (Jefferson City) along the Dry Fork of the Meramec River, and he describes the early hematite deposits in this area. Schmidt(2) and Mason(3)

(2) Schmidt, Adolf, The iron ores of Missouri: Preliminary report on the iron ores and coal fields from the field work of 1872,


redescribe some of the hematite deposits and describe others for the first time. Wheeler (4) describes the early clay deposits in the


area. Fay and Martinez (5) describe the Reed Mine and note that this


hematite deposit contained copper minerals in sufficient quantity to be considered of economic value. Maveety and Irwin (6) describe the


topography and geology of a small part of this area. Cronk (7)


redescribes some of the clay deposits and describes others in this area for the first time. Crane (8) gives additional information on


some of the previously described hematite deposits and mentions
others for the first time. Benham and Elliott(9) prepared a


geologic report and map which includes a small part of the area around St. James. Dake(10), in his work on the St. Peter sandstone,


records the textural analysis of a Roubidoux sandstone from Meramec Spring. Dake and Bridge(11) describe and figure the St. James natural tunnel. Cordry(12) describes and identifies the heavy


minerals in two Pennsylvanian sandstone samples from this area. Murphy(13) made a study of the Pennsylvanian deposits which extend


into this area. Cullison(14) analyzed Jefferson City and Cotter


sandstone samples from this area. Bridge (15) noted Gasconade


fossils at Meramec Spring. Bolon (16) and Doll (17) describe and give


(17) Doll, W. L., Hydrography of the larger springs of the Ozark region of Missouri; Missouri School of Mines and Metallurgy, Thesis, 1936, pp. 94-98.

data on Meramec Spring. McQueen (18) notes the presence of an


additional clay deposit. Beckman and Hinchev (19) describe and give


data on Brook Spring and Meramec Spring. Graue (20) has described


the important pyrite deposits.

The early history of this area is given in Goodspee'd's (21)

(21) Goodspee'd, History of Phelps County, Missouri. Reprint of all material relating to Phelps County occurring on pages 623 to 688 and 594 to 1027 from History of Laclede, Camden, Dallas, Webster, Wright, Texas, Pulaski, Phelps, and Dent Counties, Missouri. Chicago, Goodspee'd Publishing Co., 1889. Reprinted at Missouri School of Mines and Metallurgy, Rolla,
More information can be found in the works of Gerard in the Ozark region of central Missouri: Smithsonian Institution Bureau of Ethnology Bulletin 76, 1922, pp. 41, 42.

Fowke, Gerard, Aboriginal house mounds; Smithsonian Institution Bureau of Ethnology Bulletin 76, 1922, pp. 161-165.

described the aboriginal remains in this area. Beginning in 1929, Dr. C. V. Mann of Rolla, Missouri, collected material relating to the history of Phelps County. This material was used by Van Nostrand in his history of the Meramec Iron Works and by


the Phelps County Historical Society in its history of Missouri


School of Mines and Metallurgy. The latter contains information relating to this area.

Ibid., pp. 70-81.

The field geology classes of Missouri School of Mines and Metallurgy have worked in the Meramec Spring Quadrangle for over 30 years. The reports prepared by those classes are on file in the Geology Department of Missouri School of Mines.
Present work

Most of the field work for this problem was completed during June, July, and August of 1950, but some additional time was spent during September, October, and November to check and complete the work.

Acknowledgements

The writer wishes to express his thanks to Dr. O. R. Grawe, Chairman of the Geology Department of the School of Mines and Metallurgy, University of Missouri, for having suggested this problem, for criticism and suggestions during several days spent in the field, and for critically reading the manuscript in order to present the material more effectively. Mr. Robert Elgin of St. James, representative of the James Foundation at Meramec Spring, permitted the use of old photographs of Meramec Iron Works and gave freely of his knowledge of the area immediately surrounding Meramec Spring. Mr. Roy Wallace of Doolittle, Missouri loaned the logs of water wells which he drilled in the area. Dr. E. L. Clark, State Geologist, made available the logs of water wells on file at the Missouri Geological Survey and Water Resources. The citizens of the area extended many courtesies during the field work. The writer is indebted to all who have made this work possible.
GEOGRAPHY AND PHYSIOGRAPHY

Location and size of area

The north half of the Meramec Spring Quadrangle lies in eastern Phelps County and western Crawford County, Missouri. It is bounded by parallel 38°00' north latitude, the south line of Township 37 North, and by meridians 91°30' and 91°45' west longitude. The area is about 13.7 miles from east to west, 8.5 miles from north to south, and embraces approximately 116 square miles.

---

*Fig. 1. Location of the north half of the Meramec Spring Quadrangle.*

*This area is located in the northeastern part of the Salem Platform of the Springfield-Salem Plateau of the Ozark Province.*
or what is commonly known as the Ozarks.

History and Settlement

Although mounds and cairns occur throughout the Ozarks, and arrow heads, pottery, bones, and ashes have been found in many of the caves, little is known of the Indians living in the region before the arrival of the white man. In the area of this thesis, one group of mounds is located along the stream that flows across the NW sec. 31, T. 38 N., R. 7 W., and a second group is located along the stream in the SW sec. 33, T. 38 N., R. 7 W. These have been described by Fowke(27), but the large number which he noted have been destroyed by cultivation of the land. Although he calls them house mounds, their actual use is unknown because no remains of any kind have been found associated with them(28). Very likely they were tent mounds and served to keep rain water out of the wigwams. According to legend, a great battle was fought on the flat east of the site of Meramec Iron Works. The Shawnee Indians had a camp at Meramec Spring and obtained paint ore from the site of the Meramec Mine. It is probable that Spanish explorers and missionaries
reached this area from their settlement at Potosi, and it is likely that trappers and fur traders explored the region.

Meramec Iron Works

The following sketch of Meramec Iron Works was taken from Van Nostrand's admirable thesis. Much of the material in the thesis was collected by Dr. C. V. Mann of Rolla, Missouri.

The name Meramec has had many different spellings and pronunciations. The early Frenchmen called it Meramec-Siny or Meramize, and the present name is a corruption of the Indian name Miramigoua meaning Catfish River. Meramec was the form used in naming the iron works, but Meramec is usually used today.

The Shawnee Indians, on a journey to Washington, D. C. in 1825, stopped at Brush Creek Furnace in Ohio. From them, the owner of the furnace, Thomas James, learned the source of the ore which they used for their paint. On their return from Washington the same year, the Indians took James to the mine. On his return to Ohio, James sent his partner and brother-in-law Samuel Massey, and a crew of miners and workers to build the furnace and buildings which were started on August 8, 1826. The furnace was completed in January 1829 and was operated by Massey until 1847. In 1843, William James, Thomas' son, arrived to operate the mine, and in 1847, he took over the operation of the whole works.

In 1847, when Massey sold his interest in the works to Thomas James, their combined holdings consisted of about 8500 acres. Most of it was located along Meramec River and Dry Fork and was used as
MERAMEC IRON WORKS

about 1870

LEGEND
1. Charcoal House
2. Furnace and Casting House
3. Anvil Press
4. Chaffey Press
5. Flour Mill
6. Blower House
7. Blacksmith Shop
8. Forge House
9. Carpenter Shop
10. Smoky House
11. Store
12. District School
13. Old Office
14. James Reliance
15. Lodge House
16. Recreting House

President Site
Disc Site
Spring

Building
Road
Quarry

Scale in feet

Modified after Van Bostrand
a source of timber for the iron furnace.

From 1847 until his death in 1856, Thomas James was sole owner. After his death, the estate was operated by the heirs of Thomas James until his son, William James, bought out the other heirs about 1860. The iron works was a good source of income to William James who made a profit of over six thousand dollars in 1869. Under the leadership of William James, other mines became part of the estate or were leased.

A business decline which began early in the 1870's due to the general depression and to competition from more modern iron works, finally forced James into bankruptcy in 1878. About 1890, an attempt was made by some of James' employees to operate the mine and furnace but this was unsuccessful.

The original furnace, which went into blast in 1829 with a capacity of six tons per day, was replaced by a larger one in 1847. This second furnace is still standing. It was known as a cold blast furnace. Air was delivered from the blower house through an iron pipe under a pressure of 3 1/4 pounds per square inch. Charges, consisting of 640 pounds of ore, 18 bushels of charcoal, 40 pounds of limestone, and one bushel of brands (half-charred wood stumps), were placed in the furnace from the top about 100 times per day. Casting took place about 4 times per day. The average daily production was about 18 tons of pig iron.

Charcoal for the furnace was made at the place where the wood was cut. The logs were cut into 4 foot lengths, piled, covered with earth, burned from 12 to 20 days, and then quenched in water.

Pigs from the furnace either were refined at the iron works or
Fig. 2. View looking northwest at Meramec Iron Works, December, 1876. Right foreground, corner of grist mill. Center, forge house. Rear center, furnace and casting house. Rear left, chaffery forge and charcoal pile. L. H. Howard, photographer. Courtesy of Mr. Robert Elgin.

were shipped directly. In the refining process, the pigs were first converted into wrought iron in the forge house, then into anconies (bars of iron pounded into a rectangular shape in the middle but left irregular at the ends) at the ancony forge, and finally into bar iron at the chaffery forge. The chimneys of the forge house are still standing.

Two spring pole hammers and one trip hammer were used at the works. The original trip hammer, brought from Louisville, Kentucky in 1828, can still be seen a few feet west of the forge house chimneys.
During the early days, the products of the iron works were hauled to St. Louis by ox-cart. Later, they were hauled to Hermann on the Missouri River. With the building of the St. Louis and San Francisco Railroad, the hauling distance became shorter as the terminus progressed southwestward. Some iron was floated down the Meramec and Gasconade Rivers during periods of high floods.

Power at the iron works was furnished by seven undershot water wheels. Those operating the blower, hammer, and forges varied from ten to eighteen feet in diameter.

A small grist or flour mill was built at an early date and was
used until 1848. During that year, a larger mill was built which continued in operation until about 1900. The mill retained 1/8 of the grain brought for milling as a fee. It served the surrounding countryside as well as the community.

The original store was in the old office building but was later moved to a building west of the spring. All goods usually found in a general store could be bought here. The price of goods was much less than it is today but at one time the store had an annual turnover of $50,000.

A post office was established at the iron works in 1828 and served the community until 1898, when the mail was ordered sent to St. James. Between 1827 and 1838, Congress established a number of post roads which passed through the iron works.

The community also included a saw mill, carpenter shop, blacksmith shop, smoke house, boarding house, school, three churches, and many company owned houses. One of the houses still stands on the hillside about 1000 feet west of the park area. The iron works supported nearly 700 people at the peak of its production. These included miners, woodcutters, teamsters, forge men, common laborers, a chair maker, a physician and surgeon, a carriage and wagon maker, a school teacher, clergymen, a gunsmith, brick masons, blacksmiths, cabinet makers, boot makers, carpenters, wives, and children.

Thus, Meramec Iron Works was an important community for half a century. It helped attract settlers who developed the upper Meramec River area, and it was a factor in the selection of the site for the Missouri School of Mines and Metallurgy.
Population

The population of the area is concentrated at St. James, and it is more dense in the west and northwest than in the southeast. There are eight to twelve houses per section in the west and northwest compared with one or no houses per section in the southeast. This difference in population is controlled by topography. The rolling uplands are suitable for small farms whereas the highly dissected areas are suitable only for cattle, goat, and sheep grazing.

Towns

St. James, situated near the center of the northern part of the Meramec Spring Quadrangle, is the largest town in the area and the second largest in Phelps County. According to the census, it had an official population of 1988\(^{(30)}\) in 1950. Early in 1859, the town was laid out as Scioto\(^{(31)}\), but the name was changed to St. James, in honor of Thomas James, the next year\(^{(32)}\). The early history and development of St. James was intimately related to the nearby iron banks and clay pits, and to the St. Louis and San Francisco Railroad. With the arrival of the railroad in 1860, the town became the shipping point for the products of the Meramec Iron


\(^{(31)}\) Goodspeed, op. cit., p. 29.

\(^{(32)}\) Phelps County Historical Society, op. cit., p. 73.
works, the clay pits, and local farms. The closing of the iron industry seriously hindered the development of St. James, but it has continued to grow. It is still the shipping point for local agricultural products, it is the business center for the surrounding countryside, and a shirt factory is located there.

Dillon, located near the center of sec. 33, T. 38 N., R. 7 W., is a small community consisting of a church, school, general store, and a few houses. The first seat of Phelps County was located at Dillon in 1857 but was moved to Rolla in 1859. The town is rapidly dwindling.

Industry

Iron mining was the most important industry in the past, but most of the ore has been removed. Timbering was another important industry, but today only small scale operations are carried out. Clay was mined at one time, on a small scale in the area covered by this thesis, but these deposits have been worked out.

Today, the principal industry is agriculture. Cattle are raised in the areas having rolling topography; goats and sheep are raised in the areas having rugged topography, and particularly where the land is being cleared. Hay and some grain are grown on the uplands while corn is the main crop on the flood plains.

Grapes are becoming an important crop in the area underlain by the Jefferson City formation. Apparently the soil derived from that formation permits better growth and the gentle topography is better

suited to cultivation. Most of the grapes are bought by the Welsh Grape Juice Company for the manufacture of grape juice, jellies, jams, and wine.

Transportation

Railroads—The area is served by the St. Louis and San Francisco Railroad which enters the area at St. James, in sec. 20, T. 38 N., R. 6 W., trends southwestward then westward, and leaves the area along the west side of sec. 31, T. 38 N., R. 7 W. It follows the divide between the Meramec River drainage system to the south and the Spring Creek–Bourbeuse River systems to the north.

During the mining period, a spur of the Salem branch of the St. Louis and San Francisco Railroad served the timber trade as well as the mining industry in the southern part of the area. Although this spur is shown on the topographic map of the Meramec Spring Quadrangle, the track was removed about 1932.

Roads—When the field work for this thesis was begun, the author realized that a replottting of the roads on the topographic base map would be necessary in order to facilitate travel in the area and to assist in plotting outcrops. In the twenty two years since the map was edited (1928), most of the sharp turns on the highways have been removed, a few new roads have been added, and many of the roads formerly serving the mining and timber industries have become impassable. Some of the buildings have been removed and many new ones added. The field map, used as a basis for geologic mapping, was drawn so that the roads and buildings conform to their present location.
The presence of Meramec Iron Works in the area greatly influenced the early road-building program in the southern half of Missouri. By 1835, Meramec was the center of a network of roads running to St. Louis and New Madrid on the Mississippi River, to Arkansas, and to Jefferson City on the Missouri River (34). Between 1836 and 1841, new roads were authorized to be built from Meramec to Hermann on the Missouri River, to Springfield, to St. Louis, to Ste. Genevieve, to the Gasconade River, and to Steelville. In the area immediately surrounding the iron works, many roads and trails served local needs.

U. S. Highway No. 66 crosses the northwestern part of the area from St. James southwestward. It is the major cross-country highway serving the Southwest. The old route of this highway, shown as State Highway No. 14 on the topographic map, is now impassable in places.

State Highways No. 8 and No. 68 serve the eastern part of the area. Both numbers refer to the same road from St. James south-eastward to the NE sec. 3, T. 37 N., R. 6 W., where they branch, No. 8 (Steelville Road on the topographic map) going eastward to Steelville and No. 68 (Salem Road on the topographic map) going southward to Salem. State Highway No. 72 (Rolla and Salem Road on the topographic map) connects Rolla and Salem and serves the south-western part of the area.

County Highway 0 is an all-weather road along the west side of the area from State Highway No. 72 southward. County Highway 7 is
an all-weather east-west road from State Highway No. 72 in sec. 20, T. 37 N., R. 7 W. to a point east of Dean School where state maintenance ends. From the latter point, it connects with farm-to-market roads and finally with State Highway No. 68. County Highway V begins at U. S. Highway No. 66 near the northeast corner of sec. 31, T. 36 N., R. 7 W. and, except in the vicinity of the Rolla Airport, it follows the section line northward. The area is well covered by a network of good farm-to-market roads, but their usefulness is decreased by fords and low water bridges which become impassable when the streams are high.
Road log of State Highway No. 8—Geologically, State Highway No. 8 is one of the most interesting roads in this part of the Ozarks. Along its 7.85 miles from St. James on the north to the Meramec River on the east, an example of many of the geological features found in the area can be seen or reached by a short drive or walk. The itinerary from St. James is as follows:

0.00 miles Intersection, U. S. Highway No. 66 and State Highways No. 8 and No. 68.

0.15 miles Crossing, St. Louis and San Francisco Railroad.

0.60 miles Road to left, Boy's Town of Missouri and Brook Spring (p. 111)*, 2.3 mi., all-weather road.

1.10 miles "Cut", both sides of road, Pennsylvanian sandstone and clay in sink structure. About 400 ft. southwest, large Pennsylvanian sandstone outcrop in sink structure (p. 92).

1.30 miles Left side of road, Pennsylvanian in sink structure.

1.60 miles Right (south) of road, James Wine, about 0.25 mi. to the south, dump visible from road.

1.75 miles Right, scenic view south and southeast. Monadnocks on peneplain visible in distance.

1.85 miles Left side of road, Pennsylvanian in sink structure.

2.00 miles Left side of road, Pennsylvanian in sink structure.

2.20 miles Road to left, St. James Tunnel (pp. 28, 29), 1.1 mi., rough but passable road, muddy when wet.

2.40 miles Right of road, Crisp Wine, in clump of trees about

* Page number refers to description in thesis.
Road log of State Highway No. 8—Geologically, State Highway No. 8 is one of the most interesting roads in this part of the Ozarks. Along its 7.85 miles from St. James on the north to the Meramec River on the east, an example of many of the geological features found in the area can be seen or reached by a short drive or walk. The itinerary from St. James is as follows:

0.00 miles Intersection, U. S. Highway No. 66 and State Highways No. 8 and No. 68.
0.15 miles Crossing, St. Louis and San Francisco Railroad.
0.60 miles Road to left, Boy's Town of Missouri and Brook Spring (p. 111)*, 2.3 mi., all-weather road.

1.10 miles "Out", both sides of road, Pennsylvanian sandstone and clay in sink structure. About 400 ft. southwest, large Pennsylvanian sandstone outcrop in sink structure (p. 92).

1.30 miles Left side of road, Pennsylvanian in sink structure.
1.60 miles Right (south) of road, James Mine, about 0.25 mi. to the south, dump visible from road.
1.75 miles Right, scenic view south and southeast. Monadnocks on peneplane visible in distance.

1.85 miles Left side of road, Pennsylvanian in sink structure.
2.00 miles Left side of road, Pennsylvanian in sink structure.
2.20 miles Road to left, St. James Tunnel (pp. 28, 29), 1.1 mi., rough but passable road, muddy when wet.
2.40 miles Right of road, Crisp Mine, in clump of trees about 50 ft. from road.

* Page number refers to description in thesis.
200 ft. southwest of house.

2.50 miles "Cut", both sides of road, Pennsylvania in sink structure at base of Jefferson City formation.

2.70 miles Right of road, Roubidoux formation in sink structure, in drain 250 ft. from road.

2.75 miles Left side of road, Roubidoux sandstone, cross-bedded and ripple marked, in roadside drain.

3.00 miles Left side of road, base of Roubidoux, in drain.

3.55 miles Bridge, Dry Fork (pp. 23, 24).

East end of bridge, right of road, below road level, white Cryptozoan reef.

Hill above reef, natural bridge (pp. 26-28, fig. 4).

3.90 miles Left side of road, spring (p. 109).

4.15 miles Left side of road, Gasconade formation outcrop.

4.25 miles Road to the right, State Highway No. 68 (p. 17).

South to abandoned meanders of Dry Fork (p. 25, pl. II).

South to Asher Lookout Tower (p. 30).

4.50 miles Right side of road, top of Gasconade formation.

4.80 miles Both sides of road, irregularly dipping Roubidoux sandstones capping hill, sink structures.

5.70 miles

6.35 miles Left side of road, top of Gasconade formation.

6.55 miles Left side of road, Gasconade outcrop.

6.70 miles Left side of road, old Maramec Iron Works quarry, in Gasconade.

6.85 miles Road to left, Maramec Spring (pp. 102-111, fig. 12),
Meramec Iron Works (pp. 9-13, figs. 3, 3, pl. 1),
recreation area (fig. 5), 0.25 mile.

Meramec Mine, walk about 0.5 mi. west of spring
along old road.

6.95 miles Low water bridge.

7.00 miles Phelps County-Crawford County line.

7.25 miles Bridge, Meramec River (p. 23).
Airport—The Rolla Memorial Airport is situated north of U. S. Highway No. 66 in the southwest corner of sec. 22 and northwest corner of sec. 32, T. 33 N., R. 7 W. Although unsuited for large aircraft, it does serve the pleasure and commercial requirements of the area.

Canal—In connection with transportation, the following bit of information is of interest. In 1839, a Merimac Canal and Navigation Company was incorporated to build a canal up the channel of the Meramec River from the Mississippi River to the Meramec Iron Works(35). A survey was made and the requirements were drawn up.

(35) Ibid., p. 61.

but the resources of the state were insufficient so the project was abandoned in 1841.

Climate

The climate of this area is mid-continental temperate. It is variable and subject to sudden change. Cool to hot periods during the summer and warm to cold periods during the winter can be expected. The temperature may rise to 106°F Fahrenheit in the summer and fall to -20°F Fahrenheit in the winter. A mean annual temperature of 55.5°F is the result of a summer average of 75.6°F and a winter average of 34.3°F(36). Daily fluctuations in temperature of 40°F or

(36) U. S. Weather Bureau, St. Louis, Mo. Oral communication.

50°F are not uncommon, particularly in the winter.

The mean annual precipitation is 41.81 inches. May and June,
the wet months, have an average precipitation of 4.52 inches and
December, January, and February, the dry months, have an average of
2.42 inches (37). For agricultural purposes, late summer and early

(37) Ibid.

autumn are considered to be dry. In spring the rainfall may be
great enough to seriously delay planting while late summer may be so
dry as to work a hardship on cattle seeking water.

Relief

The lowest altitude, 750 feet above sea level, is in the valley
of Meramec River, in sec. 32, T. 38 N., R. 5 W. The highest
elevation, slightly over 1000 feet above sea level, is in the north-
west corner of the area, in sec. 30, T. 38 N., R. 7 W. Three
smaller areas with almost the same elevation are located immediately
to the southeast. The maximum relief is about 450 feet, but the
average local relief varies from 120 feet in the western part of the
area to 220 feet along Meramec River in the eastern part of the area.

Drainage

The drainage of the quadrangle is dendritic and almost entirely
tributary to Meramec River which flows northward near the eastern
margin of the area. The flood plain of the river varies from 0.2 to
0.4 miles wide and is bounded by bluffs and steep-sided hills of
Gasconade dolomite. The gradient is slightly less than 6 feet per
mile.

Dry Fork, the most important tributary of Meramec River in the
area, flows generally northwestward from sec. 35, T. 37 N., R. 7 W.
to its confluence with the Meramec River about a mile northeast of Meramec Spring. This tributary is perennial and has a gradient of slightly more than 5 feet per mile.

Little Dry Fork is the largest perennial tributary of Dry Fork and Norman Creek is the largest intermittent tributary. A network of branches are tributary to the larger streams.

Bourbeuse River drains most of the area north of the St. Louis and San Francisco Railroad. Its confluence with Meramec River is located in Franklin County, Missouri. Spring Creek, a tributary of the Gasconade River, drains a small area in the extreme northwestern part of the quadrangle.

An unusual feature of the drainage of this area is the lack of perennial streams between Dry Fork and Meramec River. This includes Norman Creek, Brown Hollow, and Asher Hollow which together drain about 60 square miles. These streams are dry through most of the year due to subsurface drainage which, for the most part, reaches the surface at Meramec Spring. The Roubidoux sandstone is exposed over much of the surface here, and its porous character permits rapid seepage into the underlying cavernous Gasconade dolomite.

In the area northwest of Dry Fork, the opposite is found to be true. Every stream is perennial except the very smallest. The residuum of the Jefferson City dolomite retains much of the rainfall, and the dense dolomites of that formation greatly hinder seepage into the subjacent Roubidoux formation.

Two types of meanders are found in the area. The most prominent of these are the entrenched meanders on Meramec River, Dry Fork, and Norman Creek which indicate that the present drainage
pattern of these streams has been derived from a pre-existing nature pattern. The second type of meander is typical of the flood plains. These are not well developed and are usually isolated loops.

In sections 15, 16, 21, and 22, T. 37 N., R. 6 W., one of the entrenched meanders on Dry Fork has been abandoned by the stream cutting through the narrow neck. (See Plate II.) Norman Creek has altered its course by cutting through a narrow neck in the SW\(_4\), SE\(_4\) sec. 16, T. 37 N., R. 6 W. In the Eminence and Cardareva Quadrangles, Bridge\(^{(50)}\) has found several abandoned meanders and


meanders in the process of being cut-off. He gives two possible methods by which the cut-off takes place, and suggests, with evidence, that the second is the most probable. In the first method, the stream narrows and lowers the neck of the meander by undercutting on both sides until a point is reached where the stream can complete the cut-off by breaking through at some high stage. In the second method, solution by ground water along joint and bedding planes opens subsurface channels across the narrow neck, erosion by part of the stream enlarges the channel to form a passage, and eventually all of the stream is diverted through the passage. The final phase is the collapse of the passage roof to complete the cut-off. There is no evidence to conclude which method took place on Dry Fork, but the highly jointed nature of the formations exposed in the area of this thesis suggests that the second method is more probable.
Fig. 1. Former course of Dry Fork and Norman Creek, T. 37 N., R. 7 W.

Fig. 2. Present course of Dry Fork and Norman Creek, T. 37 N., R. 7 W.
Caves

This area contains few caves compared with the number in the western part of Phelps County. None is of commercial interest or value and only one, Marcellus Cave, is worth consideration. All of the caves are found near the top of the Gasconade formation in a zone which is more susceptible to weathering than other parts of the formation.

Marcellus Cave is located in the NW^4, SW^1, NW^4, NE^1 sec. 17, T. 37 N., R. 6 W. Its mouth, 3 feet high and 5 feet wide, is about 10 feet below the Gasconade-Roubidoux contact and 21 feet above the bed of Dry Fork. The mouth opens into a small chamber off of a side passage of the main part of the cave. A few small stalactites occur in the small chamber but none in the passages. The floor of the small chamber is covered with debris and slopes downward to the side passage. The floor of the side passage is about 7 feet above the floor of the main gallery. Small streams flow through the passage and gallery. During periods of high water, much of the cave is flooded by water from Dry Fork, and at the time of the writer's visit, late July, the passages were very muddy so no attempt was made to explore the cave. It is reported to be over one mile long.

The area must contain other large caves to serve as conduits for the subsurface drainage, but no surface openings were found. A natural tunnel and a natural bridge are evidence of the former existence of other caves.

Natural bridge

This feature (See Fig. 4.), located in the SE corner sec. 33,
T. 38 N., R. 5 W., occurs about 55 feet above Dry Fork at the east end of the bluffs. The arch has a span of 15 feet, is 12 feet high, and 8 feet wide. Originally, this was a cave, trending southwestward, which had its beginning in the soluble zone 5 feet above the prominent Cryptozoan reef of the Cretaceous formation. Enlargement took place both laterally and upward until a point was reached where the roof collapsed due to its inability to support the overlying beds. The collapse was local, similar to that of a sink, and probably much of the cave became filled with material washed in through the sink. These events occurred before the area was uplifted. After the streams had been rejuvenated, Dry Fork cut its channel downward through the cave and near the sink. Much of the debris that filled the cave remnant was removed by eddies from Dry Fork.
Fork when the stream was at the same elevation as the cave. Gravity is largely responsible for keeping the arch clear of debris now.

Natural tunnel

The St. James Natural Tunnel, located near the south line of the SW₁, NE₂, SW₁, sec. 27, T. 38 N., R. 6 W., has been previously figured and described by Bake and Bridge (39). Here a valley, trending eastward, had its outlet over the present saddle and down the valley to Dry Fork. A cave, trending northwestward, from Dry Fork, extended under the valley. The cave probably was formed by the circulation of ground water. Eventually some of the water from the stream bed found its way into the cave through joints, and finally solution enlarged the joints sufficiently to permit all of the drainage to pass through the cave. The valley above the point of capture has been entrenched 20 feet. The entrenching may be due to the former presence of the cave beneath the valley and due to erosion since capture. The scenic beauty has been destroyed by the use of the mouth of the tunnel as a barn for the storage of hay and farm equipment and the area around the upper entrance as a pig sty. The mouth has been enlarged in recent years by the removal of debris from the floor. According to Bake and Bridge, a model of this tunnel was placed on the market by Ward's Natural Science Establishment (40), but no records are available at Ward's to show that this

(39) Bake, C. L., and Bridge, Josiah, op. cit., pp. 5, 6.

(40) Ibid., Footnote, p. 6.
Scenic attractions

The large springs of the Ozarks always have been prominent attractions for passing tourists and Meramec Spring, 7 miles southeast of St. James on State Highway No. 8, has been long known and often visited. Within the past few years, the trustees of the James estate have purchased a large tract of land around the spring in order to preserve its natural beauty for the public. The remains of some of the buildings of the Meramec Iron Works can be seen near the spring, and these have been partly restored. Shelters and facilities for picnics are provided. (See Fig. 5.) Hunting is not

Fig. 5. Remains of Meramec Iron Works and picnic grounds at Meramec Spring.

(41) Hosking, J. C., Jr. Written communication.
Scenic attractions

The large springs of the Ozarks always have been prominent attractions for passing tourists and Meramec Spring, 7 miles southeast of St. James on State Highway No. 8, has been long known and often visited. Within the past few years, the trustees of the James estate have purchased a large tract of land around the spring in order to preserve its natural beauty for the public. The remains of some of the buildings of the Meramec Iron Works can be seen near the spring, and these have been partly restored. Shelters and facilities for picnics are provided. (See Fig. 5.) Hunting is not
allowed because the area is a wildlife refuge, but fishing is permitted in the spring branch below the bridge.

Fishing is good in Meramec River and Dry Fork, especially for the competent angler. Hunting, other than for rabbit, squirrel, and quail, has become a thing of the past in this area. Occasionally a deer or fox is seen, and recently beavers were reported, but this is unusual. Permission to fish is often readily granted by property owners, but hunting is forbidden in many places.

Several religious organizations have cabins and camps along the Meramec River where underprivileged children and religious groups may enjoy the beauty of the Ozarks. A few private individuals have summer homes and cabins within the area.

Scenic views of this part of the Ozarks can be had conveniently from several vantage spots. The best of these is Asher Lookout Tower located in the southwest corner, sec. 36, T. 37 N., R. 6 W. An all-weather road passes the tower, a fire warden is on duty during the day through most of the spring, summer and fall, and visitors are welcome. Another vantage spot is located along State Highway No. 3 near the east side of sec. 29, T. 36 N., R. 6 W. A view to the southeast may be obtained from this point, and monadnocks on the paneplane are visible in the distance.

The best times to visit the area are in the spring when the wild flowers are in bloom and in the fall when the tree leaves have changed their color to beautiful reds and yellows.

**Wildlife**

The large variety of animals that once lived in this area have
increased greatly due to the destruction of their natural habitat, hunting and trapping. The fur-bearing animals to be found are deer, squirrels, beavers, foxes, rabbits, opossums, skunks, moles, and gophers. Those no longer found in this area are bears, wolves, panthers, weasels, minks, otters, muskrats, and raccoons. Trapping is done by the local residents in the late fall and winter when their usual occupations cannot be pursued. Hunting is done by the local residents and by visitors. The highly dissected eastern part of the area is the best place for hunting because it is less well developed culturally.

The only game birds to be found in this area are quails and doves. These are most often found on the rolling uplands or on the flood plains where seeds from grasses or cultivated crops may be obtained for food.

Fishing is a popular sport in this area, especially in the spring branch below the bridge at Meramec Spring, in Meramec River and in Dry Fork. A few of the varieties that can be obtained are bass, blue gill, trout, carp and cat.

Some of the snakes to be found in this area are copperheads, rattlesnakes, black snakes, whip snakes, garter snakes, racers and moccasins. The term moccasin is often used to refer to two different snakes, one being poisonous and the other non-poisonous. The poisonous variety is also called the “cottonmouth” whereas the non-poisonous variety is called the “water moccasin”. The only really dangerous snake in this area is the copperhead which blends with the reddish-brown soils and rocks. They are reported to be common around the old mines and rocky areas, and the farmers kill
many while mowing hay.

Campers, hunters and hikers should take adequate precautions if they are troubled by chiggers, ticks or mosquitoes. Chiggers are present throughout the spring, summer and fall. Ticks are unusually common during the spring and after rains. A few cases of Rocky Mountain Spotted fever have been reported from the Ozarks but none, to the writer's knowledge, from this area. Mosquitoes are not common except around some of the old mines that contain water or around stagnant pools in the stream beds.
DESCRIPTIVE GEOLOGY

STRATIGRAPHY

Introduction

Rocks of pre-Cambrian age are not exposed at the surface in this area and they have not been encountered in the deep wells. Cambrian formations were encountered only in the deep wells at St. James and in the shallow well at Waramac Spring. The exposed formations are principally Ordovician in age, but they are overlain by small patches of residual Mississippian and Pennsylvanian sediments which are preserved principally in sink structures.

PRE-CAMBRIAN ROCKS

Although rocks of pre-Cambrian age are not exposed in this area and have not been encountered in the deep wells, an estimate of their probable depth may be made. It is believed by the author that these rocks will be found at a depth of about 1500-1700 feet below the Gasconade-Roubidoux contact or at an elevation of about 900-1000 feet below sea level. This estimate is based on the thickness of formations encountered in the deep well at St. James and the approximate thicknesses of the undrilled formations. The actual depth at which the pre-Cambrian will be encountered in any particular well is somewhat speculative due to the fact that the sedimentary formations were deposited upon a highly uneven, eroded pre-Cambrian surface. That surface had a maximum relief of about 1500 feet, which is equivalent to that now existing in southern Missouri.
Lamotte Formation--- The Lamotte sandstone was the first sediment deposited on the pre-Cambrian granitic rocks. It is composed chiefly of sand but at the base and locally within the formation, particularly near its margins, there are conglomerates and arkoses. It has not been encountered in deep wells in this area, but it probably will be found at a depth of about 1300–1400 feet below the Gasconade-Roubidoux contact. Its thickness is likely to be quite variable, from 0 to 300 feet, due to the irregularity of the pre-Cambrian surface upon which it was deposited. Its importance as an aquifer also is quite variable.

Bonne Terre Formation--- This formation is composed principally of dolomite. It was deposited conformably upon the Lamotte sandstone. The basal portion usually is sandy and contains a few thin shale beds. It has not been encountered in deep wells in the area but would be found at a depth of about 1000–1100 feet below the Gasconade-Roubidoux contact. Its thickness is likely to vary from 200 to 350 feet. Lee (42) gives a thickness of 265 feet in a well at Salem, Missouri.

Davis Formation--- This formation is often known as the Davis shale because it contains the greatest development of shale in the whole Ozark Cambro-Ordovician section. It contains thin-bedded dolomites and shales, and it varies from predominantly bluish or greenish shale to predominantly crystalline dolomite. The Davis
formation will be encountered at a depth of slightly more than 900 feet below the Gasconade-Roubidoux contact. Its thickness is 169 feet in the above-mentioned well at Salem and is probably about the same in the Meramec Spring Quadrangle.

**Derby-Doe Run Formation**—This unit is considered to be two distinct formations by some geologists, but for mapping and well logging purposes, it usually is considered to be one. The lower, Derby, portion consists of about 40 feet of calcareous dolomite. The upper, Doe Run, portion consists of about 60 feet of argillaceous dolomite. Post-Doe Run erosion has caused a variation in the thickness of the upper portion of the formation. Forty feet of the Derby-Doe Run was penetrated by the deep well at St. James (log No. 3690). (See Table I.) The top of the formation was located at a depth of 305 feet below the Gasconade-Roubidoux contact.

**Potosi Formation**—The Potosi formation is characteristically dark brown, fine to medium crystalline, massively bedded, drusy dolomite. It usually has a foetid odor when freshly broken. This is the oldest formation that has been penetrated through its entire thickness in any well in this area. In the above-mentioned well at St. James, the thickness is 295 feet, the top of the formation being located at a depth of 510 feet below the Gasconade-Roubidoux contact. Its open, porous character make this formation one of the best aquifers of the region.

**Eminence Formation**—The Eminence formation consists of cherty dolomites which are very similar to the overlying Gasconade formation. Fossil evidence is the best criterion for distinguishing one from the other. The Proctor formation of some authors is
probably equivalent to, if not the same as, the upper beds of the Emience formation. Although the Emience is 260 feet thick in the deep well at St. James, the thickness in the area is known to be variable due to post-Emience erosion. The depth of the Emience below the Gasconade-Roubidoux contact is dependent upon the thickness of the overlying Gasconade formation. In the St. James well, the Gasconade is 260 feet thick while in another well (log No. 3074), about a half mile to the northwest, it is 290 feet thick. A third well (log No. 7152) which reaches the Emience is located at Meramec Spring. This well was started about 120-130 feet below the Gasconade-Roubidoux contact and reached the Emience at a depth of 100 feet. The irregular post-Emience erosion surface, the thinning of the overlying formations by solution, and their abnormal thicknesses in sink structures make an accurate determination of the depth of the Emience below the Gasconade-Roubidoux contact impossible.
ORDOVICIAN SYSTEM

Gasconade Formation

Introduction—The Gasconade formation is the oldest formation exposed in the area. It is the oldest Ordovician formation in Missouri and the youngest of Ulrich's Ozarkian system. The term Gasconade is used in this thesis to include all strata from the base of the Gunter sandstone to the base of the Roubidoux formation. This is the sense in which it was used by Lee (43) in mapping the Ralla Quadrangle.

The Gunter member, Van Buren formation, and Gasconade (restricted) formation were mapped as one formation because the siliceous olite bed, used by bridge (44) as the top of the Van

Buren, could not be located. McQueen (45) has been able to separate

the Van Burens from the Gasconade on the basis of the cherty

insoluble residue, but according to James (46), "...other members of

the Missouri Geological Survey and Water Resources have found that

(43) Ibid., p. 12.


the exact contact between the Van Buren and Gasconade is indeterminate."

History--Swallow (47) was the first to mention this formation

(47) Swallow, C. C., The first and second annual reports Geological Survey of Missouri, Reports, 1855, p. 126.

in print. He called it the Third Magnesian Limestone where exposed in bluffs on the Niangua River near Bryce's Spring (now Bennett Spring). Shumard (48) was the first to note the presence of the


formation within the area of this thesis, and he says, "It (Third Magnesian Limestone) constitutes the inferior beds of the bluffs of the Dry Fork of the Meramec, for a considerable distance above its confluence."

Mason (49), realizing the erroneous usage of the earlier

(49) Mason, P. L., op. cit., p. 115.

formation names, proposed the name Gasconade for outcrops on the Gasconade River and applied it to the great dolomite series underly-

sandstone. They gave the Gunter formational rank and named it from exposures at Gunter or Mahatanka Springs on the Niangua River (51).


Marbut (52) included the Gunter in the Gasconade, making it the basal member. This usage was used in publication until 1930 when Bridge (53) divided the Gasconade into two formations. He named the lower part Van Buren, from exposures near Van Buren, Missouri, and he retained the name Gasconade for the upper part. According to Bridge (54), Ulrich suggested the separation in 1923, and the Missouri Geological Survey adopted the usage in 1929. Since 1930, this separation has been variously accepted and rejected.

Distribution—— The valley of Dry Fork approximates the western limit of Gasconade outcrops in the area. Northwestward from this boundary, the formation rapidly disappears beneath the overlying Roubidoux; southeastward, progressively more of the formation is exposed in the valley walls until it caps the hills in the southeast corner. Although the average exposed thickness is about 120 feet, the small surface distribution of about 25 square miles is due to
the fact that the Gasconade is found almost exclusively in the deep narrow valleys which have been cut through the resistant Roubidoux formation.

Thickness—The total thickness of the Gasconade formation does not outcrop in the area, but a maximum of about 230 feet is present on the steep-sided hills west of Maramec River in sec. 30, T. 37 N., R. 5 W. This value is based on the vertical distance from the bottom of the Maramec River valley to the base of the Roubidoux capping the nearest hill, with allowance for dip. No single section shows the entire thickness, and isolated outcrops extent over a lateral distance of 0.8 miles.

Only three water wells reach the base of the Gasconade. Unfortunately they are located in areas where the structure is known to be complicated by the effects of solution. The formation is 260 feet thick in one well (log No. 9690) at St. James while in a second well (log No. 3074), about a half mile to the northwest, it is 290 feet thick. Thirty-five feet of Pennsylvanian sediments encountered in the second well suggest a sink structure, but it cannot be determined to what extent the structure has influenced the thickness of the Gasconade. Samples were not taken in the upper 30 feet of the first well so no comparison can be made.

The well (log No. 7152) at Maramec Spring was started about 120 to 130 feet below the Gasconade-Roubidoux contact and entered the Eminence formation at a depth of 100 feet. The formation has been thinned by solution in this vicinity so the maximum of 230 feet probably is less than normal.

The Gunter sandstone member is 30, 30, and 25 feet thick in the
wells described in the above paragraph.

In the Cardareva Quadrangle, Bridge(55) found one locality

(55) Ibid., p. 91.

which presented evidence for at least 60 feet of relief on the pre-
Gasconade erosion surface. It is entirely possible that much of the
variation in the thickness in this area is due to the same cause.

Lithologic character— The Gasconade formation consists
essentially of light gray, fine to coarsely crystalline, massive to
thin-bedded, very cherty dolomite. Although light gray is the pre-
dominant color, a few beds were found to be white, medium gray, and
dove. Light gray is often associated with finely crystalline beds
whereas the other colors are associated with the medium to coarsely
crystalline beds.

Thin beds, 0.25 to 4 inches thick, are usually concentrated in
zones which are more common below a prominent Cryptozoan reef than
above it. These are the undercut and cavernous zones on bluff
exposures, and are seldom seen on the slopes. The thicker beds, up
to 6 feet thick, protrude from the cherty slopes as step-like ledges.
Superficially, these beds resemble the Quarry ledge of the Jefferson
City formation in that both outcrop as ledges, and may become dark
gray and pitted on weathering.

Chert, although abundant in the residual material of the slopes,
is less commonly seen on the bluffs. This difference is due not
only to accumulation on the slopes but also to segregation of
disseminated silica. Where road cuts have been made, as on State
Highway No. 8 just south of Meramec Spring, accumulation can be seen
at the surface and thin beds of very porous chert outcrop in the red
clayey residuum. This chert has not been found on bluff exposures.

At least three Cryptommar reefs are present in the Gasconade, 
but only one, known as the Richland chert zone, is prominent and 
widely spread. It occurs about 60 feet below the top of the formation, 
but the distance is somewhat variable and is dependent upon the 
amount of overlying Gasconade that has been removed by subsurface 
solution and pre-Roubidoux erosion. The other reefs occur lower in 
the formation. Some individuals are cone-shaped and have a 
concretion-like structure. These are 2 to 5 feet wide and 2 to 3 
feet high. Another form consists of low domed lamellae superimposed 
one above the other and attached to a common wall between adjacent 
individuals. Open spaces, 5 to 6 inches in diameter and varying 
height, exist between the lamellae.

Near the top of the formation, a bed of ropy chert was found in 
residual material. In section, the branches show a concentric 
structure, the outer part usually being pale bluish-gray and the 
inner part dull white or hollow. A fine, white quartz druse is 
present in some of the hollows. Two gastropods were found firmly 
embedded in a specimen of this chert.

Bedded and nodular chert is not commonly seen on unweathered or 
slightly weathered surfaces. These types are more often seen in the 
Roubidoux and Jefferson City formations.

The color of the chert is white, or white with tints of blue or 
gray. This gives rise to the snow-like appearance on the cherty 
slopes. Where the chert is covered by clayey material, a reddish-
brown stain due to iron oxide covers the surface.
Quartz druse in the Gasconade is usually colorless, white, or light gray. Occasionally, it is very pale violet. The crystals are almost always small.

A sandstone bed was found on the bluff exposure on the south side of Dry Fork near the SE corner, sec. 33, T. 38 N., R. 6 W. The bed is 9 feet above the Richland chert zone, and it is 0.5 inch thick. The sand is white, medium grained, and glauconitic. This sandstone may be a lens because it could be traced laterally for only a few feet.
The following composite section was measured along State Highway No. 3 in the S\textsuperscript{1}_2, sec. 1, T. 37 N., R. 8 W. This shows the lithology of the upper part of the Gasconade formation.

Top of road cut. Elevation 970 feet.

Roubidoux formation.

Residual material. Clay, sandy, light gray to reddish-brown. Contains badly weathered, porous chert fragments with white quartz druse in the cavities. White porous chert and quartzite protrude from the clay in the form of thin ledges. 17' 00"

Sandstone, medium- to coarse-grained, very friable, and contains hollow chert pebbles up to 1" in diameter. Weathers reddish-brown. 0' 3".

Dolomite, sandy, coarsely crystalline, medium gray. Weathers reddish-brown. Badly decomposed. 0' 3"

Gasconade formation. Elevation 953 feet.

Dolomite, coarsely crystalline, medium gray. Weathers reddish-brown. Badly decomposed. 0' 7"

Dolomite, medium- to coarsely crystalline, contains ropy and porous chert. Pale purple quartz druses in cavities. 1' 6"

Chert, cryptocrystalline, white. Cavities contain white quartz druse. 3' 3"

Covered. Red sandy clay containing white chert fragments. 11' 6"

Chert, oolitic, white to gray. Pale reddish-brown quartz druses in cavities, some filled with loose oolites(?). 0' 10"

Covered. Red sandy clay containing white chert fragments. 1' 6"

Chert, cryptocrystalline, white to light gray. 1' 7"
Covered. Probably interbedded chert and dolomite.

Chert, white to gray. Lower part shows Cryptozoan structures.

Dolomite, finely crystalline, light tan to light gray. White quartz druse in cavities in thin cherty layers.

Covered. Probably interbedded chert and dolomite.

Dolomite, finely crystalline, light gray. Small white chert lenses along bedding planes. Weathers pitted.

Chert, Cryptozoan, white to dark gray. Badly fractured.

Covered. Red sandy clay containing white chart fragments.

Dolomite, medium crystalline, white to buff. Containsropy chert and white quartz druse in cavities.

Covered.

Chert, white to light gray.


Covered.

Covered. Red sandy clay containing large fragments of white Cryptozoan chert.

Chert, Cryptozoan, white.

Covered. Grass-covered chertly sandy clay.

Dolomite, finely crystalline, medium gray, thin-bedded. Irregular lens-like masses of clay containing bluish-gray chert fragments. Weathers dark gray, porous, and pitted.

Chert, Cryptozoan, white. Stained reddish-brown.
Dolomite, medium crystalline, medium gray. Contains white quartz druse in cavities and few white chert lenses. Weathers dark gray, rough, and has solution channels. 3' 9"

Dolomite, medium crystalline, gray, thick-bedded. Weathers dark gray and pitted. 8' 00"

Chert, porous, thin-bedded, white. 0' 6"

Dolomite, medium to coarsely crystalline, gray, massive. Weathers dark gray, pitted and rough. 6' 6"

Dolomite, coarsely crystalline, medium gray. Cavities contain white quartz druse and white tripolitic chert. Solution zone. 1' 1"

Dolomite, medium crystalline, gray, massive. Weathers dark gray and pitted. 4' 00"

At road level in quarry. Elevation 800 feet.
The following section was measured on the south side of Dry Fork in the S\(\frac{1}{2}\), SE\(\frac{1}{4}\), NE\(\frac{1}{4}\), sec. 33, T. 38 N., R. 6 W. and in the NE\(\frac{1}{4}\), NW\(\frac{1}{4}\), sec. 4, T. 37 N., R. 6 W. This shows the lithology of the upper part of the Gasconade formation.

Top of hill. Elevation 1010 feet.

Roubidoux formation.

Covered. Residuum containing large sandstone blocks. 30' 00"

Sandstone, medium-grained, friable, white, cross-bedded, and ripple marked. Weathers reddish-brown. 5' 08"

Covered. Residuum containing chert and sandstone fragments. 7' 02"

Sandstone, coarse-grained, slightly friable, light reddish-brown, thick-bedded, and contains white chert fragments. Weathers dark reddish-brown. 9' 07"

Sandstone, medium- to coarse-grained, friable, white, and cross-bedded. Weathers white to tan, pitted, and undercut. 4' 05"

Sandstone, medium-grained, white, and cross-bedded. Weathers reddish-brown. 3' 09"

Covered. 7' 00"

Sandstone, fine- to medium-grained, friable, white, contains white chert grains, cross-bedded, and ripple marked. Weathers reddish-brown. 4' 03"

Covered. Residuum containing large sandstone boulders probably from overlying outcrop. 31' 00"

Sandstone, medium-grained, white, contains white chert grains, and cross-bedded. Weathers reddish-brown with large pits. 1' 02"

Gasconade formation 7' 05"

Covered. 4' 05"
Dolomite, medium crystalline, light gray, thin-bedded. Contains irregular masses of medium gray chert. Weathers porous and pitted. This may have slumped from a position under the next sandstone exposed above.

Covered.

Dolomite, coarsely crystalline, light to medium gray, thick-bedded with occasional thin beds. Contains a few scattered white chert nodules. Weathers dark gray, rough, and pitted. 14" from base is a ½" bed of white, glauconitic, medium-grained sandstone.

Dolomite, medium crystalline, light gray, thin-bedded. Weathers dark gray, pitted, cavernous, and undercut.

Dolomite, finely crystalline, light gray, thick-bedded. Weathers dark gray.

Chert, Cryptozoan, white. Dome-shaped, concentric structure, 2' to 3' high and 3' to 5' wide.

Dolomite, medium crystalline, light gray to dove, contains white and gray chert fragments. Weathers black, very pitted, and cavernous.

Dolomite, medium crystalline, light gray, massive. Weathers dark gray and pitted.

Dolomite, medium crystalline, dove, thin-bedded. Weathers dark gray to tan.

Chert, Cryptozoan, white. Low domed lamellae attached to common wall between individuals. Porous and drusy.

Dolomite, finely crystalline, light gray to dove, thin-bedded. Weathers white to light gray and dove.

Covered. Residue containing chert fragments.

Dolomite, finely crystalline, dove, massive. Contains white chert masses suggestive of Cryptozoans.
Covered.

Dolomite, finely crystalline, light gray to dove, massive. Contains irregular drusy chert. Weathers gray and pitted.

Dolomite, fine to medium crystalline, light gray, thin-bedded. Contains chert nodules up to 4" in diameter. Weathers tan.

Chert, Cryptocrystalline, oolitic, white to light gray. Weathers brown to medium gray.

Covered.

Stream surface. Elevation 795 feet.
Weathering-- The Gasconade characteristically weathers to steep cherty slopes with protruding step-like ledges. These ledges are the thick, massive dolomite beds and are more resistant to erosion than the thinly laminated beds. They can be found wherever the Gasconade is present on hillsides but are best developed on the steeper slopes such as along the west side of Maramec River in sec. 7, T. 37 N., R. 5 W.

Bluffs, from 75 to 100 feet high, are formed where the larger streams are active in lateral erosion along the valley walls. An example of these bluffs can be found on the south side of Dry Fork in the SW\(^4\), SE\(^1\), sec. 33, T. 38 N., R. 6 W.

Individual beds weather differently. The massive dolomites are commonly pitted and the pits vary from circular depressions up to one inch in diameter to narrow ovals. On some beds, the pits are in rows parallel to the bedding. The thin-bedded dolomites are usually undercuts zones on an exposure and are often found near the ceiling in caves. This suggests that cave formation was initiated in these thin-bedded zones. The cherts, due to their brittle and insoluble nature, weather to sharply angular fragments which litter the slopes and hilltops.

The coloration on the weathered exposures tends toward darker shades of gray but the black color often seen is due to lichens growing on the surface.

Topographic expression--- The areas in which the Gasconade is the surface formation are deeply dissected and very rugged. Narrow valleys, steep hillsides, and bluffs are characteristic. The overlying Roubidoux sandstone is very resistant to erosion and forms a
protective cap on the less resistant Gasconade. Once a stream has cut through the Roubidoux, rapid down-cutting can take place in the Gasconade but the intervening ridges and hills will continue to be protected.

Stratigraphic relations--- The Eminence-Gasconade contact is not exposed in this area but possible evidence for an unconformity is found in the variation in thickness of the Gasconade encountered in the two deep wells at St. James. If an unconformity were the only cause for the thickness difference, a relief of 60 feet on the pre-Gasconade erosion surface would be indicated. It is likely however, that this is not the only reason for the variation in thickness. This point already has been covered in the discussion of the thickness of the Gasconade.

The Gasconade is overlain unconformably by the Roubidoux, but the only physical evidence in the area for an unconformity is the conglomeratic sandstone found immediately above the Gasconade in a few places. Dake\(^{56}\) believed that if any of the upper beds of the


Gasconade are missing, they have been removed by subsurface solution along the contact between the porous Roubidoux sandstone and the soluble Gasconade dolomite. Bridge\(^{57}\) noted evidence of a faunal


break when he wrote, "...no trace of the Tribez Hill-Stonehenge
fauna which intervenes between the Gasconade and Roubidoux faunal zones in the Appalachian trough has been found in Missouri."

Paleontology—The writer did not collect and identify fossils from the Gasconade formation but noted that gastropods are the predominant forms seen. Much of the fauna of the formation has been described in the literature. Bridge (58) recognized his *Eumphalopsis*

(58) Ibid., pp. 116, 202, 203.

zone of the Gasconade at creek level at Meramec Spring and gave this as the type locality for several species.

Correlation—The lower (Van Buren) part of the Gasconade has been traced in outcrops through parts of the Ozarks on the basis of stratigraphic position, lithology, and fossils. McQueen (59) has


made correlations in deep wells in the southern part of Missouri on the basis of insoluble residues. On the basis of gastropods found within the formation, Bridge (60) correlated the Van Buren with part


of the Chapman Ranch formation of the Arbuckle limestone in Oklahoma and the Copper Ridge dolomite in Alabama.

The upper part of the Gasconade has been traced throughout the Ozark region in outcrops and deep wells. According to Bridge (61),
part of the Gasconade fauna is found in the Onsota dolomite of Wisconsin and other parts are found in the Cheyultaneq dolomite of Tennessee and Alabama, and it seems to have local equivalents as far north as New York. It indicated that some of the fauna have been reported in the Cass Mord formation of northern Greenland and from Scandinavia.

On faunal evidence, Cloud and Barnes (62) correlated the Tanyard

formations of the Ellenburger group in the Llano region of Texas with the Gasconade (unrestricted) of the Ozarks.
Roubidoux Formation

Introduction—The term Roubidoux is applied to the rocks, principally sandstone, which overlie the Gasconade and underlie the Jefferson City. The formation is the oldest of Ulrich's Canadian system.

History—Early Missouri geologists called this formation the Second Sandstone. Shumard (63) was the first to recognize it in this area, and he says, "It (Second Sandstone) is largely developed on the Dry Fork of the Meramec, presenting there, occasionally, a thickness of 150 feet; fine exhibitions of it are to be seen in the vicinity of Meramec Iron Works."

Nason (64) was the first to use the name Roubidoux and applied it to the sandstone "overspreading the Ozark region from Cabool to Gasconade City and from Salem to Doniphan." He defined it as including "...much, if not all, of what has been called the Second Sandstone, and undoubtedly the areas of the so-called First Sandstone." He was incorrect in believing that the sandstone beds at Pacific and Crystal City, known as the First or Saccharoidal Sandstone (now St. Peter), are extention of the Second Sandstone.

Between 1892 and 1905, the name was applied to other formations or completely ignored, and the formation was given other names. Bain and Ulrich (65) reapplied the name Roubidoux to this formation,
and the terminology has been retained since that time.

Distribution--- The Roubidoux has the greatest surface distribution of any formation in the area. The surface underlain by the formation covers about 57 square miles or almost 50 percent of the northern half of the Meramec Spring Quadrangle. It forms a protective cap on the ridges and hills southeast of Dry Fork where the Gasconade is exposed, and it effectively hinders erosion into the rolling uplands where the overlying Jefferson City caps the highlands.

Thickness--- The entire thickness of the Roubidoux is present only in the western part of the area, where it is overlain by the Jefferson City formation. Its thickness varies both locally and regionally; the former being due to removal of the dolomite by solution, and the latter, to initial deposition. It is about 115 feet thick in the north at St. James, and about 130 feet thick in the south. These values are approximate because the entire formation is not exposed in any single outcrop. The exposed upper and lower contacts are usually a mile or more apart with much of the formation, especially the part above the thick sandstone member, being covered so that the intervening structural conditions could not be taken into consideration. The well logs (See Table I) can be used to determine the thickness at a particular locality, but structural conditions must be considered.

Lithologic character--- The Roubidoux in this area consists of
interbedded sandstone and dolomite. Sandstone is predominant on the outcrops, but, since the dolomite members usually are weathered and covered by cherty, sandy soil, the importance of the dolomite usually is minimized. On one 60 foot exposure, from the base of the formation to the top of the massive sandstone, 47 percent was sandstone, 13 percent was dolomite, and 40 percent was covered. This was the most dolomite seen in the formation at any locality. If it is assumed that most of the covered zones are chiefly dolomitic, then the formation is about equally divided lithologically. This compares favorably with Lee's (66) Gould Creek section both in regard to total thickness of formation from the base of the Boubidoux to the top of the massive member and in regard to percentage of rock types present.

The beds above the massive member seldom are exposed due to their thinner bedding which permits their being weathered and covered by a thick residuum on the gentle slopes. Occasionally, thin sandstone or chert beds are seen, but very rarely any dolomite. Judging from the topographic expression, the cherty residuum and the lack of outcrops, it is probable that this upper part of the formation is mostly dolomite or thin, interbedded sandstone and dolomite.

The sandstones, when fresh, are white to light gray, fine- to coarse-grained, and friable. Numerous fine, angular chert particles are mixed with the sand, giving it a speckled appearance on fresh and weathered surfaces. The quartz grains are angular due to
secondary enlargement, exhibiting well developed crystal faces surrounding rounded grains. Some beds are pelitic, especially towards the top, whereas others grade laterally or vertically into quartzite. Locally, the sandstone is conglomeratic, containing angular to subangular chert fragments up to one inch in diameter. This is especially noticeable on the upper, weathered surface of the massive sandstone member where it outcrops 50 feet southeast of the right-angle bend in the road about 0.25 miles west of the SE corner, sec. 30, T. 38 N., R. 6 W.

Dolomite below the massive sandstone resembles that of the Gasconade. It is white to light gray, fine to coarsely crystalline, thin- to medium-banded, and weathers to a dark gray, rough, pitted surface. As would be expected in this formation, some of the dolomites are sandy. The dolomite above the massive member is lithologically similar to that of the Jefferson City formation. It is dove to medium gray, fine to medium crystalline, argillaceous, and weathers to a light to medium gray, pitted surface. Thin-banded zones occur in both the upper and lower dolomites.

Nodular, banded, and Cryptozoan chert is found in the Roubidoux. The nodules have been seen only in the upper part of the formation where they occur in the thin-banded zones of the dolomite. They are usually flattened parallel to the bedding, and white to bluish-gray in color. Thin chert beds and lenses, 0.5 to 4 inches thick, are usually associated with the nodules. On a number of exposures, a thick bed of chert overlies the massive sandstone member. Its color varies from white to dark gray, and it is always badly fractured. It may be observed in situ on widely separated outcrops, such as on
the north side of County Highway 7 where it crosses Dry Fork and on the east side of State Highway Nos. 8 and 68 in the SW\textsubscript{1}, NW\textsubscript{1}, NE\textsubscript{1} sec. 33, T. 38 N., R. 5 W. Large boulders derived from the bed were found at a number of other places so it is believed that this bed is persistent throughout the area. Cryptozoan chert, similar to the smaller forms found in the Gasconade, occur in the lower part of the formation. Structures, suggestive of the Jefferson City forms, were seen near the top of the formation, but the poor exposure did not permit a positive identification.

Siliceous oolite beds occur in the upper part of the formation but only one, 6 to 8 inches thick, was seen outcropping. It is not known whether more than one bed occurs in the formation, but the large amount in the residual material strongly suggests that others are present.

Cordry\textsuperscript{(67)} has described and identified the heavy minerals in

\begin{itemize}
\item (67) Cordry, C. D., op. cit., pp. 59-85.
\end{itemize}

the Roubidoux sandstones, and Dake\textsuperscript{(68)} has made textural analyses.

\begin{itemize}
\end{itemize}
The following section was measured on the north side of Dry Fork in the SW \( \frac{1}{4} \), NE \( \frac{3}{4} \), sec. 22, T. 37 N, R. 7 W. This shows the Gasconade-Roubidoux contact and the greatest amount of Roubidoux dolomite found at any single locality.

Top of hill. Elevation 1030 feet.

Roubidoux formation.

Covered. Sandy residuum containing white chert blocks and very few sandstone fragments. 43' 00" 0'

Sandstone, medium-grained, friable, white, cross-beded, and ripple marked. Case-hardened, weathers reddish-brown. 18' 6" from base is 4' zone containing lenses of white quartzite. 29' 9" 1'

Covered. Sandy residuum containing white chert boulders and large sandstone blocks. 17' 3" 4'

Sandstone, medium-grained, friable, white, and cross-beded. Casehardened and weathers reddish-gray. 1' 10" 2'

Dolomite, medium crystalline, dove, massive. Lower part weathers slightly pitted. 4' 8" 3'

Covered. Sandy residuum containing white chert and reddish-brown stained sandstone fragments. 2' 00" 4'

Sandstone, medium-grained, quartzitic, white. Very hard, weathers white. 2' 7" 5'

Sandstone, medium- to coarse-grained, friable, white, and cross-beded. Locally quartzitic at the top, weathers reddish-brown. 1' 1" 6'

Dolomite, medium crystalline, light gray, thin-beded (\( \frac{1}{4} \) to 1 inch), thickness variable (7" to 1' 3"), weathers rough and pitted. 0' 11" 7'

Dolomite, medium to coarsely crystalline, light tan, massive. Weathers rough and pitted, thickness variable (1' to 1' 8"), 1' 4" 8'
Dolomite, fine to medium crystalline, white, massive. Weathers light gray to black, pitted but not rough.

Covered. Probably dolomite. Sandy residuum containing chart and sandstone fragments.

Sandstone, medium- to coarse-grained, friable, white to light gray, and cross-beded. Casehardened, weathers reddish-brown.

Covered. Probably sandstone.

Sandstone, medium-grained, white, and cross-beded. Locally quartzitic at the top, weathers reddish-gray.

Dolomite, sandy, fine to medium crystalline, light gray, massive. Weathers rough, pitted, and black.

Sandstone, medium-grained, friable, white, and cross-beded. Not resistant to weathering.

Sandstone, medium-grained, slightly friable, white to light tan, massive. Casehardened, weathers reddish-brown to black, rounded knobs.

Gasconade formation.

Dolomite, medium crystalline, light gray, thin-bedded. White quartz drusas in small cavities. Weathers reddish-brown to tan.

Dolomite, medium crystalline, light gray, massive. Weathers gray to black, rough, and cavernous.

Covered. Valley alluvium.

Stream surface. Elevation 875 feet.
Source of the sand—Several theories have been presented to explain the source of the sand. Early geologists believed it was derived from the St. Francis Mountains to the southeast. Lee (69)

(69) Lee, Wallace, op. cit., p. 34.

believed that the sediments overlapped from the south and the sand was probably driven from the southwest by the shore currents of the Roubidoux sea. His evidence for this theory was the greater thickness of the formation towards the south, and the occurrence of Roubidoux fossil horizons south of the Rolla Quadrangle which are below the base of the formation within the quadrangle.

Dake's (70) theory that the sands were derived from the north is generally accepted today. He discounts the St. Francis Mountains as a source because of the presence of residual Gasconade high on the flanks of the mountains and the lack of feldspar in formations higher than the Gasconade. These indicate that the St. Francis Mountains were almost completely, if not totally, covered by the Gasconade formation during Roubidoux time. He mentions dolomite wedges which thicken towards the south, and greater amounts of dolomite in the formation to the east and west as suggestive that the sediments were not derived from those directions. The remaining source would seem to be the pre-Cambrian shield to the north.

No evidence is available in the area of this thesis to form any conclusion as to the source of the sand. Problems of this nature

can be solved by a regional study.

Cross-bedding, ripple marks, and sun cracks—These features of shallow water deposition are well developed in the sandstones of the Roubidoux formation. In this area, cross-bedding is very common and can be found on most outcrops. On horizontal surfaces, as in the bed of a stream, the cross-bedding can be recognized by thin, wedge-shaped beds which coalesce with the underlying bed at the apex and are one to two inches thick at the base. These can be seen when vertical cracks or joints develop perpendicular to the base of the wedge, and a cross-section is obtained when erosion removes part of the wedge. On vertical surfaces, as on bluffs, the cross-bedding has its typical development.

Ripple marks are less common than cross-bedding but are often seen on exposed bedding planes. They may be seen as casts in the overlying bed where undercutting has occurred or as thin, wavy, iron-stained bands on fresh vertical surfaces. Cox and Dake(71)


have described in detail the types of ripple marks found in the Roubidoux in the vicinity of Rolla, Missouri. Although they do not give exact localities for their figured specimens, some probably were obtained in the area of this thesis.

Sun cracks, also known as mud cracks or desiccation cracks, are rarely seen in situ in this area. More commonly, they are found on broken slabs in streams or adjacent to large outcrops. Examples
Weathering--- The dolomites of the Roubidoux are easily removed by solution, but the sandstones, although friable on fresh surfaces or when covered by thick residual material, become case-hardened when exposed to weathering and are more resistant than the dolomites. Case-hardening is caused by the evaporation of silica- and iron-bearing water on the surface of the exposure to produce a thin ferruginous siliceous crust. The mineral-bearing water is held between the sand grains of the rock and is carried to the surface by capillary action. Oxidation of the iron at the surface produces the characteristic reddish-brown stain of Roubidoux sandstone outcrops. Residual material from the formation is sandy, and contains angular chert fragments and pieces of case-hardened and thoroughly silicified sandstone.

Topographic expression--- The Roubidoux formation is characterized by two types of topography. The first is found above the massive sandstone member where slopes are gentle and streams have low gradients. The second is found where the massive member outcrops in bluffs and steep-sided hills. (See Fig. 6.) Here, the streams have higher gradients, and small waterfalls are present. Where streams have cut through the Roubidoux, rapid down-cutting takes place in the Gasconade to form deep, steep-sided valleys, but the intervening ridges and hills are protected by the resistant sandstones.

Stratigraphic relations--- Chert pebbles in the basal Roubidoux
sandstone have been used in some areas as evidence for an unconformity between the Gasconade and Roubidoux formations. In other areas, the contact has been found to be gradational. It usually is covered in this area. At Marcellus Cave, in the NW\(\frac{1}{4}\), SW\(\frac{1}{4}\), NW\(\frac{1}{4}\), NW\(\frac{1}{4}\), sec. 17, T. 37 N., R. 6 W., the contact is gradational. A sandy, oolitic chert passes into a sandy dolomite containing thin chert stringers. This is followed by non-sandy dolomite which contains a fine, colorless to white, quartz druse in small irregular cavities.

In the cut on the north side of State Highway No. 8 in the SW\(\frac{1}{4}\), sec. 1, T. 37 N., R. 6 W., irregular-shaped, rounded, reddish-brown stained, chert pebbles, about 25 mm. in greatest diameter, were
found in a weathered, sandy bed. On removing a few of these for closer inspection, their specific gravity seemed to be much less than that of chert. The weathered surface did not react to hydrochloric acid, and upon breaking one to obtain a fresh surface, it was found to be hollow. The concentrically banded chert shell was one half millimeter thick, and a thin film of pale yellow clay coated the interior. No description of a similar occurrence could be found in the literature, and it does not seem possible that these ever were solid chert pebbles. The only plausible explanation is that they were Gasconade dolomite pebbles deposited with the basal Roubidoux sand. Subsequent to deposition, silica-bearing water began to coat the dolomite with chert. A thickness was reached where the colloidal silica could no longer penetrate the previously deposited chert (possibly the intermolecular spaces became too small) so further addition ceased, but silica-free water continued to penetrate the shell to dissolve and remove the dolomite, and the insoluble residue remained inside.

Near the center of the SW 1/4, NE 1/4, sec. 32, T. 38 N., R. 6 W. in the bed of the tributary of Luther Branch, a negative type of conglomerate was observed. The sand grains of this bed are cemented by white chert, and its upper portion is calcitic. The bed contains flat, well-rounded cavities which vary from 1 to 9 mm. in thickness and from 2 to over 40 mm. in greatest diameter. Small sizes (2 to 4 mm.) and large sizes (10 to 40 mm.) predominate. The flat sides of the cavities are essentially parallel to the bedding. A chert shell is firmly cemented to the quartzite and varies in thickness from a thin film in the larger cavities to complete fillings in the
smaller. The cavities probably are the remains of flat, well rounded Coniacian dolomite pebbles that were deposited with the basal Roubidoux sand. The fact that they are flat suggests that they were derived from a thin-bedded dolomite. The process by which the shape of the pebble was preserved is probably the same as that of the irregularly shaped pebble mentioned above.

A half mile southeast of the above locality, on the south side of Luther Branch in the NW², SE¹, SE² sec. 32, T. 38 N., R. 6 W., similar cavities, especially the larger ones, were seen in a sandy dolomite which overlies the basal sandstone.

The relation to the overlying Jefferson City formation is essentially conformable. Changes in sedimentation at the top of the Roubidoux are carried through into the base of the Jefferson City so the lithologic boundary is arbitrary. When fossils are found, the contact is drawn above the Lecanosnira fauna. In this area, no fossils were seen and the contact was usually covered so the boundary was drawn on the basis of residual material and the location of the Quarry ledge of the Jefferson City or the massive sandstone of the Roubidoux.

Where Pennsylvanian sediments lie on the Roubidoux, the contact is obviously unconformable. At least one, and perhaps several, periods of erosion occurred to cause this relationship.

Paleontology——Fossils are rare in the Roubidoux formation. None, other than Cryptomans, were seen in this area but time did not permit a detailed search. Gastropods are predominant and Lecanosnira is diagnostic of the formation according to Bridge (73).
Branson (74) lists the three species of cephalopods known to occur in the formation.

**Correlation**—The Roubidoux has been traced in outcrops and deep wells throughout the Ozark region. It has been correlated by Dake (75) with the New Richmond formation of Iowa, Minnesota, and Wisconsin, and with the middle part of the Prairie du Chien formation of Illinois. According to Bridge (76), the _Leganospira_ fauna of the Roubidoux is found in the Longview limestone of Alabama, in the Middel Lower limestone of Pennsylvania and Tennessee, in the lower part of Division C of the Beekmantown of New York, and northeastward in Scotland and Scandinavia. It is considered to be equivalent to the Middle Canadian in the Arbuckle and Wichita Mountains of Oklahoma by Ulrich and Cooper (77). Cloud and Barnes (78) consider it


to be correlative with the German formation of the Ellenburger group in the Llano region of central Texas.
Jefferson City Formation

Introduction—The term Jefferson City is used in this thesis to include all strata above the Roubidoux and below the Carboniferous outliers. On the basis of Cullison's work, this definition includes the Jefferson City (restricted) and Cotter formations.

Although most of his work was done in the Rolla Quadrangle, he does give an analysis of a Cotter sandstone sample from an outcrop located in the NW corner, NE¼, NW¼ sec. 29, T. 38 N., R. 7 W. Other sandstone outcrops, located on the west side of the road about 0.4 mile south of the NW corner sec. 6, T. 37 N., R. 7 W. and on both sides of the road about 0.1 mile east of the NW corner sec. 28, T. 28 N., R. 7 W., are probably Cotter in age. It seemed best to map these two formations as one unit because size, heavy mineral, and insoluble residue analyses are the most accurate methods for making a separation and time did not permit such determinations.

History—Shumard was the first to recognize the strata of this formation in this area, and he wrote, "The ridges to the north of the Dry Fork of the Meramec are underlain by this (Second Magnesian Limestone) formation." The name Jefferson City was first proposed by Winslow from the type section at Jefferson City.


Shumard, R. F., op. cit., p. 236.

Winslow, Arthur, Lead and zinc deposits: Missouri Geological
Missouri to replace the term Second Marnesian Limestone of earlier geologists. He placed the base of the formation at the top of the Marseau (Roubidoux) sandstone, and the upper boundary was placed at the base of the Saccharoidal (St. Peter) sandstone. Lee \(^{(82)}\)

\(^{(82)}\) Lee, Wallace, op. cit., p. 35.

continued this usage in the Rolla Quadrangle but noted that the higher beds, if deposited at all, were largely removed by pre-Mississippian erosion. Bridge and Charles \(^{(83)}\) observed Cotter fossils in the upper part of the formation near Rolla, and Ulrich, in 1928, identified a sandstone outcrop north of Rolla as basal Cotter. As a thesis problem, Cullison \(^{(84)}\) traced this sandstone into the Rolla Quadrangle and revised the Jefferson City formation there. His findings have since been published \(^{(85)}\). In a later work, Cullison \(^{(86)}\) used the term Jefferson City as a group name and


subdivided it into two formations. The lower he called Rich Fountain from outcrops at Rich Fountain, Missouri (87). In it he included some of the upper beds of the Roubidoux. The upper formation he named Theodosia from Theodosia Post Office, Ozark County, Missouri (88). In it he included beds which previously had been called upper Jefferson City and lower Cotter. He retained the name Cotter for higher beds. This subdivision has not yet been accepted by later authors who use the terms Jefferson City (unrestricted) or Jefferson City (restricted) and Cotter.

Distribution—The Jefferson City formation is confined, with two exceptions, to the uplands in the western part of the area, with an extension eastward to St. James. This is divided into two unequal parts by Little Dry Fork and Burgher Branch, the southern part containing about 10 square miles and the northern part about 24 square miles. The two exceptions are located in sink structures in sections 31 and 32, T. 37 N., R. 6 W.

Thickness—The maximum thickness is found in the northwestern part of the area where the surface elevation is the greatest. It is about 240 feet thick at the head of Franz Branch and at least 350
feet thick on Spring Creek. These values may not be accurate due to the presence of numerous sink structures along the divide between the two streams. Fortunately, many wells have been drilled through this formation, and a better idea of the thickness at individual localities may be obtained from them. (See Table I.) In the well (log No. 3589) located at the center, SW\(_1^1\), NE\(_1^1\) sec. 31, T. 38 N., R. 7 W., the Roubidoux had not been reached at a total depth of 245 feet. This is the maximum value found in any well. In using these logs, one important thing must be remembered. If the well has been drilled into a sink structure, abnormal thicknesses will be found.

An excellent example of this is an occurrence in the SE\(_1^2\), NE\(_1^2\), SW\(_1^2\) sec. 19, T. 37 N., R. 7 W. The surface elevation of the well (log No. 4180) at this location is 990 feet. According to the well log, 130 feet of Jefferson City sediments were penetrated. In the stream bed 300 feet to the east, the upper sandstone of the Roubidoux outcrops at an elevation of 965 feet and can be seen dipping towards the well. This shows that 105 feet of Jefferson City beds were lowered into the Roubidoux, and only 25 feet normally would have been cut by the well.

Lithologic character--- 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. The lower part consists essentially of light gray to dove, fine to medium crystalline, medium-bedded, siliceous dolomite. On weathering, these beds exhibit a characteristic pitted surface. This part of the formation also contains beds of the other rock types. Some of the beds have
a distinctive odor when struck with a hammer due to enclosed organic material. These have been called stinkstones.

The well known Quarry ledge of the Jefferson City (See Fig. 7.) outcrops as a prominent ledge about 30 to 35 feet above the base of the formation. It is 8 feet thick and composed of medium gray, very finely crystalline, siliceous dolomite. It appears massive on outcrops, but close inspection reveals poorly developed bedding or parting planes 0.5 to 1 foot apart which permit it to be split into blocks suitable for building. Segregated silica gives the rock a mottled appearance and partly causes the pitted surface on weathering. The pitting is also due to variation in granularity and porosity of the dolomite.

Fig. 7. Quarry ledge of the Jefferson City formation, south side of stream, about 200 feet SW of road intersection near center, sec. 30, T. 37 N., R. 7 W.
The upper part of the formation is typically a buff, fine to medium crystalline, medium-beded, argillaceous dolomite. This rock is easily decomposed and seldom occurs except on very steep slopes. Thin beds of the other rock types occur in this part.

Sandstones are seldom seen in situ. The most prominent are those found near the tops of the hills in the northern part of the area. They are white, very friable, and composed of fine, well-rounded quartz grains. Thin sandstone beds occur above the Quarry ledge, but they have been seen only where road cuts have been made in the residual material. They are usually porous and soft, and originally, may have been sandy dolomite or dolomitic sandstone before the weathering processes removed the dolomite. These beds can be seen on the north side of County Highway F near the center of the S6 sec. 30, T. 37 N., R. 7 W.

Grayish-blue, chalcedonic chert is characteristic of the Jefferson City formation. Other colors are white and light to dark gray. Nodules, lenses, and thin beds of chert are associated with the thin-beded, argillaceous dolomite, and all three may be found in the same thin-beded zone. Thick chert beds are present in the formation but it is believed that they are not widespread. One such bed, about 2 feet thick, outcrops in the bed of Little Dry Fork on the south side of the road near the center of the S6 sec. 30, T. 37 N., R. 7 W. It is about 10 feet above the base of the formation. Another bed, 3 to 4 feet thick, outcrops along the road between Cleino School and the bridge over Little Dry Fork on the south line sec. 8, T. 37 N., R. 7 W. It is believed that this is the basal bed of the formation at this outcrop. Changes in slope
and accumulations of chert fragments suggest the presence of thick chert beds or lenses higher in the formation.

Pale bluish-green clay, up to 1 inch thick, occurs interbedded with the argillaceous dolomite in the lower part of the formation. Thin films occur higher in the formation. These beds are the result of solution of the dolomite and concentration of the argillaceous material along bedding planes. They are quite characteristic of the formation.
The following composite section was measured on the west side
of Little Dry Park at the center of the NE, sec. 19, T. 37 N., R. 7 W.
This shows the Roubidoux-Jefferson City contact and the lower part
of the Jefferson City formation.

Top of nose. Elevation 1065 feet.

**Jefferson City formation.**

Covered. Residuum containing fragments of
white calcite chert, white sandy chert, and
white to blue chalcedonic chert. 17' 00"

Dolomite, very finely crystalline,
siliceous, medium gray. Weathers dark
gray and pitted. Often appears massive
but close inspection reveals thick bedding.
Often exposed and prominent. Quarry ledge. 8' 00"

Dolomite and chert interbedded. Dolomite,
medium crystalline, dove. Chert, white to
light gray in thin beds and lenses. 0' 10"

Chert, white to blue, chalcedonic. Thickness
variable. Weathered surface contains
very small pits. Upper surface shows
solution channels. 0' 3"

Dolomite, very finely crystalline, dove,
massive. Few white chert nodules in lower
8". Weathered surface contains small pits. 1' 6"

Dolomite, very finely crystalline,
argillaceous, dove, thin-bedded. Thin pale
green clay partings. Non-resistant. 3' 2"

Dolomite, sandy, medium crystalline, dove,
massive. Non-resistant to weathering. 1' 1"

Dolomite, fine to medium crystalline,
argillaceous, tan, thin-bedded. Pale green
clay partings up to 8" thick. Non-
resistant to weathering. 1' 3"

Dolomite, very finely crystalline,
siliceous, pale tan to dove, 3" to 1" beds.
Weathers gray and slightly pitted. 7' 00"

Covered. Probably thin-bedded dolomite. 1' 4"
Dolomite, very finely crystalline, light gray, thin-bedded. White to pale bluish-gray chart lenses at base.  

Dolomite, finely crystalline, medium gray, siliceous, massive. Resistant to weathering. Feathers pitted to smooth.  

Dolomite, very finely crystalline, medium gray, thin-bedded. Upper part light gray, with pale green clay partings and few pale gray, flat chert nodules.  

Dolomite, finely crystalline, argillaceous, light gray, thin-bedded. Few dove to pale bluish-gray chart lenses. Non-resistant.  

Dolomite, very fine to finely crystalline, dove, medium- to thick-bedded.  

Roubidoux formation.

Sandstone, quartzitic, medium grained, white to dove and bluish-gray. Oolitic, especially at base. Upper and lower surface uneven. Weathers white to light gray.  

Dolomite, finely crystalline, argillaceous, dove to medium gray, thin-bedded. Pale green clay partings up to $\frac{1}{2}$" thick. Upper and lower surface uneven.  

Dolomite, very finely crystalline, dark gray, local irregular and concentric knob-like white chert masses suggest Cryptozoans.  

Dolomite, finely crystalline, grayish-brown to dark gray, thin-bedded. Contains white to bluish-gray chalcedonic chert nodules and lenses.  

Chert, chalcedonic, white to light bluish gray, laminated.  

Dolomite, very finely crystalline, argillaceous, dove to light gray, thin-bedded.  

Sandstone, oolitic, quartzitic, white. Lower part appears cross-bedded, upper
part banded. Few blue chalcedonic chert nodules. Upper surface appears ripple marked but exposure insufficient for positive determination. High oolite content suggests that this is a siliceous oolite. Upper surface uneven.

Sandstone, quartzitic, medium-grained, colorless to light gray. Small lenses are white due to chert cement.

Dolomite, finely crystalline, dark gray, thin-beded. Contains flattened white chert nodules. Upper surface uneven.

Sandstone, medium-grained, white, chert cement, bedding uneven.

Stream level. Elevation 950 feet.
Weathering--- On gentle slopes, the Jefferson City weathers to a sandy clay containing chert fragments. The residuum is often more than 3 feet thick so few outcrops are present. This condition is found throughout most of the area, and it makes mapping difficult. On the steeper slopes, especially where the Pennsylvanian sandstones form a protective cap on the ridges, outcrops are more numerous. Thin, discontinuous ledges protrude from the residual material, and thin dolomite slabs, a few sandstone fragments, and chert fragments litter the slopes. There is less chert on these slopes than on Gasconade slopes.

The lower part of the formation is known as the pitted member because of the characteristic surface exhibited by many of the beds on weathering. The quarry ledge of this member is the most resistant bed of the formation. It usually outcrops, but if covered, its location can often be recognised by a change in slope. The upper part of the formation is known as the cotton rock member but the author has seen little resemblance to cotton, unless it is because the rock is soft. The beds are more argillaceous in this member, and they are easily decomposed.

The soil produced by the Jefferson City is yellowish-brown to reddish-brown in color. Locally, near the sandstones, it may be a dark shade but usually it is lighter than that of the Roubidoux. This color difference is an aid in mapping but it is not diagnostic.

Topographic expression--- Gentle slopes, rounded hills, and rolling uplands are characteristic of topography developed on the Jefferson City formation. (See Fig. 8.) Slopes are slightly more steep below the quarry ledge than above it, and they rise rather
Fig. 3. Rolling uplands and gentle slopes developed on the Jefferson City formation, view SW from road, SW\(\frac{1}{4}\) sec. 21, T. 37 N., R. 7 W.

steeply in the vicinity of St. James and the Rolla Airport where Pennsylvanian sandstones hinder headward erosion. Sandstones in the Jefferson City are too thin to have any influence on the topography, but short lenses cause local breaks in the slopes.

Stratigraphic relations—The relation with the underlying Roubidoux formation has been discussed in connection with that formation. The relation with the overlying Mississippian and Pennsylvanian outliers is unconformable. Certainly several periods of pro-Pennsylvanian erosion occurred to remove all of the Jefferson City and younger deposits in the northeastern corner of the area so that Pennsylvanian sediments could be deposited on the Roubidoux formation. A well defined contact between the Jefferson City
formation and the younger sediments is not exposed. The Jefferson City-Pennsylvanian contact is present on the south side of the railroad cut on the west line, sec. 31, T. 38 N., R. 7 W., but the critical zone is covered by 2 to 3 feet of slumped material.

Paleontology--- Few fossils were seen in the formation and no attempt was made to search for them. Faunal lists have been published in many of the geologic reports, and Cullison (89) lists and figures species found in this region.

A Cryptozoan colony (See Fig. 9.) is exposed in the stream bed 100 feet west of the road intersection near the center of sec. 30,

---

Fig. 9. Cryptozoan colony in the Jefferson City formation, in stream bed 100 feet west of road intersection near center, sec. 30, T. 37 N., R. 7 W.
T. 37 N., R. 7 W. Individuals are from 10 inches to 3 feet in diameter, and erosion has removed the upper part so the concentric structure can be seen. The laminae are from $\frac{1}{4}$ to 1 inch thick, have no visible internal structure, and some have irregularly arranged ridges covering the outer surface. These ridges, about $\frac{1}{4}$ inch high, give the surface the appearance of a brain. Some of the laminae are composed of light gray chert whereas others are finely crystalline, light gray dolomite. The colony is 15 feet below the top of the quarry ledge which is exposed on the hillside to the southwest.

Although their origin has been questioned, the colonial manner of growth, concentric structure, and raised ridges strongly suggest that they are organic.

About 250 feet down stream from the above locality, on the east side of the road, dome-shaped masses, 9 to 12 inches in diameter and 2 to 3 inches high, rise smoothly on the upper surface of a dolomite bed. A Cryptozoan colony is probably present in the underlying bed, and the domes are the surface expression of deposition over the spherical individuals.

An occurrence similar to the first mentioned above is present in the stream bed 50 feet east of the road in the NW$^1$, NE$^1$, SW$^1$ sec. 31, T. 38 N., R. 7 W. This colony is about 95 feet above the base of the formation.

Trilobite fragments were found attached to the surface of a chert slab which had weathered from a bed 1$\frac{1}{2}$ inches thick. The bed is in an undercut zone in thin-bedded dolomite immediately below the quarry ledge. The locality for this occurrence is 250 feet southwest of the intersection of Little Dry Fork and the $37^\circ 55'$ parallel
in sec. 18, T. 37 N., R. 7 W. The slab has been sent to Dr. Josiah Bridge at the U. S. National Museum for possible identification but identification has not been received.

Correlation—The Jefferson City and Cotter formations have been traced in outcrops and deep wells through much of the Ozark region. They have been correlated faunally by Bridge (90) with part


of the Shakopee dolomite of Wisconsin, the Newala limestone of Alabama, and the upper part of Division C of the Beekmantown of New York. The Jefferson City formation was correlated by Ulrich and Cooper (91) with the lower part of the Upper Canadian in the Wichita


and Arbuckle Mountains of Oklahoma, with part of the Ellenburger limestone of the Llano Uplift in Texas, and with the lower part of the Newala formation of Alabama. They correlated the Cotter formation with the top of the Ellenburger in Texas, with the middle Upper Canadian in Oklahoma, with the Shakopee in the Upper Mississippi Valley, with part of the Ogdensburg of New York, and with the upper part of the Newala of Alabama. Cloud and Barnes (92)

(92) Cloud, P. E., Jr., and Barnes, V. E., op. cit., p. 34.

believed the Honeycut formation of the Ellenburger group in the Llano region of Texas to be essentially correlative with the Jefferson City of the Ozarks. Cullison has found faunal equivalents
of his Rich Fountain formation of the Jefferson City group in the lower part of the Post-Mittany division of the Knox dolomite in the Appalachian Valley. He correlated his Theodosia formation of


the Jefferson City group with the Shakopee dolomite of Minnesota and with the upper Knox dolomite of Virginia, and he added that it is probably equivalent to the formations which Bridge correlated with the Jefferson City and Cotter formations (94). His Cotter fauna has

(94) Ibid., p. 32.

equivalents in the upper Knox dolomite fauna of the Appalachian Valley, and in the Shakopee fauna of Minnesota (95).

(95) Ibid., p. 39.
SILURIAN SYSTEM

Rocks of Silurian age have not been found in this part of the Ozark region of Missouri, and it is generally believed that this part of Missouri was above sea level during Silurian time. If any sediments were deposited, they were too thin to remain through the subsequent long periods of erosion.

DEVOINIAN SYSTEM

Rocks of Devonian age have not been found in the northern half of the Meramec Spring Quadrangle but they may have been present at one time. Bridge and Charles(96) have described an outcrop of


fossiliferous quartzite 30 feet long and 3 to 6 feet thick in the NE ¼, NW ¼ sec. 3, T. 37 N., R. 8 W., near Rolla, which they believed to be of Onondaga age and equivalent to the upper part of the Grand Tower formation of southeastern Missouri and southern Illinois. A similar outlier, if present in the Meramec Spring Quadrangle, could be overlooked easily if it is remembered that most of the field work for this thesis was carried out during the summer months and underbrush was abundant in the wooded areas.
MISSISSIPPIAN SYSTEM

Introduction—Small patches of chert boulders containing Mississippian fossils have been found in many places in the Ozarks. Although found only as residual material, some relations suggest that the formation is present but covered. Others suggest that the boulders have weathered from the basal Pennsylvanian.

The largest patch found in this area is located just south of the center of the NE², SW² sec. 3, T. 37 N., R. 7 W. It extends on both sides of the road which formerly existed in this section. Good collecting material can be obtained in the road. Although the patch is on a slope, the elevation is about 1010 feet. Smaller patches are located at the center of the west line of sec. 30, T. 38 N., R. 7 W. at an elevation of about 1040 feet and in the NE², NE², SW² sec. 28, T. 38 N., R. 7 W. at the same elevation. Other accumulations may be present which were not found.

Lithologic character—Quartzitic sandstone is the most common type of fossiliferous material. The interiors of the boulders are hard and dense, but the outer, weathered parts are soft and very porous. Color is a function of degree of weathering, the interiors being translucent bluish-white, and the surfaces dark reddish-brown. Fossils are found throughout the boulders, often with no order or arrangement. In a few boulders, they are found in bands which suggest bedding. They are more prominent in the weathered zone where every megascopie cavity is the mold of a fossil. The cavities range in size from less than ³⁄₄ mm. due to crinoid columnals, to over 20 mm., due to brachiopods, cup or horn corals, and crinoid columnals.
White chert boulders are also common. They resemble the sandstone boulders in that the interior is hard, the weathered exterior is very soft, and the surfaces are stained by iron oxides. These, too, are very porous, and every cavity is a fossil mold.

Non-fossiliferous chert and sandstone boulders are associated with the fossiliferous material. These boulders, especially those of sandstone, are larger than those usually found associated with the Jefferson City formation, but they may be residual from the upper part where some of the sandstones are locally rather thick. They could have been derived from the Pennsylvanian but sandstone boulders of that age are usually very much larger. It is probable that the non-fossiliferous material is residual from all three sources.

Lee(97) found fossiliferous siliceous colite and non-fossiliferous limestone in the Rolla Quadrangle which he believed to be Mississippian, but none of these rocks was found in this area.

Bridge(98) did not concur with Lee's identification in the case of the siliceous colite. He believed that the fossil-resembling cavities in the colite are accidental, and that the rock is from the Jefferson City formation.

Paleontology--- Time did not permit an attempt to identify the
fossils found in these rocks. The fauna includes crinoids, brachiopods, corals, gastropods, blastoids, and bryozoans. Their abundance is approximately in the order listed. Bridge (99) has

(99) Ibid., pp. 558-575.

published faunal lists of species found in residual chert and sand-sandstone from the Rolla Quadrangle in the vicinity of Rolla. It seems safe to conclude that most, if not all, of the species identified by him are present in the residual Mississippian from this area.

Age and correlation—Bridge (100) found one boulder containing

(100) Ibid., pp. 564-575.

a fauna equivalent to that of the Fern Glen formation. Four boulders were found to represent an intermediate stage between the Fern Glen and the Burlington white chert from Louisiana, Missouri, and eight boulders had a faunal assemblage which correlated with Lower Burlington forms. Although the evidence was too incomplete to make positive correlations, other boulders had fauna suggestive of either Keokuk or Lower Warsaw. He found none to be older than Fern Glen or younger than Lower Warsaw, and he found none from the Upper Burlington. He notes that specimens in the Missouri School of Mines collection suggest that the Upper Burlington was present but that it is not commonly preserved. This evidence places the age of the residual material as ranging from basal Sangamon to basal Meramecian.
PENNSYLVANIAN SYSTEM

Distribution--- The area underlain by Pennsylvanian sediments is difficult to determine due to the lack of undisturbed outcrops. When seen in road cuts, railroad cuts, and outcrops, the beds usually are dipping at high angles and a sink structure is obviously present. The Pennsylvanian occurs principally in the northwestern part of the area and around St. James, and in small, isolated patches over the rest of the area. On the accompanying geologic map, the Pennsylvanian sediments underlie not more than 4 square miles. This distribution is based on well logs and outcrops. It is entirely probable that more of the uplands in the vicinity of St. James and the Rolla Airport are underlain by Pennsylvanian sediments but until more evidence is available, such as well logs, the true distribution cannot be determined.

Thickness--- The thickness of the Pennsylvanian deposits is extremely variable. This is due to sink structures, the uneven pre-Pennsylvanian surface, and erosion taking place today. In the railroad cut (See Fig. 10.) at the center, NE\(^4\) sec. 32, T. 38 N., R. 7 W., a 70 foot section is exposed although the cut is only 35 feet deep. The base of the Pennsylvanian is not exposed here, and some of the beds are missing due to faulting in the sink structure.

Two wells, one at St. James (Log No. 9618) and the other at the Rolla Airport (Log No. 6208), encountered 60 feet of Pennsylvanian sediments. In the extreme northeastern part of this area and extending northward into the Vienna Quadrangle, Murphy\(^{101}\) noted

\(^{101}\) Murphy, T. D., op. cit., p. 35.
that 150 feet of relief on undisturbed Roubidoux had been filled by Pennsylvanian sediments. Bridge (102) mentioned this locality and

probably observed it first. The locality, on the east side of the road in the NW\(^2\) sec. 19, T. 38 N., R. 5 W., was visited by the writer. The Roubidoux sandstone outcrops in the ditch from the base of the hill to nearly the top. Overlying the sandstone is an oolitic, sandy, chert breccia. This is followed, progressing upward, by white clay, maroon clay, and residual material containing abundant maroon chert pebbles.

Lithologic character—The Pennsylvanian deposits consist of
sandstones, clays, chert conglomerates, chert breccias, and sandy clays. The sandstones are usually white to light gray, medium to coarse grained, and quartztic. On weathering, they become dark reddish-brown due to the presence of iron oxide. Large, residual boulders derived from this sandstone greatly resemble the Roubidoux sandstones, but generally, the Roubidoux sandstones exhibit better developed bedding and the sand grains of the Roubidoux are slightly more coarse. Actually, it is doubtful whether a positive identification could be made on an individual sandstone fragment.

White to medium gray chert pebbles and fragments, and even sandstone fragments, are found in some sandstone beds. The clays are white, maroon, or green, and some of the beds are sandy or conglomeratic. Maroon chert pebbles are commonly seen in the residual material but none was seen in the beds.

Due to the highly disturbed nature of the deposits and the lateral gradation of the beds, correlations cannot be carried from one outcrop to another. On a single outcrop, the beds can be traced laterally by their weathering characteristics but not by their detail lithology. Thus, a clay bed will remain predominantly clay and weather as such, but it may become sandy or conglomeratic, and the color may change gradually or sharply from, for example, green to maroon. The relationships can be seen best on the north side of the railroad cut at the center. NW$_{4}$ sec. 32, T. 38 N., R. 7 W.

The green or maroon clay is the best positive identification for Pennsylvanian deposits. On the hillsides or slopes where no clay can be seen, the only method of identification is the presence of conglomerate, breccia, or sandstone boulders. The iron content in
the sandstone is often concentrated in small hematite concretions which on weathering, stand out in knobs on the surface. Many of the boulders exhibit almost no bedding, and some are extremely large. Often the boulders or outcropping beds are found in a roughly circular area which suggests that a sink structure is present.

About 400 feet southwest of the bend in State Highway Nos. 3 and 68 in the NE 4, NE 1, SW 1 sec. 29, T. 38 N., R. 6 W., the sandstone can be followed most of the way around the structure, and one mass protruding from the hillside is 40 feet by 30 feet by 9 feet in size.

Cordry (103) has identified and described the heavy minerals

(103) Cordry, C. D., op. cit., pp. 52-85.

found in Pennsylvanian sandstone samples from the vicinity of Rolla, Missouri.

Topographic expression—The numerous Pennsylvanian outcrops in the vicinity of St. James and the Rolla Airport strongly suggest that they are responsible for the steep slopes which rise to the higher elevations in those areas. The presence of Pennsylvanian deposits in every road cut and railroad cut westward from the middle of sec. 23, T. 38 N., R. 7 W. is a good indication that they have hindered headward erosion by Prans Branch and Spring Creek into the divide. To some extent, the sandstones of the Jefferson City formation may have influenced the topography in these areas but until more information is available on the distribution of the Pennsylvanians, exact conclusions cannot be reached.

Stratigraphic relations—The Pennsylvanian rests with profound unconformity on the Roachidean and Jefferson City formations.
It may also rest on Devonian and Mississippian rocks, but the relationship has not been observed. That the pre-Pennsylvanian topography was rugged is evidenced by the 150 feet of relief found on the Roubidoux in the northeast corner of the area.

Paleontology—Pennsylvaniaan fossils have not been found in the clays of the Ozark region, but Mississippian fossils have been found in the basal chert conglomerate in other areas.

Age and correlation—On the basis of geologic position and the character of certain clays, McQueen (104) correlated these deposits with the lower part of the Cherokee group of the Pennsylvanian system. He correlated the clays with the Cheltenham clay in the St. Louis area and northern Missouri, and the basal chert conglomerate with the Graydon formation.

QUATERNARY SYSTEM

Alluvium

Thick deposits of boulders, gravel, sand, and silt are found in the flood plains of the larger creeks and streams. Chert is the most common rock of the larger sizes because dolomite is easily worn and dissolved, and sandstone is easily broken in the process of transportation. The material is fairly well sorted and roughly stratified. The beds are usually lenticular and exhibit graded bedding with coarse material at the bottom and finer towards the top. This material, where overlain by soil, makes the best agricultural land in this area.
STRUCTURE

Regional

The strata in most of the Ozark region have slight regional dips away from the St. Francois Mountains. In the northern half of the Keramee Spring Quadrangle, the regional dip is about 20 feet per mile to the northwest. The value is nearly twice as great as the average dip on the northwest flank of the Ozarks, but such an anomaly is common when small areas are considered alone.

Complicating the calculations are the low folds which, although not of great importance when long distances are involved, cause erratic values over short distances. Structural highs, removal of parts of formations due to subsurface solution, and local variations in dip are other factors of importance locally but not regionally.

Folds

Low, broad folds, trending northwest, have been superimposed on the regional dip. Although they are not prominent, they can be detected in a few places where the streams, flowing northeast, have cut across the folds and exposed some prominent bed. The wavelength of the folds is about 3 miles, and the amplitude is about 20 feet.

On the east side of Dry Fork, beginning near the center of the north line of sec. 35, T. 37 N., R. 7 W. and continuing south, a prominent bed of the Roubidoux can be seen rising gradually to higher elevations above the stream. On the west side of Little Dry Fork near the center of the NE \(^3\) sec. 19, T. 37 N., R. 7 W., the Quarry ledge of the Jefferson City can be traced across the crest of
a fold. The lack of continuity of the Gasconade in the bed of Dry Fork through sec. 13, T. 37 N., R. 7 W., and the Roubidoux in the "window" in the Jefferson City in sec. 19, T. 37 N., R. 7 W., are additional evidences of the folding that has taken place. The deep pools in the bed of Dry Fork northward from the center of the south line of sec. 23 and southward from the center of the north line of sec. 35, T. 37 N., R. 7 W., suggest that the easily eroded Gasconade dolomite has been elevated in the crests of folds while the intervening distance contains a trough which has placed the resistant Roubidoux sandstones in a position to hinder downcutting. The Gasconade was not seen to outcrop in sec. 35, but it may be present beneath the alluvium or in the stream bed where the pools are over 12 feet deep.

By carefully plotting several thousand aneroid barometer readings, Lee(105) found two series of folds in the Rolla Quadrangle.


The most prominent series trends N 20°-30° W while the poorly developed series trends N 78°-90° W. Time did not permit a detailed study of the folding in the Meramec Spring Quadrangle but certainly both series of folds are continuous into this area.

Faults

Recognition of faulting in the Gasconade or Jefferson City formations is difficult due to the covering of residual material and the lithologic similarity of the beds. The best exposures are to be found in the Roubidoux because of its large and numerous outcrops,
Fig. 11. Fault, down-thrown side on the right, north side of Little Dry Fork, near center of sec. 9, T. 37 N., R. 7 W.

but even in this formation, small faults can be seen only along valley walls.

No large faults occur in this area, and only one small fault (See Fig. 11.), located on the north side of Little Dry Fork in the SE1/4, SW1/4, NW1/4 sec. 9, T. 37 N., R. 7 W., was seen. This is a normal fault which strikes N 67° W, dips 80° NE, and has a throw of 3 feet. The down-thrown face is smooth and quartzitic except where weathering has formed pits or where fault breccia, consisting of chert fragments and quartzite, adheres to the face. The up-thrown face is almost entirely covered, and erosion has removed any slickensides that may have been present on either face. The fault could not be traced to the northwest nor could it be found on the south side of Little Dry Fork. The small displacement suggests that
the fault is local, but a second possibility is that the fault dies out to the northwest and continues southeast beneath the valley alluvium. Haxoeyt and Irwin (106) described this fault and noted its discovery by Mr. Wallace Lee. It is probable that other small faults are present in this area but do not occur where they can be readily seen. The similar strike and high dip of this fault with those in the Rolla quadrangle suggest that all occurred at about the same time and are due to relief of stresses set up by the folding.

Faulting has occurred during the development of the sink structures, and slickensides can be seen on some of the resistant beds. Slickensides can be seen on Pennsylvanian sandstone outcrops on the north side of State Highway No. 6 and No. 68 at the bend in the SW¼ sec. 29, T. 38 N., R. 6 W. and on the east side of the road in the northwest corner sec. 27, T. 38 N., R. 7 W.

Joints

Nearly vertical joints are common in all of the formations in this area but are best observed in the sandstones of the Roubidoux formation. A few random strike measurements were made, and it was found that over a third of them lie between north and N 20° W. The joints probably are due to relief of stresses set up by the folding, but some appear to be related to the solution of underlying beds and consequent subsidence.

Sink structures

Sink structures in the Ozark region have been described in numerous publications of the Missouri Geological Survey and Water
Resources, and the theoretical aspects, as presented by Lee(107) in


the Rolla Quadrangle, are entirely applicable to this area.

The structures are formed by collapse of the overlying beds into solution caverns in the dolomites. Although all of the formations are subject to subsurface solution, the subsequent displacement of beds is more often recognized in the resistant Roubidoux and Pennsylvanian sandstones than in the easily weathered Gasconade or Jefferson City dolomites. The smaller and shallower structures may be due to solution in the dolomites of the Roubidoux, but the larger and deeper structures are probably related to larger caverns in the Gasconade and possibly the Eminence.

The presence of a sink structure is readily detected where basin-like depressions occur at the surface. In the case of the sink about 0.2 mile south of the NE corner sec. 23, T. 37 N., R. 6 W., the size is sufficiently large to warrant mapping as a topographic depression. This is over 1000 feet in greatest diameter and, although on a hillside, it is about 50 feet deep. Smaller depressions, 100-300 feet in diameter and 10-20 feet deep, occur at the NE corner sec. 19, T. 37 N., R. 6 W., in the SW1/4, SW1/4 sec. 35, T. 37 N., R. 7 W., and in the SW1/4, SW1/4, SW1/4 sec. 34, T. 37 N., R. 7 W. These are in the process of being filled by soil and residuum, and no rocks outcrop in them. Several very small depressions, 20-30 feet in diameter and 5-10 feet deep, also occur in the area. All of these contain water after heavy rains, but they soon become dry by drainage into subsurface channels. The fact that they
are topographic sinks suggests that a comparatively recent origin can be assigned to them.

Sink structures occur throughout the area but are seen only where the displaced beds are exposed. These vary from shallow saucer-like structures in which the beds are very slightly warped, to inverted cone-shaped structures in which the beds dip at progressively higher angles until they are nearly vertical at the center. Concentric faulting is often associated with these structures, and slickensides are common. All of the formations have been seen to dip steeply in these structures, but the Roubidoux and Pennsylvanian sandstones are most often exposed. It would serve no useful purpse to describe and give the location of all of the sink structures in this area, but the following may be of interest. In the bed of Luther Branch in the 32 sec. 32, T. 38 N., R. 6 W., a Roubidoux sandstone bed dips 31° W. and forms a small dam across the stream. An unusual condition has developed along the intermittent stream in the NW 1/4 sec. 1, T. 37 N., R. 6 W. Here, a Gasconade outcrop has been isolated by Roubidoux sandstones in sink structures. Most of the known Pennsylvanian deposits occur in sink structures, and their presence is often indicated by the roughly circular pattern of outcrops or residual boulders. A very good section through a sink structure may be seen in the railroad cut at the center, NW 1/4 sec. 32, T. 38 N., R. 7 W. (See Fig. 10.) This shows down-warping and faulting in Pennsylvanian sediments. The broken and faulted nature of the Pennsylvanian deposits indicate that the structures developed after the sediments were consolidated, or at least the latest movement occurred after that time.
Sink structures are largely responsible for the early development of this region because of the presence of mineral deposits in them. Although all of the obvious deposits have been exhausted, others, less obvious or still covered, may be present. Grawe\(^{(108)}\)


has described the deposits of pyrites and iron ore associated with sink structures in this area, and McQueen\(^{(109)}\) has described the clay deposits associated with the same type of structure.

ECONOMIC GEOLOGY

Building Stone

The rocks of this area have been used for building stone to a greater extent in the past than they are being used today. Both the Gasconade dolomite and Roubidoux sandstone were used in the construction of Meramec Iron Works, but the former was used largely as a flux in the manufacture of iron. The Gasconade was obtained from quarries located along State Highway No. 8 in the SW $\frac{1}{4}$ sec. 1, T. 37 N., R. 6 W. and in the NW $\frac{3}{4}$ sec. 6, T. 37 N., R. 5 W. The Roubidoux was obtained along the stream in the NW $\frac{1}{4}$ sec. 1, T. 37 N., R. 6 W. and at its head. The Quarry ledge of the Jefferson City formation was used for building purposes in the vicinity of St. James, but the quarry, located in the NW $\frac{3}{4}$, SE $\frac{1}{4}$ sec. 30, T. 38 N., R. 6 W., has been abandoned for many years. Residents of the area have used the rocks, especially slabs of the Roubidoux sandstone, for retaining walls, foundations, and even the outer walls of houses, but usually the high cost of stone construction prohibits their use.

Clay

Most Pennsylvanian exposures show interbedded impure clays, sandstones, breccias, and conglomerates, but under favorable circumstances, the clay has been deposited and preserved in sufficient purity and quantity to be of economic value. These deposits occur in sink structures. The most complete, recent discussion of the clay of this region is that of McQuee(110).
Although many economic clay deposits occur in Phelps County, especially north of St. James and in the vicinity of Rolla, only six have been found in the northern half of the Marmamc Spring Quadrangle. These include the Hall Pit located near the center, SW¼ sec. 24, T. 38 N., R. 7 W., the Goettleman Pit No. 1 located in the SE½ SW¼ sec. 30, T. 38 N., R. 7 W., the Goettleman Pit No. 2 located in the NE¼ SW¼ sec. 30, T. 38 N., R. 7 W., the Hawkins Bank (Hill Pit) located near the center, NW¼ sec. 6, T. 37 N., R. 7 W., and an unnamed pit just north of the center of the south line sec. 31, T. 38 N., R. 7 W. Wheeler(111) and Cronk(112) described the older pits which contained flint fire clay. According to McQueen(113), diasporite and burley clays were obtained from a pit located in the NE¼ SE¼ sec. 29, T. 38 N., R. 7 W.

All of the pits are worked out, but it is possible that new deposits will be found in the northwestern part of the area and in the vicinity of St. James. Any future prospecting must be done by drilling through the residuum because all exposed deposits have been tested and mined.

(110) Ibid., pp. 120-201.


Coal

Coal has not been found in the area covered by this thesis, but small deposits have been found to the north in sec. 2, T. 78 N., R. 2 W., and to the southeast in sec. 21, T. 36 N., R. 4 W. According to Shumard (114), these were mined by Mr. Samuel Massay for use at


the Meramec Iron works, but the high pyrite content made the coal unsuitable for the smelting of iron. If coal is found in this area, it will be associated with Pennsylvanian sediments, and the deposits, small and of poor quality, will be suitable only for private use.

Copper

Although copper has been reported from only six mines in this area, it probably occurs, at least as a trace, in all of the sink deposits. Crowe (115) reports chalcopyrite and brochantite from the


Powell Prospect in the SE1, SW1, NW1 sec. 7, T. 37 N., R. 5 W.,
chalcopyrite, malachite, and azurite from the Flat Rock Mine in the NE1, NW1, SE1 sec. 6, T. 37 N., R. 6 W., azurite and malachite from the Crisp Mine in the SW1, SE1, NW1 sec. 38, T. 38 N., R. 6 W., and copper sulphide and carbonates from the Decamp Mine in the SW1, SW1, NE1 sec. 32, T. 37 N., R. 6 W.

Reed Mine, located in the SE1, Lot 2, NW1 sec. 31, T. 37 N., R. 6 W., is one of the few sink deposits that contained copper minerals in sufficient quantity to warrant an attempt to mine them.
Fay and Martinez (116) have described, figured, and given analyses of samples from the mine. Azurite and malachite were found with iron in a zone about two feet thick. Selected samples from this zone contained from 5.15 to 10.18 percent copper. Hematite was found above the copper-bearing zone, and marcasite was found below it. Grave (117) noted that several mines, including the Reed, were later reopened as iron or pyrite mines when the low copper content and high transportation costs made them uneconomic.

The writer found malachite on a dump in the Moselle Mine No. 9 at the center of the south line, 36\(\text{°}\) sec. 29, T. 38 N., R. 6 W.

Iron

Limonite occurs in the residual soil of all of the formations in the area, but hematite, the chief ore mineral, occurs only in structural basins. These deposits, known to the white man since 1835 when Thomas James visited the site of the Meramec Mine, were, for the most part, depleted by 1900. After 1900, the mines were re-prospected and some were reopened for the iron sulphides, pyrite and marcasite, which occurred below the hematite. These were used as a source of sulphur in the manufacture of sulphuric acid. By 1940, most of the ore had been removed, and the mines have been closed since that time. All of the pits now contain water or debris.

No attempt will be made to describe each mine because this has
been done in numerous publications. The earlier authors (118)

Schmidt, Adolp., op. cit., pp. 80-83, 144-146, 157, 158, 207.
Fay, A. H., and Martinez, C. E., op. cit., pp. 4, 7-10, pl. 2.

described or mentioned the mines in connection with hematite pro-
duction. The latest and most complete publication, principally con-
cerned with sulphide production, is that by Grave (119) in which the


land owner, location, altitude, history, description, stratigraphy, struc-
ture, ore, production, and future of every important mine is
given.

The following list includes all of the mines that the author
could find in this area and their locations. Possibly other small
mines or prospects exist that have become filled with debris and
were not seen.

Cooper Mine-- SE1, NW2 sec. 17, T. 37 N., R. 6 W.
Crisp Mine-- SW1, SE2, NW2 sec. 28, T. 38 N., R. 6 W.
DeCamp Mine-- SW1, SW2, NW2 sec. 32, T. 37 N., R. 6 W.
Dry Fork Mine-- NE1, NW2 sec. 13, T. 37 N., R. 7 W.
Flat Rock Mine-- NE2, NW2, SE2 sec. 6, T. 37 N., R. 6 W.
James Mine-- SW1, SE2, SE2 sec. 29, T. 38 N., R. 6 W.
Lenox Mine No. 1-- NE1, Lot 2, NW2 sec. 31, T. 37 N., R. 6 W.
Lenox Mine No. 2—NE^1, Lot 1, SW^1, sec. 31, T. 37 N., R. 6 W.

Luther Mine—NE^1, NE^1, SW^1, sec. 1, T. 37 N., R. 7 W.

Marmee Mine—SE^1, SW^1, SW^1, sec. 1, T. 37 N., R. 6 W.

Moselle Mine No. 2—Sec., 3. line, SW^1, sec. 29, T. 38 N., R. 6 W.

Powell Prospect—SE^1, SE^1, NW^1, sec. 7, T. 37 N., R. 5 W.

Railroad Bank No. 2—SW^1, NE^1, sec. 8, T. 37 N., R. 6 W.

Reed Mine—SW^1, Lot 2, NE^1, sec. 31, T. 37 N., R. 6 W.

Santee & Clark Mine—NW^1, NE^1, SW^1, sec. 33, T. 38 N., R. 6 W.

South Mountain Mine—SW^1, NW^1, sec. 23, T. 38 N., R. 6 W.

Thornton Mine—NE^1, SE^1, NW^1, sec. 33, T. 38 N., R. 6 W.

Verkamp Prospect—NW^1, SW^1, NE^1, sec. 32, T. 38 N., R. 6 W.

Willford Mine—SE^1, NE^1, SW^1, sec. 36, T. 37 N., R. 6 W.

On the accompanying geologic map, it was necessary, in most instances, to place the mine symbol beside the sink structure symbol due to the small scale of the map.

Sand and Gravel

All of the larger streams contain sand and chert gravel beds that are suitable for local use. Although the sand and gravel is usually mixed in all proportions, some bars contain a high percentage of sand and others a high percentage of gravel. The gravels have been used for local road material, and the sand has been used in private construction, but none has been shipped from the area. Distance from market and transportation costs are among the chief deterrent factors involved in their use.

Water Resources

Ponds—The inhabitants of the area depend upon ponds as a
source of water for their stock when perennial streams or springs are unavailable. For that reason, increasing numbers of ponds have been dug in recent years to keep pace with the growing cattle industry. Although the residual soil is sandy and contains many chart fragments, the high clay content makes it sufficiently impervious to retain water through an average summer. Properly designed ponds can be constructed with partial financial aid given by the Federal Government.

Springs—Springs occur throughout the area except in the drainage basins of Asher Hollow, Brown Hollow, and Norman Creek where the water, seeping into subsurface channels in the Gasconade, eventually reaches the surface through Marmeco Spring. Small springs, amounting to little more than seeps, occur in the Roubidoux and Jefferson City formations, but the larger ones are confined to the Gasconade. They do not appear to be characteristic of any particular horizon in the Gasconade, some emerging from thin-bedded zones and others from joints in the thicker beds. An unusual location for a perennial spring is that on the northeast side of the saddle at the center of the south line of the SW\(^1\) of NW\(^2\) sec. 21, T. 37 N., R. 6 W. This spring, about 30 feet above the elevation of Norman Creek and the abandoned meander of Dry Fork, must have its catchment area to the southeast. This requires that channels carry the water northwestward through the narrow neck to the outlet. It does not seem possible that sufficient water could be derived from the small area to the northwest to last through the summer, especially when the formations dip away (northwest) from the spring. Another spring, 0.35 mile southeast of the above-mentioned spring,
must have its source in the same area. This spring occurs at the base of the hill in the bend of the private drive. The spring located on the north side of State Highway No. 8 and No. 68 in the NW\textsuperscript{2}, NE\textsuperscript{1} sec. 3, T. 37 N., R. 6 W. has been used for many years by the local residents who have not had a sufficient supply of water on their property. Other springs are located in the valley about 200 feet northwest of the St. James tunnel, in the tributary of Dry Fork in the SW\textsuperscript{1}, SE\textsuperscript{1} sec. 8, T. 37 N., R. 6 W., in the tributary of Little Dry Fork near the center, NW\textsuperscript{1}, NE\textsuperscript{1} sec. 15, T. 37 N., R. 7 W., on the north side of Dry Fork just north of the center of sec. 22, T. 37 N., R. 7 W., and in the tributary of Franz Branch in the NE\textsuperscript{1}, SE\textsuperscript{1}, SW\textsuperscript{1} sec. 8, T. 37 N., R. 7 W. Although the local residents may drink the water, it is inadvisable for visitors to drink from the springs unless they are accustomed to it or unless it has been boiled.

Meramec Spring— This spring (See Fig. 12.), sixth largest in Missouri, is located in the NW\textsuperscript{1}, SE\textsuperscript{1} sec. 1, T. 37 N., R. 6 W. It is 6.85 miles southeast of St. James via State Highway No. 8. The spring issues from a circular basin in the Gasconade dolomite at the base of a bluff. Part of the water is diverted to generate electricity for private use while the rest flows over and through an old rock dam, into the spring branch, and finally into Meramec River a half mile to the north. The water has a clouded or milky appearance due to the very small air bubbles included, and it is muddy after heavy rains. The spring, the picturesque valley, and the remains of the Meramec Iron Works make this an interesting tourist attraction. Although the property is privately owned, visitors are welcome,
facilities for picnics are provided, and fishing is permitted below the bridge.

Fig. 12. Meramec Spring, NW$^4$, SE$^4$ sec. 1, T. 37 N., R. 6 W.

It is generally believed that the spring obtains its water from the area to the south, southwest, and west. Asher Hollow, Brown Hollow, and Norman Creek, draining about 60 square miles, are usually dry except after heavy rainfall. The water, normally carried on the surface by these streams, seeps into subsurface channels and, for the most part, emerges at Meramec Spring. Some of the water may be derived from Dry Fork in this manner. The muddy character of the water after heavy rains and the floating debris that has been reported thrown out by the spring suggest that some of the subsurface channels are open at the surface at their upper end.

Meramec Spring has been mentioned and described in many
publications in connection with the Meramec Iron Works, springs of Missouri, and places to visit in Missouri, but the best, recent description is that of Beckman and Hinchey (120). In this publica-

(120) Beckman, H. C., and Hinchey, N. S., op. cit., pp. 94-97.

tion, they give a complete story of the geologic processes that have occurred in the formation of the spring, a description of the surrounding area, and data on the rate of flow. They give the average rate of flow for the years 1922-1929 as 149 second-feet or 96,300,000 gallons per day.

Brook Spring—This spring is located in the SW_4, SW_2 sec. 22, T. 38 N., R. 6 W. It is about 2.3 miles east of St. James, on the property of Boy's Town of Missouri. The water issues in an artificial hexagonal rock basin, flows into a larger basin, and empties into a tributary of Dry Fork. From a large stone building on the hill overlooking the spring, stone steps lead down to the spring. Beckman and Hinchey (121) briefly describe the spring and

(121) Ibid., p. 65.

give some measurements of the rate of flow. About 0.65 second-feet or 420,000 gallons per day is probably the usual rate.

Streams——As has been mentioned earlier, there are no perennial streams in the area between Dry Fork and the Meramec River. This condition must be considered when purchasing property requiring a constant, inexpensive source of water. North and west of Dry Fork, the situation is reversed in that all but the smallest streams are perennial. This situation is reflected in the more numerous well-
kept farms and the greater amount of stock being raised north and
west of Dry Fork. Although hydroelectric power is being developed
on the spring branch at Meramec Spring, the volume of water is too
small in the other streams for economic use.

Wells—Water has been obtained from all of the Ordovician
formations exposed in this area and from the unexposed Cambrian
Derby-Doe Run and Eminence formations. In the area north and west
of Dry Fork, water for ordinary household use is obtained from the
Roubidoux or Jefferson City formations, but larger rates of flow are
obtained from the former than from the latter. South and east of
Dry Fork, all of the wells have been drilled into the Gasconade or
Eminence formations for a sufficient supply because the Roubidoux,
due to structural and topographic conditions, is a poor aquifer.
Here, most of the water seeps into the subjacent Gasconade and that
remaining in the Roubidoux seeps down dip until it encounters the
deeper valleys which effectively drain the formation.

Water well and prospect hole logs—The logs of water wells
and prospect holes in this area are condensed from those on file at
the Missouri Geological Survey and Water Resources, Rolla, Missouri.
(See Table I.) In order that these logs may be referred to in the
body of this thesis, they are arranged according to the log number.
The data on each well are arranged in the following order: Log
number, owner, location, surface elevation, depth to each contact,
total depth, and sample analyst. In giving the location of a well,
certain obvious letters and numbers are omitted in order to
facilitate typing. Thus, in the first well listed, the designation
NW. cor. SW. NE. 12-37-7 means NW. corner, SW. NE. sec. 12,
T. 37 N., R. 7 W. In listing the formation names, only the first letter of the name is used where the name is obvious. If confusion seems possible, the first two or three letters are used. When only one formation is encountered from surface to total depth, the entire name is used. Time did not permit an attempt to check the locations, elevations, or depths.
The geologic history of an area as small as the one covered by this thesis must be considered in conjunction with that of adjacent areas and that of the Ozark region as a whole. The earliest event recorded in the exposed rocks of this area is the presence of the Ordovician sea from which limestone beds of Gasconade age were deposited. All of these limestones have since been altered to dolomite. The small amount of argillaceous material in the rocks indicates that the seas were rather clear. The many Cryptosomas suggest that the seas were warm and sufficiently shallow to permit sunlight to penetrate to the depth at which these supposed algae were growing. Although the Gasconade sea was continually rising, or the sea floor subsiding, conditions must have been relatively stable for short periods. This would be necessary during the period of growth of the prominent Cryptosoma reef which has been found throughout much of the Ozark region.

The retreat of the Gasconade sea brought on a short period of erosion. That period was short is suggested by the small amount of conglomeratic material found in the base of the Roachdoux. This is not conclusive evidence because the material may have been predominantly dolomitic or the Gasconade, at that time, may not have had a sufficiently high silica content to produce large quantities of chert. The present high silica content may have been introduced during the later period of dolomitization. There is little evidence of erosion on the Gasconade surface and no great local relief has been found. A faunal break is the main evidence for a period of non-deposition at this time.
The presence of older Roubidoux beds to the south which do not exist towards the north indicates that the invading sea came from the south. With the advance of the Roubidoux sea, the conditions of deposition were quite different from those of the Gasconade. Similar limestones were deposited in the lower part, but interbedded thin and thick sandstones suggest that the sea was shallower and the area was closer to a land mass which furnished the sand. If a land mass was not close, currents must have been favorable for carrying sand to this area from some distant source. Cross-bedding and ripple marks in the sandstones indicate that at the time of their deposition, the sea was very shallow; sun cracks indicate that there were periods of emergence.

Post-Roubidoux faulting occurred but the exact date cannot be determined because the displacement is seen only in the sandstones of the Roubidoux. Residual material completely covers other evidence. In adjacent areas, the evidence points to a post-Jefferson City date and it is possible, since most of the faults have the same general northwest strike, that all faulting in this region has occurred at about the same time.

A faunal break rather than a lithologic break is the best evidence for post-Roubidoux emergence. A slight warping at this time is suggested by local lithologic breaks, and locally, a very thin chert conglomerate has been reported found at the contact, but the evidence is meager. Certainly this erosion interval was not much longer than others that occurred during late Roubidoux and early Jefferson City time.

More normal marine conditions were prevalent when the Jefferson
City sea covered this area. The sandy beds are relatively rare but the presence of ripple marks and sun cracks in some of the sandstones suggests that short periods of shallow water and emergence occurred. The presence of Cryptozoan colonies is evidence that the earlier Jefferson City sea was shallow, warm and clear. This is assuming that the colonies required physical conditions similar to those required by the corals today. At times throughout the Jefferson City, the seas contained fine sediments which were deposited with the limestone. This produced the argillaceous dolomites and the thin clay partings which have resulted from the solution and removal of the dolomite.

At the close of Jefferson City time, the Ozark region was slightly tilted, elevated, and subjected to erosion for a short period. The greater thickness of Gtter sediments towards the south suggest that depression was greatest in the south and advancing seas came from that direction. Conditions of deposition were somewhat similar to those of the Roubidoux. Although argillaceous limestones were the principal sediments deposited, shifting currents carried sand into the area and deposited it in continuous beds and local lenses.

The history of the area throughout the remainder of the Ordovician, all of the Silurian, and part of the Devonian is largely unknown. The presence of later Ordovician formations not too far removed from this area suggests that they may have been present but have since been removed. Silurian rocks have not been reported from this region, and it is probable that this was a positive area at that time. If they were present, they too, have since been removed.

The next event in the geologic history is the occurrence of the
Devonian Grand Tower sea in this area. Whether this was an extension of the sea from southeast Missouri or whether the sea covered the whole Ozark region is unknown due to the lack of outcrops across the intervening distance. Pre-Grand Tower erosion must have been extensive to place these beds directly on the Jefferson City; and relief must have been well developed so that the single remaining outlier could be deposited in a place protected from the subsequent long periods of erosion. The Grand Tower remnant probably was trapped in a sink structure just as the Mississippian and Pennsylvanian outliers.

Again, the history is interrupted until Mississippian time when the land was submerged into the Fern Glen sea. The fossiliferous, residual charcoals of this and the younger Burlington, Keokuk, and lower Warsaw formations are all that remain of the extensive limestone and sandstone beds that once covered this area.

After the lower Warsaw sediments had been deposited, the region was uplifted and tilted, and erosion took place to remove all but the patches of residual Mississippian boulders, all of the Jefferson City formation in some areas, and part of the Roubidoux formation. The 150 feet of relief on the Roubidoux filled by Pennsylvanian sediments indicated that large valleys were present on the pre-Pennsylvanian surface. When the Pennsylvanian Cherokee sea advanced over the region, the land remained, with very slight fluctuations, at or near sea level. The presence of coal and fire clay pockets suggest that swamps existed locally, and it may be that these swampy areas developed in the submerged valleys along the early Pennsylvanian shore line.
After the deposition of the Cherokee sediments, the Ozark region was again uplifted and there is no evidence to suggest that it has ever been resubmerged. During and following the uplift, caverns developed in the older formations, and sinks formed when the cavern roofs could no longer support the overlying sediments. This permitted the Pennsylvanian sediments to slump far below their level of deposition. Some sink deposits show evidence of slump while the clay was still plastic which indicates that the structure developed shortly after the clay was deposited. Other sink deposits show slickensides on the faulted sandstones which could not occur unless the sediments were consolidated. The probable answer is that these structures have developed at different times, and periodic movement has occurred in individual sinks as the underlying cavern continued to enlarge.

There is no record of geologic events in the Ozarks during the remainder of the Paleozoic, all of the Mesozoic, and most of the Tertiary. All evidence suggests that this region has been above sea level since Cherokee time. There is evidence that two periods of peneplanation and uplift occurred but the record of the earlier Tertiary peneplane has been removed in this area. The remains of the later peneplane can be seen in the flat uplands, entrenched meanders, and the monadnocks which rise above the elevation of the uplands.
CONCLUSIONS AND SUMMARY

1. A geologic map of the north half of the Meramec Spring Quadrangle has been prepared.

2. The geography and geology of the area have been described.

3. Literature pertaining to this area has been cited so that more detailed information on a particular subject may be readily obtained.

4. A more detailed study is needed in order to determine the distribution of the Cotter formation.

5. More evidence, such as well logs, is needed to accurately determine the distribution of the Pennsylvanian deposits.

6. The cultural features on the topographic map need revision.
BIBLIOGRAPHY


Bridge, Josiah, A study of the faunas of the residual Mississippian of Phelps County (central Ozark region), Missouri Journal of Geology, Vol. XXV, No. 6, 1917, pp. 58-75.


Cloud, P. E., Jr., and Barnes, V. E., Paleocology of the early Ordovician sea in central Texas: Report of the committee on a treatise on marine ecology and paleocology, 1947-1948, National Research Council, Division of Geology and Geography, April 1948, pp. 33, 34.


Fowke, Gerard, Cave explorations in the Ozark region of central Missouri: Smithsonian Institution Bureau of Ethnology Bulletin 76, 1922, pp. 41, 42.


Goodspeed, History of Phelps County, Missouri: Reprint of all material relating to Phelps County occurring on pages 623 to 688 and 974 to 1027 from History of Laclede, Camden, Dallas, Webster, Wright, Texas, Pulaski, Phelps, and Dent Counties, Missouri. Chicago, Goodspeed Publishing Co., 1889. Reprinted at Missouri School of Mines, Rolla, Missouri, February 1943, 79 pp.

Owens, C. R., and Sullivan, J. S., A study of sandstone members of
the Jefferson City and Cotter formations at Rolla, Missouri;

James, J. A., Geology of the Berryman area, Washington County,
Missouri: Missouri School of Mines and Metallurgy, Thesis, 1948,
p. 49.

Lee, Wallace, The geology of the Rolla Quadrangle: Missouri Bureau
of Geology and Mines, ser. 2, Vol. XII, 1913, pp. 11, 12, 33, 34,
35, 41, 42, 59, 60, 62-76.

(The Geographical Press, Columbia University, N. Y.)

Marbut, C. F., The geology of Morgan County; Missouri Bureau of

Maveety, R. R., and Irwin, J. S., Topography and geology of the
Panther Bluffs area: Missouri School of Mines and Metallurgy,

McQueen, H. S., Insoluble residues as a guide in stratigraphic
studies: Missouri Bureau of Geology and Mines 56th Biennial Report,

McQueen, H. S., Fire clay districts of east central Missouri;
Missouri Geological Survey and Water Resources, ser. 2, Vol. XXVIII,
1943, pp. 120-201, map accompanying report.

Murphy, T. D., A study of the basal Cherokee in the Rolla area;

Nason, F. L., A report on the iron ores of Missouri; Missouri

Phelps County Historical Society, The history of Missouri School of
Mines and Metallurgy. Rolla, Mo., Phelps County Historical Society,
1941, 1020 pp.


Schmidt, Adolf, The iron ores of Missouri: Preliminary report on
the iron ores and coal fields from the field work of 1872,
Geological Survey of Missouri, 1873, pp. 20-23, 144-148, 157, 158,
207.

Shumard, B. F., Reports on the Geological Survey of the State of
Missouri, 1855-1871; Missouri Bureau of Geology and Mines, 1873,
pp. 236-240, 249, 255, 256.

Swallow, G. C., The first and second annual reports; Geological
Survey of Missouri, 1855, p. 126.


VITA

Harold Edward Mueller was born on February 4, 1922 at St. Louis, Missouri. He attended Harrison Grade School and Normandy High School in St. Louis, being graduated in 1938 and 1939 respectively. He worked for Leon the Tailor in St. Louis from June 1939 until June 1942, and for Emerson Electric Manufacturing Company of St. Louis from June 1942 until October 1942. He enlisted in the United States Navy in October 1942, attended several service schools, spent sixteen months in the British Solomon Islands, and was honorably discharged in January 1946 with the rate of Aviation Radioman Second Class. He entered the School of Mines and Metallurgy of the University of Missouri, Rolla, Missouri in June 1946 and completed the courses required for the Degree of Bachelor of Science, Geology Major in January 1950. He elected to continue his education by enrolling in the School of Mines and Metallurgy as a candidate for the Degree of Master of Science, Geology Major in January 1950. While attending the School of Mines and Metallurgy, he was employed by the school library as a student assistant, by Alcoa Mining Company of Houston, Texas on a part-time basis, and by the Geology Department as a graduate assistant.
Structure sections to accompany geologic map.

Horizontal scale 1: 62500
<table>
<thead>
<tr>
<th>No.</th>
<th>Sec.</th>
<th>Owner</th>
<th>Location</th>
<th>Address of Holder (Front)</th>
<th>Death to</th>
<th>Total Depth</th>
<th>Details/Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>11349</td>
<td>11348</td>
<td>G. Kelene</td>
<td>15-27-7</td>
<td>22:31</td>
<td>2569</td>
<td>2838</td>
<td>F. Wilson</td>
</tr>
<tr>
<td>11348</td>
<td>11347</td>
<td>G. Brown</td>
<td>11-27-7</td>
<td>2988</td>
<td>988</td>
<td>1095</td>
<td>B. Pietsch</td>
</tr>
<tr>
<td>11347</td>
<td>11346</td>
<td>C. Jones</td>
<td>16-27-7</td>
<td>2964</td>
<td>2964</td>
<td>1256</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11346</td>
<td>11345</td>
<td>C. Jones</td>
<td>16-27-7</td>
<td>3250</td>
<td>3250</td>
<td>1256</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11345</td>
<td>11344</td>
<td>C. Jones</td>
<td>16-27-7</td>
<td>3250</td>
<td>3250</td>
<td>1256</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11344</td>
<td>11343</td>
<td>C. Jones</td>
<td>16-27-7</td>
<td>3250</td>
<td>3250</td>
<td>1256</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11343</td>
<td>11342</td>
<td>C. Jones</td>
<td>16-27-7</td>
<td>3250</td>
<td>3250</td>
<td>1256</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11342</td>
<td>11341</td>
<td>C. Jones</td>
<td>16-27-7</td>
<td>3250</td>
<td>3250</td>
<td>1256</td>
<td>J. Olson</td>
</tr>
</tbody>
</table>

**TABLE I**

**WATER WELL AND PRODUCT HOLE LOW**

<table>
<thead>
<tr>
<th>Hole</th>
<th>Collar</th>
<th>Depth to</th>
<th>Total</th>
<th>Details/Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>11349</td>
<td>11348</td>
<td>22:31</td>
<td>2569</td>
<td>F. Wilson</td>
</tr>
<tr>
<td>11348</td>
<td>11347</td>
<td>2988</td>
<td>988</td>
<td>B. Pietsch</td>
</tr>
<tr>
<td>11347</td>
<td>11346</td>
<td>2964</td>
<td>2964</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11346</td>
<td>11345</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11345</td>
<td>11344</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11344</td>
<td>11343</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11343</td>
<td>11342</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11342</td>
<td>11341</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
</tbody>
</table>

**TABLE II**

**WATER WELL AND PRODUCT HOLE LOW**

<table>
<thead>
<tr>
<th>Hole</th>
<th>Collar</th>
<th>Depth to</th>
<th>Total</th>
<th>Details/Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>11349</td>
<td>11348</td>
<td>22:31</td>
<td>2569</td>
<td>F. Wilson</td>
</tr>
<tr>
<td>11348</td>
<td>11347</td>
<td>2988</td>
<td>988</td>
<td>B. Pietsch</td>
</tr>
<tr>
<td>11347</td>
<td>11346</td>
<td>2964</td>
<td>2964</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11346</td>
<td>11345</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11345</td>
<td>11344</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11344</td>
<td>11343</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11343</td>
<td>11342</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
<tr>
<td>11342</td>
<td>11341</td>
<td>3250</td>
<td>3250</td>
<td>J. Olson</td>
</tr>
</tbody>
</table>