GEOLOGY OF BOONE COUNTY MISSOURI

by

A. G. UNKLESBAY

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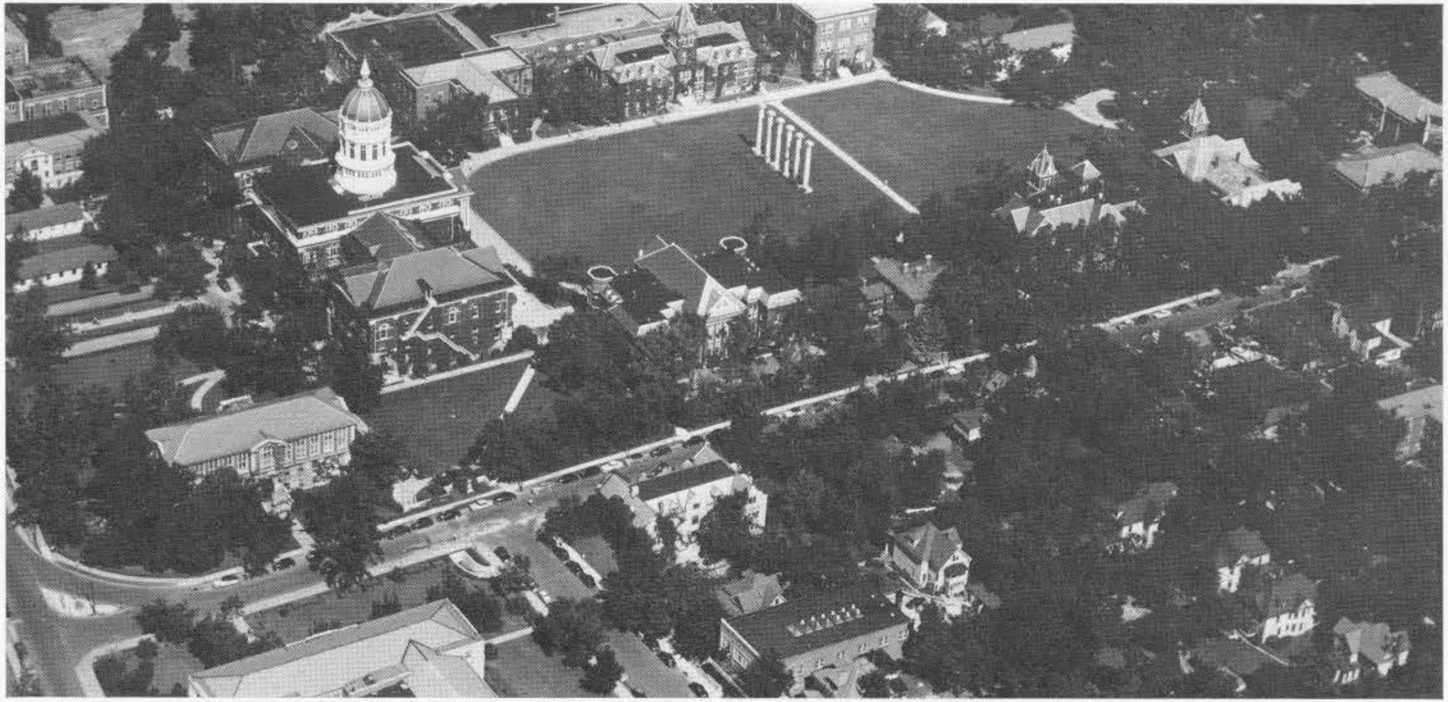
Rolla, Missouri



Aerial View of West Campus, University of Missouri, Columbia. (Courtesy Stephens College)

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LETTER OF TRANSMITTAL

Rolla, Missouri

August 25, 1952

Honorable Forrest Smith

Governor of Missouri

Jefferson City, Missouri

Dear Governor Smith:

I have the honor and pleasure to transmit herewith a report on THE GEOLOGY OF BOONE COUNTY, MISSOURI, by A. G. Unklesbay.

This report brings together a great amount of geological data accumulated over many years by students and staff members of the Geology Department of the University of Missouri. It will serve as a handbook and guide to future students and geologists interested in this area, as well as a valuable reference to all persons interested in the geological features and resources of this county.

In addition this report contributes to a better understanding of the geological conditions of central Missouri and will serve as a nucleus for further studies in this region.

Respectfully submitted,

EDWARD L. CLARK,

State Geologist

Geology of Boone County, Missouri

By A. G. Unklesbay

ABSTRACT

Boone County varies in topography from relatively flat uplands to rather rugged hills. The exposed rocks range in age from Upper Ordovician to Pleistocene, but the Silurian and Permian periods, and the Mesozoic Era, are not represented by sediments in the county. Much of the area is mantled by glacial drift. The geologic structure is relatively simple and the Brown's Station anticline is the only structure of prominence in the county. The important mineral resources of the county are coal, limestone, and water.

INTRODUCTION

Boone county has been visited by many geologists and geology students and published information on the area dates back to as early as 1874. The area contains a rather wide variety of geologic phenomena which make it significant in the understanding of the

Fig. 1. Index map showing location of Boone County.

geologic processes operative in central Missouri. Because of this wide variety, it is a very satisfactory area for the teaching of geology and many geologists have started their careers here. Others have brought to a climax their formal academic training as graduate students in this area.

The only previous report which discusses the general geology of the county was prepared by Broadhead and published by the Missouri Geological Survey in 1898. The county had been visited by other geologists before that time, and the water supply, coal, and clay resources had been partially described before 1896. Since Broadhead's report, the area has been discussed in many reports which will be mentioned in appropriate places in the following pages. Among the outstanding geologists who have contributed to the knowledge of the area are Branson, Buehler, Dake, Hinds, McQueen, and Winslow.

The efforts of a number of people have contributed to the preparation of this report, and to them the author is greatly indebted. Dr. Edward L. Clark has given much encouragement and many valuable suggestions. Dr. W. V. Searight has aided greatly in interpreting problems of Pennsylvanian stratigraphy; Dr. E. B. Branson was very helpful in pointing out poorly known exposures and in the interpretation of the Devonian strata. Many helpful suggestions and comments have been made by colleagues in the Department of Geology at the University of Missouri.

During the summer of 1949, when much of the final mapping was done, I was aided by Messrs. Leon S. Ditzell, C. Elton Gore, Thomas D. Rush, and James R. Taylor. Also helpful during the same summer were James W. Danser, Elmer D. Patterson, and Carl B. Rexroad. To the many other former graduate students of the University, whose reports have added much to the details of the work, I am duly grateful. The maps were drafted by Roger Miller.

GEOGRAPHY

Location and area.—Boone County comprises an area of about 683 square miles in the central part of Missouri. It lies between 38° 40′ and 39° 15′ north latitude, and between 92° 5′ and 92° 35′ west longitude. The county is about 41 miles in its greatest north-south length and about 22 miles in its greatest east-west width. The southwestern boundary is formed by the Missouri River, and the southeastern boundary is formed almost entirely by Cedar Creek. Both of these streams follow rather sinuous courses which give considerable irregularity to the county's outline (fig. 1).

Culture.—Columbia, the county seat and the largest city in the county (1950 census 31,736), is in the central part of the county. Centralia, in the northeastern corner has a population of 1,996 and is the second largest city. Other smaller towns and villages having populations of less than 600, which serve as trading centers for their respective areas, are Ashland, Hallsville, Harrisburg, Hartsburg, Huntsdale, Rocheport, and Sturgeon. The population of the county (1950 census) is 48,171.

Two major highways cross the county and intersect at Columbia. U. S. Highway 40 extends east-west across the middle width and provides connections with St. Louis and Kansas City; U. S. Highway 63, extending north-south along the mid-length of the county, connects with Jefferson City to the south and with U. S. Highway 24 at Moberly on the north. In addition, the county is served by a network of secondary roads, and most parts of the area are easily accessible.

The Gulf, Mobile and Ohio Railroad and the Wabash Railway cross the northeastern corner of the county through Centralia from where the Wabash extends a branch line to Columbia by way of Hallsville and Brown's Station. The Missouri-Kansas-Texas Railroad is along the southeastern edge of the county essentially parallel with the Missouri River. A branch of this line extends from McBaine to Columbia.

The industrial pursuits of the area are rather varied, but for the county as a whole agriculture takes the lead. Agriculture is especially important in the upland areas where there are good soils derived largely from glacial materials and where the area is rather flat and in a youthful stage of regional development. The fertile soil of the Missouri River flood plain is used for truck gardening in the vicinity of Hartsburg. In the areas northeast of the river flood plain, stream dissection has been much more complete, and these maturely dissected areas are given over to timber growth and grazing.

The Devonian and Mississippian limestones are the basis for considerable quarrying for road metal, agstone, and building stone. Mississippian limestone is used in the manufacture of rock wool at Easley. The Pennsylvanian coals form the basis for a limited mining industry, but the mines of the county by no means supply the area's needs. The clays and shales associated with the coals supply material for a small amount of brick and tile manufacture. Several small manufacturing plants of rather diverse nature are located at Columbia and Centralia.

Education is also an important pursuit with Columbia, the home of the State University of Missouri, Stephens College, and Christian College.

PHYSIOGRAPHY

Topography and drainage.—Boone County contains a variety of topographic features ranging from rugged maturely dissected hills to flat flood plains and flat uplands. The northeastern portion of the county between Sturgeon and Centralia is a flat upland plain which averages about 850 to 900 feet above sea level. This upland extends southward from Centralia towards Hallsville and Murry but is somewhat dissected by the upper portion of Silver Fork and its tributaries. In this same general area, a few portions of the plain grade gradually upward so that the highest point in the county is slightly above 940 feet (about one mile north of Murry). The area between Harg and Englewood, northeast of Ashland, is also relatively high and flat (plate I).

Southwestward from this upland area the land surface is more completely dissected in a wide zone extending to within a few miles of the Missouri River. Over most of this region the interstream areas stand at about the same elevation so that the skyline is remarkably uniform.

The most rugged part of the county lies between this dissected upland and the flood plain of the Missouri. This portion is three to five miles wide. It parallels the Missouri River and extends some distance up the tributary valleys. In this rugged area the local relief ranges up to about 250 feet and there is very little flat upland or lowland. Many of the slopes are very steep and there are many vertical bluffs along the Missouri River and some of the major tributaries (plate II A).

The river flood plain varies in width but along much of the southwestern part of the county it is as much as two miles wide. The lowest part of the county is about 540 feet above sea level and is on the flood plain at the extreme southern tip of the county.

Some portions of the county within the wide dissected zone contain areas of well developed karst, or sinkhole, topography. One of these areas is between Littles Branch and Perche Creek in sections 19, 20, 29, and 30, T. 49 N., R. 13 W., and another is in the vicinity of Pierpont between Bonne Femme and Little Bonne Femme creeks in sections 7, 8, 17, and 18, T. 47 N., R. 12 W. (plate II B).

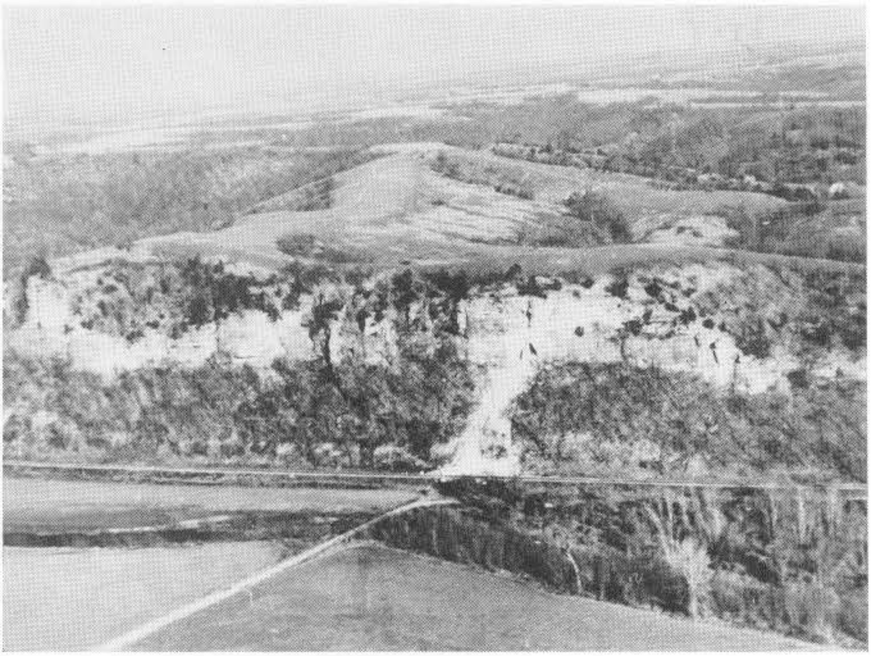
Ralphford's Cave in the southeastern part of the county is

Plate 1

A. View looking southeast from the SW¼ sec. 11, T. 46 N., R. 12 W. Shows relatively undissected upland plain (Ditzell).

B. Aerial view of flat upland area northeast of Hallsville.

Plate II



A. Aerial view of bluff along M-K-T railroad north of Wilton, near center of sec. 22, T. 46 N., R. 13 W. Shows flat flood plain of Missouri River in foreground, bluff capped by Burlington limestone, and maturely dissected upland.

B. Aerial view of karst topography in vicinity of Pierpont, sec. 7, T. 47 N., R. 12 W.

fairly well known. It is in the east wall of the valley of Cedar Creek in the NW¼NE¼ sec. 34, T. 47 N., R. 11 W. The opening to this cave is about 15 feet high and 30 feet wide.

Drainage from most of the county is into the Missouri River. Perche creek is the largest stream in the county. It enters the county near the northwestern corner and flows southward across the western half. On the Missouri River flood plain it turns southeastward and parallels the river for about five miles before entering it at a place where the river approaches a steep bluff. Some of the smaller streams also show this type of deferred or yazoo tributary junction. The chief tributaries of the Perche enter it from the east or northeast. These include the Hinkson which rises in the area northeast of Columbia and is fed by Grindstone and Hominy creeks, the Silver Fork which rises in the dissected plain southwest of Centralia, Rocky Fork which originates in the area around Hinton and is fed by Kelley's Branch and Clay's Fork. Callahan Creek enters Perche Creek from the northwest and drains much of the west-central part of the county. The Bonne Femme and Little Bonne Femme creeks are the chief drainage lines within the southern third of the county, and they empty into the Missouri on the big bend in the Easley-Providence area.

A few small streams flow northward from the vicinity of Sturgeon and Centralia and become tributaries of Salt River.

Cedar Creek forms the southern portion of the Boone-Callaway County boundary and provides drainage for a narrow zone along the eastern border.

Many of the streams of Boone County flow through notably sinuous courses. Some of them are of more than ordinary interest because they represent incised meandering developed under conditions of static rejuvenation. That is, they have become incised on a static land area because of the slow lowering of their outlet and not on a rising land area as is the case in ordinary incised meanders. Streams of this type are characterized by meanders which develop overlapping asymmetrical upland spurs with a nearly vertical bluff on the upstream side, a long gentle slope on the back or downstream side, and a long gentle slope (the slip-off slope) leading down to the apex of the meander. These are well illustrated in section 19, T. 48 N., R. 12 W., at the southeastern edge of Columbia. In ordinary intrenched meanders the valley walls are essentially parallel to each other and the spurs are symmetrical.

Tarr[1] studied the streams of the northern slopes of the Ozark Plateau and described Hinkson Creek as a typical example of static rejuvenation. The same principles applied to the Hinkson can also be applied to several other streams in the county, especially Cedar, Perche, Bonne Femme, and Little Bonne Femme creeks.

It was Tarr's opinion that these streams began flowing upon a post-glacial drift surface of slight relief and incised themselves as their outlet, the Missouri River, was slowly lowered in post-glacial time.

Tarr also devoted considerable attention to drainage changes in Hinkson Creek southeast of Columbia. He pointed out that the present course of this stream in the northeastern portion of section 18 is much shorter than the earlier course which curved widely up into the SE¼ section 7 through the present site of Stephens Lake, then southeastward across the NE¼ section 18 into the western portion of section 17 to the position now occupied by Hominy Creek, then back to its present channel in the NE¼ section 18. This earlier course is well marked by the now abandoned sinuous valley which surrounds the isolated hills in the NW¼ section 17 and the eastern portion of the NE¼ section 18, and the hill in the southern half of the SE¼ section 7, now the site of Stephens College Country Club.

Just east of the center of section 19, T. 48 N., R. 12 W., the apices of two Hinkson and Grindstone creek meanders approach each other very closely. Tarr suggests that in time these meanders will merge and one stream will be diverted or "pirated" into the other.

[1]Tarr, W. A., Intrenched and incised meanders of some streams on the northern slope of the Ozark Plateau in Missouri: Jour. Geol., vol. 32, pp. 583-600, 1924.

STRATIGRAPHY OF EXPOSED ROCKS

General Statement.—The exposed indurated rocks of Boone County range in age from Lower Ordovician (Jefferson City formation) to Middle Pennsylvanian (Marmaton). The Silurian period is not represented by sediments in this area.

The older rocks are exposed in the southern and southwestern portions of the county where they have been reached by the downward cutting of the Missouri River and its tributaries. With exception of a few scattered occurrences of the Middle Ordovician St. Peter sandstone, the Jefferson City is overlain by Middle Devonian limestone. This limestone and the Jefferson City formation form a narrow band-like outcrop pattern along the southern and southwestern margins of the county.

Limestones of Early and Middle Mississippian age overlie the Devonian beds unconformably and are exposed over a very large portion of the county. The most widespread of these is the Burlington limestone which is exposed in many places.

Late Mississippian and Early Pennsylvanian time is not clearly represented by rocks in this area, and the Middle Mississippian limestones are unconformably overlain by clay, coal, shale, and limestone of the Middle Pennsylvanian Cherokee group. The Cherokee is in turn overlain by the Marmaton group. No indurated rocks younger than Marmaton are present in the county.

Much of the county is mantled by deposits of Recent and Pleistocene age. These consist of glacial drift and loess, both of which attain considerable thickness. The drift is at least 140 feet thick in the northern part of the county and the loess reaches thicknesses of as much as 20 feet along the Missouri River bluffs.

ORDOVICIAN SYSTEM

LOWER SERIES

JEFFERSON CITY FORMATION

Name.—The name Jefferson City was first used by Winslow in 1894 when he wrote[2] "From the mouth of the Moreau to Gray's creek, above Jefferson City, a series of sections were measured, beginning with one at the mouth of the Moreau, illustrated in figure 62. They show in great detail the composition of what we have named the Jefferson City limestone". The limestone to which he referred was underlain by a sandstone, which he called the Moreau, and overlain by the St. Peter sandstone, which he then referred to as the Crystal City sandstone. The Jefferson City limestone was included by Winslow (p. 331) as a member of the Gasconade and indicated to be approximately equivalent with the Potosi. These formations, along with others, he placed in the Ozark stage of the Lower Silurian (the term Ordovician had not at that time come into general usage in this country).

The limestone which Winslow called Jefferson City had been designated as the Second Magnesian limestone by Swallow in 1885,[3] Meek in 1873,[4] Shepard in 1898,[5] and other early workers.

In 1911 Ulrich[6] used the term Jefferson City formation to include the beds between the Roubidoux formation and the Yellville limestone. During later studies in the Ozark region Ulrich recognized a three-fold subdivision of the Jefferson City as it was originally interpreted and began to restrict the name to the lowermost of the three divisions. The middle of the three became known as the Cotter and the upper one as the Powell. Ulrich did not publish this subdivision, but the terms Cotter and Powell were used by Ulrich and Bassler in 1915,[7] and by Purdue and Miser (1916)[8] in northwestern Arkansas. This restricted usage of Jefferson City was fol-

[2]Winslow, Arthur, Lead and zinc deposits: Missouri Geol. Survey, vol. 6, p. 373, 1894.

[3]Swallow, G. C., The second annual report, 1854: The First and Second Annual Reports of the Geological Survey of Missouri, Geol. Survey of Missouri, 1855.

[4]Meek, F. B., Miller, Morgan, and Saline counties: Reports on the Geological Survey of the State of Missouri, 1855-1871, Missouri Bur. of Geology and Mines, Jefferson City, 1873.

[5]Shepard, E. M., A report on Greene County: Reports on areal geology, Missouri Geol. Survey, vol. 12, pt. 1, 1898.

[6]Ulrich, E. O., Revision of the Paleozoic Systems: Geol. Soc. Amer. Bull., vol. 22, pp. 281-680, pls. 25-29, 1913.

[7]Ulrich, E. O. and Bassler, R. S., Bibliographic index of American Ordovician and Silurian fossils: U. S. Nat. Mus. Bull. 92, vol. 2, 1915.

[8]Purdue, A. H. and Miser, H. D., Eureka Springs-Harrison folio, U. S. Geol. Survey, Geol. Atlas, folio no. 202, 1916.

lowed by Weller and St. Clair[9] in their report on Ste. Genevieve County, and has since been the generally accepted usage of the term.

In 1944, Cullison[10] subdivided the restricted Jefferson City of Ulrich into two unconformable formations, the Theodosia above and the Rich Fountain below, and proposed the retention of Jefferson City as a group term as it had been used by Dake in 1921.[11] Cullison's differentiation was based on "the wide extent of the basal conglomerate in the overlying Theodosia formation, the great wealth of trilobite remains in the (subjacent) Rich Fountain formation and the rather striking faunal discontinuity between the two". This proposed subdivision has not had general acceptance. Inasmuch as these units are not clearly discernible in Boone County, the term Jefferson City formation will be used in this report.

Distribution and thickness.—The Jefferson City formation is exposed in the bluffs and tributary valleys along the Missouri River and Cedar Creek in the southern part of Boone County. The lower part of the formation does not crop out in the county, but there is a fairly complete exposure of the upper part near the center of the north line of sec. 1, T. 45 N., R. 13 W., where Gore in 1949[12] measured a thickness of about 66 feet.

The uppermost part of the Jefferson City is well exposed along the M-K-T railroad north of the mouth of Little Bonne Femme Creek between Easley and Providence (plate III A).

At the eastern edge of the NW¼SW¼ sec. 12, T. 46 N., R. 13 W., the uppermost 50 feet of the formation is exposed in a cliff along a small stream.

Northward from the belt of outcrop this formation dips beneath the surface and has been penetrated by wells in many places in the county. The average thickness penetrated is about 390 feet.

Lithology.—The Jefferson City formation as known in Boone County consists predominantly of dolomite, but it also contains lesser amounts of magnesian limestone, shale, sandstone, and chert. Most of the dolomite is of the "cotton rock" type which is light yel-

[9]Weller, Stuart and St. Clair, S., Geology of Ste. Genevieve County, Missouri: Missouri Bur. Geology and Mines, 2d. ser., vol. 22, pp. 74-75, 1928.

[10]Cullison, James S., The stratigraphy of some Lower Ordovician formations of the Ozark Uplift: Univ. Missouri School of Mines and Met. Bull., Tech. Ser., vol 15, no. 2, 1944.

[11]Dake, C. L., The problem of the St. Peter sandstone: Univ. Missouri School of Mines and Met. Bull., Tech. Ser., vol. 6, 1921.

[12]Gore, C. E., Geology of southern Boone County, unpublished Master's thesis, Univ. of Missouri Library, 1949.

lowish-gray to nearly white, argillaceous, siliceous, fine-grained to earthy in texture, and relatively soft. It commonly weathers to light gray or to light yellowish-gray smooth surfaces. Some of the dolomite is dense, light to dark gray and rather hard. This type of rock weathers to dark brownish-gray, with hackly, solution-pitted surfaces. For the most part, the dolomite occurs in beds which range from less than one inch to a few feet in thickness. The bedding in most places is fairly even but at several localities it is crumpled and distorted.

The shale is present as thin partings between the dolomite layers and commonly has a distinctive pale green color. The color seems to be due to the presence of a phosphatic compound.[18] In many places there is sand and silt in the shale. There is some question as to whether the shale is of primary depositional origin or is an accumulated residue left after solution of portions of the dolomite along bedding planes. The shale seems to be most abundant in areas where the crumpling of the bedding is prevalent and both the sand and silt as well as the disturbance of bedding may be the result of solution and subsequent subsidence.

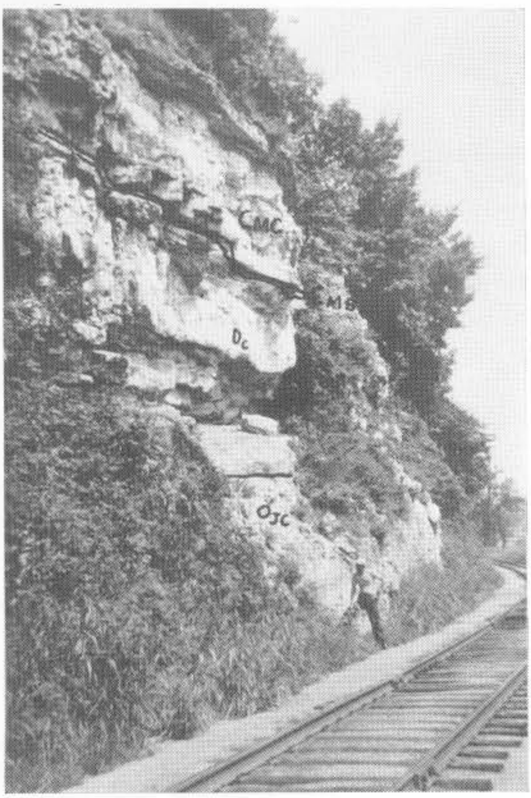
In a few places the dolomite is arenaceous and a few thin beds of gray sandstone are scattered through the section. These sandstones are less than six inches thick in Boone County but reach thicknesses of a few feet in adjacent areas.

Chert is rather abundant in the Jefferson City formation in this area. For the most part it is bluish-gray and chalcedonic, but some of it is light to dark gray and finely banded. The later is cryptocrystalline in texture. The bluish chalcedonic variety serves as a useful index for the Jefferson City where it occurs as float on weathered and covered slopes. The chert occurs as nodules of various shapes ranging from small spherical balls to lentil-like masses several inches in diameter. Oolitic texture is commonly found in both types mentioned above. On many weathered slopes some of the chert is tripolitic.

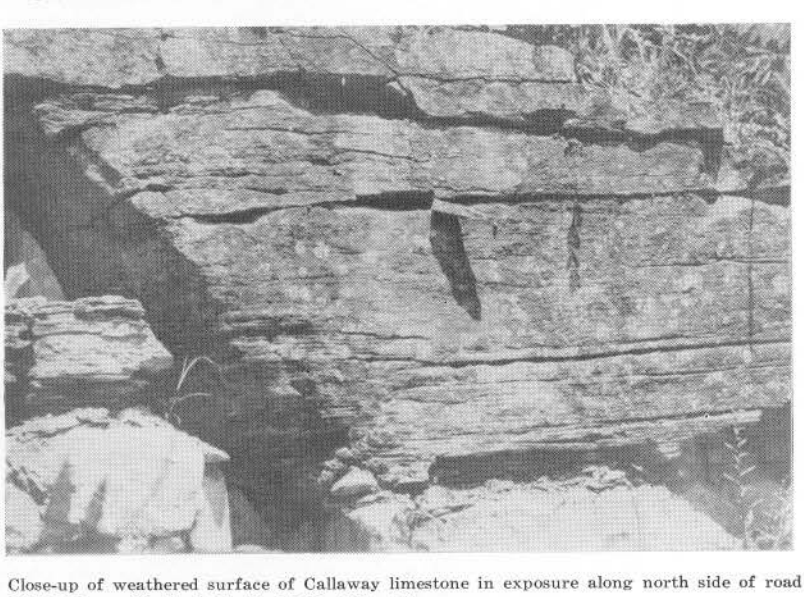
The following measured sections illustrate the typical lithologic features of the Jefferson City formation in Boone County.

[18]Phelps, W. B., oral communication, 1951.

Plate III



A. Bluff along M-K-T railroad just north of the bridge over Little Bonne Femme Creek, NE¼ sec. 33, T. 47 N., R. 13 W. Shows exposure of Jefferson City (Ojc), Callaway (Dc), Bushberg (Cmb), and Chouteau formations (Cmc). (Rush).



B. Close-up of weathered surface of Callaway limestone in exposure along north side of road in NE¼NE¼ sec. 20, T. 46 N., R. 11 W. (Ditzell).

Section measured by Gore, near the center of the north line of sec. 1, T. 45 N., R. 13 W.

	Thickness Feet	Inches
Ordovician System		
Lower Series		
Jefferson City formation		
21. Same lithology as number 20.	3	
20. Dolomite, light gray, medium crystalline, sandy, argillaceous, thin bedded. Abundant blue and brown chalcedonic chert in beds up to 3 inches in thickness.	2	
19. Dolomite, gray to brown some greenish stain, medium crystalline, sandy. Contains many cavities filled with calcite. Nodules of blue and white, chalcedonic chert 1 foot in thickness.	3	
18. Shale, light green, very thin bedded, arenaceous, dolomitic; weathers to yellow and green color.		3
17. Dolomite, light brown to gray, medium crystalline, very sandy with many argillaceous impurities.	1	2
16. Dolomite, same as number 15. Lighter in color and thin bedded. Upper 2 feet more argillaceous and arenaceous.	4	10
15. Dolomite, light to dark brown, medium crystalline, sandy, with calcite veins. Contains many brown and white chert pebbles. This dolomite is massively bedded and weathers to a rough, pitted surface.	2	9
14. Shale, white to green, very thin bedded, siliceous, dolomitic, silty, contains reworked chert that is blue and white banded. Chert pebbles up to 5 inches in diameter. This zone is intensely folded, apparently from solution work and collapse.	1	8
13. Dolomite, light brown, very sandy, finely crystalline, with many veinlets of calcite. Thin bedded and weathers to smooth surface.	1	6
12. Dolomite, white to light brown, very sandy argillaceous. Massively bedded and weathers to pitted surface. Small lenses of white and brown chalcedonic chert.	3	3
11. Same lithology as number 10 with interbedded chert same as above. Few thin layers of gray to brown, fine grained, argillaceous sandstone.	4	
10. Siltstone, white to tan, very argillaceous and dolomitic, with beds 3 to 4 inches in thickness; weathers to very smooth surface. Blue and white, chalcedonic chert lenses common.	4	3

	Thickness Feet	Inches
Ordovician System—Continued		
Lower Series		
Jefferson City formation		
9. Covered interval.	4	
8. Dolomite, light brown, coarsely crystalline, silty. Fractures into small blocks. Grades upward into more argillaceous dolomite. Few scattered blue and white, chalcedonic chert nodules.	3	4
7. Dolomite, white to buff, very thin bedded, highly argillaceous, finely crystalline, with numerous thin shale partings.	1	9
6. Covered interval.	4	
5. Dolomite, light gray, medium crystalline, with glassy luster grading upward into a light brown, finely crystalline, sandy dolomite with both massive and thin undulatory beds.	5	10
4. Dolomite, light gray, medium crystalline. Has a glassy luster on fresh surface. This unit is very oolitic. Oolites are white and round with concentric rings. This lithology grades upward into gray-white, dolomitic, very arenaceous phases. The lower part of this unit is a lentil of blue and white, massive, chalcedonic chert that is undulatory and varies from 1 to 1½ feet in thickness.	3	11
3. Dolomite, light to medium gray, medium crystalline, very sandy. Thin undulatory bedding. Sand is medium-grained. Shale partings between beds which are the result of solution work. Lower 1 foot crumpled and brecciated.	2	5
2. Siltstone, dirty white to gray, very argillaceous, dolomitic. Thin bedded and grades laterally into a fine grained, sandy phase which forms a reentrant.		8
1. Dolomite, light tan to brown, medium crystalline, massively bedded, silty, arenaceous with argillaceous streaks. Weathers to sandy, pitted surface.	8	6
Total	65	11

In Fox Hollow the following section is exposed along a small creek on the north side of the road in the west center of the NE¼SE¼ sec. 12, T. 46 N., R. 13 W. (Rush, 1949).

Soil cover with occasional small Callaway exposures and a debris of mixed Callaway and Jefferson City rock.

	Thickness	
	Feet	Inches
Ordovician System		
Lower Series		
Jefferson City formation		
8. Dolomite, argillaceous and silty, gray, massive-bedded. Weathers to a very hackly surface.	3	7
7. Dolomite, argillaceous, gray, in beds 6 to 8 inches thick. Shale partings between the beds as well as along the smooth regular contacts of the zone with the zones above and below.	7	2
6. Same as zone 8, but with a fairly persistent 2 inch band of blue chert nodules near the center of the zone. The nodules are white and tripolitic where they are much weathered.	6	5
5. Dolomite, very fine-grained, argillaceous, tan and gray, in thin ½ to ¼ inch beds. The top contact has a very irregular and undulating place which consists of a ½ inch bed of brownish gray shale.	2	3
4. Dolomite, massively bedded as in zone 1.	3	7
3. Dolomite, top 40 inches tan silty, with occasional small chert nodules interbedded; lower 4 inches of this bed grades to silty sandstone which is quite persistent laterally and is very crumpled and undulating. Middle 38 inches similar to upper part of the 40 inch bed. Lower 30 inches very thinly bedded, gray, argillaceous, with thin greenish shale partings.	9	0
2. Dolomite, two beds separated by 1 inch undulating bed of green sandy shale. Topmost bed is 45 inches of silty dolomite with blue and gray chert lenses which are irregular and undulating, and extend to as much as 20 inches in length. Lower bed is 23 inches of intermingled brownish-gray and tan silty dolomite. Medium-bedded and hackly on weathered surfaces.	5	9
1. Dolomite, light gray, argillaceous, very oolitic in places. Occasional calcite veinlets. Massively bedded in beds from 6 to 25 inches thick. Beds undulate slightly. Thin shale partings between most beds. This zone has a tendency to form a prominent ledge which stretches laterally for more than 500 yards.	5	8
Total	43	5

The base of the section is in a small stream.

Structure.—The Jefferson City beds have a slight regional dip toward the northeast, but in many places the regional dip is obscured by local structures. Small faults and folds are present in many places and dips of a few degrees are commonly observed. In a few places the beds dip as much as 35 degrees, but such steep structures are of local extent. One small anticlinal fold is visible in a quarry northwest of Hartsburg in the SE¼NW¼ sec. 8, T. 45 N., R. 12 W. Most of the folding of the beds is pre-St. Peter in age and the Jefferson City beds are truncated by the erosional surface upon which the St. Peter or the Devonian limestones were deposited. Most of the remnants of St. Peter in the area are associated with highly deformed Jefferson City beds.

Much of the crumpling and brecciation of the Jefferson City appears to have been caused by subsidence and differential movement between beds subsequent to removal of parts of the formation by ground-water solution. It seems quite likely that much of the folding may be attributed to such movement rather than to regional diastrophism.

Paleontology.—The Jefferson City formation contains a scant fossil record and in Boone County it is essentially barren. Branson and Mehl[14] described the conodonts, Ulrich, Foerste, Miller, and Unklesbay (1944)[15] summarized the cephalopod fauna, and Branson (1944)[16] presented summary information on the fauna. Cullison (1944)[17] made a very comprehensive study of the Jefferson City fauna, but none of his specimens came from Boone County.

Stratigraphic relations.—As previously stated, the base of the Jefferson City is not exposed in Boone County. It is known, however, from well studies in the county and from exposures in adjacent areas, that this formation overlies the Roubidoux formation. In exposures within the county it is overlain by the St. Peter sandstone in some places and by Middle Devonian limestones of the Cooper-Callaway interval. The upper surface of the Jefferson City is one of erosion and, hence, is very uneven. A considerable period of erosion prior to St. Peter deposition is suggested. In southern Mis-

[14]Branson, E. B. and Mehl, M. G., Conodonts from the Jefferson City (Lower Ordovician) of Missouri: Univ. of Missouri Studies, vol. 8, pp. 39-65, 1933.

[15]Ulrich, E. O., Foerste, A. F., Miller, A. K., and Unklesbay, A. G., Ozarkian and Canadian cephalopods pt. III: Longicones and Summary: Geol. Soc. Amer., Special Paper 58, pp. 1-226, pls. 1-68, 1944.

[16]Branson, E. B., The geology of Missouri: Univ. of Missouri Studies, vol. 19, no. 3, p. 54, pl. 7, 1944.

[17]Cullison, J. S., op. cit., 1944.

souri and northern Arkansas 1200 to 1500 feet of sediments occupy the interval equivalent to the Jefferson City-St. Peter contact exposed in Boone County.

Age and correlation.—The age of the Jefferson City is now generally regarded as late Lower Ordovician.

In the days of Swallow, Meek, and Winslow, the term Ordovician had not been generally used in this country, and Winslow in 1894[18] placed the Jefferson City formation in his Ozark Stage of the Lower Silurian. He considered it to be part of the Gasconade and believed it to be partially equivalent to the Potosi.

Gallaher in 1900[19] was the first to apply the term Ordovician to these beds. In Ulrich's revision of the Paleozoic (1911)[20] the Jefferson City was included in the upper part of his Ozarkian system. He correlated it with the Shakopee dolomite of Wisconsin. Ulrich later changed his interpretation and placed these beds in the Canadian system. Bridge in 1930[21] correlated the Jefferson City with the Shakopee dolomite, the Newala limestone of Alabama, and the uppermost part of Division C of the Beekmantown of New York. Shimer and Butts (1934)[22] and Edson (1935)[23] interpreted it as partially equivalent to the Knox dolomite of Tennessee and Kentucky. In 1938 Ulrich and Cooper[24] included the Jefferson City in the lower part of the Upper Canadian system.

Cullison (1944)[25] correlated his Rich Fountain formation with the "Post-Nittany" division of the Knox dolomite. His Theodosia formation was correlated with the Shakopee of Wisconsin.

Topographic expression.—The area of Jefferson City outcrop in the southern part of the county is for the most part, a maturely dissected region with rounded hills and steeply sloping valley walls. Where the hills adjoin the Missouri River flood plain the Jefferson City forms prominent ledges and vertical bluffs.

[18]Winslow, Arthur, op. cit., 1894.

[19]Gallaher, J. A., Preliminary report on the structural and economic geology of Missouri: Missouri Bur. Geology and Mines, vol. 13, 1900.

[20]Ulrich, E. O., op. cit., 1911.

[21]Bridge, Josiah, The geology of the Eminence and Cardareva quadrangles: Missouri Bur. Geology and Mines, 2d ser., vol. 24, pp. 126-128, 1930.

[22]Shimer, H. W. and Butts, Charles, Correlation charts of geologic formations of North America: Geol. Soc. America Bull., vol. 45, pp. 909-936, 1934.

[23]Edson, F. C., Resumé of St. Peter stratigraphy: Amer. Assoc. Petroleum Geologists Bull., vol. 19, pp. 1110-1130, 1935.

[24]Ulrich, E. O. and Cooper, G. A., Ozarkian-Canadian Brachiopods: Geol. Soc. America, Special Paper 13, 1938.

[25]Cullison, J. S., op. cit., 1944.

MIDDLE SERIES

ST. PETER SANDSTONE

Name.—The St. Peter standstone was first named by J. N. Nicollet in 1843.[26] The name was applied to a sandstone and an overlying limestone exposed at the mouth of St. Peter's River (now called Minnesota River) at Ft. Snelling, Minnesota. Owen in 1847[27] restricted the term to the sandstone and mentioned its presence along the St. Peter's River near Lake St. Croix, Minnesota. It was later recognized that this sandstone was a widespread unit of thick friable quartz sandstone which was called the First, or Saccharoidal sandstone by Shumard[28] and Meek,[29] Crystal City sandstone by Winslow,[30] the Cap-au-Gres by Keyes,[31] and the Pacific by Ball and Smith in 1903.[32] Gallaher[33] was the first to apply the term St. Peter to this sandstone in Missouri, and he implied that it had also been called the Fourth sandstone and the Last Infusorial sandstone. Keyes[34] proposed shortening the name to Peter sandstone, but this has not been accepted. Very comprehensive studies of the St. Peter have been made by Dake in 1918[35] and 1921,[36] Broadhead,[37] Trowbridge,[38] Thiel,[39] and Edson.[40]

Distribution and thickness.—The St. Peter sandstone spreads over a large part of the Mississippi Valley region. In Boone County

[26]Nicollet, J. N., Report to illustrate a map of the basin of the upper Mississippi River: U. S. 26th Congress, 2d Sess., Sen. Document 237, 1843.

[27]Owen, D. D., Preliminary report of the geological survey of Wisconsin and Iowa: U. S. Gen. Land Offc. Rept. 1847, pp. 160-173, 1847.

[28]Shumard, B. F., Description of geological section on Mississippi River from St. Louis to Commerce: First and Second Annual Reports of the Geological Survey of Missouri, Geol. Survey of Missouri, pt. 2, pp. 137-184, 1855.

[29]Meek, F. B., Report on Moniteau County: First and Second Annual Reports of the Geological Survey of Missouri, Geol. Survey of Missouri, pt. 2, pp. 97-119, 1855.

[30]Winslow, Arthur, Lead and zinc deposits, sec. I: Missouri Geol. Survey, vol. 6, pp. 352, 353, 356, 357, 1894.

[31]Keyes, C. R., Some geological formations of the Cap-au-Gres uplift: Iowa Acad. Sci., Proc., vol. 5, pp. 58-63, 1898.

[32]Ball, S. H. and Smith A. F., The geology of Miller County: Missouri Bur. Geology and Mines, 2d ser., vol. 1, pp. 1-207, 1903.

[33]Gallaher, J. A., Biennial report of the Bureau of Geology and Mines: Missouri Bur. Geology and Mines, p. 21, 1898.

[34]Keyes, C. R., Complexity of Peter sandstone: Pan Am. Geologist, vol. 37, pp. 245-246, 1922.

[35]Dake, C. L., The sand and gravel resources of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 15, 274 pp., 47 pls., 1918.

[36]Dake, C. L., The problem of the St. Peter sandstone: Univ. Missouri School of Mines and Met. Bull., Tech. Ser., vol. 6, pp. 1-225, pls. 1-30, 1921.

[37]Broadhead, G. C., The Saccharoidal sandstone: Am. Geologist, vol. 34, pp. 105-110, 1904.

[38]Trowbridge, A. C., The origin of the St. Peter sandstone: Iowa Acad. Sci., Proc., vol. 24, pp. 171-175, 1927.

[39]Thiel, G. A., Sedimentary and petrographic analysis of the St. Peter sandstone: Geol. Soc. Amer. Bull., vol. 46, pp. 559-614, 1935.

[40]Edson, F. C., op. cit., 1935.

this sandstone is exposed in scattered isolated localities with no apparent continuity of the formation between exposures. One of the best exposures is about 100 yards north of the road at the center of the eastern edge of section 12, T. 46 N., R. 13 W. Others are in the NE¼NE¼NE¼ sec. 30, T. 46 N., R. 12 W.; center section 24, T. 45 N., R. 11 W.; and center section 9, T. 45 N., R. 12 W.

In most exposures in this county the sandstone appears to occupy channel-like depressions in the top of the Jefferson City formation. It seems quite likely that the sand was deposited in old valleys of the pre-St. Peter erosion surface of the Jefferson City formation, and that it has been protected from later erosion by its position. It is, of course, possible that the sandstone was a widespread unit and that most of it has been removed by pre-Middle Devonian erosion.

Study of well cuttings from the northern part of the county indicates that the St. Peter is continuous over wide areas in the subsurface.

The thickness in Boone County ranges from a few inches to as much as 30 feet.

Lithology.—The St. Peter of Boone County is much like that of other areas. It is a remarkably pure quartz sand which averages well above 98 per cent silica (Dake, 1921).[41] It is composed of fine to medium grains which are well rounded and spherical. The larger grains are frosted and pitted.

The small amount of impurity present is composed of iron oxide, clay, and heavy minerals, all of which are very irregularly distributed throughout the formation. The sandstone is remarkably free from mica, chert, and carbonate materials.

Where exposed in Boone County the St. Peter is massive and, except for a few places, shows very little bedding. Cross-bedding which is prevalent in some localities is not well developed in this area.

On fresh surfaces the sandstone is white and friable, but on weathered surfaces it is usually case-hardened and ranges through various shades of gray and red.

Paleontology.—The fauna of the St. Peter is a meager one, and within Boone County the formation is unfossiliferous.

The most extensive assemblage reported from this formation

[41]Dake, C. L., op. cit., 1921.

was collected near St. Paul, Minnesota and was described by Sardeson in 1910.[42] This assemblage consisted of 13 species of pelecypods, 7 of gastropods, 3 of cephalopods, 3 of brachiopods, a doubtful bryozoan, and a sponge. It seems quite clear that marine fossils occur well down in the St. Peter.

Dake in 1921[43] reported poorly preserved fossils from Cape Girardeau County, Missouri, and he also reported that tubular cavities referred to *Scolithus* were known from numerous localities in Missouri and Illinois, and that they occurred at the top, near the middle, and at the base of the formation.

Stratigraphic relations.—Much has been written about the origin and the stratigraphic relations of the St. Peter. It seems to have been deposited upon an old erosion surface and regionally it lies upon beds ranging in age from Upper Cambrian to early, middle, or late Lower Ordovician. In Missouri it overlies only the Lower Ordovician strata. It is overlain by beds ranging upward from late Ordovician.

In Boone County, the St. Peter sandstone appears to be discontinuous and to lie in depressions in the Jefferson City formation. It is overlain by limestones of the Cooper-Callaway interval.

Age and correlation.—The St. Peter is generally regarded as of Chazyan age and is probably equivalent to the Valcour limestone of New York and the lower part of the Simpson group of Oklahoma. Shimer and Butts (1934)[44] place the St. Peter as pre-Chazyan. Edson (1935)[45] states that it was deposited during the long interval between Beekmantown and Black River time. Branson and Mehl (1933)[46] on the basis of conodont studies correlate the St. Peter with the pre-Chazyan Harding sandstone of Colorado. In Missouri it is known to be younger than the Everton and older than the Dutchtown.

Topographic expression.—In the few places in the county where the St. Peter sandstone is exposed, it characteristically forms smoothly-rounded barren knobs or low promontories on hillsides. Where this rock lies just beneath the soil its presence can often be detected by a concentration of small evergreens.

[42]Sardeson, F. W., The St. Peter sandstone: Minnesota Acad. Sci., vol. 4, pp. 64-88, 1910.
[43]Dake, C. L., op. cit., 1921.
[44]Shimer, H. W. and Butts, Charles, op. cit., 1934.
[45]Edson, F. C., op. cit., 1935.
[46]Branson, E. B. and Mehl, M. G., op. cit., 1933.

DEVONIAN SYSTEM

Introductory statement.—The first report of Devonian rocks in Missouri was made by Owen in 1852[47] when he reported tracing a Devonian limestone from Callaway County northward toward Iowa. Since that time the Devonian rocks have been studied by many workers and were comprehensively described by Branson in 1923.[48]

Within the state most of the Devonian period is represented, but within Boone County only Middle Devonian rocks are present. A possible exception to this is a small shale section which may represent the Upper Devonian Grassy Creek shale.

Branson (1923[49] and 1944[50]) has described the Cooper, Ashland, and Callaway formations in Boone County. It is very difficult to trace these units separately or to differentiate between them in the field. They almost certainly represent facies variations within a major stratigraphic unit, and are so treated here.

Branson (1923)[51] described an exposure in the bluffs about halfway between Easley and Providence as showing the Callaway filling an old valley in the Cooper, and then follows with the statement,

> "South of the outcrop mentioned above the writer has not identified with certainty any outcrop of Callaway for about twenty miles. The Cooper occurs, a few feet thick, and it is impossible to differentiate positively between Cooper and Callaway owing to the absence of fossils. However, this absence of fossils indicates that the rocks are Cooper."

The various lithologies described as being characteristic of the Callaway include types very similar to the typical Cooper, and inasmuch as the Callaway has many unfossiliferous beds, the lack of fossils does not seem to be sufficient evidence for calling the rocks Cooper. In the exposures mentioned above, Branson has interpreted the massive blue-gray unfossiliferous beds as Cooper and the gray-brown, more evenly bedded strata, as Callaway. In these exposures the former lies below the latter. However, in the creek valleys and ravines extending eastward from the Missouri River in southern Boone County and in the Penitentiary Quarry adjacent to U. S. Highway 63, these two lithologies do not maintain a constant relationship but seem to be irregularly interbedded. In such places

[47]Owen, D. D., Report of geological survey of Wisconsin, Iowa, and Minnesota, and incidentally of a portion of Nebraska Territory: 638 pp., Philadelphia, 1852.

[48]Branson, E. B., The Devonian of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 17, pp. 1-279, pls. A-H, 1-71, figs. 1-10, 1923.

[49]Branson, E. B., idem.,

[50]Branson, E. B., op. cit., 1944.

[51]Branson, E. B., op. cit., 1923.

it is impossible to differentiate between the Cooper and the Callaway as distinct stratigraphic units.

It does seem reasonable, however, to consider the so-called Cooper as a lithographic facies of the Callaway; this facies is well developed in Cooper County and interfingers with typical Callaway in the Boone County area. Insoluble residue studies of these limestones further indicate a facies relationship as indicated by McNeal[52] in his statement,

> "I have finally come to the conclusion that the beds that are called Cooper are the same beds that occur below the Ashland limestone and the lower brecciated limestone along the Missouri north of Easley. My residue studies indicate that the Cooper beds are a lithographic facies of the Callaway limestone."

In its type locality, the Ashland appears to lie upon a lithographic limestone and grades gradually upward through fine grained limestone into a sandy phase which is present elsewhere in the Callaway. At a locality west of Ashland where the *Rensselandia*-bearing bed occurs, the beds beneath it are not lithographic but seem to be one of the fine-grained phases of the Callaway. It seems reasonable then to consider the Ashland as a clastic facies of the Callaway consisting of scattered concentrations of organic remains such as might accumulate in depressions in the floor of the ocean.

MIDDLE SERIES

CALLAWAY FORMATION

COOPER LIMESTONE FACIES

Name.—The Cooper limestone was first called "Cooper marble" by Swallow (1855)[53] when he described it from exposures in Cooper County where, ". . . it is best developed on Clear Creek, and on the LaMine, between the mouths of Clear Creek and Otter Creek . . ."

Distribution and thickness.—The Cooper facies is not continuous over large areas but has been described by Branson as outcropping in Pettis, Cooper, Morgan, Moniteau, Saline, Boone, Ralls, and Marion counties. It varies greatly in thickness and ranges from a fraction of an inch to as much as 30 feet. The average is less than 15 feet.

[52] McNeal, Robert P., letter dated Feb. 15, 1950.

[53] Swallow, G. C., The second annual report, 1854: The first and second annual reports of the Geological Survey of Missouri, Geol. Survey of Missouri, 1855.

Lithology.—Typically the Cooper facies is a sub-lithographic to very fine-grained bluish-gray limestone, but away from the type area, the color ranges from light gray to nearly black. It is massively bedded and remarkably free from impurities. Veinlets and calcite-filled cavities are not uncommon.

Paleontology.—The Cooper facies is only sparsely fossiliferous and the species it contains are not diagnostic. Branson (1923[54] and 1944[55]) has listed the known fauna for the Cooper of Missouri. At no place in Boone County are beds of Cooper lithology very fossiliferous, although Branson has reported *Turbinopsis providensis* (Broadhead) from the western part of the county. This species also occurs in the Callaway.

Stratigraphic relations.—In many places the Cooper facies lies upon an old erosion surface, and in most of its areal extent it lies upon the Jefferson City. In a few places, however, beds of Cooper lithology rest upon the St. Peter. According to Branson's interpretation the Cooper is overlain in a few places by his Ashland formation and in some places by more typical Callaway limestone, but in most of its areal extent it is overlain by Bushberg sandstone. In a few places where the Bushberg is absent the Chouteau lies directly upon the Cooper.

Within Boone County the beds of Cooper lithology are found most commonly resting upon the Jefferson City, but in the southern part of the county there are many exposures where typical Cooper lithologies are interbedded with beds of typical Callaway lithology, and it seems that these are simply interfingering facies.

Age and correlation.—When Swallow named the Cooper he correlated it with the Onondaga. Branson (1944)[56] indicated that it grades eastward into his Mineola and northward into the Wapsipinicon near the Iowa line. These beds are all referable to the Taghanic Stage of Cooper.[57]

[54]Branson, E. B., op. cit., 1923.

[55]Branson, E. B., op. cit., 1944.

[56]Branson, E. B., op. cit., 1944.

[57]Cooper, G. A., et al., Correlation of the Devonian sedimentary formations of North America: Geol. Soc. Amer. Bull., vol. 53, pp. 1729-1794, 1 pl., 1 fig., 1942.

CALLAWAY LIMESTONE FACIES

Name.—As previously stated, Owen[58] was the first to note the occurrence of Devonian rocks in central Missouri, and those which he described are part of the Callaway facies as now recognized.

Swallow (1855[59] and 1860[60]) also mentioned the occurrence of Devonian rocks in Callaway County. Broadhead (1873)[61] recognized as Devonian beds in Warren County which are now referred to the Callaway.

The name Callaway was not applied to these limestones until 1894 when Keyes[62] applied the term to two limestones which were later regarded as being distinct units. Keyes used the term also in reports in 1895[63] and 1896.[64]

In 1909[65] Greger recognized that Keyes had confused the St. Laurent of southeastern Missouri with Callaway of the central part of the state and suggested restriction of the term. Wilson (1922),[66] Branson (1923[67] and 1944[68]), and other workers have used the Callaway essentially as designated by Greger, but they have differed as to age relationships.

Distribution and thickness.—The Callaway facies is best developed and best exposed in the type area in Callaway County. From this area it extends outward in all directions except south where it has been eroded away, and is exposed to the west in Boone, Cooper, and Moniteau counties. Southwestward it is exposed in Cole County, and eastward in Montgomery, Warren, and Lincoln counties. In northeastern Missouri it is exposed in Ralls and Pike counties.

In Boone County the Callaway is exposed only in the southern portion of the county, mostly along the Missouri River and Cedar

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[58]Owen, D. D., op. cit., 1852.

[59]Swallow, G. C., op. cit., 1855.

[60]Swallow, G. C., Description of new fossils from the Carboniferous and Devonian rocks of Missouri: St. Louis Acad. Sci., Trans., vol. 1, pp. 635-660, 1860.

[61]Broadhead, G. C., Warren County: Reports on the Geological Survey of the State of Missouri, 1855-1871, Missouri Bur. of Geology and Mines, Jefferson City, 1873.

[62]Keyes, C. R., Paleontology of Missouri, pt. I: Missouri Geol. Survey, vol. 4, pp. 30, 43, 1894.

[63]Keyes, C. R., Characteristics of Ozark mountains: Annual report for 1844, Missouri Geol. Survey, vol. 8, pp. 317-352, 1895.

[64]Keyes, C. R., Clay deposits: Missouri Geol. Survey, vol. 11, pp. 35-48, 1896.

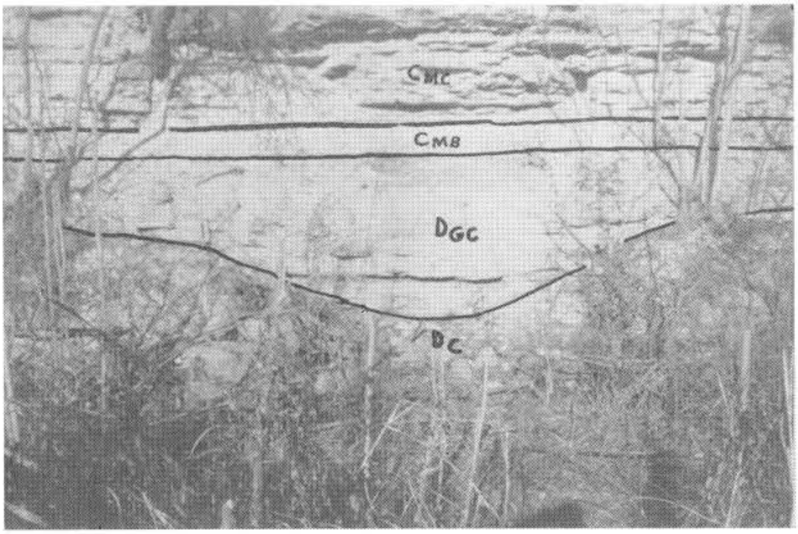
[65]Greger, D. K., The Devonian of central Missouri: Am. Jour. Sci., 4th ser., vol. 27, pp. 374-375, 1909.

[66]Wilson, M. E., The occurrence of oil and gas in Missouri: Missouri Bur. Geol. and Mines, 2d ser., vol. 16, 1922.

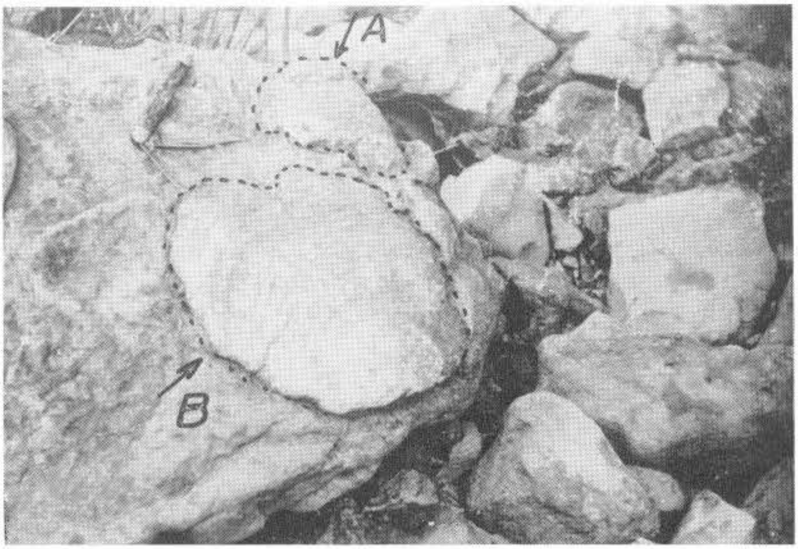
[67]Branson, E. B., op. cit., 1923.

[68]Branson, E. B., op. cit., 1944.

PLATE IV



A. View of exposure along M-K-T railroad about one mile south of Providence. Shows depression in Callaway (Dc) limestone filled with Grassy Creek shale (Dgc) and overlain by Bushberg sandstone (Cmb) and Chouteau limestone (Cmc). (Rush)



B. Close-up of block of sandstone from Callaway formation containing (A) *Hexagonaria* and (B) *Favosites*. SW¼NE¼ sec. 9, T. 46 N., R. 11 W. (Ditzell)

Creek. Representative sections of the Callaway exposed in the area are present near center of sec. 24, T. 46 N., R. 13 W.; in the south-central part of sec. 30, T. 46 N., R. 13 W.; in the NW¼NW¼ sec. 34, T. 47 N., R. 13 W.; and in the NW¼NW¼ sec. 20, T. 46 N., R. 11 W. The northernmost exposure is a small inlier in the bed of Bonne Femme Creek at the center of the north edge of sec. 28, T. 47 N., R. 12 W.

In the type area the thickness of the Callaway averages between 35 and 40 feet. In Boone County the thickness ranges from a fraction of an inch to as much as 60 feet. The thickness is highly variable because the Callaway was deposited upon an erosion surface and was itself eroded before being covered by younger sediment.

Lithology.—The Callaway limestone facies varies in lithology from place to place. In many localities the variations are rather marked over short distances and may be either horizontal or vertical in extent.

The dominant lithology is relatively pure, light gray to dark blue, fine-grained to sub-lithographic limestone which is very fossiliferous in some places.

Another phase of the Callaway consists of white to light gray crystalline limestone which is locally fossiliferous and which is irregularly distributed as lentil-like masses ranging from a few inches to as much as 4 feet in thickness. Also in some areas a light to dark brown, fine-grained to dense, thin-bedded limestone is present. Some beds of this phase are fossiliferous.

Some portions of the Callaway, particularly in the lower part, are quite sandy. The concentration of sand ranges from a few scattered grains to well-cemented beds of sandstone. The sandy phases are more prevalent in the eastern part of the county near Cedar Creek. In the SW¼NE¼ sec. 9, T. 46 N., R. 11 W., sandy layers are well developed about 14 feet below the top of the Callaway and consist of two types. One is characterized by fine to medium grained, whitish-gray to yellowish-brown, nonfossiliferous, sandy, limestone which occurs in even beds about 6 inches thick (plate V A). The individual beds are quite strongly cross-laminated (plate V B). The other type consists of friable, light brown to dark reddish-brown, irregularly bedded, non-calcareous, vermicular, sandstone. These beds are interlayered with the sandy limestone. One of the sandy limestone layers contains an abundance of fossil coralla of *Hexagonaria* and *Favosites* (plate IV B).

Typical exposures of the Callaway in eastern Boone County are described below.

A portion of a measured section of the Callaway formation exposed on the right bank of Conner Creek in the NE¼SW¼ sec. 17, T. 46 N., R. 11 W.

	Thickness Feet	Inches
Devonian System		
Upper Series		
Callaway formation		
9. Covered, other outcrops appear above, but covered intervals make it undesirable to measure them.		
8. Limestone, dark yellowish-gray, fine-grained, regularly bedded in thin beds ½ to 2 inches thick, weathers to a hackly surface, light buff-gray to dark brownish gray color, non-fossiliferous.	2	6
7. Limestone, dark brownish-gray, fine to medium-grained, regularly and irregularly bedded, hackly surface, thinly bedded in beds ½ to 8 inches thick, become lighter in color toward top of bed, stylolites present, non-fossiliferous, weathers light buff-gray to dark gray color.	3	11
6. Limestone, light, olive gray, fine-grained, irregularly bedded, beds very brecciated, non-fossiliferous, in some places bed is more dense than fine-grained portion and is darker in color, stylolitic, weathers whitish-gray to gray color.	5	4
5. Limestone, dark brownish-gray, fine to medium-grained, not as fine as no. 3, irregularly bedded, non-fossiliferous, beds very brecciated, some chert nodules at bottom of bed, weathers dark gray to brownish-gray.	1	6
4. Limestone, light olive-gray, dense, irregularly bedded, breaks with a semi-conchoidal fracture, one bed, non-fossiliferous, weathers light gray to medium gray.	4	6
3. Limestone, light olive-gray, irregularly bedded in thin beds, fine to medium grained, sandy in top portion which is possibly due to weathering, non-fossiliferous, weathers dark brownish-gray to light gray.	0	6
2. Conglomerate, dark gray chert with a light gray to medium gray, medium grained limestone.	0	2
Unconformity		

PLATE V

A. Exposure of sandstone (A) and sandy limestone in the Callaway formation in the SW¼NE¼ sec. 9, T. 46 N., R. 11 W. (Ditzell)

B. Cross-lamination in sandy limestone of the Callaway formation at the same location as the above figure. (Ditzell)

Ordovician System
Lower Series
Jefferson City formation

1. Limestone, orange-gray, fine to medium grained, porous, massive, solution cavities prominent, no apparent bedding, nonfossiliferous.	1	8
Total	20	1

Another portion of a measured section of the Callaway formation taken from an exposure along Fowler Creek, in the NE¼SE¼ sec. 24, T. 46 N., R. 12 W., is as follows:

Mississippian System
Kinderhookian Series
Sulphur Springs group
Bushberg formation

5. Clay, green to brownish-buff, intermingling of clay colors, very sandy, calcareous.	0	3
Unconformity		

Devonian System
Middle Series
Callaway formation

4. Limestone, light buff-gray, dense, brittle, small cavities and crystals of calcite in top portion, some cavities filled with greenish material similar to that in Bushberg, irregularly bedded, weathers to knobby, uneven surface.	10	10
3. Limestone, brownish-gray, fine-grained throughout, apparently non-fossiliferous, regularly bedded in one bed, resistant to weathering.	1	1
2. Limestone, brownish-gray, dense, lithographic, regularly bedded in thick beds over 8 inches thick, apparently nonfossiliferous, crystals of calcite present, weathers to knobby surface, brittle.	15	1
1. Limestone, light gray to brownish-buff, fine-grained, crystalline, small patches and thin bands appear as darker gray in places, irregularly bedded, weathers in smooth surface that is gray in color, hard, fracture semi-conchoidal, forms bottom of stream bed.	2	0
Total	29	3

Paleontology.—Many of the beds of the Callaway facies are very fossiliferous. Faunal lists have been published by Greger (1909)[69] and Branson (1923[70] and 1944[71]). No detailed work has been done on the possibilities of zonation of the formation, but Peery[72] noted some zonal distribution of certain forms. He noted that the lowermost beds of the formation are characterized by reefs of *Hexagonaria davidsoni* (Edwards and Haime) and *Favosites alpenensis* (Winchell). The latter is present in smaller numbers and also has a wider stratigraphic range. *Atrypa reticularis* (Linnaeus) occurs throughout the formation but is very abundant near the base. *Stropheodonta demissa* (Conrad) is most abundant near the middle of the formation, but is not as abundant as the *Atrypa*. A zone of stromatoporoids occurs about 20 feet below the top in the type area and is associated with *Diplophyllum callawayensis* (Branson). The upper part of the formation is characterized by reefs of the bryozoan *Lioclema* and by the coral *Favosites limitaris* (Rominger).

There are only a few fossiliferous localities in the Callaway of Boone County and most of them are in the southeastern part of the area near Cedar Creek.

Gore[73] noted that some of the weathered surfaces of the Callaway show fine layering suggestive of algal structure. This feature is rather persistent in the southern part of the county and is an aid in differentiating the Callaway and Chouteau in areas where these two units possess strikingly similar lithology.

Stratigraphic relations.—The Callaway limestone facies lies unconformably upon rocks older than Devonian, and in its area of extent it is known to lie upon the Jefferson City, St. Peter, and Plattin formations. Evidence suggests that it grades into the Mineola, Ashland, and Cooper facies, upon which it rests and it is therefore conformable with them.

In most of its Boone County extent the typical Callaway lies upon the Jefferson City, but in a few places along the western margin of the county it lies upon and is interbedded with beds which Branson has called Cooper. In the type area of the Ashland, Bran-

[69]Greger, D. K., op. cit., 1909.

[70]Branson, E. B., op. cit., 1923.

[71]Branson, E. B., op. cit., pp. 144-145, 1944.

[72]Peery, T. E., The stratigraphy of the western half of the Fulton quadrangle: unpublished Doctor's dissertation, Univ. of Missouri, Columbia, Missouri, 1940.

[73]Gore, C. E., The geology of southern Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1949.

son interpreted the Callaway as being unconformable upon the Ashland, but evidence for this is meager. With exception of one small exposure, the Callaway is overlain unconformably by the Bushberg sandstone. The exception mentioned is about one-half mile south of Providence along the Missouri River bluff, where shales believed to represent the Grassy Creek are between the Callaway and the Bushberg.

Age and correlation.—Earlier workers differed somewhat on the age of the Callaway. Swallow in 1855[74] correlated the Devonian in Callaway County with the Onondaga. Broadhead in 1873[75] referred part of the Callaway to the Lower Devonian, and part of it to the Hamilton. Keyes (1894,[76] 1895,[77] and 1896[78]) regarded the Callaway as equivalent to the Hamilton. Branson (1918)[79] referred it to the Upper Devonian and was followed in this by Wilson (1922)[80] and by Buehler on the 1922 Geological Map of Missouri. In 1923[81] Branson regarded the Callaway as equivalent to the Late Hamilton.

ASHLAND LIMESTONE FACIES

Name.—In 1923[82] Branson described a member of the Callaway in Boone County as being abundantly supplied with *Rensselandia missouriensis* (Swallow). In 1941[83] he named this member the Ashland formation and described it as follows:

> "About seven miles southeast of Ashland, and nine miles northeast of Jefferson City, in Sec. 1, T. 47 N., R. 12 W., a unique limestone crops out in an area of about 10 acres. The maximum thickness of the limestone is about 15 feet. The stone is very compact and so crowded with fossils that few good specimens have been recovered. The name Ashland is being used for the formation."

A typographical error in the original description quoted above has led to much confusion regarding the so-called Ashland. The type locality is actually in the NE¼SW¼ sec. 1, T. 46 N., R. 12 W., Boone County, and is about three-tenths of a mile north of Sycamore

[74]Swallow, G. C., op. cit., 1855.
[75]Broadhead, G. C., op. cit., 1873.
[76]Keyes, C. R., op. cit., 1894.
[77]Keyes, C. R., op. cit., 1895.
[78]Keyes, C. R., op. cit., 1896.
[79]Branson, E. B., Geology of Missouri: Univ. Missouri Bull., vol. 19, no. 15, 1918.
[80]Wilson, M. E., op. cit., 1922.
[81]Branson, E. B., op. cit., 1923.
[82]Branson, E. B., op. cit., p. 34, 1923.
[83]Branson, E. B., Devonian of central and northeastern Missouri: Kansas Geol. Soc., 15th Ann. Field Conf. Guidebook, pp. 34-38, 81-85, 1941.

School, along an old abandoned roadway. This locality is 9 miles (airline distance) north-northwest of Jefferson City (plate VI).

Distribution and thickness.—In the type locality the Ashland extends over only about 10 acres. Also in Boone County a limestone closely resembling the Ashland occurs in a tributary to Fox Hollow in the NE¼SE¼ sec. 12, T. 46 N., R. 13 W. This section is poorly exposed for about 200 yards north of the road. Branson (1941[84] and 1944[85]) reports that the Ashland has been found at only one place west of the Missouri River, that is, about 6 miles southwest of Lupus. Here the outcrop is reported to be only a few hundred feet in extent and the formation is about 6 feet thick. Three small exposures, all less than 3,000 square feet, occur in an area 3 to 6 miles southwest of Hannibal, and Branson (1941)[86] reports that the lithology and fossils are almost identical with the type locality. In the summer of 1950 Tedford McCarty discovered a small exposure of identical beds in the NW¼NW¼ sec. 23, T. 45 N., R. 11 W., Callaway County.

Lithology.—At the type locality the Ashland consists of a coarsely crystalline clastic limestone which ranges in color from nearly white to light brown and in, some places to light olive gray. Some of the beds are dense and massive and others are porous and less compact. Fragmental internal molds of the brachiopod *Rensselandia missouriensis* (Swallow) are very abundant and in some places the rock is essentially a mass of these molds.

Paleontology.—The species *Rensselandia missouriensis* (Swallow) is exceedingly abundant in the Ashland. In fact, as already stated, the rock is largely composed of closely packed internal molds of this species. Fraunfelter (1951)[87] has recently completed a rather detailed study of the fauna and lists 34 species of brachiopods along with a few trilobites and the coral genera *Hexagonaria* and *Favosites.*

Stratigraphic relations.—Branson interpreted the Ashland as having been deposited upon the eroded Mineola in some places, upon the eroded Cooper in others, and in the areas southwest of Hannibal upon the Kimmswick. He also interpreted it as being

[84]Branson, E. B., idem., 1941.

[85]Branson, E. B., op. cit., p. 138, 1944.

[86]Branson, E. B., op. cit., 1941.

[87]Fraunfelter, George H., The *Rensselandia* beds (Middle Devonian) of central Missouri: unpublished Master's thesis, Univ. of Missouri Library, 1951.

Plate VI

Type section of the Ashland facies of the Callaway NE¼SW¼ sec. 1, T. 46 N., R. 12 W., about three-tenths of a mile north of Sycamore School. (Fraunfelter)

unconformably overlain by the Callaway. Its validity as a distinct formation has been questioned by many.

Rather careful examination of the few exposures known suggest that it is a facies development within the Callaway formation and seems to consist of accumulations of broken shells which gathered together in scattered depressions in the floor of the ocean.

The name Ashland is preoccupied. [88, 89, 90] However, if used as a facies term, as it is here, to denote the *Rensselandia*-bearing beds of the Callaway formation, it seems that continued use of the term in a local sense is more satisfactory than introducing another new term into the literature.

Age and correlation.—*Rensselandia* which occurs so abundantly in the Ashland is generally regarded as an indicator of Middle Devonian age. Correlation with units in other areas may only be done indirectly by reference to the position of the Ashland with respect to the Callaway.

MISSISSIPPIAN SYSTEM

KINDERHOOKIAN SERIES

SULPHUR SPRINGS GROUP

GRASSY CREEK FORMATION

Name.—The Grassy Creek shale was named by Keyes in 1898[91] for exposures near Louisiana, Missouri. He described it as consisting of six feet of black and green shale immediately underlying the Louisiana limestone. This unit has been variously treated, and its history was well treated by Branson and Mehl in 1933.[92] In 1913[93] Keyes suggested subdividing the shale into two units, retaining the name "Grassy" for the lower black shale and applying the name Saverton to the upper green shales. This proposal has

[88]Williams, H. S., The Paleozoic faunas of Maine: U. S. Geol. Survey Bull. 165, pp. 21, 45, 49-51, 52-54, 1900.

[89]Smith, E. A. and McCalley H., A report on the valley regions of Alabama: Ala. Geol. Survey Bull. 9, p. 8, 1904.

[90]Condra, G. E. and Bengston, N. A., The Pennsylvanian formations of southeastern Nebraska: Nebraska Acad. Science, pub. 9, no. 2, pp. 7-24, 1915.

[91]Keyes, C. R., Some geological formations of the Cap-au-Gres uplift: Iowa Acad. Science, Proc., vol. 5, pp. 58-63, 1898.

[92]Branson, E. B. and Mehl, M. G., Conodonts from the Grassy Creek shale of Missouri: Univ. of Missouri studies, vol. 8, no. 3, pp. 169-259, pls. 13-21, 1933.

[93]Keyes, C. R., Marked unconformity between Carboniferous and Devonian strata in Upper Mississippi Valley: Am. Jour. Sci., 4th ser., vol. 36, pp. 160-164, 1913.

been the source of much disagreement. Weller in 1935[94] used only the term Saverton and interpreted the black shales at the type locality along Grassy Creek as part of the Maquoketa. In 1943 Williams[95] recognized both the Saverton and Grassy Creek units. In 1948 Weller[96] also recognized both units and placed them in the Fabius group of the Kinderhookian Series.

Lithology.—Typically the Grassy Creek is dark gray to black, fissile shale which in some places weathers to a soft clay and in others to a greenish or bluish shale retaining the slabby character. Branson has suggested that the green shale called Saverton by Keyes is weathered Grassy Creek.

The Grassy Creek shale of Boone County is not like that of other well-known localities. It consists of a basal, fine to medium grained, calcareous sandstone overlain by gray to brown shale. The brown shale at the top of the formation is very fissile. The lithology in Boone County is shown in the following section measured by T. D. Rush in 1949 at the base of the Missouri River bluffs near the center of sec. 28, T. 47 N., R. 13 W. (plate IV). The bottom of the exposure rests in a depression in the Callaway limestone and is partly obscured by the roadbed of the railroad which follows the base of the bluffs. The top of the small bluff consists of several feet of Chouteau limestone debris and soil.

Section at base of Missouri River bluff, near center of sec. 28, T. 47 N. R. 13 W.

	Thickness	
	Feet	Inches
Mississippian System		
Kinderhookian Series		
Chouteau group (undifferentiated)		
6. Limestone, thin-bedded, earthy, gray, with irregular thin gray shale partings. . .	3	9
Bushberg formation		
5. Sandstone, light green, non-calcareous, friable. In one irregular bed.		4
Clay shale, light green, non-calcareous. . .		4
Sandstone, tan, friable, thin-bedded, fine-grained.		6
Total	1	2

[94]Weller, J. M., "Grassy Creek" shale: Illinois State Acad. Sci., Trans., vol. 28, no. 2, pp. 191-192, 1935.

[95]Williams, J. S., Stratigraphy and fauna of the Louisiana limestone of Missouri: U. S. Geol. Survey, Prof. Paper. 203, 9 pls., pp. 35-36, 46, 1943.

[96]Weller, J. M., et al., Correlation of the Mississippian formations of North America: Geol. Soc. Amer. Bull., vol. 59, pp. 91-196, 1948.

	Thickness Feet	Inches
Mississippian System—Continued		
Kinderhookian Series		
Grassy Creek formation		
4. Shale, brown, fissile, speckled with dark brown fossil plant fragments.	1	9
3. Shale, gray, silty, coarsely laminated.	2	10
2. Sandstone, light gray, conglomeratic, very similar to zone number 1, but more compact.		10
1. Sandstone, somewhat iron-stained, conglomeratic, calcareous. Contains large chert pebbles and is in thin beds 1 inch to 3 inches thick. At the top of this zone is a 1 inch layer of soft pale green sandstone which is non-resistant and forms a noticeable reentrant in the bluff.	1	4
Total	6	9

The sandstone of bed 1 is probably not of stratigraphic significance.

Distribution and thickness.—The Grassy Creek is best known and has its best development in Ralls, Marion, Pike, and Lincoln counties in northeastern Missouri. It is also known in St. Louis County. Subsurface studies indicate that this formation extends northward into Iowa where the exposures are called the Sweetland Creek shale. In central Missouri only scattered local accumulations are known, and in Boone County the only exposure of this formation is in the section described above.

Paleontology.—It is difficult to give a meaningful summary of the Grassy Creek fauna based on published reports because of the confusion concerning the status of the Grassy Creek and Saverton terms. Different writers have had different interpretations of these formations, and some have failed to report the exact position of the fossils listed or described.

Rowley in 1907[97] noted that his Hamilton shale on Grassy Creek and several of its tributaries contained fish teeth and linguloid brachiopods, but he was including a lower portion that has since been determined to belong with the Maquoketa. It was in this lower part that the brachiopods occurred.

In 1914 Branson[98] listed 14 species of fish, and Branson and

[97] Rowley, R. R., Geology of Pike County, Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 8, pp. 24-26, 1907.

[98] Branson, E. B., The Devonian fishes of Missouri: Univ. of Missouri Bull., (Sci. ser. 2) pp. 59-74, 1914.

Mehl[99] described a very large "Grassy Creek" conodont fauna. However, they did not report separately on the faunas of the "black" and the "green" beds now called Grassy Creek and Saverton respectively. Branson in 1944[100] indicates that the Grassy Creek has yielded an invertebrate fauna containing brachiopods, corals, and a few fragments of uncertain identity. However, the "black" shales contain only a meager fauna and much of the same macrofauna listed by Branson has been collected from the "green" (or Saverton) by Williams.[101] Also reported are plant remains referred to *Ptychostylus tumidus* (Gurley). The latter are abundant in the Boone County exposure near Providence.

Stratigraphic relations.—In northeastern Missouri the Grassy Creek shale lies unconformably upon the Callaway in some localities, on Maquoketa shale in others, and in Pike and Ralls counties it lies on Silurian beds. In St. Louis County it is unconformable upon the Maquoketa, in Jefferson County upon the Fernvale, and in Warren County upon the Kimmswick.

At some places in Pike County the Grassy Creek is conformably overlain by the Louisiana limestone and in others unconformably by the Hannibal formation. At most places in central Missouri where the upper contact is exposed the Grassy Creek is overlain unconformably by the Bushberg.

Age and correlation.—There is no general agreement concerning the age of the Grassy Creek shale; lying as it does near the Devonian-Mississippian boundary it has been variously interpreted, and different workers have had differing opinions concerning its age.

These may be summarized as follows:

1897	Keyes	Upper Devonian
1907	Rowley	Hamilton (Mid-Devonian)
1911	Ulrich	Basal Mississippian
1914	Branson	Upper Devonian
1918	Branson	Basal Mississippian
1922	Branson	Mississippian
1922	Keyes	Mississippian
1924	Krey	Basal Mississippian

[99]Branson, E. B. and Mehl, M. G., Conodonts from the Grassy Creek shale of Missouri: Univ. of Missouri studies, vol. 8, no. 3, pp. 169-259, 1933.

[100]Branson, E. B., op. cit., p. 167, 1944.

[101]Williams, J. S., op. cit., pp. 30-31, 1943.

1928	Moore	Basal Mississippian
1948	Weller	Kinderhookian (Fabius Group-Devonian or Mississippian).

Branson and Mehl, after their very complete studies of the conodont fauna in 1933, concluded that the Grassy Creek formation belongs near the top of the Upper Devonian. They correlated it with the lower Huron of Ohio, the Rhinestreet of New York, and the Woodford of Oklahoma.

The shale mentioned above that is exposed near Providence was included in this study by Branson and Mehl, and the beds between the Callaway and Bushberg contain a typical Grassy Creek conodont fauna.

BUSHBERG FORMATION

Name.—Prior to 1933 the beds here described as Bushberg were called Sylamore and were believed to be equivalent to the Sylamore sandstone of Arkansas. In 1933 Branson and Mehl[102] studied the conodont fauna and decided that these beds were equivalent to the sandstone which Ulrich (1904)[103] had called the Bushberg for exposures at Bushberg in Jefferson County, Missouri. Ulrich considered the Bushberg to be the top member of his Sulphur Springs formation.

Early workers recognized the presence of this sandstone in the geologic section and it was variously interpreted. Broadhead (1873)[104] recognized it in Warren County and referred to it as "the Old Red sandstone" and Meek (1873)[105] observed a "green arenaceous band 0-8 inches" between the Chouteau and Cooper in Saline County. Stewart (1896)[106] mentioned the occurrence of the sandstone near Providence, and Van Horn (1905)[107] described it near Sandy Hook in Moniteau County as being 3 feet thick. Van Horn referred it to the Devonian. Branson for some time designated the

[102]Branson, E. B. and Mehl, M. G., Conodonts from the Bushberg sandstone and equivalent formations of Missouri: Univ. of Missouri studies, vol. 8, pp. 265-301, 1933.

[103]Ulrich, E. O., in Buckley, E. R. and Buehler, H. A., The quarrying industry of Missouri: Missouri Bur. of Geology and Mines, vol. 2, 2d ser., p. 110, 1904.

[104]Broadhead, G. C., op. cit., p. 46, 1873.

[105]Meek, F. B., op. cit., 1873.

[106]Stewart, Alban, A geological section at Providence, Missouri: Kansas Univ. Quart., vol. 4, p. 161, 1896.

[107]Van Horn, F. B., The geology of Moniteau County, Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 3, p. 47, 1905.

"Sylamore" of central Missouri and the "Phelps"[108] of southwestern Missouri as one formation, and he continued to interpret them in this way until 1933.

Moore (1928)[109] recognized a close relationship between the "Sylamore" of central Missouri, the Sylamore of southwestern Missouri and northern Arkansas, and the Hardin sandstone of Tennessee.

Distribution and thickness.—The Bushberg sandstone is traceable along a very narrow band across the eastern two-thirds of central Missouri, and in a large part of the southwestern part of the state. Its thickness averages 5 to 20 feet in St. Louis and Jefferson counties, and in Montgomery and Warren counties it changes abruptly from very thin beds to deposits 50 to 60 feet thick.

In Boone County most of the exposures of this formation are along the bluffs of the Missouri River and Cedar Creek and their tributaries in the southern part of the county. It is also exposed in the NW¼NW¼NW¼ sec. 33, T. 50 N., R. 12 W., where it has been elevated by the folding of the Brown's Station anticline and has been cut into at the junction of two small creeks (plate IX).

In most of the county the Bushberg averages about 6 to 8 inches in thickness, but it is considerably thicker at the creek junction mentioned above. The thickness here has not been accurately determined because the base is not exposed, but it has been estimated to exceed 2 feet. The upper few inches are characteristically greenish, but the lower part is medium to dark brown.

Lithology.—The Bushberg of central Missouri is variable in lithology, but for the most part it consists of medium-grained calcareous sandstone. It ranges from white to brown, but the most characteristic color is a watery green. Portions of the formation are spotted with brown limonite stains. In most localities the Bushberg is poorly cemented and is easily crumbled, but in a few places it is firmly cemented and appears quartzitic. The individual grains are dominantly quartz and they closely resemble the grains of the St. Peter sandstone from which they may have been derived. Also in some localities there are numerous small black phosphatic pellets and fragmentary fish teeth.

[108]Shepard, E. M., A report on Greene County: Missouri Geol. Survey, vol. 12, pt. 1, pp. 77-82, 1898.

[109]Moore, R. C., Early Mississippian formations in Missouri: Missouri Bur. Geology and Mines, vol. 21, 2d ser., pp. 113, 135, 1928.

In most of the Boone County exposures, the Bushberg is thin, poorly cemented, and greenish in color. These characterisics are particularly common in the southern part of the county. At the creek junction in the NW¼NW¼NW¼ sec. 33, T. 50 N., R. 12 W., about 2½ miles northwest of Brown's Station, this greenish sand is very thin. It is, however, underlain by at least 2 feet of medium to dark brown, fine to medium-grained, cross-laminated, ripple-marked sandstone. This sandstone is unlike any found elsewhere in Boone County and it might even be a separate stratigraphic unit. It contains calcareous oolites which were studied and described by Swartzlow in 1929.[110] In the creek bed this sandstone has the appearance of many thin beds dipping rather steeply to the northeast. However, close examination reveals that this apparent dip is really cross-lamination.

Unusual lithology is also present in the northwestern corner of the NE¼SW¼ sec. 24, T. 46 N., R. 13 W., where the sandstone occupying the Bushberg position consists of a conglomerate of dark chert pebbles and granules in a matrix of loosely consolidated light gray to green friable sandstone.

Paleontology.—The fossil content of the Bushberg has been summarized by Branson (1938[111] and 1944[112]). The first fossils reported from this sandstone and the fossils most commonly found in it are fish teeth of *Ptyctodus calceolus* (Newberry and Worthen) which are abundant in almost all localities. Also present in large numbers and great variety are the conodonts of which Branson and Mehl,[113] and Branson[114] reported 16 genera and 53 species. An invertebrate fauna has been reported from a locality near Montgomery City and includes five species of brachiopods, four species of pelecypods, two species of gastropods, and two species of trilobites.[115]

Morey[116] listed 24 species of ostracodes from a few scattered localities, and Peck[117] described six species of charophytes.

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[110] Swartzlow, Carl R.. Origin and occurrence of oolites in the Sylamore formation in central Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1929.

[111] Branson, E. B., Stratigraphy and paleontology of the Lower Mississippian of Missouri, pt. I: Univ. of Missouri Studies, vol 13, pp. 150-180, 1938.

[112] Branson, E. B., op. cit., pp. 180-186, 1944.

[113] Branson, E. B., and Mehl, M. G., op. cit., pp. 265-301, 1933.

[114] Branson, E. B., op. cit., pp. 159-183, 1938.

[115] Branson, E. B., op. cit., pp. 182-183, 1938.

[116] Morey, Philip S.. Ostracoda from the basal Mississippian sandstone in central Missouri: Jour. Paleontology, vol. 9, pp. 316-326, 1935.

[117] Peck, R. E., The North American trochiliscids. Paleozoic Charophyta: Jour. Paleontology, vol. 8, pp. 88-119, 1934.

Stratigraphic relations.—In its areal extent the Bushberg is known to lie upon the Jefferson City, Powell, Joachim, St. Peter, Plattin, Kimmswick, and Callaway formations. In many places joints and crevices in the underlying formations are filled with the greenish sand of the Bushberg, and the surface upon which the sandstone lies is clearly one of erosion. In Boone County the Bushberg lies upon the Callaway limestone wherever the lower contact is exposed. At the locality northwest of Brown's Station the base of the sandstone is not exposed and the underlying formation has not been determined. The stratigraphic position of the cross-laminated sandstone here is not clear, but it is below the greenish sandstone and clay which occurs elsewhere in the county.

The upper part of the Bushberg is well exposed at many places in Boone County, and in all of the exposures it appears to grade conformably upward into the Chouteau limestone. This distinctive thin greenish sandstone is very persistent laterally and can be traced from central Missouri into southwestern Missouri where it lies beneath the Chattanooga shale and is called Sylamore.

Age and correlation.—As already stated the beds herein described as Bushberg were for some time called Sylamore and thought to be equivalent to the Sylamore of Arkansas. There is not yet conclusive evidence to prove this correlation wrong. More detailed study may demonstrate that this greenish sand of Boone County is continuous with the Sylamore of Arkansas. It is possible that it varies in age from place to place, but in Boone County it is restricted to the pre-Chouteau Kinderhookian and appears to be the initial deposit of the Chouteau sea. The greenish sandstone in southwestern Missouri is not only pre-Chouteau, but is also pre-Chattanooga and post-Fortune.

Topographic expression.—The Bushberg is so soft and easily eroded, and so thin that it has little effect on the formation of topographic features However, where the Callaway and Chouteau limestones are exposed in steep slopes or vertical bluffs, the position of the Bushberg is commonly represented by a reentrant which aids in defining the Devonian-Mississippian boundary.

CHOUTEAU FORMATION

Name.—The term Chouteau was first used by Swallow in 1855[118] for rocks exposed at Chouteau Springs, Cooper County. He de-

[118]Swallow. G. C., op. cit., pp. 98, 101, 103, 1855.

scribed it as consisting of the two distinct subdivisions lying between the "Encrinital limestone" and the "Vermicular sandstones and shales" although the "Vermicular sandstone" is not present at Chouteau Springs. His upper unit consisted of thick-bedded brownish gray, earthy, silico-magnesian limestone and was reported to be 40 to 50 feet thick. The lower unit was of compact, blue or drab, thin-bedded limestone about 20 feet thick. In the original description Swallow referred the Chouteau to the Chemung.

It is evident that the "Encrinital limestone" as identified is the unit now called Burlington. The "Vermicular" is the Hannibal of northwest Missouri and the Northview of southwest Missouri. The section Swallow[119] described as being south of Marston's bridge in bluffs of the Lamine River has been studied by Branson, and the latter was of the opinion that the "Vermicular sandstone" and the "Lithographic limestone" below it are the Northview formation and the lower Chouteau of present usage, and that they should be included in the Chouteau. Investigations by Beveridge and Clark[120] in west-central and southwestern Missouri show that facies changes in the Chouteau will account for these different interpretations.

In 1861 Meek and Worthen[121] proposed that the Chouteau be regarded as Carboniferous but this was not generally accepted, and as late as 1895 Stuart Weller, while recognizing the Carboniferous affinities of the fauna, still considered the Chouteau to be contemporaneous with the Chemung.[122]

In 1896 H. S. Williams presented rather conclusive evidence that the Chouteau should be regarded as part of the Carboniferous,[123] and Weller later agreed.[124]

Moore, in 1928,[125] applied the name Sedalia to the silico-magnesian bed of the upper part of the Chouteau, and restricted the name Chouteau to the lower limestone of Swallow's Chouteau. Moore did not know, but suspected, that the unit he called Compton in southwest Missouri was Chouteau in age. He also applied the

[119]Swallow, G. C., op. cit., 1855.

[120]Beveridge, T. R. and Clark, E. L., Personal communication, 1951.

[121]Meek, F. B. and Worthen, A. H., Remarks on the age of the Goniatite limestone at Rockford, Indiana, and its relations to the "Black Slate" of the western states: Am. Jour. Sci., vol. 32, pp. 167-177, 1861.

[122]Weller, Stuart, A circum-insular Paleozoic fauna: Jour. Geology, vol. 3, pp. 903-917, 1895.

[123]Williams, H. S., On the origin of the Chouteau fauna: Jour. Geology, vol. 4, pp. 283-290, 1896.

[124]Weller, Stuart, Correlation of the Kinderhook formations of southwestern Missouri: Jour. Geology, vol. 9, pp. 130-148, 1901.

[125]Moore, R. C., Early Mississippian formations in Missouri: Missouri Bur. Geology and Mines, vol. 21, 2d ser., pp. 61, 149-154, 1928.

name Reeds Spring to a cherty limestone which Branson[126] interpreted as the top member of the Chouteau in southwestern Missouri, but which is considered by Moore and others as being early Osagean in age.

In this report the name Chouteau is used in the unrestricted sense of Swallow.

In present usage the term Chouteau in central Missouri is applied to the limestone between the Bushberg sandstone and the Burlington limestone. In the bluffs of the Missouri River near Easley the Sedalia of Moore can be recognized, but elsewhere in the county the upper part of the Chouteau is not so distinct from the lower. The relationship between the Chouteau of central Missouri and the Compton-Northview-Pierson-Reeds Spring sequence of the southwestern part of the state is being investigated.

Distribution and thickness.—The Chouteau is widely distributed in Missouri and forms a belt of almost continuous outcrop from the northeastern to the southwestern part of the state. It extends some distance north and west of the outcrop belt beneath younger rocks, but the exact limits of its extent will not be known until more detailed subsurface work is done.

In Boone County the Chouteau is well exposed in the steep slopes of the stream valleys in the southern and southwestern part of the county. The best exposures are in the river bluffs and quarries along the M-K-T Railroad in the vicinity of Easley and Wilton. In this area it is about 60 to 68 feet thick. From the river bluffs and steep slopes in the southern part of the county the formation extends northward under cover of younger rocks but has been exposed by the combined effect of structural uplift and stream erosion in several places southwest of and northeast of Columbia.

The most extensive of these exposures are along the small creek in the SW¼ sec. 28, T. 50 N., R. 12 W., and a tributary to this creek in the NW¼ sec. 33, T. 49 N., R. 12 W. In this area the Chouteau is approximately 68 feet thick and the section is exposed from the top of the Bushberg to the bottom of the Burlington. Other smaller exposures in this area occur in the SE¼ sec. 20, SW¼ sec. 21, NE¼ sec. 29, and NW¼ sec. 28, T. 50 N., R. 12 W.

In the NW¼ of sec. 8, and the NE¼ sec. 7, T. 50 N., R. 12 W., the Chouteau is exposed in the creek under the bridge and in the small tributary valleys to Rocky Fork Creek. Very small exposures

[126]Branson, E. B., op. cit., p. 190, 1944.

were mapped by Allen[127] along the north side of Missouri Highway 124 in the SW¼SE¼NW¼ sec. 17, and in the center of the S½NE¼ sec. 18, T. 50 N., R. 12 W. Allen also indicated small exposures in the eastern portion of the NE¼NW¼ sec. 20, T. 50 N., R. 12 W.

Southwest of Columbia the Chouteau is exposed in the bed of Gans Creek upstream from the road intersection in the NW¼NW¼ sec. 7, T. 47 N., R. 12 W., and in the bed of a small creek in the NW¼-SE¼SW¼ sec. 2, T. 47 N., R. 13 W. Only the uppermost part of the formation is exposed at these localities.

Lithology.—Throughout its areal extent the Chouteau varies considerably in lithology. Limestone, dolomite, chert, siltstone, and shale occur alone and in various combinations. In the outcrop belt which extends from St. Louis County westward to Pettis County the dominant rock types are limestone and dolomite. From Pettis County southward into Arkansas there are several facies changes in the formation; thick siltstones and shales are present and permit subdividing the formation.

In southwestern Boone County the Chouteau is dominantly limestone and can be divided into two fairly distinct parts which closely resemble the divisions described by Swallow in his original description.

The upper part consists primarily of massively bedded siliceous magnesian limestone which weathers to smooth rounded ledges. The weathered surfaces vary from brown to yellowish buff, but the fresh rock varies from brownish gray to light bluish gray. This upper portion is for the most part very evenly fine-grained and earthy. In most localities numerous calcite concretions and calcite-lined vugs are present. These are as large as 5 or 6 inches in diameter. Small amounts of pyrite are present and locally there are concretionary masses of chert which is characteristically banded in light gray and white. This upper portion constitutes most of what Moore called Sedalia in 1928.

McQueen and Aid[128] made a study of the rock-wool possibilities of this upper unit, which they also called Sedalia. They sampled the unit at various places along the M-K-T lines in the Easley-Providence area of southeastern Boone County. Analyses made of

[127]Allen, W. B., Geology of the Brown's Station anticline: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1941.

[128]McQueen, H. S. and Aid, Kenneth, Rock wool resources in central Missouri: Missouri Geol. Survey and Water Resources, 59th Biennial Report of the State Geologist, App. 2, 24 pp., 1937.

these samples published by McQueen and Aid indicate the following range in distribution of the various components of the rock:

SiO_2	10.76 to 45.4	per cent
Residue	2.68 to 8.10	"
Fe_2O_3	.57 to 1.21	"
Al_2O_3	.60 to 4.07	"
$CaCO_3$	26.36 to 65.84	"
CaO	14.86 to 37.11	"
$MgCO_3$	15.21 to 29.76	"
MgO	7.27 to 14.23	"

The lower part of the Chouteau formation is characterized by thin-bedded, fine-grained, gray limestone with sub-conchoidal fracture and a hackly weathered surface. There are two widespread mottled zones in the lower part of the formation and they are of considerable value in tracing the formation areally. These zones consist of intermingled limestone and dolomite and the differential weathering of these materials cause the mottled appearance of the rock. In the quarry at the rock-wool plant at Easley, and in an abandoned quarry south of Wilton the mottled zones are well developed and exposed. The lower zone is 4 feet thick and the upper one is about 10 feet. They are about 4 feet apart in most localities.

Near the base of the Chouteau there is considerable chert which is distinctive in having a bluish color and waxy lustre. In some localities the chert is composed of alternating gray and white bands. This banded chert is peculiar to the Chouteau in this area and is not easily confused with the chert from the Ordovician or Devonian beds. It is very similar, however, to the chert of the Hampton formation in Iowa and the Reeds Spring of southwestern Missouri.

Small veinlets of calcite are present throughout the formation and minute amounts of pyrite and chalcopyrite fill small cracks and fissures in the lower part of the unit.

A measured section below the dam of the University of Missouri Game Preserve Lake in the SW¼NE¼ sec. 19, T. 46 N., R. 11 W.

	Thickness Feet	Inches
Mississippian System		
Osagean Series		
Burlington formation		
22. Limestone, white-gray to medium gray, coarse-grained portions within the beds, irregularly bedded in thin and thick beds, weathers light gray to brownish-gray, weathered surface hackly, crinoidal, calcite crinoid stems noticeable, stylolitic. . .	9	4

Mississippian System—Continued
Osagean Series
Burlington formation

	Thickness Feet	Inches
21. Covered interval.	8	4
20. Limestone, white to white-gray, fine-grained, very crinoidal, irregularly bedded, stylolitic, crinoid stems give bed coarse-grained appearance, weathers to semi-hackly surface light gray to brownish-gray.	4	5
19. Limestone, pinkish-gray to light orange-gray, coarse-grained, crinoidal, stylolitic, regularly bedded, weathers light gray to dark brownish-gray, crinoid stems more abundant than in beds below.	2	1
18. Limestone, light buff-gray to orange-gray, mediumly fine-grained, crinoidal, regularly bedded, weathers light gray to dark gray, bottom portion more sandy than top portion; where externally weathered it becomes dolomitic and sandy, becomes pinkish in color in top portion, stylolitic.	6	3
17. Limestone, light buff-gray to light orange-gray, medium-fine-grained, stylolitic, crinoidal, regularly bedded, darker in color toward top portion, crinoid stems of calcite in places, weathers light gray to dark brownish-gray.	3	6
16. Limestone, light orange-brown to dark orange-brown, fine-grained, dolomitic, porous, fossiliferous with corals and bryozoa, regularly bedded, cherty 18 inches from top, weathers to light gray to dark brownish-gray, chert in nodules 4 inches to 6 inches thick intermittently distributed, stylolitic.	3	7
15. Limestone, dark orange-brown, fine-grained but coarser than no. 14, crinoidal, crinoid stems of white calcite give beds white spotted appearance, some ferruginous stains.	3	9
14. Limestone, dark orange-brown to brownish-gray in some places, dolomitic, sandy, porous, massive, regularly bedded in one bed, stylolitic fine-grained.	3	4
13. Limestone, light gray to dark gray, bedded in two beds, stylolitic, weathers dark orange-brown to dark brownish-gray, more crystalline in bottom bed (11 inches thick), top bed 13 inches thick, separated in places from no. 14 by stylolites or by		

Mississippian System—Continued

	Thickness	
	Feet	Inches
Osagean Series		
Burlington formation		
chert lenses 1 inch to 2 inches thick, chert is white with some gray coloring.	2	0
12. Limestone, buff to light orange-gray, fine to coarse-grained, coarsely crystalline, crinoidal, stylolitic, regularly bedded in one bed.	0	10
Conformable—no evidence of unconformity visible.		
Kinderhookian Series		
Chouteau formation		
11. Limestone, light gray to dark gray, fine to coarse-grained, crinoidal, crinoid stems present where bed has coarsely crystalline appearance, stylolitic, weathers to dark buff-gray to brownish stages, varies laterally and from light gray to light buff in color.	4	1
10. Limestone, orange-brown to buffish-gray near top, silty to sandy, dolomitic, apparently non-fossiliferous, calcite in small crystals, stylolitic, thickly bedded in regular beds, weathers to dark orange-brown to dark gray, small cavities give porous appearance in portion of the beds.	4	7
9. Limestone, light olive-gray to light buff-brown to light gray, silty, slightly dolomitic, some small crystals of calcite, apparently non-fossiliferous regularly bedded, upper 30 inches thinly bedded, weathers to sandy or silty material in hackly beds, stylolitic, separated from no. 10 by stylolite, color changes laterally. ..	4	1
8. Limestone, light olive-gray to light brownish-gray, fine to medium-grained, crystalline, darker color in fine-grained portion of bed, regularly bedded in beds 8 inches to 20 inches thick, mottled appearance on both weathered and fresh surfaces, weathers medium gray to dark brownish-gray, breaks with conchoidal fracture, lithology varies laterally in beds, chert zone 2 feet from top, chert light to dark gray on interior of nodules with yellowish-buff outer portion, bedding becomes more hackly near top where weathered; ferruginous stains on weathered surface, stylolitic.	6	2

Mississippian System—Continued
Kinderhookian Series
Chouteau formation

	Thickness Feet	Inches
7. Limestone, light buff to light brownish-buff, fine-grained, crystalline, sandy or silty, large crystals of calcite 1 inch or more in diameter scattered throughout, stylolitic, regularly bedded in beds 2 inches to 13 inches thick, weathers to light yellowish-brown to light buff-gray, chert layer with nodules 3 inches to 4 inches thick five inches from top, chert like no. 5, calcite filled veins, beds become lighter in color toward top, darker around chert nodules.	3	2
6. Limestone, light olive-gray to brownish-gray with dark gray mottling in places, fine-grained, crystalline, one bed, mottled weathered surface medium gray to buff to dark brownish-gray, small crystals of calcite present.	0	11
5. Chert, whitish-gray to light gray to dark gray, nodular, mottled appearance, lining of calcite within some nodules with a limestone like no. 4 between and surrounding some nodules, this is a distinct bed.	0	5
4. Limestone, light yellow-buff to light buff-gray, dolomitic in places, very calcareous in others, stylolites between beds, sandy, large crystals of calcite present which are as much as 3 inches in diameter, apparently non-fossiliferous, regularly bedded in beds 2 inches to 6 inches thick, weathers to a brownish-gray.	3	1
3. Limestone, light buff-gray to light olive-gray, fine to medium-grained, crystalline, similar to no. 1, apparently non-fossiliferous, small crystals of calcite very scattered throughout, breaks with conchoidal fracture, some ferruginous stains present, chert nodules at bottom 2 inches to 3 inches in diameter, chert nodules are light gray to dark gray to brownish-gray, chert in 5 inch bed with a 3 inch bed above, regularly bedded in two beds.	1	4
2. Limestone, light buff to light olive-gray to dark gray, fine-grained, crystalline, not fine-grained like no. 1, very slightly crinoidal, stems of calcite, regularly bedded in 2 inch to 3 inch beds, some		

Mississippian System—Continued Kinderhookian Series Chouteau formation	Thickness Feet	 Inches
scattered crystals of calcite present, some fresh and weathered pyrite, weathered surface brownish-gray.	1	2
1. Limestone, light gray to light olive-gray, dark gray in minute places, fine-grained, finely crystalline, breaks with conchoidal fracture, slightly crinoidal, stems of calcite, darker gray places have pyrite present, regularly bedded in one bed, some ferruginous staining, weathers to brownish-gray.	0	2
Total	76	10

The section of Chouteau described below is exposed in an old abandoned quarry 50 feet north of the road in the SW¼NW¼ sec. 23, T. 46 N., R. 13 W. The lower brown beds of the Burlington overlie zone 9 of the Chouteau, but are poorly exposed on the gentle hillside that extends upward from the top of the quarry.

	Thickness Feet	 Inches
Chouteau group (Undifferentiated)		
9. Dolomite, tan, silty, earthy, in massive beds. The dolomite gets increasingly sandy toward the obscured contact with the Burlington.	15	
8. Dolomite, tan to light gray, earthy, silty, massive beds, with some fine-grained, calcareous, tan, sandstone lenses.	10	5
7. Upper mottled zone of dolomite and limestone, light and dark gray mottling.	3	2
6. Limestone, one bed of light gray, clastic, silt-sized, with irregular dark blue to black very thin shale partings running through it.		8
5. Limestone, one massive bed, argillaceous, finely crystalline, olive gray, with scattered masses of calcite crystals.	3	1
4. Limestone, brown, sub-lithographic, with small masses of calcite crystals. Weathers to a finely mottled surface of light tan and light gray.	2	
3. Lower mottled zone. Two beds of dark and light gray mottled limestone and dolomite, with several lenses of chalcedonic, light to dark gray and brown chert, each about 3 inches thick.	2	3

	Thickness Feet	Inches
Mississippian System—Continued		
Osagean Series		
Chouteau group (Undifferentiated)		
2. Limestone, massive 20 inch beds, olive gray, finely crystalline, with smooth conchoidal fractured surfaces. Several very thin calcareous shale partings running discontinuously throughout. Top bedding plane is very irregular and undulating. . .	5	7
1. Limestone and dolomite, dark and light gray, finely mottled, both very dense and the entire zone having an uneven and rounded weathered surface, mottling is much finer than above mottled zones. . . .	1	1
Total	43	3

Paleontology.—Although much of the Chouteau is unfossiliferous, it is productive of fossils in some localities. Branson and several of his students at the University of Missouri worked for several years on the Chouteau fauna, and the results have been summarized by Branson in his publications.[129] In the use of these faunal summaries one must remember that Branson included the Fern Glen, Reeds Spring, Pierson, and all of the St. Joe in the Chouteau. The Chouteau has yielded a large variety of forms in Boone County and the most fossiliferous exposures are those northwest of Brown's Station and in the bluffs of the Missouri River along M-K-T Railroad near Easley and Providence.

Stratigraphic relations.—The Chouteau of Boone County,and the area to the northeast, is essentially a lithologic unit composed of limestone and dolomite lying between the Bushberg sandstone and the Burlington limestone. The contact with the Bushberg appears to be conformable as there is a gradual transition from the sandstone through shaly limestone upward to relatively pure limestone. However, Branson[130] reports that in some places (not in Boone County) the Burlington rests directly on the Bushberg, and Weller[131] indicates a time lapse between the Bushberg and the Chouteau.

The contact with the Burlington appears to be gradational in some places, and the plane of contact is difficult to define. This relation is well exposed in the spillway for the dam on the University Game Preserve and is described in the measured section made at this locality and presented above.

[129]Branson, E. B., op. cit., 1938, 1944.

[130]Branson, E. B., op. cit., p. 178, 1944.

[131]Weller, J. M., Correlation of the Mississippian formations of North America: Geol. Soc. Amer. Bull., vol. 59, pp. 91-196, 1948.

At several places in the southern part of the county the fine-grained dolomitic part of the upper Chouteau grades upward into yellowish brown siltstone, and the siltstone grades into the yellowish brown crinoidal limestone of the Burlington. The contact is not sharp.

In other places, as in the bluffs near Easley and Providence, there is a rather abrupt change in lithology between the fine-grained dolomitic upper part of the Chouteau and the crinoidal lower Burlington. However, there is no evidence of any erosion surface between them.

It is true that the thickness of the Chouteau is variable and that the Chouteau is entirely missing in some places in Callaway County. It seems possible that deposition may have been continuous from Chouteau to Burlington in some localities and not in others. Strata and fossils of Fern Glen and early Osage age have not been recognized in this area.

The Sedalia, named by Moore in 1928,[132] is regarded by many as a valid formation. However, in Boone County it seems best to regard it as a member of the Chouteau with which it seems closely allied.

Age and correlation.—When Swallow first used the term Chouteau he referred the beds to the Chemung. However, it is now generally agreed that the Chouteau is Kinderhookian in age. Weller places the Chouteau in his Easley group of the Kinderhookian Series, but this group term has not been generally accepted in Missouri. Branson objected to the continued usage of the term Kinderhook and referred the Chouteau to the "Lower Mississippian". The Northview and Compton of southwestern and west-central Missouri are Chouteau in age. The Fern Glen, Reeds Spring, Pierson, and the upper portion of the St. Joe are not Chouteau as believed by Branson; they are younger than the Chouteau of central Missouri.[133]

The Chouteau is generally regarded as being equivalent to the Hampton formation of Iowa, the Coldwater shale of Michigan, and the lower part of the Cuyahoga group of Ohio, Kentucky, and Tennessee.

Topographic expression.—Where the Chouteau is exposed in the southern part of the county it characteristically forms steep bluffs and prominent ledges. Caves and sinkholes are not very common in the Chouteau of this area.

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[132]Moore, R. C., op. cit., p. 61, 1928.

[133]Beveridge, T. R. and Clark, E. L., personal communication, July, 1951.

OSAGEAN SERIES

BURLINGTON FORMATION

Name.—At least part of the beds now included in the Burlington were recognized as a stratigraphic unit as early as 1852 by Owen.[134] He referred to them as the "Encrinital group of Burlington". He also recognized an "Encrinital group of Hannibal" which was immediately under the "Encrinital group of Burlington". The term "Encrinital" was used without a place-name designation by Swallow, Shumard, Meek, and Broadhead, and by many other early workers.

In 1857, James Hall[135] used the term Burlington limestone to include both "encrinital groups" of Owen and he described the Burlington as overlying the "Chemung" and underlying the Keokuk limestone. This definition has been followed generally except that Weller (1926)[136] regarded the Fern Glen formation as belonging to the lower part of the Burlington. The upper portion of the Sedalia of Moore[137] is thought to include beds which are early Burlington.

Distribution and thickness.—The Burlington is very widespread in Missouri. It crops out over a wide belt from southwestern Missouri around the northern and eastern sides of the Ozark Uplift to the northeastern part of the state and extends on into Iowa and Illinois. North and west of the outcrop area it extends some distance beneath younger formations.

Within Boone County the Burlington is probably the most widely exposed indurated formation. The major area of outcrop in this county extends from the bluffs and steep slopes of the Missouri and its tributaries northward beyond U. S. Highway 40. In addition, the Burlington is exposed in a relatively wide belt trending N. 15° W., across the northeastern part of the county. In this area it has been brought up by the folding of the Brown's Station anticline. Along this anticline the entire thickness of the Burlington may be observed between the Chouteau and the Cherokee and it is approximately 170 feet.

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[134] Owen, D. D., op. cit., pp. 90-140, 1852.

[135] Hall, James, Observations upon the Carboniferous limestones of the Mississippi Valley: Am. Assoc. Adv. Sci., Proc., vol. 10, pp. 53-57, 1857.

[136] Weller, Stuart, Faunal zones in the standard Mississippian section: Jour. Geology, vol. 34, pp. 320-335, 1926.

[137] Moore, R. C., op. cit., pp. 61, 149-154, 1928.

In the bluffs along the Missouri River, and along Cedar Creek the entire succession is not well exposed, but the preserved portion of it is from 50 to 55 feet thick.

Lithology.—Characteristically the Burlington is a fairly coarse-grained, clastic limestone composed largely of crinoid fragments. In many places it is made up almost entirely of crinoid columnals and plates cemented with calcium carbonate. On a freshly broken surface the cleavage surfaces give the limestone the appearance of a crystalline rock. On weathered surfaces the crinoid remains, as well as other fossil fragments, stand in relief. Small grains and crystals of pyrite, limonite, sphalerite, and galena are sparsely scattered throughout the formation.

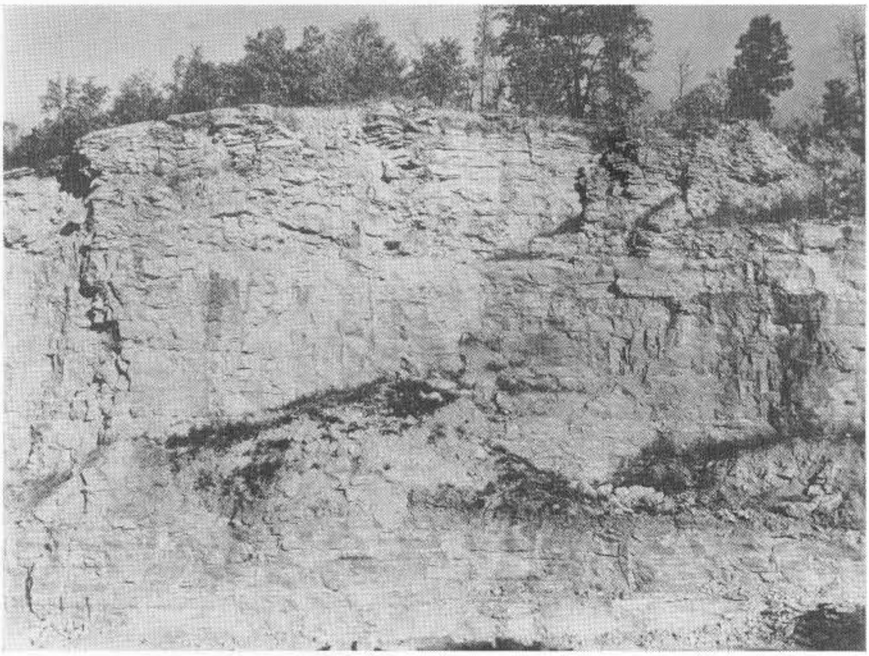
In most areas the Burlington can be subdivided into an upper and lower portion. The upper part is commonly white to light gray or buff, and the lower portion is characteristically buff to reddish-brown. This latter unit is commonly referred to as the "Lower Brown Beds of the Burlington".

In addition to the distinctive crinoidal characteristic of the Burlington, it is also characterized by an abundance of chert. This chert is more abundant in the upper portion. It is present in zones of nodules along the bedding planes or parallel to the bedding, as discontinuous lenses, and in some places, as continuous beds extending as much as several hundred feet laterally (plate VII A). The nodules are round to oblate or ovoid, and range in size from half an inch to three feet or more in length. The chert is sharply set off from the surrounding limestone. The outer portions of many of the nodules and lenses are altered to tripoli, probably by ground-water action. This alteration is for the most part superficial, and the inside of the nodules is generally composed of fresh, dense chert. Some of the nodules enclose vugs lined with quartz crystals. Some enclose well preserved fossils. In such cases the fossils are remarkable for the excellent preservation of delicate structures. A few of the nodules are banded in gray to brown bands, but most of them are very uniform in color throughout.

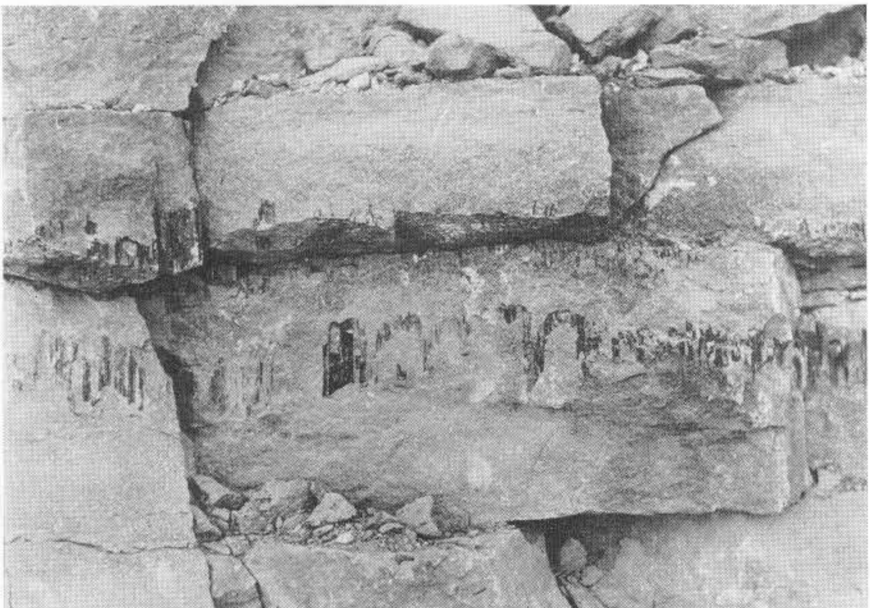
Much chert has been left after the weathering and removal of the more soluble limestone, and the creek beds throughout the Burlington outcrop area are abundantly supplied with chert fragments which have become reddish-brown through weathering.

Except for the color differences between the lower and upper part of the Burlington and for the distribution of the chert, the Bur-

Plate VII



A. Burlington limestone in quarry at south end of College Avenue, Columbia, Missouri. NW¼ sec. 19, T. 48 N., R. 12 W. Light horizontal streaks are chert layers.



B. Close-up of Burlington limestone showing bedding characteristics and stylolites.

lington is essentially homogeneous throughout. Consequently it is difficult to determine the relative position, within the formation, of an isolated exposure.

Within Boone County the Burlington contains a rather distinctive bed of medium to dark gray, porous, finely crystalline, dolomitic limestone. At the Garrett quarry north of Columbia in the SW¼-NE¼NW¼ sec. 2, T. 48 N., R. 13 W., this bed is about 1½ feet thick, and it is at least this thick at the Dodd quarry near Riggs, SW¼SE¼-SE¼ sec. 27, T. 51 N., R. 13 W. The lower part of this bed is not exposed in the Dodd quarry, but at Garrett's quarry about 8½ feet of Burlington lies below it, and the bottom of the Burlington is not exposed; hence, the exact stratigraphic position of the dolomitic layer is not known. However, several logs of wells in the county indicate a dolomitic layer 20 to 40 feet above the base of the Burlington which may be this bed.

The Burlington is commonly in massive beds, some beds being as much as 10 feet thick. This massive bedding is particularly common in the lower portion of the formation (plate VII B).

The following section was measured along the railroad track approximately one mile northwest of Wilton at the southern edge of sec. 22, T. 46 N., R. 13 W.

	Thickness Feet	Thickness Inches
Mississippian System		
Osagean Series		
Burlington formation		
15. Lithology same as no. 14. This interval is partly covered.	15	
14. Limestone, medium brown, coarsely crystalline, very crinoidal, massively bedded, with interbedded zones of dark gray fine-grained limestone. Drusy calcite common. Weathers to a very rough surface.	12	
13. Limestone, orange brown, medium-grained, silty, with limonite specks throughout. These 6 to 8 inch beds are interbedded with dolomitic limestone as in no. 12. Occasional lenses and nodules of chert. Some drusy calcite.	10	
12. Limestone, light brown, medium-crystalline, slightly silty, dolomitic, thin-bedded; very sparsely crinoidal. A 3 inch bed of chert at the top.	1	

	Thickness Feet	Inches
Mississippian System—Continued		
Osagean Series		
Burlington formation		
11. Limestone, light brown to tan, coarsely crystalline, thin-bedded, highly weathered, crinoidal. Twelve inch bed of chert nodules 8 inches above the base of the unit. Chert is white to brown, dull to vitreous, and partly tripolitic.	8	
10. Siltstone, tan to medium brown, fine-grained, dolomitic. Very argillaceous. . . .	7	
Total	53	
Kinderhookian Series		
Chouteau formation		
9. Dolomite, light gray to light brown, fine-grained, slightly silty. Massive-bedded and more sandy toward the top.	10	
8. Limestone, tan, fine-grained, silty, dolomitic. Weathers to light brown, smooth surface.	3	6
7. Limestone, dark brown, fine-grained to dense, brittle, compact, very thin-bedded, with many calcite masses.	2	6
6. Same lithology as no. 5. Calcite masses abundant. Some chert.	2	
5. Limestone, tan to light gray, fine-grained, very silty, with iron oxide staining. Zones are dolomitic.	3	
4. Limestone, light brown, dense to fine-grained, has sharp fracture. Weathers to light gray and smooth surface.	3	
3. Limestone, olive gray, fine-grained, silty, fossiliferous, thin bedded. Weathers to light tan and light gray, hackly, and uneven surface. Numerous light tan shale partings between beds. A few massive 8 inch beds of dolomite the same color as the limestone. A little light gray to light brown, porcelaneous to waxy chert near the top. This zone is covered by soil and debris over a large part of its extent.	20	6
2. Limestone, brown to gray, finely crystalline to dense, massive-bedded, weathers to medium gray. Eighteen to 20 inch beds. Part of this interval is covered.	14	6
1. Limestone, light to dark bluish gray, mottled, fine-grained, massive and thin-bedded, weathers to a very dark gray surface.	10	
Total	68	6

Branson (1944)[138] described the Burlington exposed in the old quarry at the southern end of Edgewood Avenue in Columbia (SE¼-NE¼SE¼ sec. 14, T. 48 N., R. 13 W.) as follows, (word order slightly modified):

Surface of Burlington covered with loess and weathered Burlington.

	Thickness Feet	Inches
7. Limestone appearing lighter in color than no. 5 and much more uniform in color. Weathered surface of limestone light brownish gray made up mainly of protruding crinoid stems. Weathering has produced alternating reentrants one inch to two inches apart, the surface fluted with horizontal ridges about one inch wide and one inch to a half inch high. Chert rare, a few small nodules and short stringers.	30	
6. Chert and limestone alternating about twice as much limestone as chert. Beds rather regular. Limestone beds one foot to one and one-half feet thick. Chert beds one foot to an inch or less in thickness. The top bed of chert runs through the 1,000-foot length of quarry as a good marker and no beds of chert are present above.	18	
5. Limestone, coarsely crystalline, bluish gray on dry unweathered surfaces with thin coating of wood brown on weathered surfaces. Scattered chert nodules, small and rare. Fossils are abundant but do not show on freshly broken surfaces.	18	
4. Chert nodules, a discontinuous bed, in some places absent for a hundred feet or more, in other places as persistent as no. 2. Maximum thickness about ten inches.		8
3. Limestone like no. 1 but with a discontinuous chert nodule bed three feet from the bottom. Limestone beds six inches to one foot thick.	4	
2. Chert, white to bluish gray in middle of nodules. An almost continuous bed of nodules ranging up to one foot in thickness.	1	

[138]Branson, E. B., op. cit., p. 227, 1944.

	Thickness Feet	Inches
1. Limestone, coarsely crystalline, mostly pale, mousegray with horizontal streaks of brown along stylolites. Lighter colored on weathered surfaces. Chert nodules, mainly in the beds, most of them less than a foot in length and less than four inches thick. One nodule 30 inches long by four inches thick. Stylolites four inches to a foot apart, fossils abundant but not apparent on unweathered surfaces.	10	
Total	81	8

Bottom of quarry about stream level.

A measured section made along the road down Devils Backbone in the SE¼SE¼ sec. 34, T. 47 N., R. 11 W., and in the NE¼NW¼ sec. 3, T. 46 N., R. 11 W., is as follows:

	Thickness Feet	Inches
Mississippian System		
Osagean Series		
Burlington formation		
9. Soil covered.	1	0
8. Limestone, light buff-gray to light brown, fine to coarsely-crystalline, fossiliferous, crinoid stems and brachiopods abundant, regularly bedded in beds 6 inches or more thick, stylolitic, chert nodules and lenses 6 inches more or less in diameter scattered throughout, crinoid stems of calcite, weathers light to dark gray.	8	0
7. Limestone, light buff-white to buff, fine to coarsely-crystalline, regularly bedded in beds 6 inches or more thick, chert scattered throughout, stylolitic, crinoidal, weathers light gray to dark gray, becomes light in lower 1 foot and more regular.	6	6
6. Limestone, white to light whitish-gray, finely-crystalline in places to coarsely-crystalline in others, regularly bedded, chert nodules and lenses in thin beds, stylolitic, crinoidal, fossiliferous, abundant fresh and weathered pyrite which stains beds, beds 3 inches or more thick, lithology changes from finely-crystalline to coarsely-crystalline at different elevations and changes in color to light buff, weathers light gray to dark gray.	23	8

	Thickness Feet	Thickness Inches
Mississippian System—Continued		
Osagean Series		
Burlington formation		
5. Limestone, light gray to medium gray, dense to medium-grained, regularly bedded in thick and thin beds 3 inches or more in dense phases, some scattered chert in nodules and lenses, stylolitic, weathers light gray to dark gray.	6	3
4. Limestone, white to light whitish-gray, finely crystalline in places to coarsely-crystalline in others, regularly bedded in beds 2 inches or more thick, stylolitic, crinoidal, fossiliferous, thick chert beds in lower 10 feet as much as 1 foot in thickness, light yellowish-gray color in some places, weathers light gray to dark gray. .	28	11
3. Limestone, light gray to pinkish-gray to purplish-gray to buff-brown in others, coarsely-crystalline, regularly bedded in beds 4 inches to 2 feet in thickness, chert nodules and lenses scattered throughout, crinoidal with crinoid stems giving rock white spotted appearance, beds become light brown about 5 feet below purplish-gray colored zone which divides these beds from above, stylolites more prominent in lower beds, weathers to light brown to dark gray.	31	4
2. Limestone, light tan to orange brown, sandy to silty, stylolitic, crinoidal with stems giving a white spotted appearance to rock, massively bedded, with few bedding planes, weathers buffish-brown to brownish-gray.	15	6
Unconformity (?)		
Kinderhookian Series		
Chouteau formation		
1. Limestone, light brown to orange-brown, massively bedded in thick beds, some crinoid stems but few compared with no. 2 above, brachiopods fairly common, stylolitic, weathers to dark orange-brown to brownish-gray. Base of no. 1 is covered by flood plain of Cedar Creek.	27	8
Total	148	10

Paleontology.—The abundant and well preserved fossils of the Burlington have made it the object of much paleontological research ever since the early days of geological investigation in the mid-continent area.

Owen and Shumard studied the Burlington as early as 1852,[139] and they were followed by Hall in 1859,[140] Swallow in 1860,[141] Meek and Worthen (1860-1869),[142, 143, 144, 145, 146] Worthen in 1882,[147] S. A. Miller in 1891,[148] and Miller and Gurley (1890-1896).[149, 150, 151, 152, 153] In addition, Rowley published several papers on the Burlington fauna between 1890 and 1902,[154, 155, 156, 157, 158, 159] and Wachsmuth and Springer published their classic crinoid studies from 1879 to

[139]Owen, D. D. and Shumard, B. F., Description of seven new species of crinoids from the sub-Carboniferous limestone of Iowa and Illinois: Phila. Acad. Nat. Sci. Jour., vol. 2, pp. 89-94, 1852.

[140]Hall, James, Contributions to the paleontology of Iowa: Iowa Geol. Survey, vol. 1, pt. 2, sup., 94 pp., 1859.

[141]Swallow, G. C., Description of new fossils from the Carboniferous and Devonian rocks of Missouri: St. Louis Acad. Sci., Trans., vol. 1, pp. 635-660, 1860.

[142]Meek, F. B. and Worthen, A. H., Descriptions of new species of Crinoidea and Echinodermata from the Carboniferous rocks of Illinois and other western states: Phila. Acad. Nat. Sci., Proc. 1860, pp. 379-397, 1860.

[143]Meek, F. B. and Worthen, A. H., Remarks on the age of the goniatite limestone at Rockford, Indiana, and its relations to the "Black Slate" of the western states, and to some of the succeeding rocks above the latter: Am Jour. Sci., vol. 32, pp. 167-177, 1861.

[144]Meek, F. B. and Worthen, A. H., Descriptions of new species of Crinoidea, etc. from Paleozoic rocks of Illinois and some of the adjoining states: Phila. Acad. Nat. Sci., Proc. 1865, pp. 143-155, 1865.

[145]Meek, F. B. and Worthen, A. H., Remarks on some types of Carboniferous Crinoidea with descriptions of new genera and species of the same and one of Echinoidea: Phila. Acad. Nat. Sci., Proc. 1868, pp. 335-359, 1868.

[146]Meek, F. B. and Worthen, A. H., Descriptions of new Carboniferous fossils from the western states: Phila. Acad. Sci., Proc. 1869, pp. 137-172, 1869.

[147]Worthen, A. H., Description of 54 new species of crinoids from the lower Carboniferous limestones and coal measures of Illinois and Iowa: Illinois State Mus. Nat. Hist., Bull. 1, 1882.

[148]Miller, S. A., Description of lower Carboniferous crinoids from Missouri: Missouri Geol. Survey Bull., vol. 4, 40 pp., 5 pls., 1891.

[149]Miller, S. A. and Gurley, W. F. E., Description of some new genera and species of Echinodermata from Coal Measures and sub-Carboniferous rocks of Indiana, Missouri, and Iowa: Cincinnati Soc. Nat. Hist. Jour., vol. 13, pp. 3-25, 1890.

[150]Miller, S. A. and Gurley, W. F. E., Description of some new genera and species of Echinodermata from Coal Measures and sub-Carboniferous rocks of Indiana, Missouri, and Iowa: Pamphlet, 59 pp., 10 pls., Cincinnati, Ohio, 1890.

[151]Miller, S. A. and Gurley, W. F. E., Description of some new species of invertebrates from Paleozoic rocks of Illinois and adjacent states: Illinois State Mus. Nat. Hist. Bull., vol. 3, 81 pp., 8 pls., 1893.

[152]Miller, S. A. and Gurley, W. F. E., Description of new and remarkable fossils (crinoids) from Paleozoic rocks of Mississippi Valley: Illinois State Mus. Nat. Hist. Bull., vol. 8, 66 pp., 5 pls., 1896.

[153]Miller, S. A. and Gurley, W. F. E., New species of crinoids from Illinois and other states: Illinois State Mus. Nat. Hist. Bull., vol. 9, 66 pp., 1896.

[154]Rowley, R. R., Some observations on natural casts of crinoids and blastoids from the Burlington limestone: Am. Geologist, vol. 6, pp. 66-67, 1890.

[155]Rowley, R. R., Description of some new species of crinoids, blastoids, and brachiopods from the Devonian and sub-Carboniferous rocks of Missouri: Am. Geologist, vol. 12, pp. 303-309, 1893.

[156]Rowley, R. R., New species of crinoids, blastoids, and cystoids from Missouri: Am. Geologist, vol. 25, pp. 65-75, 1900.

[157]Rowley, R. R., Description of new species of fossils from the Devonian and sub-Carboniferous rocks of Missouri: Am. Geologist, vol. 25, pp. 261-273, 1900.

[158]Rowley, R. R., Notes on the fauna of the Burlington limestone at Louisiana, Missouri: Am. Geologist, vol. 26, pp. 245-251, 1900.

[159]Rowley, R. R., New species of fossils from the sub-Carboniferous rocks of northeastern Missouri: Am. Geologist, vol. 29, pp. 303-310, 1900.

1895.[160, 161, 162] Weller's brachiopod monograph[163] has remained a classic among Mississippian paleontologic references.

In 1922 Van Tuyl[164] discussed the Burlington of Iowa, and Laudon,[165] in 1937, defined crinoid zones in the Burlington of northern Missouri and Iowa. A. K. Miller[166] described a few Burlington goniatites and Cline[167] has studied the blastoids.

Branson (1944)[168] presented a summary faunal list of the Burlington of Missouri which includes 70 species of crinoids, 40 species of blastoids, and 84 species of brachiopods. In addition, there are many other species of the minor groups.

The most characteristic feature of the Burlington is the abundance of crinoid fragments, but there are also several characteristically abundant brachiopods. Among these are *Spirifer grimesi* Hall, *Athyris lamellosa* L'Eveille, and *Spirifer rowleyi* Weller.

Age and correlation.—In central Missouri the Burlington is the oldest formation of the Osagean Series. In eastern Missouri and western Illinois the Fern Glen formation is regarded by Weller (1948)[169] to be the basal formation of the Osage.

Branson (1944)[170] proposed a three-fold (lower, middle, upper) subdivision of the Mississippian System and if this proposal were followed, the Burlington would be called lower Middle Mississippian in age.

The Burlington of central Missouri is continuous with the Burlington of Iowa and Illinois and grades laterally into a portion of the "Boone" of Arkansas and Oklahoma. It is probably equivalent to the upper part of the Madison of the Rocky Mountains, the Fort Payne chert of Alabama and Georgia, part of the Cuyahoga forma-

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[160] Wachsmuth, Charles and Springer, F., Revision of the Palaeocrinoidea: Phila. Acad. Nat. Sci., Proc. 1879, pp. 226-378; 1881, pp. 177-414; 1885, pp. 225-364; 1886, pp. 64-226.

[161] Wachsmuth, Charles and Springer, F., New species of crinoids and blastoids: Ill. Geol. Survey, 1st ser., vol. 8, pp. 155-208, 1890.

[162] Wachsmuth, Charles and Springer, F., The North American Crinoidea Camerata: Harvard Coll. Museum Comp. Zoology Memoirs, vols. 1 and 2, 837 pp., 83 pls., 1895.

[163] Weller, Stuart, The Mississippian Brachiopoda of the Mississippi Valley basin: Illinois Geol. Survey, Mon. 1, 598 pp., 1914.

[164] Van Tuyl, Francis Maurice, The stratigraphy of the Mississippian formations of Iowa: Iowa Geol. Survey, vol. 30, pp. 118-142, 1922.

[165] Laudon, L. R., Stratigraphy of northern extension of Burlington limestone in Missouri and Iowa: Am. Assoc. Petrol. Geologist Bull., vol. 21, no. 9, pp. 1158-1167, 1937.

[166] Miller, A. K., Burlington goniatites: Am. Jour. Sci., 5th ser., vol. 30, no. 179, pp. 432-437, 1935.

[167] Cline, L. M., Blastoids of the Osage group, Mississippian, pt. 1, the Genus *Schizoblastus*: Jour. Paleontology, vol. 10, pp. 260-281, 1936: pt. 2, the Genus *Cryptoblastus*: Jour. Paleontology, vol. 11, pp. 634-649, 1937.

[168] Branson, E. B., op. cit., pp. 229-234, 1944.

[169] Weller, J. M., op. cit., p. 120, 1948.

[170] Branson, E. B., op. cit., p. 184, 1944.

tion of Kentucky and Tennessee, and to part of the Price formation of Virginia.

Stratigraphic relations.—In Boone County the Burlington rests on Chouteau limestone. In some localities the contact appears to be conformable and gradation is gradually upward without sharp lithologic break. This is particularly evident in the southeastern part of the county and is well shown in the wall of the spillway of the dam in SW¼NE¼ sec. 19, T. 46 N., R. 11 W.

In other localities the top of the Chouteau seems to have been eroded and the Burlington appears unconformable with the Chouteau. In fact, Peery[171] reports that along the Middle River near Fulton the Burlington lies upon a thin sandstone which in turn lies directly upon Snyder Creek shale. Also in other areas east of Boone County the Chouteau is irregular in thickness and patchy in distribution.

Along the Missouri River bluffs in southwestern Boone County the thick Chouteau exposed shows little more than a lithologic break with the Burlington. Yellowish-brown crinoidal limestone beds are parallel to the massive dolomitic limestone beds of the upper Chouteau; in a few places a very thin shale lies between them.

A bed of light brown argillaceous calcareous siltstone three feet thick, lies at the contact between the Burlington and Chouteau in southwestern Boone County. The absence of crinoid fragments suggests that this bed does not belong to the Burlington; however, it contains some sand which suggests that it may be an initial deposit of the Burlington stage of deposition. It might also be interpreted as a weathered part of the upper Chouteau.

The Burlington is the surface formation in much of Boone County, but it is unconformably overlain in a large part of the area by Pennsylvanian sandstone and conglomerate which is referred to the Cherokee. In many areas it is covered by glacial material.

Topographic expression.—The topographic expression of the Burlington limestone is diverse, and varies with the conditions under which it is exposed.

In areas where the streams have been rejuvenated and downward cutting has been relatively rapid, the limestone forms steep cliffs and overhanging ledges. These cliffs and ledges are well exemplified along Hinkson Creek south and southeast of Colmbia and

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[171] Peery, T. E., op. cit., p. 114, 1940.

along Cedar Creek in the southeastern part of the county. In localities where stream erosion has been active on both sides of a spur, narrow elongate steep-walled pinnacles are developed. These are well shown by "The Pinnacles" about five miles north of Hinton. (Se¼ sec. 12, T. 50 N., R. 13 W., plate XI B, and by the "Devil's Backbone" about two and one-half miles southeast of Englewood. (Sec. 34, T. 47 N., R. 11 W., and sec. 3, T. 46 N., R. 11 W.) Also along Cedar Creek the Burlington has been eroded so that it stands as "needles" and "chimney rocks". In some of the steep bluffs, old underground drainage channels are exposed and form caves.

Because of its purity and coarse texture, the Burlington is readily soluble by acidic ground water. Accordingly, where this formation underlies a relatively flat upland area, sinkholes and caverns are abundant and well developed. The upland area south of Columbia, particularly in sections 7, 8, 17, and 18 of T. 47 N., R. 12 W., is a region of well-developed karst topography resulting from solution of the Burlington, (plate II B). The Rock Bridge and Devil's Ice Box in this area are well-known solution phenomena. Also, the area northwest of Columbia, sections 19, 20, 29, and 30, T. 49 N., R. 13 W., contains many sinkholes. Among the best-known caves in the Burlington of this area are:

Holten's cave—near center NW¼ sec. 30, T. 49 N., R. 13 W.

Hunter's cave—NW¼ sec. 28, T. 47 N., R. 12 W.

Tumblin cave—NW¼ sec. 29, T. 47 N., R. 13 W.

Rocheport cave—SE¼ sec. 17, T. 48 N., R. 14 W. This cave has an opening about 30 feet high and 60 feet wide.

In areas where slopes underlain by Burlington have become fairly steep, the surface is strewn with chert fragments left after solution of the limestone, and the soil is commonly rocky and of poor quality.

BURLINGTON-KEOKUK?

In a few localities, the bryozoan *Archimedes* is abundant in beds which are very similar to the typical Burlington except that they are slightly more thin-bedded and carry a small amount of greenish clay material. The most important of these localities are:

1. Near the center of the SW¼ sec. 33, T. 50 N., R. 14 W.
2. Center of the SE¼ sec. 7, T. 49 N., R. 12 W.
3. NE¼NW¼ sec. 29, T. 50 N., R. 12 W.

Also, a few fragmentary specimens of *Archimedes* have been found in chert-float in the bed of South Fork near Carlisle Schhool in sec. 22, T. 48 N., R. 12 W.

If the usual custom were followed, these beds would be referred to as the Keokuk formation, and inasmuch as Condra and Elias (1944)[172] do not list any Burlington *Archimedes*, perhaps that is correct. However, there is little other evidence to suggest that these beds are not part of the Burlington limestone. The apparent absence of *Archimedes* from the Burlington may be due to the custom of referring all *Archimedes*-bearing beds to the Keokuk regardless of other evidence.

PENNSYLVANIAN SYSTEM

DESMOINESIAN SERIES

CHEROKEE GROUP

Name and definition.—Haworth and Kirk in 1894 applied the name Cherokee to Pennsylvanian strata exposed along the Neosho River, near Galena in Cherokee County, Kansas.[173] As they defined it, the Cherokee included the shales above the Galena limestone (Mississippian) and below the Oswego (Fort Scott) limestone. Marbut (1898)[174] also recognized this succession and subdivided it into lower (below base of Tebo coal) and upper (above base of Tebo coal) parts. In 1915[175] Hinds and Greene presented a very thorough discussion of the Cherokee and regarded it as a formation. They proposed that the base of the Bevier coal should be regarded as the boundary between the upper and lower parts of the formation.

In more recent literature the Cherokee has been regarded as a group[176, 177, 178] and is subdivided into formations, most of which are

[172]Condra, G. E. and Elias, M. K., Study and revision of *Archimedes*: Geol. Soc. Amer., Special Paper 53, 243 pp., 41 pls., 1944.

[173]Haworth, E. and Kirk, M. Z., The Neosho River section, Kansas Univ. Quarterly, vol. 2, pp. 105-106, 1894.

[174]Marbut, C. F., Geological description of the Calhoun sheet: Reports on areal geology, Missouri Geol. Survey, vol. 12, pt. 2, pp. 119, 121, 123, 1898.

[175]Hinds, Henry and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 13, pp. 16, 38-60, 1915.

[176]Moore, R. C., Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey, Bull. 22, pp. 55-56, 1935.

[177]Moore, R. C., Classification of Pennsylvanian rocks in Iowa, Kansas, Missouri, Nebraska, and northern Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 32, no. 11, pp. 2011-2040, 1948.

[178]Moore, R. C., Divisions of the Pennsylvanian System in Kansas: Kansas Geol. Survey, Bull. 83, pp. 37-47, 1949.

named for the associated coals.[179, 180]

McQueen defined the top of the Cherokee as the base of the Squirrel sandstone, but this boundary is not now recognized by the Missouri Geological Survey.

The Cherokee is defined [181] as extending from the base of the Pennsylvanian to the base of the Fort Scott limestone. McQueen, however, defined the top as the base of the Squirrel sandstone.

The term Cherokee has also been used for lower Cambrian slates in western North Carolina, Cambrian limestone in northwestern North Carolina, and for Mississippian limestone in southwestern Missouri and southeastern Kansas. None of these are now regarded as valid.

The Cherokee group consists mostly of shale, but there is also much sandstone and coal, and minor amounts of limestone. As many as 15 coal beds have been recognized in Kansas, but in central Missouri only four are generally developed. In the Forest City Basin the Cherokee group reaches a maximum thickness of about 700 feet, but in Boone county the thickness is only about 100 feet.

"GRAYDON" FORMATION

Introductory statement.—Lying upon the eroded surface of the Burlington limestone in much of Boone County and central Missouri is a very irregular deposit which varies from a fine-grained sandstone, through coarser sandstone containing chert fragments, to a chert conglomerate.

Whether this material constitutes a depositional feature of an encroaching sea or originated as a weather residuum on top of the Burlington limestone is uncertain. Perhaps each of these ideas may be used to explain the presence of different parts of the deposit and perhaps much of it has had a complex history involving both suggested origins. The fact that a similar deposit, which may be a continuation of the one being considered, is known upon older formations would suggest that it was at least in part a depositional feature. Bedding is evident only in the sandstone portions but suggests a depositional origin for the finer sediments.

[179]McQueen, H. S., Geology of the fire clay districts of east central Missouri: Missouri Geol. Survey and Water Resources, 2d ser., vol. 28, pp. 29-92, 1943.

[180]Branson, E. B., Geology of Missouri: Univ. Missouri Studies, vol. 19, no. 3, pp. 271-277, 1944.

[181]Greene, F. C. and Searight, W. V., Revision of the classification of the post-Cherokee beds of Missouri: Missouri Geol. Survey and Water Resources, Rept. Inv. No. 11, pp. 3, 4, 1949.

The material under consideration has often been referred to as the "Graydon" and has been regarded by some geologists as a correlative of the type Graydon formation.

Name.—The type Graydon was first discussed in print by Winslow[182] who described the section in the vicinity of Graydon Springs, Polk County Missouri. He used the term "Graydon Springs sandstone and conglomerate", and he credits the name to Dr. W. P. Jenney. Shepard[183] shortened the term to Graydon sandstone and used it to include the coarse sandstone and chert conglomerate deposits which fill channels and depressions in the pre-Cherokee and earlier land surface from central to southwestern Missouri. Subsequent writers have favored the shorter term.[184, 185, 186] McQueen[187] used the term "Graydon formation".

Distribution and thickness.—Sandstones, residual chert, and conglomerates which have been referred to the Graydon formation are widespread through north-central, west-central, and southwestern Missouri. They are particularly common in the outcrop areas of the Cherokee, but are not known to be continuous with each other or to be of the same age.

Within Boone County this formation is apparently continuous beneath all of the Cherokee and is exposed at many places. Its presence is often obscured by slumping of the overlying Cheltenham clay.

Because of its position on an eroded Burlington surface, this unit varies greatly in thickness and ranges from a few inches to as much as 50 feet. One of the thickest and best exposures in Boone County is in the W½NE¼ sec. 11, T. 49 N., R. 12 W., east of O'Rear school. The deposit at this place is in a depression in the Burlington and is about 20 feet thick.

In the southern part of the county, south of the main area of Pennsylvanian outcrop, there are many small (50 to 100 square feet) isolated exposures of fine sandstone lying upon the Burlington. Whether these are part of this formation is uncertain, but they have been referred to the Pennsylvanian.

[182]Winslow, Arthur, Lead and zinc deposits, sec. 1: Missouri Geol. Survey, vol. 6, pp. 422-425, 1894.

[183]Shepard, E. M., A report on Greene County: Reports on areal geology, Missouri Geol. Survey, vol. 12, pt. 1, pp. 126-136, 1898.

[184]Shepard, E. M., Underground waters of Missouri: U. S. Geol. Survey, Water Supply Paper 195, p. 22, 1907.

[185]Branson, E. B., op. cit., p. 37, 1941.

[186]Branson, E. B., op. cit., p. 274, 1943.

[187]McQueen, H. S., op. cit., pp. 33-38, 1943.

Lithology.—The lithology of the "Graydon" in Boone County, as elsewhere, is highly variable. In some places (e.g. center N½ sec. 22, T. 49 N., R. 14 W.) it consists of rather fine, angular to subangular quartz sand with considerable ferruginous material. In other places (e.g. SW¼ sec. 11, T. 48 N., R. 14 W.) it consists of a matrix of fine sand enclosing iron-stained angular chert fragments ranging up to several inches in dimension. In still other places this deposit consists almost entirely of angular chert fragments of pebble and cobble size (e.g. SE¼SW¼SW¼ sec. 9, T. 48 N., R. 12 W.)

At no place is the bedding consistent or well defined. The chert fragments are clearly derived from the Burlington limestone.

Paleontology.—The "Graydon" contains no fossils that are diagnostic of its age. The fossils that have been found in it are poorly preserved plant fragments and the chert contains casts and molds of many Burlington fossils.

Age and correlation.—As nearly as can be determined the formation is post-Burlington and pre-Cheltenham in age. Although it is usually referred to the Cherokee time, it seems likely that much of it may actually be late Mississippian or early Pennsylvanian in age. In any case, it represents weathering and deposition during the interval between Burlington deposition and the accumulation of the Cheltenham clay. It is also likely that it was not all deposited contemporaneously and its age may vary considerably from place to place.

McQueen[188] suggests a "tentative correlation with an arkosic sandstone in the Cherokee group of the Forest City Basin . . ." He also suggests a possible correlation with the Saline Creek cave conglomerate of Morgan and Miller counties. Greene and Pond[189] have proposed a correlation of the type Graydon with the Clear Creek sandstone in Vernon, Barton, Cedar, and St. Clair counties.

Stratigraphic relations.—Within its known areal extent this formation rests upon rocks ranging in age from Ordovician to middle Mississippian, and it marks one of the great Paleozoic unconformities of Missouri.

In Boone County it lies upon the Burlington limestone, and the chert in it was derived from the Burlington. It is overlain by the Cheltenham clay of Cherokee age.

[188]McQueen, H. S., op. cit., p. 38, 1943.

[189]Greene, F. C. and Pond, W. F., The geology of Vernon County, Missouri: Missouri Bureau of Geology and Mines, vol. 19, 2d ser., p. 44, 1926.

As previously stated this deposit in Boone County may not be a direct continuation with the type Graydon, but it occupies a position between the Burlington and the Cherokee. In some areas, however, more than one sandstone occurs in this same interval, and whether this one is truly Graydon has not been determined. It is, however, lithologically similar to the type section.

CHELTENHAM FORMATION

Name.—Wheeler in 1896[190] first applied the name Cheltenham to a fire clay near the base of the Cherokee in the Cheltenham district of the southern portion of the city of St. Louis. McQueen in 1929[191] suggested that a similar fire clay in east-central Missouri might be equivalent to the Cheltenham, and this was later confirmed by Allen.[192]

McQueen (1943)[193] defined the Cheltenham as a formation and designated its stratigraphic position between the Graydon and Loutre formations. He defined the Cheltenham as consisting of three divisions, lower, middle, and upper and described them in great detail.

Distribution and thickness.—The Cheltenham is fairly widespread in central and east-central Missouri, but it is not present as a continuous deposit of clay over any large area. Throughout its areal extent it is variable in thickness. The lower member ranges from 0 to 30 feet in thickness, the middle one from 6 to 20 feet, and the upper from 0 to 15 feet.

In Boone Couny the Cheltenham is present at most exposures of the lower part of the Pennsylvanian and may be a nearly continuous deposit of variable thickness over much of the northern part of the county. It is well exposed in the pit of the brick plant just east of Columbia. Other good exposures are in the NW¼NW¼NW¼ sec. 4, T. 49 N., R. 12 W., SW¼SW¼ sec. 34, T. 49 N., R. 11 W., S½NW¼-NE¼ sec. 12, T. 49 N., R. 12 W., NE¼NE¼SW¼ sec. 36, T. 50 N., R. 13 W., NE¼SW¼NW¼ sec. 33, T. 50 N., R. 13 W.

At most exposures in this county the thickness is between 20 and 25 feet.

[190] Wheeler, H. A., Clay Deposits: Missouri Geol. Survey, vol. 11, p. 247, 1896.

[191] McQueen, H. S., Geologic relations of diaspore and flint fire clays of Missouri: American Ceramic Society Journal, vol. 12, p. 690, 1929.

[192] Allen, V. T., The Cheltenham clay of Missouri: Missouri Geol. Survey and Water Resources, 59th Bienn. Rept., App. V, pp. 7-17, 1937.

[193] McQueen, H. S., op. cit., pp. 39-71, 1943.

Lithology.—The lithology and mineralogy of the Cheltenham was discussed in great detail by Allen in 1937,[194] and by McQueen in 1943.[195] The formation consists dominantly of clay. The lower member is black to dark brown or gray, semi-flint to flint fire clay. The middle member consists of light gray, fairly hard semi-plastic clay, which is locally mottled with purple and red at the top and base. The upper unit is light to dark gray plastic clay with a silica content of more than 50 per cent. Most of the Boone County Cheltenham seems to belong to the middle member.

Danser (1950)[196] made some mineralogic observations on samples from north-central Boone County and concluded that the clay was composed mainly of kaolinite with a minor amount of illite. The accessory minerals are quartz, selenite, calcite, pyrite, and marcasite. In many exposures selenite crystals are abundant and well developed, and in some places the pyrite and marcasite are so abundant that the clay is without value for ceramic use.

Paleontology.—No fossils have been recovered from the Cheltenham except for isolated fragments of fossilized wood. In the NW¼NW¼NW¼ sec. 23, T. 48 N., R. 12 W., a three-foot length of what appears to be a fossil tree trunk, about twelve inches in diameter, was found in vertical position in the Cheltenham clay, with the upper end truncated by the "Tebo" coal.

Stratigraphic relations.—In most of the exposures of this formation in Boone County the Cheltenham lies directly upon the "Graydon". In a few places, however, the clay and the chert fragments are so intermixed that it is difficult to determine whether the material should be regarded as clayey "Graydon" or whether it is Cheltenham clay mixed directly with residual Burlington chert.

The subdivisions established by McQueen in 1943 are difficult to recognize in most of the county. He regarded the clay at the brick plant just east of Columbia as his upper unit. The flint clay exposed two miles east of Columbia, SE¼SW¼ sec. 17, T. 48 N., R. 12 W., he regarded as the westernmost extent of his lower member of the Cheltenham.

At the brick plant, and at two other localities in sec. 1, T. 49 N., R. 13 W., (SW¼SW¼ and SE¼NW¼) the Cheltenham is overlain by the Loutre limestone and clay. In some localities, however, it is

[194]Allen, V. T., op. cit., pp. 11-23, 1937.

[195]McQueen, H. S., op. cit., pp. 40-70, 1943.

[196]Danser, J. W., Geology of T. 50 N., R. 13 W., Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1950.

overlain by the "Tebo" formation. A good exposure of the latter relation is along the south bank of the south fork of Grindstone Creek in the NW¼NW¼NW¼ sec. 23, T. 48 N., R.12 W.

Age and correlation.—The Cheltenham formation, like the Graydon, is usually referred to the Cherokee. However, it seems possible that it may represent a very long period of time. As pointed out by McQueen in 1943, the early Pennsylvanian geologic history of central Missouri is undoubtedly very complex and the Cheltenham is probably the result of long periods of weathering and erosion.

The succession between the "Tebo" coal and the Burlington limestone, which in this county is occupied by the "Graydon", Cheltenham, and Loutre formation, is represented in Kansas by several cyclothems.

LOUTRE FORMATION

Name.—In some areas the interval between the Cheltenham and the "Tebo" formations is occupied by clay and nodular limestone to which McQueen[197] applied the name Loutre formation. This name was used because these beds are well exposed along the Loutre River and Little Loutre Creek in Audrain, Callaway, and Montgomery counties. The type section defined by McQueen was in a pit of the Laclede-Christy Clay Products Company, on the east side of Little Loutre Creek valley, SE¼NE¼ sec. 9, T. 49 N., R. 6 W.

Distribution and thickness.—Part of the formation is present in almost all exposures where the Cheltenham-"Tebo" portion of the column is exposed. It varies in thickness, ranging from a few inches to as much as 25 feet. Some of the best exposures in Boone County are in the pit of the brick plant east of Columbia, in the SE¼NW¼ sec. 1, T. 49 N., R. 13 W., and in the NW¼NE¼ sec. 7, T. 51 N., R. 13 W.

Lithology.—The Loutre formation consists mostly of clay, but in many localities a limestone is present in the lower part.

The clay is characteristically green or greenish gray and varies from a soft plastic to hard semi-plastic character. The lower and upper parts of the clay succession are commonly high in iron and alkali and hence are not satisfactory for ceramic use. The middle part of the clay section, that is commonly on top of the limestone, is

[197]McQueen, H. S., op. cit., p. 71, 1943.

in some places suitable for refractory purposes. Most of the clay contains limestone nodules. (For analyses of the Loutre clay see McQueen, 1943, pages 74, 75). In several places this clay contains many well-formed selenite crystals; this is particularly true in the road cut about a quarter of a mile west of Rucker.

The limestone associated with the clay is commonly in a bed 2 to 3 feet thick, but in some outcrops it is represented only by a zone of limestone boulders or nodules. Where present as a bed, it is hard and dense, and is usually mottled in various shades of gray through dark brown. This limestone has a distinctive weathered surface which is very uneven and "knobby". Good exposures of the limestone occur in the pit at the brick plant east of Columbia and in the bed of Hinkson Creek just above the bridge in the NW¼ sec. 27, T. 49 N., R. 12 W.

The following section is exposed on the left bank of an east branch of Hinkson Creek in the N½NE¼ sec. 12, T. 49 N., R. 12 W.

	Thickness Feet	Inches
Pennsylvanian System		
Desmoinesian Series		
Cherokee group		
"Tebo" formation		
5. Unconformably overlies the Loutre		
Loutre formation		
4. Clay-shale, variegated, light blue-gray to buff orange. Highly iron-stained weathering zone in upper foot. Few calcareous nodules.	1	3
3. Limestone, blue-black, nodular, conglomerate and pyritic. Weathers to balls and nodules to form a rubble. Ironstone concretions throughout.	1	
2. Clay, calcareous, reddish-brown.		1½
1. Clay, silty, bright green, alkaline.		½
Total	2	5

Paleontology.—Fossils are rare and poorly preserved in the Loutre limestone. Fragmentary remains of small brachiopods, gastropods, and fusilinids have been found, but the fauna has not been carefully studied.

Stratigraphic relations.—The Loutre formation lies upon the Cheltenham and in most places where the contact is visible it seems to be one of unconformity. In many places the lower clay of the

Loutre lies in depressions in the top of the Cheltenham. The Loutre is overlain unconformably by the "Tebo" formation.

Age and correlation.—It is difficult to make a precise age assignment for the Loutre or to make exact correlations. It's time equivalents would be the beds deposited in the later part of "pre-Tebo time" which is presumably Cherokee.

Beds of uncertain age associated with the Loutre.—An isolated exposure in a small valley on the Dometrorch Farm in the SE¼-SW¼ sec. 3, T. 48 N., R. 14 W., reveals a pre-"Tebo" section that is unlike any other known in this area.

The "Tebo" coal is in its normal position below the Ardmore limestones and both have been well exposed in a small strip mine. A short distance downstream from the stripping operation the section below the Tebo is as follows:

	Thickness Feet	Thickness Inches
Pennsylvanian System		
Desmoinesian Series		
Cherokee group		
"Tebo" formation		
12. "Tebo" coal.		
11. Clay, oxidized to reddish orange; probably is the weathered underclay of the coal.	2	
10. Limestone and clay, limestone is nodular, mixed with and embedded in gray clay with yellow mottling. Weathered surface with clay removed gives appearance of bed of nodular limestone.	2	8
9. Clay-shale, dark brown to gray, iron stained.		4
8. Coal smut, lensing and poorly developed.		½ to 2
7. Clay-shale, dark brown to gray, iron-stained.		4
6. Limestone, nodular, sparingly fossiliferous. Nodules are yellowish gray to buff on weathered surface. Very finely crystalline and reddish brown on fresh surface. Zone of ironstone concretions at the base.	2	8
5. Shale, clayey, dark brown to greenish, thin layer of carbonaceous material at top and bottom.		3
4. Clay, light to dark gray, waxy surface, yellow to orange stain.	5	6
3. Shale, black, carbonaceous, coal-like but more slabby		7

	Thickness	
Pennsylvanian System—Continued	Feet	Inches
"Tebo" formation		
2. Coal, impure but hard and glassy.		4½
1. Clay, dark to medium gray, hard, waxy, contains plant fragments. The bottom of the lowest clay bed is not exposed but about 40 feet downstream there is a small exposure of limestone that closely resembles the Loutre.	2	
Total	17	10½

About one-quarter mile downstream from the last mentioned limestone exposure the Burlington limestone is exposed in the bed of the creek, but there are no other beds exposed in this area.

The significance of this section is not easily determined because it is isolated and not traceable into other sections. The presence of three "coal horizons", beds 2, 5, and 8, seem to indicate that at least three cycles of deposition are represented between the "Tebo" coal and the lowermost limestone. There is no similar evidence elsewhere in the county.

Dr. W. V. Searight examined the section and suggested that beds 2, 5, and 8 were possibly the equivalents of the Weir-Pittsburgh, "Pilot", and Scammon coals respectively. If this be true, this section records deposition which elsewhere in the county is represented only by the Loutre clay. The differences between this section and those of the remainder of the county suggest that this area perhaps had a different depositional history, and at least records geologic time not represented by deposition elsewhere in the county.

"TEBO" FORMATION

Name.—The term Tebo was first used by Marbut (1898)[198] for a coal exposed on Tebo Creek in Henry County, Missouri. The term was applied only to the coal until 1943 when McQueen proposed that it be raised to formational rank and include the underclay and the "roof slate" associated with the coal. Although the Tebo coal of the type locality in Henry County is not the first coal bed below the Ardmore limestone, McQueen applied the name to the first coal bed below the Ardmore in Boone and Callaway counties.

The Cherokee group is being currently revised by the Missouri Geological Survey after considerable study of the succession in

[198]Marbut, C. F., op. cit., p. 36, 1898.

western Missouri. The Tebo is regarded by the Survey as a valid term, but there is little possibility that the coal to which the name "Tebo" has been applied in Henry County is the same as that to which the name has been applied in northern Missouri and in Boone County. Until relations between western and northern areas have been established, and in order to avoid repeated revisions, the name "Tebo" in Boone County is used in the same sense as that of McQueen[199] but with quotations to indicate that its use is not in accord with that of Henry County.[200]

Distribution and thickness.—This formation is present over a fairly large area in central and western Missouri. It is variable in thickness but averages about five feet.

In Boone County this formation is widespread in the area north of U. S. Highway 40 with a few extensions south of the road in the vicinity of and east of Columbia. Some of the best exposures are: SE¼SE¼SW¼ sec. 7, T. 50 N., R. 13 W.; NE¼NE¼SW¼ sec. 18, T. 50 N., R. 13 W.; SE¼SE¼SE¼ sec. 27, T. 50 N., R. 13 W.; NE¼SW¼NW¼ sec. 26, T. 50 N., R. 13 W.; N½NE¼ sec. 12, T. 49 N., R. 12 W.; SE¼-SE¼SE¼ sec. 11, T. 49 N., R. 13 W.; NW¼NW¼NE¼ sec. 7, T. 51 N., R. 13 W.; SE¼SW¼ sec. 3, T. 48 N., R. 14 W.; NW¼NW¼NW¼ sec. 23 T. 48 N., R. 12 W.; SE¼SW¼SW¼ sec. 29, T. 49 N., R. 12 W.

Lithology.—In McQueen's definition of the "Tebo" formation he designated three members, an underclay, a coal, and a black "roof slate". All of these units are well represented in Boone County and have the characteristics described by him.

The fresh underclay is dark to light gray, but in weathered exposures it is yellowish or bluish-gray. It is fairly hard and breaks with a conchoidal fracture. On weathered exposures the clay commonly contains much selenite and melanterite. This clay ranges from 15 inches to 3 feet in thickness.

The coal varies greatly in thickness, in some places being represented only by a smut, and in others by a coal as much as three feet thick. In places where the thickness is greater than a few inches, the coal is usually hard and brittle with a bright lustre. In most exposures the coal contains a considerable amount of iron sulphide and selenite, and melanterite develops on weathered surfaces.

In the SE¼SW¼ sec. 3, T. 48 N., R. 14 W., the "Tebo" coal is 18

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[199]McQueen, H. S., op. cit., pp. 78-79, 1943.

[200]Searight, W. V., Personal communication, May 1, 1951.

to 20 inches thick and is being mined for local consumption. At the other exposures the coal is not thick enough for commercial production.

The upper member of the "Tebo" formation consists mostly of slaty, hard, fissile black shale which weathers into thin plates. This shale characteristically contains many flat discoidal phosphatic concretions, and in a few localities there are large pyritiferous concretions. In some places the portion of the shale immediately over the coal is soft and crumbly and contains many specimens of *Marginifera muricatina* Dunbar and Condra.

Paleontology.—The shale above the "Tebo" coal is fossiliferous in many localities. The most abundant species found is *Marginifera muricatina* Dunbar and Condra. In some places the large pyritiferous concretions yield partially pyritized cephalopods. At the locality on Bear Creek in the SE¼SW¼SW¼ sec. 29, T. 49 N., R. 12 W., these concretions yield *Metacoceras, Mooreoceras,* and *Gonioloboceras.*

Bailey[201] described the microfauna of the Cherokee and lists several foraminifers, ostracodes, and conodonts from the shale above the "Tebo" coal.

Stratigraphic relations.—The "Tebo" formation lies unconformably upon the Loutre and is in turn overlain by the Ardmore formation.

McQueen[202] suggested that the "Tebo" coal might be the correlative of the lower Ardmore coal of north-central Missouri. The Croweberg coal of Kansas occupies a similar stratigraphic position, but it is regarded by the Missouri Geological Survey as distinct from the "Tebo".[203] Correlation with the Mineral coal of Kansas appears to be more probable.[204]

ARDMORE FORMATION

Name.—In 1893 Gordon[205] described an "irregular, marly and concretionary limestone underlying the Bevier coal . . ." and called it the Ardmore limestone for its good exposures near Ardmore in

[201]Bailey, W. F., Micropaleontology and stratigraphy of the Lower Pennsylvanian of central Missouri: Jour. Paleontology, vol. 9, pp. 483-502, 1935.

[202]McQueen, H. S., op. cit., 1943.

[203]Searight, W. V., Personal communication, May 1, 1951.

[204]Searight, W. V., Idem., 1951.

[205]Gordon, C. H., A report on the Bevier sheet: Reports on areal geology, Missouri Geol. Survey, vol. 9, p. 20, 1896.

Macon County, Missouri. Cline[206] re-defined the term to apply to all the limestones and intervening shales between the "lower Ardmore coal" (Tebo) and the top of the Ardmore as previously defined. McQueen in 1943[207] used the term in a formational sense to include these same beds. Because of its widespread areal distribution and its prominence in the Cherokee section, it is important as a stratigraphic marker.

Distribution and thickness.—This formation is one of the most persistent of the Cherokee group. It is widespread in central and western Missouri and extends into Iowa and Kansas. It is widespread in Boone County and is exposed almost everywhere that the Bevier coal has been mined or exposed. Among the best exposures are the following: Along Nelson Creek, a tributary to Hinkson Creek, in the SW¼SE¼NE¼ sec. 27, T. 49 N., R. 12 W.; in a small stream east of U. S. Highway 63, one-half mile south of Hinton, near the east edge of sec. 11, T. 49 N., R. 13 W.; in the bed of an east branch to Hinkson Creek, N½NE¼ sec. 12, T. 49 N., R. 12 W.; in small creek draining Hughes strip mine, NW¼SE¼ sec. 12, T. 50 N., R. 14 W.; Dometrorch Farm, SE¼SW¼ sec. 3, T. 48 N., R. 14 W.; in Bear Creek, NE¼NE¼NE¼ sec. 30, T. 49 N., R. 12 W.; NE¼NW¼SW¼ sec. 7, T. 50 N., R. 13 W.; SE¼SE¼SW¼ sec. 7, T. 50 N., R. 13 W.; SE¼SW¼NW¼ sec. 26, T. 50 N., R. 13 W.

New road cuts along U. S. Highway 40 west of Columbia have exposed the middle portion of the Ardmore formation just east of the center of the north edge of sec. 3, T. 49 N., R. 14 W.

Throughout its areal extent the Ardmore ranges in thickness from a few inches to more than 26 feet. In Boone County it averages 14 to 16 feet.

Lithology.—The Ardmore formation consists of limestones with interbedded shales. The number of limestones varies from place to place and in some localities there are as many as five. Throughout most of Boone County there are four limestones separated by shales.

The lowermost of these four limestones is in most places a single bed of very hard finely crystalline dark gray to black limestone which averages about 12 inches in thickness. It is only sparingly

[206]Cline, L. M., Traverse of Upper Des Moines and Lower Missouri Series from Jackson County, Missouri to Appanoose County, Iowa: Am. Assoc. Petrol. Geologists Bull., vol. 25, pp. 53-54, 1942.

[207]McQueen, H. S., op. cit., pp. 83-89, 1943.

fossiliferous. At the Dometrorch Farm this bed is jointed into large rhomboidal blocks, and thus closely resembles the Houx limestone which characteristically shows this rhomboidal block development. In a few localities this lower bed contains large masses of marcasite.

The second limestone in most places is dark brown on fresh surfaces but weathers to light tan or gray. It is dense, finely crystalline, and fossiliferous. The bedding is wavy and uneven. This limestone averages about three feet in thickness.

The third limestone is the least persistent member of the formation and varies from place to place. In some places it is a fairly well defined bed of brownish gray limestone, in others it is a very nodular bed of brown limestone, and in still other places this member is represented only by a zone of calcareous nodules in shale.

The top limestone is a very distinctive bed of light to dark brown hard nodular limestone. On a weathered surface this limestone has a pronounced "lumpy-bumpy" surface and is light yellow to light gray. The lower part of the bed is commonly very fossiliferous and yields many fine specimens of *Neospirifer cameratus* Morton.

The first, second, and top limestones of the Ardmore in this area are the most persistent ones of the formation. The variation in the number of limestones present is due to variation within the interval between the second and top limestone. The beds of this interval vary from calcareous nodules in shale to one or more well-defined limestone beds.

The shales of the Ardmore vary somewhat from place to place. The shale above the first limestone varies in thickness from as little as 20 inches to as much as five feet. It varies in color from medium gray to black, and is iron stained on weathered surfaces. In a few places the upper few inches is very soft, thin-bedded, and very fossiliferous.

The shale above the second limestone is, for the most part, a soft clay-shale mottled light and dark gray and bearing an abundance of *Mesolobus mesolobus* (Norwood and Pratten) in many exposures.

Where the third limestone is well developed the shale over it is greenish gray, sandy and silty, and very calcareous. Where this limestone is not well developed this shale lies above the softer clay-shale and a shale containing limestone nodules lies between them.

Typical sections of the Ardmore are the following:

Section exposed in bank of small creek near Hughes strip mine northeast of Harrisburg. NW¼SE¼ sec. 12, T. 50 N., R. 14 W.

	Thickness Feet	Inches
Pennsylvanian System		
Desmoinesian Series		
Cherokee group		
Bevier formation		
11. Bevier coal.		
10. Covered interval, probably underclay.	3	
Ardmore formation		
9. Limestone, very nodular, dark to light brown, weathers to light yellow and gray.	3	
8. Shale, greenish gray, sandy, silty, uneven lamination with many calcareous nodules.	2	
7. Limestone, dark greenish gray.		7
6. Clay-shale, soft, mottled light and dark gray.		15
5. Limestone, dark brown, dense, fossiliferous. Bedding very wavy and uneven. Weathers to light yellowish gray.	3	
4. Clay-shale, soft, light gray, very thinly laminated, fossiliferous.		6
3. Shale, dark to medium gray with black carbonaceous films on bedding planes. Slightly iron-stained on weathered surface.	5	
2. Limestone, dark gray to black, dense, crinoidal, wavy bedding.		11
1. "Tebo" formation. Black fissile shale.	2	4
Total	21	7

Section in the bed of an east branch of Hinkson Creek N½NE¼ sec. 12, T. 49 N., R. 12 W.

	Thickness Feet	Inches
Pennsylvanian System		
Desmoinesian Series		
Cherokee group		
8. Covered interval. Glacial debris to top of hill.	40	
Ardmore formation		
7. Limestone, dense, hard, knobby, blue-gray, fossiliferous. Resistant to weathering and forms prominent bench.	1	
6. Covered interval.	3	
5. Limestone, dense, hard, brownish-gray, single bed.		10
4. Clay-shale, blue-gray, iron stained, contains many *Mesolobus*. Forms re-entrant beneath overhanging limestone.	1	4

3. Limestone, slabby, bedding nonpersistent, very fossiliferous. Weathered surface very slabby.	1	2
2. Shale, blue-gray with nodules of blue-black limestone. Bed weathers to semi-plastic clay. *Dictyoclostus* and *Juresania* abundant.	1	3
1. Limestone, hard, knobby, blue-black. Very fossiliferous. In two beds, upper one about 12 inches thick. Lower bed next to contact with "Tebo" coal; contains massive marcasite.	1	4
Total	9	11

Paleontology.—The limestones and shales of the Ardmore are locally very fossiliferous. In Boone County they yield abundantly *Mesolobus mesolobus* (Norwood and Pratten), *Neospirifer cameratus* Morton, *Composita subtilita* Shepard, *Derbya crassa* Meek and Hayden, *Dictyoclostus* spp., and *Juresania* spp. Other forms are present but are less abundant. One large colony of *Chaetetes milleporaceous* Edwards and Haime was taken from the top bed of the Ardmore north of Harrisburg, SE¼ sec. 36, T. 51 N., R. 14 W. This is the only occurrence of this species known in the Ardmore.

The microfossils of this formation were reported by Bailey in 1935.[208] Johnson studied the fusulinids of the Pennsylvanian of Boone County and reported only *Wedekindellina* from the Ardmore.[209] More recently Orlansky[210] reports two varieties of a species of *Fusulina*, as yet unnamed, in the Ardmore of Boone County. The species and varieties are not known elsewhere. *Hemigordius* cf. *regularis* Plummer is also present in the Ardmore of Boone County.[211]

Stratigraphic relations.—The Ardmore formation lies upon the "Tebo" formation without any sharp break or evidence of unconformity. Within Boone County it appears that these formations may be part of the same cycle of deposition. The Ardmore is overlain by the underclay of the Bevier formation and the uneven character of the upper surface of the topmost limestone suggests that the relationship is unconformable.

[208]Bailey, W. F., op. cit., 1935.

[209]Johnson, C. H., Lower Pennsylvanian fusulinids of Boone County, Missouri: Unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1939.

[210]Orlansky, Ralph, A stratigraphic study of fusulinid Foraminifera in the Cherokee group (Pennsylvanian) of western Missouri and Kansas: Unpublished Master's thesis, School of Mines and Metallurgy of the Univ. of Missouri, Rolla, Missouri, pp. 26, 71, 72, 1951.

[211]Orlansky, Ralph, op. cit., pp. 26, 74-77, 1951.

Age and correlation.—The Ardmore has been traced westward into eastern and southeastern Kansas[212] and northward into Iowa.[213] It has been identified with the Verdigris limestone of Oklahoma and has been correlated with the Oak Grove limestone of Illinois and the Hamden limestone of Ohio.[214]

"BEVIER" FORMATION

Name.—Gordon[215] applied the name Bevier to a coal of commercial importance being mined near Bevier, Macon County, and in other areas in central and western Missouri. McQueen (1943)[216] used the term as a formation name and included in it the underclay, the coal, and the black shale or "roof slate" above the coal.

Evidence indicates that the Bevier coal includes two cyclic successions represented in the type area, and in Boone County by two benches of coal separated by a clay or sandstone parting. The name Bevier as originally applied to the coal is useful and should be retained. The nomenclature of the rocks including the two benches of the Bevier is being revised and the name as a formational designation will be restricted by the Missouri Geological Survey.[217] In this report the formation as defined by McQueen is retained but designated as "Bevier".

Distribution and thickness.—The "Bevier formation" is widespread in central and western Missouri and continues into Kansas and Iowa. In some areas the coal is thick enough to mine on a commercial scale. In the north Missouri area it is the thickest minable coal bed.

In Boone County the "Bevier formation" is present along and north of U. S. Highway 40 in the eastern part of the county and extends northwestward across the county south of the Brown's Station anticline. Throughout this area the formation is six to seven feet thick and has been the basis of a mining industry at Lindbergh, Columbia, Brown's Station, Pratherville, Butler, Harrisburg, and Rucker. It does not extend south of U. S. Highway 40 west of Columbia.

[212] Abernathy, G. E., The Cherokee group of southeastern Kansas: Kansas Geol. Soc., Guidebook 11th Ann. Field Conference, pp. 18-23, figs. 5, 6, 1937.

[213] Cline, L. M., op. cit., p. 35, 1941.

[214] Moore, R. C., et al., Correlation of Pennsylvania formations of North America: Geol. Soc. America, Bull., vol. 55, pp. 657-706, 1944.

[215] Gordon, C. H., op. cit., p. 20, 1896.

[216] McQueen, H. S., op. cit., p. 89, 1943.

[217] Searight, W. V., Personal communication, May 1, 1952.

Lithology.—The lowermost member of the "Bevier formation" consists of dark gray, hard, plastic clay ranging from 14 to 36 inches in thickness.

The coal member, averaging about 40 inches in thickness, consists for the most part of a good bituminous coal. In most exposures there is a one inch clay parting which divides the coal into two benches about eight inches from the bottom of the coal. Locally there are small concentrations of pyrite and marcasite, and in some places small fissures are filled with selenite. In weathered exposures the coal is soft and crumbly and somewhat iron stained.

The top member of the formation is, in most places, composed of a dark gray to black fairly soft carbonaceous shale which is variable in thickness but ranges up to three feet. In some places this shale is fossiliferous. Where this soft dark shale is not present the coal is overlain by unfossiliferous sandy yellow to brown shale which seems to be a part of the Lagonda. Whether the black shale was removed by erosion or never deposited is not known. In portions of the Hughes strip mine northeast of Harrisburg the coal is immediately overlain by glacial till.

Paleontology.—Complete study of the flora or fauna of this formation has not been made. This shale above the coal in Boone County has yielded *Echinoconchus semipunctatus* Shepard, *Dictyoclostus americanus* Dunbar and Condra, *Pseudorthoceras knoxense* McChesney, *Mooreoceras* sp. and *Metacoceras* sp. Fragmental remains of pelecypods and gastropods are also present.

Bailey[218] reported the presence of plant spores in the coal and black shale. Root impressions are very common in the underclay of the coal.

Stratigraphic relations.—The "Bevier formation" lies upon the upper limestone of the Ardmore and is overlain by the Lagonda.

Age and correlation.—The coal of this formation is widespread in Missouri, Kansas, and Iowa. Its exact equivalent in Illinois is not known, but Wanless[219] has suggested that it is probably equivalent to the Linton (No. IV) coal of Illinois and Indiana.

[218] Bailey, W. F., op. cit., 1935.

[219] Wanless, H. R., Pennsylvanian correlations in the Eastern Interior and Appalachian coal fields: Geol. Soc. America, Special Paper 17, p. 77, 1939.

LAGONDA FORMATION

Name.—The term "Lagonda Sandstones and Shales" was used by Gordon in 1893 to designate the "arenaceous deposit, varying from 18 to 50 feet in thickness, overlying the Bevier Coal and constituting the uppermost division of the Lower Coal Measures"[220] The name was derived from Lagonda post office, Chariton County, near which this stratigraphic unit is well developed.

McQueen[221] used the term in a formational sense to include the shales between the Bevier coal and the "Squirrel" sandstone, and used the base of the "Squirrel" sandstone as the top of the Cherokee group. At the Lawrence Conference[222, 223] it was agreed to define the top of the Cherokee as the base of the Fort Scott limestone thereby placing the "Squirrel" sandstone, Breezy Hill limestone, and Mulky coal in the Cherokee. Gordon's Lower Coal Measures essentially coincided with the Cherokee, but he stated that the top of his Lagonda was near the base of the Macon City (Mulky) coal.[224] In this report, therefore, the term Lagonda is not used in the original sense as defined by Gordon but it includes beds between the Bevier coal (except the fossiliferous shales on the coal) and the top of the Cherokee (to the base of the Fort Scott). It here includes the "Squirrel" sandstone, the Mulky coal, and the Breezy Hill limestone. Revision of the classification of this portion of the succession will be necessary as the result of recent studies made by the Missouri Geological Survey.[225] The successions bearing on this revision are so remote from Boone County that discussion is beyond the scope of this report. It seems, however, that the Mulky Coal and Breezy Hill limestone should constitute a separate formation.[226]

Distribution and thickness.—The Lagonda formation is widespread in central and western Missouri and ranges from a few feet to as much as 50 feet in thickness.

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[220] Gordon, C. H., op. cit., pp. 19-20, 1896.

[221] McQueen, H. S., op. cit., p. 90, 1943.

[222] Moore, R. C., Classification of Pennsylvanian rocks in Iowa, Kansas, Missouri, Nebraska, and northern Oklahoma: Amer. Assoc. Petroleum Geologists Bull., vol. 32, pp. 2011-2040, 1948.

[223] Greene, Frank C., and Searight, W. V., Revision of the classification of the post-Cherokee Pennsylvanian beds of Missouri: Missouri Geol. Survey and Water Resources, Rept. Investigations no. 11, 22 pp., 1949.

[224] Gordon, C. H., A report on the Bevier sheet: Reports on areal geology, Missouri Geological Survey, vol. 9, pp. 16-20, 1896.

[225] Searight, W. V., Personal communication, May 1, 1951.

[226] Howe, W. B., Bluejacket sandstone of Kansas and Oklahoma: Am. Assoc. Petroleum Geologists Bull., vol. 35, pp. 2087-2093, 1951.

In Boone County the Lagonda is present in a wide belt south of the axis of the Brown's Station anticline extending from east and southeast of Columbia northwesterly across the county toward Harrisburg and Rucker. It is well exposed in the strip mines of the Bevier coal. Within the area it averages 15 to 19 feet in thickness and in sections 7, 8, and 9 of T. 50 N., R. 13 W., it reaches thicknesses of as much as 30 feet.

Lithology.—The Lagonda formation is composed predominantly of gray to yellow, sandy, and somewhat micaceous shales locally iron stained. In some localities this shale grades into a plastic gray clay. In some areas there is a sandstone member (the "Squirrel" sandstone), a coal member (the Mulky), and a limestone (the Breezy Hill). The latter two may not properly belong in this formation.

Excellent exposures of the complete formation occur on the south bank of North Fork Grindstone Creek in the SE¼SE¼ sec. 10, T. 48 N., R. 12 W., and in the S½SE¼NE¼ sec. 8, T. 50 N., R. 13 W. At the first-mentioned locality the following section is exposed:

Section exposed on the left bank of the North Fork Grindstone Creek, SE¼SE¼ sec. 10, T. 48 N., R. 12 W.

	Thickness Feet	Inches
Pennsylvanian System		
Desmoinesian Series		
Marmaton group		
Fort Scott formation		
11. Blackjack Creek limestone member.	1	4
Cherokee group		
Lagonda formation		
10. Shale, iron stained, calcareous, gray to brown.	1	2
9. Shale, medium to dark gray, non-calcareous, poorly laminated.	2	6
8. Shale, brownish gray, argillaceous and very calcareous, thinly laminated.	1	
7. Black smut. Represents Mulky coal. ...		¾
6. Clay, greenish-gray to yellow, soft, plastic, non-calcareous.	2	4
5. Clay, dark gray, non-plastic, blocky fracture. Crumbles readily.	2	3
4. Breezy Hill limestone. Zone of very calcareous clay and shale with nodules of impure limestone. Light to dark brown.	1	
3. Siltstone, massive, light to medium bluish-gray, non-calcareous.	2	6

Pennsylanian System—Continued	Thickness	
Marmaton group	Feet	Inches
2. "Squirrel" sandstone. Siltstone and sandstone with sandstone dominating. Forms ragged ledges.	4	6
1. Claystone and silty shale, medium gray, irregular fracture, with scattered reddish calcareous nodules. Weathered slopes have shaly appearance so that lamination is better than it appears on fresh surface.	1	8
Total	19	11

The shale part of this formation is highly variable. At the brick plant east of Columbia it is a soft gray clay-shale with some micaceous sandy layers. In a road cut on the east side of U. S. Highway 63 opposite the intersection with Missouri Highway 124, SW¼ sec. 12, T. 50 N., R. 13 W., the shale is very sandy and ferruginous. In the strip pits in the vicinity of Harrisburg both types of shale are found within short distances. In some areas in central Missouri fairly large proportions of the Lagonda are composed of plastic clay and these have been analyzed and described by McQueen.[227]

Danser (1950)[228] reported that in much of T. 50 N., R. 13 W., the Lagonda is divisible into two parts. The lower portion, 14 to 20 feet thick, consists of light blue-gray to light brown thin-bedded clay-shale. The upper portion, about 10 feet thick, is sandy and locally contains selenite crystals and hard brown calcareous concretions.

In some areas the entire shale section is occupied by the "Squirrel" sandstone.

"Squirrel" sandstone.—This sandstone unit was named by well drillers because its irregular character and distribution causes it to appear to jump around in the section. It is the sandstone of Gordon's Lagonda.

The occurrence of this sand is very irregular and it ranges from sandy lenses in the shale to thick massive sandstone beds which in some areas replaces the shale completely and has the appearance of a channel fill. In sec. 23, T. 49 N., R. 12 W., it lies directly upon the Ardmore limestone and replaces the Bevier coal. It is possible that some of the small lenses may be unrelated to the more massive

[227]McQueen, H. S., op. cit., p. 91, 1943.

[228]Danser, J. W., Geology of T. 50 N., R. 13 W., Boone County, Missouri: Unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1950.

beds, but in many places the thicker beds are interfingered with the shale and grade laterally into discontinuous lenses. The relation between the sandstone and shale is suggestive of rapidly shifting conditions of deposition.

The sandstone is irregular in character. Where it is thin and discontinuous it is commonly soft, micaceous, fine to medium grained, and it varies in color from yellow to gray. The more massive beds are usually hard, medium to coarse grained, reddish yellow to brown, and in most places cross laminated.

Breezy Hill limestone.—At two localities in the county rocks are exposed which seem to be representative of the Breezy Hill as named by Pierce and Courtier.[229]

At the type locality at Breezy Hill northwest of Mulberry, Kansas, it is an impure concretionary to nodular limestone ranging from 6 inches to 2 feet in thickness. It lies at the base of the Mulky underclay.

In the S½SW¼SW¼ sec. 9, T. 50 N., R. 13 W., there is a single bed of limestone which is light brown, hard, and finely crystalline. It is about 4 feet below the base of the Blackjack Creek limestone.

In the south bank of the North Fork of Grindstone Creek, in the SE¼SE¼ sec. 10, T. 48 N., R. 12 W., there is a one-foot bed of iron stained limestone nodules intermixed with calcareous clay and shale. This zone is about 4 feet below a coal smut believed to represent the Mulky coal.

At other places in the county there is a calcareous shaly zone at about the same position within the Lagonda and it perhaps represents the Breezy Hill horizon.

Paleontology.—Fossils are uncommon in the Lagonda and to date only the microfossils have been discussed in print. Bailey[230] reported microfossils as being abundant above and below a limestone which he indicates as being between the "Squirrel" sandstone and the Mulky Coal at the brick plant east of Columbia. Davies[231] described an ostracod fauna from the same limestone. If their interpretations are correct, this limestone is the Breezy Hill. However, if the limestone of this section is correlated with the Houx limestone

[229]Pierce, W. G. and Courtier, W. H., Geology and coal resources of the southeastern Kansas coal field: Kansas Geol. Survey, Bull. 24, pp. 33-35, 1937.

[230]Bailey, W. F., op. cit., 1935.

[231]Davies, J. D., Stratigraphy and ostracod distribution of the Cherokee formations of Randolph, Chariton, and Boone counties: Unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1936.

as a reference horizon as seems probable, then the limestone associated with the fossiliferous beds is the Lower Fort Scott (Blackjack Creek). In the latter case the fossils they described belong in the Marmaton group.

The first known occurrence of fossils in the Lagonda of Boone County was discovered during the course of this investigation. In the pit at the brick plant east of Columbia a gray soft clay-shale layer about four feet below the lowest reddish sandy zone was found to contain a large number of linguloid brachiopods.

Stratigraphic relations.—The Lagonda lies upon the "Bevier formation" and at least in places is overlain unconformably by the Blackjack Creek limestone, the lowest member of the Fort Scott formation.

Age and correlation.—The Lagonda is in the upper part of the Cherokee group. Although the term is not in general use outside of Missouri, similar beds occupy a similar stratigraphic position in Kansas and Iowa. In Kansas these beds are thought to comprise the upper part of the Bevier cyclothem. The Breezy Hill cyclothem, and the lower part of the Blackjack Creek cyclothem[232] may not belong to the Lagonda formation.[233]

MARMATON GROUP

General statement.—That portion of the geologic column from the base of the "Squirrel" sandstone to the top of the Desmoinesian Series has been variously classified and named by different workers in mid-continent stratigraphy.

Keyes[234] applied the name Henrietta to several limestones with interbedded shales between the Cherokee shale and the Pleasanton shale. The name was derived from the Henrietta escarpment near Henrietta, Johnson County, Missouri. Keyes' Henrietta included the Pawnee limestone at the top, the Marmaton formation in the middle, and the Fort Scott limestone at the base. This was the first use of the term Marmaton and it was used for rocks exposed on the Marmaton River in Vernon County, Missouri and Bourbon County, Kansas.

[232]Moore, R. C., Frye, J. C., Jewett, J. M., Lee, Wallace, and O'Connor, H. G., The Kansas Rock Column: Univ. Kansas Publication, State Geol. Survey, Bull. 89, 1951.

[233]Howe, W. B., op. cit., 1951.

[234]Keyes, Charles R., Stages of the Des Moines, or coal-bearing series of Kansas and southwestern Missouri and their equivalents in Iowa: Iowa Acad. Science, Proc., vol. 4, pp. 23-24, 1897.

In 1898 Haworth[235] used the term Marmaton formation to include all beds above the Cherokee shales and below the top of the Pleasanton. This definition included the Henrietta and Pleasanton and extended up to the base of the Hertha limestone. Haworth continued to use the term in this way until 1913.[236]

In 1915[237] Hinds and Greene defined the Henrietta to include the Pawnee limestone, the Labette shales (the same beds which Keyes had called Marmaton), and the Fort Scott limestone. This differed from Keyes' original definition in that the Lexington (Mystic) coal was placed in the Cherokee. The term Marmaton was therefore abandoned by Hinds and Greene. This definition of the Henrietta was generally followed until 1931 when Moore[238] dropped the name from the Kansas classification and treated its subdivisions as parts of his Okmulgee group, which was later replaced by his Marmaton and Cherokee groups.

However, as early as 1917 Moore and Haynes[239] revived the Marmaton formation to include the beds between the top of the Cherokee and the base of the Hertha and discontinued the use of Henrietta in Kansas. The subdivisions of the Henrietta were then regarded as members of the Marmaton.

In 1932, Dunbar and Condra[240] used the Marmaton as a group term and divided it into the Pleasanton shale above and Henrietta formation below. In the same year Moore, and Moore and Condra redefined and restricted the Marmaton and discarded the terms Pleasanton and Henrietta.[241]

This definition restricted the Marmaton to beds below the unconformity separating the Desmoinesian and Missouri Series (then considered to be at the base of the Hertha limestone).

In 1936 Moore[242] redefined the Marmaton to include the beds between the base of the Fort Scott limestone and the top of the Nowata shale and proposed the abandonment of the term Henrietta.

[235]Haworth, E., Stratigraphy of the Kansas Coal Measures: Kansas Univ. Geol. Survey, vol. 3, pp. 92-94, 1898.

[236]Haworth, E., Special report on well waters in Kansas: Kansas Univ. Geol. Survey, Bull. 1, p. 79, 1913.

[237]Hinds, Henry and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 13, pp. 19, 61, 1915.

[238]Moore, R. C., Kansas Geol. Society, 5th Ann. Field Conf. Guidebook, 1931.

[239]Moore, R. C. and Haynes, W. P., Oil and gas resources of Kansas: Kansas Geol. Survey, Bull. 3, p. 91, 1917.

[240]Dunbar, C. O., and Condra, G. E., Brachiopoda of the Pennsylvanian System in Nebraska: Nebraska Geol. Survey, 2d ser., Bull. 5, 1932.

[241]Moore, R. C., A reclassification of the Pennsylvanian System in the northern Mid-continent region: Kansas Geol. Society, Guidebook 6th Ann. Field Conf., pp. 79-98, 4 figs., formation chart (2d ed. by Moore and Condra on geologic section by Betty Kellett), September, 1932.

[242]Moore, R. C., Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey, Bull. 22, pp. 57-58, November 15, 1935 (issued August 31, 1936).

In the meantime the Missouri Survey continued to use the term Henrietta as it had been defined by Hinds and Greene in 1915,[243] Greene in 1933 and 1935,[244, 245] McQueen and Greene in 1938,[246] Grohskopf, Hinchey, and Greene in 1939,[247] and Clair in 1943.[248]

Such usage made the term Henrietta essentially synonymous with the Marmaton as defined by Moore in 1936.

In Iowa, Cline in 1941[249] also used the term Henrietta in a similar manner to the way it had been used in Missouri. However, Cline in 1939[250] and McQueen in 1943[251] altered the span of the term and included in it the upper beds of the Cherokee, that is, they drew the base of the Henrietta at the base of the "Squirrel" sandstone.

Jewett in 1945[252] followed Moore's 1936 definition of the Marmaton and suggested that the type section be regarded as the exposures along the Marmaton River from Uniontown to Fort Scott, Kansas.

At the Lawrence Conference[253, 254] the name Henrietta was abandoned and the Marmaton agreed upon as including the strata from the base of the Fort Scott limestone to the disconformity that marks the upper limit of the Desmoinesian series.

Within Boone County the Marmaton rocks are limited essentially to the various members of the Fort Scott formation but in one locality northwest of Brown's Station limestones are exposed which appear to be referable to the Myrick Station of the Pawnee.

FORT SCOTT FORMATION

Name.—The name Fort Scott was first used in a stratigraphic sense by Swallow in 1866[255] when he used it to designate several

[243]Hinds, Henry and Greene, F. C., op. cit., 1915.

[244]Greene, F. C., Oil and gas pools of western Missouri: Missouri Bur. Geology and Mines, 57th Bienn. Rept., App. 2, p. 16, 1933.

[245]Greene, F. C., Oil and gas developments in Missouri, 1933-1934: Missouri Geol. Survey and Water Resources, 58th Bienn. Rept., App. 3, 1935.

[246]McQueen, H. S. and Greene, F. C., The geology of northwestern Missouri: Missouri Geol. Survey and Water Resources, 2d ser., vol. 25, pp. 24-25, 1938.

[247]Grohskopf, J. G., Hinchey, N. S., and Greene, F. C., Subsurface geology of northeastern Missouri: Missouri Geol. Survey and Water Resources, 60th Bienn. Rept., App. 1, pp. 21-22, 1939.

[248]Clair, J. R., The oil and gas resources of Cass and Jackson counties, Missouri: Missouri Geol. Survey and Water Resources, 2d ser., vol. 27, p. 17, 1943.

[249]Cline, L. M., Traverse of upper Des Moines and lower Missouri series from Jackson County, Missouri, to Appanoose County, Iowa: Am. Assoc. Petroleum Geologists Bull., vol. 25, pp. 23-72, 1941.

[250]Cline, L. M., Unconformity at the base of the Pennsylvanian Henrietta group in Iowa (abstract): Geol. Soc. America Bull., vol. 50, p. 1905, 1939.

[251]McQueen, H. S., op. cit., 1943.

[252]Jewett, J. M., Stratigraphy of the Marmaton group, Pennsylvanian in Kansas: Kansas Geol. Survey, Bull. 58, 1945.

[253]Moore, R. C., op. cit., p. 2027, 1948.

[254]Greene, F. C. and Searight, W. V., op. cit., p. 5, 1949.

[255]Swallow, G. C., Preliminary report, Kansas Geol. Survey, p. 25, 1866.

beds of differing lithology in the vicinity of Fort Scott, Bourbon County, Kansas. As originally used, the name was applied to the Fort Scott marble series, the Fort Scott marble, Fort Scott coal series, and the Fort Scott limestone. Hay (1887)[256] described a series of limestones, apparently the same ones mentioned by Swallow, and called them the Fort Scott cement limestone. The "cement" beds later became known as the Lower Fort Scott limestone. Haworth and Kirk in 1894,[257] proposed the name Oswego to include all the beds mentioned by Swallow. However, the term Oswego had been preoccupied and Haworth and Bennett[258] re-established the term Fort Scott limestone.

As presently understood the Fort Scott formation consists of three members, the Blackjack Creek limestone at the bottom, the Little Osage member in the middle, and the Higginsville limestone at the top.[259, 260] Jewett in 1941[261] suggested that the type section for the Fort Scott be regarded as the exposures in a quarry in the NE¼ sec. 19, T. 25 S., R. 25 E., Bourbon County, Kansas.

Distribution and thickness.—The Fort Scott formation is widespread in central Missouri and extends westward into Kansas and northward into Iowa. Its thickness is variable but probably does not exceed 60 feet.

Within Boone County this formation is exposed in many localities north of U. S. Highway 40 to the south of the southwestern flank of the Brown's Station anticline. It extends south of U. S. Highway 40 only in the area east of Columbia. It is less widespread than the older Cherokee beds and in many localities only the lower part of the formation is present in the tops of the hills. This is particularly true in the area north of Harrisburg.

The full thickness is exposed in the W½SW¼ sec. 11, T. 50 N., R. 13 W., along the west bank of an intermittent stream which flows south-southwest into Silver Fork. Nearly complete sections may also be examined along U. S. Highway 63 near the center of section 13, T. 50 N., R. 13 W., and in the NW¼SE¼ sec. 32, T. 50 N., R. 12 W.

[256]Hay, Robert, Natural gas in eastern Kansas: Kansas State Board of Agriculture, 5th Bienn. Rept. (1885-87), pt. 2, pp. 198-208, 1887.

[257]Haworth, E. and Kirk, M. Z., The Neosho River section: Kansas Univ. Quarterly, vol. 2, pp. 105-107, 116, 1894.

[258]Haworth, E. and Bennett, John, General stratigraphy (of Kansas): Kansas Univ. Geol. Survey, vol. 9, p. 81, 1908.

[259]Moore, R. C., op. cit., p. 2025, 1948.

[260]Greene, F. C. and Searight, W. V., op. cit., pp. 5-6, 1949.

[261]Jewett, J. M., Classification of the Marmaton group, Pennsylvanian in Kansas: Kansas Geol. Survey, Bull. 38, pt. 2, pp. 303-304, 1941.

Lithology.—The Fort Scott in this area consists dominantly of limestone, but it also contains considerable shale and minor quantities of coal and sandstone. The lithology of the individual members is discussed separately.

Blackjack Creek limestone member.—This lowest member of the Fort Scott formation was known for many years as the "Lower Fort Scott", but in 1941 Cline[262] proposed the name Blackjack Creek which had been suggested by Frank C. Greene in personal communication. Cline designated as the type section the exposures along Blackjack Creek four miles southeast of Fayetteville in Johnson County, Missouri.

The Blackjack Creek limestone extends over much of central and western Missouri and into Kansas and Iowa. It varies greatly in thickness, ranging from a zone of calcareous nodules to a massive limestone more than 15 feet thick. Throughout most of Boone County it is about 4 feet thick. It is well exposed in the west bank of the creek in the NW¼NW¼ sec. 14, T. 50 N., R. 13 W. At the brick plant east of Columbia it is about a foot thick.

Where the Blackjack Creek limestone is well developed it consists of two parts. The lower consists mostly of an earthy argillaceous grayish-brown limestone. The surface weathers to a reddish-yellow. This has been called the "cement rock" layer. This part contains large brachiopods and large crinoid stems. The upper part, which is known only at two places in the county but which has been recognized elsewhere by Jewett (1945)[263] and Cline (1941),[264] is light greenish-gray, irregularly bedded, and coarsely crystalline. It contains many colonies of *Chaetetes* and because of them has been confused by some with the Higginsville limestone. Two localities where this layer is exposed are: In the north bank of a small creek in the NE¼NW¼ sec. 29, T. 50 N., R. 12 W., and in a road ditch on the west side of the road near the center of the south half of the NE¼ sec. 30, T. 50 N., R. 12 W.

Little Osage member.—In eastern Kansas and western Missouri the interval between the Blackjack Creek limestone and the Higginsville limestone has been called the Little Osage shale by Jewett.[265] The type exposure is in the NE¼SE¼ sec. 2, T. 24 S., R. 25

[262]Cline, L. M., op. cit., p. 36, 1941.
[263]Jewett, J. M., op. cit., pp. 22-23, 1945.
[264]Cline, L. M., op. cit., 1941.
[265]Jewett, J. M., op. cit., p. 306, 1941.

Plate VIII

A. Cross-laminations in the Bushberg sandstone(?) NW¼NW¼ sec. 33, T. 50 N., R. 12 W. These laminations have the appearance of dipping beds caused by structure. (Allen)

B. Weathered bed of Houx limestone showing solution work along the rhomboidal joint pattern. SW¼ sec. 27, T. 49 N., R. 12 W.

E., Bourbon County, Kansas. As presently defined this member includes the Summit coal and the Houx limestone.

In northern Missouri the Little Osage includes several units which can be readily differentiated in Boone County. These include the Summit coal bed and its caprock, the Houx limestone. The Blackwater Creek shale rests on the Houx. Sandstone in the upper part of the member appears to be of sufficient importance to merit a name and is here described under the new name Flint Hill sandstone.

Within Boone County the lower part of the member is rather uniform and consists of gray to brown, soft shale which grades upward into the underclay of the Summit coal. In most of the area the underclay is only a few inches thick and the coal is only a thin, black, sooty shale or black smut. However, in the vicinity of Harris' Mine in the NW¼ sec. 14, T. 50 N., R. 13 W., the coal is 28 inches thick and has been mined on a small commercial scale in the northwestern and south-central part of this section. This coal was named by McGee[266] in 1892.

The interval between the coal and the Houx limestone is composed of comparatively hard, black, platy, and fissile shale which contains lenticular phosphatic concretions of a few centimeters diameter. In one locality, NE¼ sec. 8, T. 50 N., R. 13 W., these shales contain large pyritiferous concretions which contain cephalopods and pelecypods.

The Houx limestone appears to be the same one named Summit by McGee in 1892.[267] The name Houx was suggested by Frank C. Greene and first published by Cline in 1941.[268] Its type locality is on the Houx Ranch, Johnson County, Missouri. This limestone is typically very hard and compact. It is known locally by farmers and miners as "blue bell-rock", so called because the fresh rock is bluish-gray and has a distinctive ring when struck with hammer or pick. It is finely crystalline, and in most places dense, massive, and fossiliferous. On a weathered surface the color is yellowish-brown to buff and the fossils stand out in relief. The fossils have not been systematically studied, but the fauna contains many common Pennsylvanian brachiopods and gastropods. Johnson (1939)[269] reported that the only fusulinid present is a small species of *Fusulina*.

[266]McGee, W J, Notes on the geology of Macon County, Missouri: St. Louis Academy of Science, Trans., vol. 5, pp. 305-336, 1892.

[267]McGee, W J, op. cit., 1892.

[268]Cline, L. M., op. cit., p. 36, 1941.

[269]Johnson, C. H., op. cit., 1939.

In some localities, as at the brick plant east of Columbia, the Houx is about 4 feet thick and has a thin, shaly parting near the middle. However, in others, as along the creek south of Missouri Highway 124, SW¼ sec. 11, T. 50 N., R. 13 W., it appears on weathered surfaces to be composed of as many as five or six layers of limestone with very thin, shaly partings.

The Houx has a well developed joint pattern which results in the formation of large rhomboidal blocks and because of this feature it has been called the "Rhomboidal limestone" in the early reports (plate VIII B). This joint pattern is well developed and exposed in the bed of the creek in the SW¼ sec. 11, T. 50 N., R. 13 W.; in the bed of Kelley Branch in the NE¼SE¼ sec. 24, T. 50 N., R. 13 W.; at the brick plant east of Columbia; and in Nelson Creek, sec. 27, T. 49 N., R. 12 W. Some other Pennsylvanian limestones, for example the lowermost Ardmore bed on the Dometrorch Farm west of Columbia, have the same feature and confusion results from the use of "Rhomboidal" as a name.

Within Boone County the Houx is the most persistent and easily recognized bed of the Fort Scott formation.

The interval above the Houx, up to the Higginsville limestone, is variable in Boone County. In most places it is occupied by soft, soapy red and green shales which appear to be similar to the Blackwater ("Backwater") Creek shale of Clair.[270] However, in sections 11 and 14, T. 50 N., R. 13 W., and extending northward into southeastern Grundy County, this interval is partially occupied by a channel-type sandstone associated with siltstone and shale.[271] This unit is well exposed in the sections mentioned near Flint Hill School and the channel-type sandstone is here designated the Flint Hill sandstone. The type section is in the W½SW¼ sec. 11, T. 50 N., R. 13 W., and has been measured as follows:

[270]Clair, J. R., op. cit., pl. I, 1943.
[271]Greene, F. C. and Searight, W. V., op. cit., p. 6, 1949.

	Thickness Feet	Inches
Pleistocene System		
11. Glacial drift, yellowish brown sandy clay with chert cobbles and boulders at the base.	0-2	
Pennsylvanian System		
Desmoinesian Series		
Marmaton group		
Fort Scott formation		
Higginsville limestone member		
10. Limestone, grayish brown, finely crystalline, hard, massive, fossiliferous, irregular bedding, appears brecciated. Contains small veinlets of calcite which are white and reddish brown. Weathers to very light gray.	3	
Little Osage member		
9. Shale, light bluish gray to light gray, thin bedded, fissile, silty, sandy, calcareous.	17	5
8. Flint Hill sandstone, gray to yellowish brown, fine to medium grained, massive, resistant, friable, calcareous. Locally contains brownish-red and purple streaks. Weathers to tan and light grayish brown.	5	8
7. Blackwater Creek shale, reddish yellow to bluish gray, soft, pliable, thin-bedded.	12	
6. Houx limestone, dark gray, finely crystalline, fossiliferous, hard, massive, tough. Weathers to tan and brown.	2	6
5. Shale, carbonaceous, black, hard, thin-bedded, fissile. Contains gray nodules of calcium phosphate.	2	7
4. Summit coal, black, hard, shiny, blocky.	2	5
3. Shale, soft, bluish gray, plastic.	4	8
Blackjack Creek limestone member		
2. Limestone, gray to dark gray, finely crystalline, hard, fossiliferous, earthy, nodular, poor bedding. Weathers to gray and light brown.	3	5
Lagonda formation		
1. Clay shale, bluish gray to gray, thin-bedded, pliable, soft.		4
Total	55	0

Higginsville limestone member.—The name Higginsville was introduced by Cline in 1941 at the suggestion of Frank C. Greene. Although the type locality has not been designated, this member is well exposed east of Higginsville in Lafayette County, Missouri.

The general distribution of this limestone is similar to the other members of the Fort Scott, but in Boone County it is much more restricted. It is the thickest limestone of the Fort Scott formation and is 4 to 10 feet in Boone County. The following are good exposures in the county: right bank of a tributary to Hinkson Creek, SW¼ sec. 7, T. 49 N., R. 11 W.; northeast corner of road intersection of Routes 63 and 124, SW¼NE¼ sec. 13, T. 50 N., R. 13 W.; road cut just south of center of sec. 32, T. 50 N., R. 12 W.; in slope southeast of house, NW¼NE¼NE¼ sec. 19, T. 50 N., R. 12 W.; along top of ridge north and south of Route 124, in the western portion of sections 11 and 14, T. 50 N., R. 13 W.; in road ditch and road bed in the NW¼SE¼ sec. 27, T. 49 N., R. 12 W.; and in small creek bed NW¼SW¼ sec. 34, T. 49 N., R. 12 W.

The Higginsville limestone is light to medium gray, commonly granular to finely crystalline. In this county in most exposures the limestone is light gray. On weathered surfaces it appears to be finely brecciated. This characteristic aids greatly in identification of this bed, and has been reported from some of the exposures in Kansas. (Jewett, 1945).[272]

The upper portion, in many places, contains numerous masses of the fossil coral *Chaetetes*. The coralla vary from 4 to 16 inches in diameter and are flattened or spheroidal in shape. They are more resistant to weathering than the enclosing matrix and stand out as nodes on weathered surfaces. For the most part the bedding of this limestone is very uneven and wavy.

Paleontology of the Fort Scott.— Most of the Fort Scott is highly fossiliferous. In addition to the common Pennsylvanian macrofossils it also contains fusulinids and other foraminifers, ostracodes, and conodonts. Branson (1944)[273] published a faunal list of the "Henrietta" and most of the forms thus listed are from the Fort Scott beds.

Davies in 1936[274] described the ostracodes, and Ellison in 1941[275] listed conodonts from the shales between the limestones. The black shale above the Summit coal contains large pyritiferous limestone concretions which have yielded *Metacoceras*, *Mooreoceras*, and *Pseudorthoceras*.

[272]Jewett, J. M., op. cit., p. 25, 1945.

[273]Branson, E. B., op. cit., pp. 298-327, 1944.

[274]Davies, J. D., op. cit., 1936.

[275]Ellison, Samuel, Revision of the Pennsylvanian conodonts: Journal Paleontology, vol. 15, pp. 105-143, 1941.

The Blackjack Creek bed characteristically contains large brachiopods and crinoid stems which are widely scattered. Where the upper part of this unit is well developed it contains many colonies of *Chaetetes*. Johnson[276] reported the occurrence of *Fusulina girtyi* (Dunbar and Condra), *F. megista* Thompson, and *F. stookeyi* Thompson.

The Houx is very fossiliferous. The fossils are prominent and abundant on weathered surfaces but difficult to remove. The fauna contains no diagnostic forms but consists mainly of the brachiopod genera *Composita, Crurithyris,* and *Phricodothyris*. *Fusulina girtyi* (Dunbar and Condra) has been reported by Johnson.[277]

The Higginsville contains large numbers of *Chaetetes* and has been called the "*Chaetetes* limestone". It can be confused with the upper part of the Blackjack Creek which also contains this coral.

Jewett[278] reported a great abundance of fusulinids in the Higginsville of Oklahoma and Kansas, but they are not abundant in Boone County. This bed also contains several of the common Marmaton brachiopods and large crinoid stems.

Stratigraphic relations.—The Fort Scott is the lowermost unit of the Marmaton group as currently defined and it overlies the shales above the Mulky coal. It is in turn overlain by the Labette formation.

Within Boone County the lower contact of the Fort Scott is well marked and clearly exposed in many localities. The upper contact is not well known. In most localities glacial drift lies immediately on the Higginsville limestone. In localities where present, the overlying Labette shale is only poorly developed.

Age and correlation.—The Pennsylvanian sub-committee of the National Research Council[279] indicates that the Fort Scott is approximately equivalent to the upper part of the Carbondale of Illinois, the Wetumka of Oklahoma, and the upper part of the Allegheny of the Appalachian area.

LABETTE FORMATION

In a few of the Higginsville limestone exposures a soft gray shale lies upon the limestone. The shale is overlain by another thin limestone which is presumably Pawnee. Although the exposures

[276]Johnson, C. H., op. cit., 1939.
[277]Johnson, C. H., op. cit., 1939.
[278]Jewett, J. M., op. cit., p. 26, 1945.
[279]Moore, R. C., et al, op. cit., 1944.

are poor and the relationships not well understood, the shale appears to represent the Labette formation.

PAWNEE FORMATION

Myrick Station limestone member.—At two localities the limestone mentioned in the preceeding paragraph is partially exposed. In the SE¼NW¼ sec. 26, T. 48 N., R. 12 W., it consists of a single bed of gray to white coarsely crystalline limestone about 2 feet thick. In the NE¼NE¼SW¼ sec. 32, T. 50 N., R. 12 W., a similar limestone appears to be about five feet above the Higginsville. It is poorly exposed in a road cut and appears to be about three to four feet thick. It is separated from the Higginsville by the soft gray shale referred to the Labette formation.

It is improbable that this limestone is a part of the Higginsville. It probably represents the Myrick Station limestone of the Pawnee formation.

POST-MYRICK STATION SANDSTONE

In the vicinity of Gilaspy School, in sections 14, 23, and 26, T. 49 N., R. 12 W., there is a sandstone overlying the steeply tilted Myrick Station limestone. It contains fragments of plant remains, but does not contain fossils of diagnostic value. In general appearance this sandstone is similar to other Pennsylvanian sandstones of the area and it is probably of Pennsylvanian age. The lithologic details of this bed are discussed in the following pages.

CHANNEL SANDSTONES

Scattered and isolated bodies of sandstone have been known for some time in Boone County, but prior to 1950 little detailed work had been done on them and there was considerable uncertainty regarding their origin. Some were referred to the "Graydon", some to the "Squirrel", and there has also been some tendency to call any and all of the sandstones channel fillings.

In 1950, Rexroad[280] investigated several of these sandstone bodies and made mechanical and mineralogical analyses which shed some light on their origin and relationships. The results of this study indicate that the sandstone of the county (exclusive of the St. Peter and the sandstones in the Callaway and the Bushberg)

[280]Rexroad, Carl B., An investigation of the Pennsylvanian channel-form sandstones of Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri Library, 1950.

can be divided into four units: 1) those which seem to be related to or to be part of the "Graydon", 2) those representing or related to the "Squirrel" sandstone, 3) the Flint Hill sandstone, and 4) the post-Myrick Station channel fillings.

The sandstones which appear to be part of the "Graydon", but not continuous with it, occur as isolated bodies lying upon weathered Burlington surfaces or within depressions in the Burlington. They are numerous in much of the area of Burlington outcrop but are mostly small, many being only a few feet in dimension. They seem to have been deposited upon a karst topography which was developed upon the Burlington in late Mississippian and early Pennsylvanian time. Although portions of this sandstone appear to be channel-like in form and portions appear to be part of a blanket deposit, it is possible that they are related to the so-called "Graydon" which lies upon the Burlington and beneath the Cheltenham.

In contrast to the other three, this sandstone is characterized by an absence of biotite and chlorite and a rarity of muscovite. It has a greater percentage of tourmaline, zircon, and staurolite than the other sands, and the grains are predominantly sub-rounded. Feldspar is rare in this sand.

The "Squirrel" sandstone appears to be a facies development within the Lagonda formation, but in a few localities the channel-like characteristics are so prominent and the contacts so completely masked, that it is difficult to be certain whether the sand exposed is actually the "Squirrel" or another channel development. In some areas the "Squirrel" is well developed as a channel-fill, in others as a blanket sand, and in still others as a sandy zone in the Lagonda shale. These various facies can be traced from one to another and it seems that the sandstone was deposited in "Lagonda time" upon an uneven surface partly in marine water and partly in the channels of streams flowing into the marine basin. In most of the areas where the channel-fill character seems apparent there is nothing over the sand with which to date it, but in the NW¼NW¼ sec. 26, T. 50 N., R. 13 W., this sand is clearly overlain by the upper part of the Lagonda shale and the sandstone body of channel-like cross-section extends downward through the Ardmore and Loutre formations into the Cheltenham clay. Petrographic studies indicate a relationship between the sandstone at the following localities: SE¼NW¼ sec. 13, NW¼NE¼ to the SE¼SW¼ sec. 23, T. 50 N., R. 13 W.; SE¼NW¼ sec. 2, T. 49 N., R. 13 W.; and from SW¼SW¼ sec. 1

into NE¼NW¼ sec. 12, T. 49 N., R. 13 W. It also seems probable that these are all part of the same sandstone as that exposed from the S½NE¼ to the NE¼NE¼ sec. 11; in the SE¼NW¼ sec. 13, T. 50 N., R. 13 W.; in the NE¼ sec. 12, T. 49 N., R. 13 W., and along the east side of the road between sections 6 and 7, T. 49 N., R. 12 W.

The "Squirrel" contrasts with the other sandstones examined in having a higher percentage of ilmenite.

The Flint Hill sandstone is known in only one locality in Boone County. It lies between the Houx and Higginsville limestones of the Fort Scott formation and grades laterally into soft clay shales. In the type area it appears to be of channel-fill character. In contrast with the other sandstones studied, it is relatively high in biotite, magnetite, and hematite, and low in tourmaline.

In two localities in the county, SE¼ sec. 14, NE¼ sec. 23, T. 49 N., R. 12 W., and N½ and SE¼ sec. 26, T. 49 N., R. 12 W., a sandstone is exposed which overlies the steeply tilted beds of a portion of the Brown's Station anticline. This sandstone has been mentioned by Allen[281] and by Taylor.[282] It contains fragments of plant remains, but does not contain any fossils of precise diagnostic value. It overlies the upturned edges of the Myrick Station limestone and is therefore post-Myrick Station in age. This sandstone contains a relative abundance of aggregates of sericite and other "schistose" particles which are not present in abundance in the other three sandstones examined.

PLEISTOCENE

Introductory statement.—Much of Boone County is covered by a heterogeneous mantle of clay, sand, and gravel deposited by one or more of the great ice sheets of the Pleistocene. This material has received very little attention other than its relation to the soils and their distribution. Kirkpatrick as early as 1891[283] noted glacial striae on some of the rocks of central Missouri and also noted the existence of copper inclusions in some of the boulders.

Tarr[284] noted that Columbia was near the southern border of the glacial area and stated that only the Kansan ice sheet reached

[281]Allen, W. B., Geology of the Brown's Station anticline: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1941.

[282]Taylor, J. R., The geology of east-central Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1950.

[283]Kirkpatrick, J. W., Boulder of copper and glacial striae in central Missouri: Science, vol. 18, pp. 344-345, 1891.

[284]Tarr, W. A., Native silver in glacial material at Columbia, Missouri: Am. Journal of Science, 4th ser., vol. 40, p. 219, 1915.

Plate IX. Map of County showing approximate area now overlain by glacial drift.

this far south. He also noted that some of the rocks in the glacially deposited material contained small amounts of the silver-bearing mineral pyrargyrite.

In 1938 Fletcher[285] attempted to show by petrographic methods the existence of two separate drift sheets in the NW¼ sec. 8, T. 49 N., R. 12 W., but his evidence is not convincing.

Holmes in 1942[286] discussed the glacial deposits of Missouri and stated that the major portion of the material in Boone County belongs to the Kansan glaciation, but he described a boulder near Gilaspy School which seems to have been affected by two glaciations and regards it as conclusive evidence that Boone County has been visited by both the Nebraskan and Kansan ice sheets.

Patterson[287] mapped the drift border in the county and made a number of measured sections. He did not find any locality where two drift sheets could be clearly distinguished.

Nature of the drift.—The glacial material deposited in Boone County varies greatly in its composition. The particles range in size from clay to coarse gravel and large boulders. For the most part it consists of a reddish yellow to brown heterogeneous mixture of clay, sand, and gravel. The color is largely due to oxidation after deposition and in a few places, such as in the Hughes Strip Mine near Harrisburg, where the drift appears to have been unaffected since deposition, it is medium to dark gray.

The coarser materials in the drift vary greatly in lithology and among them have been found fragments of white and red quartzite, diorite, basalt, granite, mica schist, porphyry, sandstone, limestone, and coal. The last three appear to be of fairly local origin, but the others appear to have come from as far north as Minnesota and southern Canada.

Extent of the drift.—It seems quite likely that the glacial deposits at one time covered almost all of Boone County and the southern edge of the ice sheets was approximately at the present position of the Missouri River. Stream erosion since the melting of the ice sheet has removed much of the drift in the county so that its present extent is more or less restricted to the less dissected upland areas and the tops of the hills and ridges.

[285]Fletcher, H. C., An interpretation and differentiation of glacial deposits by use of petrographic methods: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1938.

[286]Holmes, C. D., Nebraskan-Kansan drift boundary in Missouri: Geol. Soc. America Bull., vol. 53, pp. 1479-1490.

[287]Patterson, E. D., Geologic interpretation of the occurrence of glacial drift in Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1950.

The general outline of the drift is shown in plate IX which is a reduced modification of a map made by Patterson.[288]

In the upland area of the northeastern part of the county, that is, in the area extending from Sturgeon to Centralia, the glacial drift is thick and wells in the area have penetrated as much as 140 feet of drift overlying the bedrock. This thick drift obscures the underlying formations so that the distribution of the Pennsylvanian and Mississippian cannot be accurately determined.

Some of the localities where good exposures of the glacial drift can be seen are in sec. 34, T. 47 N., R. 12 W., southeast of Englewood; in the south-central part of sec. 12, T. 46 N., R. 12 W., on Fowler Creek; in sec. 18, T. 46 N., R. 12 W., in the University of Missouri Game Preserve; south-central part of sec. 6, T. 49 N., R. 12 W., at Rocky Fork Creek; and in sec. 18, T. 50 N., R. 13 W., in the Hughes Strip Mine, northeast of Harrisburg.

Loess.—In the western and southern parts of the county the glacial drift is mantled over large areas by a deposit of loess. This material is composed mostly of silt blown from the flood plain of the Missouri River and deposited on the upland. There is a possibility that much of it accumulated when the river was swollen with meltwater from the waning ice sheet and was laden with fine sediment. It is also likely that some of it has accumulated since the disappearance of the ice and some may still be accumulating at a very low rate.

The loess is variable in thickness. The greatest thickness, as much as 20 feet, is on the tops of the bluffs near the river. The thickness decreases gradually away from the river.

[288] Paterson, E. D., op. cit., 1950.

STRUCTURAL GEOLOGY

General statement.—In general, the geologic structure of Boone County is simple. For the most part the beds are nearly level but they have a slight regional dip from the Ozark uplift. This general trend is modified in a few places by localized folding and faulting. Most of the local structures are small and of little significance, but one, the Brown's Station anticline, is of significant magnitude. Other smaller ones will also be mentioned for the sake of completeness.

Brown's Station anticline.—This anticline was described in general terms by Hinds[289] who credits the name to Marbut. It was studied in some detail by Markham in 1919[290] and in still greater detail by Allen in 1941.[291]

This structure extends northwest-southeast across part of northern Boone County. In general it trends N. 15° W. It is prominent in the area between Rucker and Brown's Station and affects local structures southeastward into Callaway County. This fold brings to the surface beds as old as the Bushberg in the NW¼NW¼ sec. 33, T. 50 N., R. 12 W., (plate VIII A). In sections 17, 20, 28, and 29, T. 50 N., R. 12 W., the Chouteau is exposed rather widely. On the crest of the fold the Chouteau beds are essentially horizontal, but along the southwest side they dip sharply to the southwest. The Burlington is exposed in a belt two to three miles wide surrounding the Chouteau. This belt of Burlington extends northwest from near Brown's Station to the vicinity of the Pinnacles and beyond Riggs to the vicinity of Roche Perche Church south of Rucker. The south side of the structure is fairly well exposed, but the north side is largely concealed by drift. In a well in the SW¼SE¼ sec. 14, T. 51 N., R. 13 W., the drift is 140 feet thick and rests directly upon Burlington limestone. Similar conditions exist in another well near the center of sec. 13, T. 51 N., R. 13 W., under the 100 feet of drift.

One of the best exposures along the southwestern side of the

[289]Hinds, Henry, Coal deposits of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 11, p. 93, 1912.

[290]Markham, E. O., Geology of the Sturgeon quadrangle, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1919.

[291]Allen, W. B., Geology of the Brown's Station anticline: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1941.

fold is in the valley of a small creek in the north half of sec. 29, T. 50 N., R. 12 W. Where this creek crosses the road at the north edge of the section, the Chouteau beds are nearly horizontal. Downstream they dip steeply southwest. The Chouteau is overlain by the Burlington which also dips rather steeply. In the vicinity of the bridge in the north-central part of the section the Burlington strikes N. 20° W., and dips 30° to the southwest (plate X B). Downstream from the bridge the dip decreases. The lower part of the Cherokee is not well exposed, but the Lagonda shale and the Blackjack Creek limestone are exposed about one-quarter mile west of the bridge where they dip to the southwest at only 2°.

In the roadcut at the junction of U. S. Highway 63 and Missouri Highway 124, west of the Pinnacles, the Ardmore limestone, the Bevier coal, and the Lagonda shale dip steeply to the southwest.

Small exposures of the Chouteau limestone occur in the north parts of sections 17 and 20, T. 50 N., R. 12 W., at an altitude of about 860 feet which is higher than the Burlington exposures to the north and west. These Chouteau exposures probably indicate the approximate crest of the anticline. In the valley of Silver Fork in sec. 32, T. 51 N., R. 12 W., the Burlington is exposed at an altitude of about 760 feet which indicates that the northeast flank of the anticline dips to the northeast about 100 feet in 2 miles. The Burlington dips northeastward under the drift so that the details of the structure are concealed.

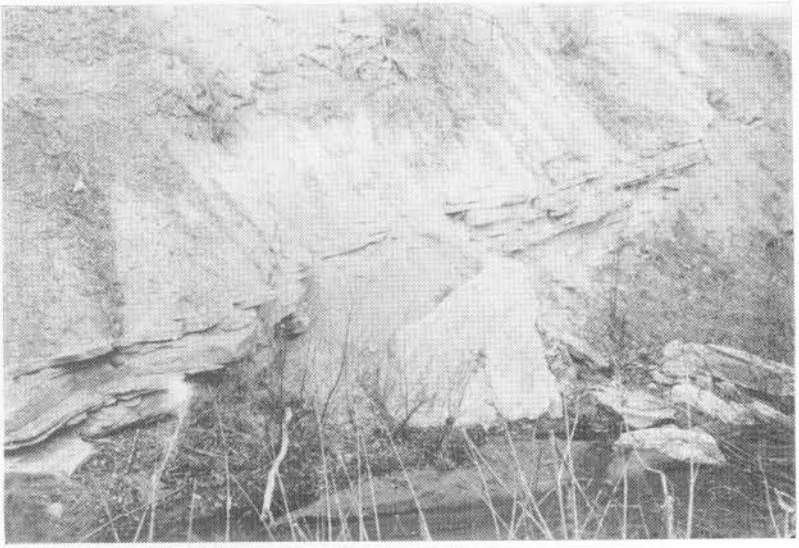
In the NE¼ sec. 27, T. 49 N., R. 12 W., and in the east half of sec. 3, T. 48 N., R. 12 W., the Houx limestone and "Squirrel" sandstone dip 12° southwest (plate X A).

Allen concluded that the Brown's Station anticline does not extend northwest of the vicinity of the Pinnacles. It is true that northwest of this area the beds flatten out, but the exposures of the Burlington at about 750 feet in the vicinity of Riggs and at about 740 feet in the vicinity of Roche Perche Church, indicate that the structure continues into the Rucker area.

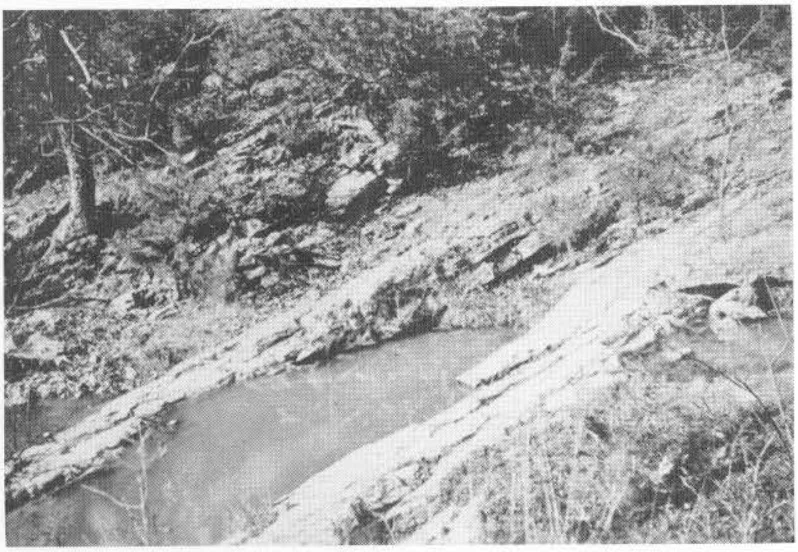
Probably the most complex structures in the county are in the vicinity of Gilaspy School in sections 26 and 27, T. 49 N., R. 12 W. Here on the southwestern limb of the Brown's Station anticline, there is one fairly large fold and several smaller folds which have been cut by a small fault.

These folds affect the beds from the Burlington to the Fort Scott limestone. Steeply dipping beds are exposed along Nelson

Plate X



A. Dipping beds of Squirrel sandstone. E½, sec. 27, T. 49 N., R. 12 W. Beds dip 10° SW. Flank of Brown's Station anticline.



B. Dipping beds of Burlington limestone, NE¼NW¼ sec. 29, T. 50 N., R. 12 W. Beds are dipping 30° SW. Flank of Brown's Station anticline.

Creek in the N½ sec. 21, T. 49 N., R. 12 W. A series of small anticlines may be observed in the bed of the creek extending northeast from Gilaspy School.

In the creek southeast of the schoolhouse there are similar small folds in the Ardmore limestone. About 200 feet east of the bridge south of the schoolhouse the upper part of the Fort Scott limestone is adjacent to the Ardmore, indicating a fault with the upthrown side on the east. Allen (1941) made a detailed study of the Gilaspy School area and suggested that a fault extends across the area between the creeks east of the schoolhouse. This fault seems to trend N. 35° W. and is exposed in both creeks. Small anticlines and synclines are exposed in the bed of the creek west of the school across the NE¼ sec. 27, T. 49 N., R. 12 W.

Minor folds of small extent and of no regional significance are common throughout the area of Pennsylvanian rocks. They possibly were formed at about the same time as the Brown's Station anticline, but some of them may be the result of deposition on an uneven floor in Pennsylvanian time.

Structures in beds older than Burlington.—In a few localities in the southern part of the county the Jefferson City formation has been somewhat folded and crumpled. In some of these places the deformation is fairly pronounced but the structures are localized and appear to have no regional significance. Most of them are associated with remnants of the St. Peter sandstone. Whether the presence of the St. Peter was a factor in determining the position of the fold or whether the St. Peter was protected from erosion because of its position with reference to the fold has not been determined.

Possibly, much of the deformation in the Jefferson City is the result of collapse and subsidence subsequent to or accompanying solution.

Major faulting is not common in the county, but several local faults are evident. Probably the largest of these is exposed in Fox Hollow and was described by Rush.[292] It appears to be a normal fault, upthrown on the east side, trending a few degrees east of north. In Fox Hollow, in the SE¼ sec. 12, T. 46 N., R. 13 W., the Chouteau limestone and Jefferson City dolomite are exposed along the bank of a small creek at nearly the same level. These two for-

[292]Rush, T. D., The geology of southwestern Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1950.

mations are separated horizontally by a narrow ravine filled mostly with soil and loose debris. On the south side of the major valley and west of the ravine, the Chouteau beds dip steeply westward from the apparent fault and become horizontal in a very short distance. This is on the downthrown side of the fault if one is present and the steep dips appear to be the result of drag. As nearly as can be determined the throw is about 120 feet.

North and south of Fox Hollow there are no exposures which show conclusive evidence of faulting. The Chouteau-Callaway succession of beds, however, rises about 120 feet from west to east across the areas to the north and to the south of Fox Hollow. Two miles south of Fox Hollow, along a southward extension of the fault trace, Ordovician, Devonian, and Mississippian beds are exposed along a small stream. The exposures are discontinuous, but the dip of the beds is sufficient to account for the rise of the beds without a fault. It seems, therefore, that a monoclinal fold which changes into a normal fault is present in the Fox Hollow area.

A very similar structure was noted by McQueen and Aid[293] and was described by Gore.[294] In an old quarry about a mile south of Wilton the quarry face is composed of Chouteau and Burlington limestone. About a quarter of a mile to the southeast a cliff at the same altitude as that of the quarry is composed of Jefferson City dolomite. Inasmuch as the beds do not appear to dip at either place, it is probable that a fault lies between them. About one-eighth of a mile northeast of the quarry, exposures of the Jefferson City are at about the same altitude as the quarry floor, and immediately to the north, the Jefferson City caps a fairly high hill. West of the hill the top of the Jefferson City is about 140 feet lower than the top of the hill. Although the exposures in this area are not good, it seems certain that there is a fault between the low and high positions of the Jefferson City beds. This fault has about the same trend as the one exposed in Fox Hollow. Northeast of Fox Hollow in the NW¼SW¼ sec. 25, T. 46 N., R. 12 W., the faulted beds dip fairly steeply to the west and it may be that the fault changes northward into a monoclinal flexure.

Another locality that has structural interest is along U. S. Highway 63 in the extreme southern part of the county. In the bed of

[293]McQueen, H. S. and Aid, Kenneth, Rock wool resources in central Missouri: Missouri Geol. Survey and Water Resources, 59th Bienn Rept. of the State Geologist, App. II, pl. IV, opp. p. 12, 1937.

[294]Gore, C. E., The geology of southern Boone County, Missouri: unpublished Master's thesis, Univ. of Missouri, Columbia, Missouri, 1949.

a small stream which runs along the west side of the highway south of the Penitentiary Quarry, there are blocks of Burlington, Callaway, and Jefferson City limestones, and some large remnants of St. Peter sandstone. In one area all of these are within a radius of 300 yards. Cursory examination of this area has caused many observers to assume that the distribution of these rocks is the result of faulting. However, after careful examination of the area and its environs, Gore (1949)[295] concluded that these blocks were displaced by collapse of a large solution structure. The Jefferson City-Callaway contact can be traced around the upper part of the valley wall without evidence of displacement, and the beds themselves show no evidence of structural deformation.

[295]Gore, C. E., op. cit., 1949.

ECONOMIC GEOLOGY

Introductory statement.—The mineral resources of Boone County are non-metallic in nature. Among the materials utilized commercially are coal, limestone, clay, and water. The soils are, of course, important economically, and are of geologic origin, but inasmuch as they are not mined, quarried, sold in quantity, or used in some manufacturing process, they are not treated here as a mineral resource.

COAL

by WALTER V. SEARIGHT and A. G. UNKLESBAY

Coal is the most important mineral resource of Boone County. Mining began early in the history of the county. Although most of the production until recent years was from hand labor, annual production as early as 1889 was 31,405 tons.

Coal mining in the area early in the century (1912) was described in detail by Hinds.[296] Thirty mines had been or were in operation at the time. Most of them were small and mined coal to supply local trade.

A little more than a decade later, about 1923, according to an unpublished manuscript by Tarr, 25 small hand-operated mines were producing coal for local consumption. Comprehensive surveys have not been made since that time. The introduction of mechanized strip mining has almost eliminated the small mines, and most of the coal is now mined by a few large operators.

Three commercial operators are now mining coal in the county. The Marriott-Reed Coal Company is mining coal from large open pits in sections 15 and 22, T. 49 N., R. 11 W.; the Hughes Coal Company is operating strip mines of considerable size in the vicinity of Harrisburg; and Taylor Barnes is mining coal from a pit near Butler.

Workable coal beds in the county are the Summit, the Bevier, and one or more beds lying not far below the Bevier. Except for the Bevier the beds are commonly considerably less than 2 feet thick and have not been commercially important.

[296]Hinds, Henry, Coal deposits of Missouri: Missouri Bur. Geology and Mines, vol. 11, 2d ser., pp. 90-103, 1912.

Bevier coal.—The Bevier coal bed is believed to be persistent under Boone County except where it has been removed by post-Pennsylvanian erosion. The distribution in the county is indicated on the geologic map (plate XIII). The line of outcrop of the coal has been drawn from information based on the outcrop of the coal, strip pits, mine shafts, drill records, and on outcrops of beds associated with the coal bed. In many places data are sufficient to indicate the boundary of the coal with precision. Elsewhere the boundary is drawn as accurately as evidence permits. The map shows the general area underlain by Bevier coal. Future prospecting may show that in some places the outcrop coincides with the boundary indicated on the map. In other places the outcrop may extend somewhat beyond it or it may lie within it.

Several factors prevent precise placement of the outcrop line in the absence of detailed drilling data. The most important of these factors is the presence of glacial deposits over the coal and the rocks associated with it. These glacial and related deposits consist of loose unindurated materials which lie above the coal everywhere in the county except where they have been removed by erosion. In most places, even where the coal has been cut through by post-glacial erosion, alluvium and slope mantle (colluvium) effectively conceal the coal. In places the coal and associated beds have been removed prior to glaciation and their position is now occupied by drift.

In addition, the coal does not lie flat below the surface nor does it have a uniform dip. The coal may rise more steeply than data indicate and thus be absent locally where it is presumed to be present. If the reverse be true, coal extends beyond the boundary indicated.

The Bevier coal has been reported in two places outside the mapped boundary. It was mined from a shaft 28½ feet deep southwest of Centralia in the SW¼ sec. 36, T. 51 N., R. 12 W., about 1912. Before that time it was mined from a shaft 3 miles south of Sturgeon.

The distribution of the coal shows the relation between the extent of the coal and geologic structure of the county. The portion mapped lies mostly south of the Brown's Station anticline; the coal continues around the southeastern end of the plunging anticline and cannot be traced, owing to lack of data, in the direction of Hallsville. Distribution north of Harrisburg suggests that the Brown's Station anticline tends to close toward the northwest. The presence of the coal south of Sturgeon and southeast of Centralia suggests that the bed may continue northeast of the Brown's Station anticline. Data are inadequate to determine the position and extent of coal outside the area mapped.

Character and thickness.—In Boone County and in counties to the north and northwest, the Bevier coal commonly consists of two benches or beds separated by clay or sandstone. At Columbia and probably continuing southeastward into Callaway County only a single bench, the upper, is present.

The lower bench is relatively thin. It varies from a thickness of 3 inches northeast of Columbia to 9 or 10 inches near Rucker and Harrisburg. The upper bench is fairly uniform in thickness, probably averaging about 32 inches. It varies locally from 30 to 40 inches thick.

The parting between the benches of the Bevier coal in the county is less than an inch to two inches thick and, owing to the thinness of the parting, the two benches are mined together.

The total thickness of the Bevier probably averages 36 inches in the county. It ranges from 30 inches near Columbia to more than 40 inches near Harrisburg.

Mining conditions.—Beds above the Bevier consist of shale, sandstone and drift. These beds can be removed readily by heavy stripping machinery, but are not good roof materials for underground mining. Underground mining requires extensive roof support. The coal is separated from the Ardmore limestone ("sumprock") below it by a foot or less of underclay ("fireclay") and squeezing is therefore not a problem in underground mining.

In some areas, particularly east and northeast of Columbia, the coal is boken by vertical joints which are filled with clay. The clay fillings or dikes are 6 inches or more thick and extend for distances of at least a few scores of feet. The coal is commonly more or less disturbed along these "horsebacks". The "horsebacks" are a handicap in underground mining. They are likewise troublesome in strip mining because the coal associated with them lies unevenly.

Chemical character.—The Bevier of this county is a high volatile bituminous coal of good quality. As elsewhere in northern Missouri the percentage of volatile matter is high and that of fixed carbon relatively low. Ash content varies from place to place and is locally high but in some areas is relatively low. None of the coal, however, is low-ash coal. The sulphur content is within the usual range of sulphur in coals of this rank and for this area heating value is good. Analyses of coal from the Bevier bed of Boone County are representative of this bed and indicate the chemical characteristics and heating values to be expected from the coal before washing and preparation.

ANALYSES OF BEVIER COAL IN AND NEAR BOONE COUNTY

Lab. No.	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B.t.u.
336[1]	2.39[6]	35.81	48.24	13.56	5.38	12,210
	——[7]	36.70	49.40	13.90	5.58	12,510
314[2]	3.40[6]	36.87	42.84	16.89	5.77	11,213
	——[7]	38.17	44.35	17.48	5.97	11,612
75,556[3]	10.50[6]	37.30	43.95	8.25	3.34	11,860
	——[7]	41.68	49.10	9.22	3.73	13,251
——[4]	12.68[6]	37.28	41.69	8.35	3.00	11,268
	——[7]	42.69	47.75	9.56	3.43	12,094
11,482[5]	10.76[6]	33.63	42.40	13.21	5.06	10,841
	——[7]	37.69	47.51	14.80	5.67	12,148

[1]Missouri Bur. Geology and Mines, rept'd by Tarr; Anderson's Mine, 8 miles northeast of Columbia, Missouri.

[2]Missouri Bur. Geology and Mines, rept'd by Tarr; Richard's Mine, 2½ miles east of Columbia, Missouri.

[3]Sample by Missouri Bur. Geology and Mines, Analysis U. S. Bureau Mines; 2 miles south of Columbia, Missouri.

[4]Analysis quoted by Div. of Mine Inspection, 63rd Ann. Rept., 1950, p. 40, 1951, Marriott-Reed Coal Company, western Callaway County.

[5]Analysis U. S. Bureau Mines, 4½ miles north of Columbia.

[6]As received.

[7]Moisture-free.

These analyses indicate that the Bevier coal here is chemically comparable with this coal elsewhere in northern Missouri and that it is likewise comparable in heating value (B.t.u.). The volatile matter as received ranges from 35.81 to 37.30 percent; fixed carbon from 41.69 to 48.24 percent; ash from 8.25 to 16.89 percent; and sulphur from 3.00 to 5.77 percent. As received heating values range from 10,841 B.t.u. to 12,210 B.t.u., volatile matter in moisture free analyses ranges from 36.70 to 42.69 percent; fixed carbon from 44.35 to 49.40 percent; ash from 9.22 to 17.48 percent; and sulphur from 3.43 to 5.69 percent. Calorific value of moisture-free samples ranges from 11,612 B.t.u. to 13,251 B.t.u. Both ash and sulphur are within the range commonly found in Bevier coal. The Bevier coal of northern Missouri commonly ranges between 12,000 B.t.u. and 13,000 B.t.u. moisture-free. Variations commensurate with those indicated by analyses from Boone County are thus characteristic. Modern methods of cleaning and preparation tend to remove much of the ash, mineral matter, and sulphur (mostly in pyrite) thus increasing the volatile matter and fixed carbon in the coal marketed, and increasing the heating value of the coal considerably. The Bevier coal of Boone County is a very satisfactory fuel which will probably be utilized in the future.

"Tebo" coal.—The Tebo coal is thin at most localities in Boone County and has not been produced on a commercial basis, but it has been mined in small quantities for home consumption in the SE¼ sec. 1, T. 49 N., R. 12 W., and in the SE¼ sec. 3, T. 49 N., R. 14 W. At both of these places the coal is about 14 to 16 inches thick and is of low grade.

Summit coal.—The Summit coal is represented in most of the county only by a thin smut. Hinds[297] reported that several small mines had been opened in the Summit in the creek valley north and south of Dripping Springs Church.

In sections 11 and 14, T. 50 N., R. 13 W., the Summit is about 28 inches thick. It is overlain by 20 to 30 inches of dark fissile shale which in turn is overlain by the Houx limestone. The shale and limestone are fairly competent roof-rocks in this area and the Summit coal can be mined by underground room and pillar methods. At the present time Mr. J. D. Harris is operating a small slope mine in the NE¼NW¼NW¼ sec. 14, T. 50 N., R. 13 W. Other abandoned mines are present along the creek about a mile south of Harris' mine. The Summit coal in this vicinity is of fair quality. No analyses are available.

Coal production.—Coal has probably been mined in Boone County from early days of settlement. Records before 1889 are incomplete or lacking, but in 1889, 31,405 tons were reported, suggesting a long history of production before that time. The annual tonnage of coal mined in the county since the beginning of 1889 is tabulated as follows:

[297]Hinds, Henry, op. cit., 1912.

COAL PRODUCTION IN BOONE COUNTY[1]
1889 - 1950 Inclusive

In most cases exclusive of mines producing less than 1000 tons annually.

Year	Tons	Year	Tons	Year	Tons
1950	45,001	1929	36,042	1908	25,868
1949	55,665	1928	35,793	1907	33,034
1948	52,405	1927	20,782	1906	40,626
1947	58,414	1926	26,742	1905	40,786
1946	45,586	1925	15,527	1904	37,920
1945	51,410	1924	19,338	1903	19,752
1944	43,599	1923	12,200	1902	27,006
1943	55,303	1922	13,557	1901	22,629
1942	39,293	1921	16,128	1900	18,619
1941	22,189	1920	18,950	1899	20,280
1940	15,816	1919	18,416	1898	13,779
1939	14,391	1918	16,129	1897	9,180
1938	12,443	1917	16,410	1896	14,751
1937	15,627	1916	18,556	1895	21,090
1936	29,758	1915	17,450	1894	19,038
1935	26,053	1914	12,514	1893	11,650
1934	43,692	1913	15,791	1892	15,636
1933	49,262	1912	19,696	1891	16,340
1932	54,277	1911	22,031	1890	17,000
1931	34,964	1910	19,885	1889	31,405
1930	36,525	1909	18,000		
				Total	1,667,999

[1]Sources of data as follows: 1889-1923 from Mineral Resources of United States, U. S. Geological Survey, published annually: 1924-1932 Mineral Resources of United States, U. S. Bur. Mines, published annually: 1933-1947 Minerals Yearbook, U. S. Bur. Mines, published annually: except 1894-95 and 1945-1950 Missouri State Mine Inspection reports. 1920-1925 includes production of other counties.

Other records do not agree precisely with these figures,[298] but variations average little more than 1000 tons per year. The records show that although the coal tonnage has never been a large part of that produced in the state, production has been continuous for more than 60 years.

Reserves.—Reserves of coal in Boone County were estimated by Henry Hinds[299] in 1912 to be 846,706,000 tons. The map showing the area underlain by Bevier coal accompanying this report (plate XIII) indicates that roughly 105 square miles, only 61 per cent of Hinds' estimates, are presumed to be underlain by this coal. In Hinds' estimates, it was assumed that of the coal beds in the coun-

[298]Searight, W. V., Coal production, distribution, and consumption in Missouri: Missouri Geol. Survey and Water Resources, Inf. Circ. no. 3, p. 42, 1949.

[299]Hinds, Henry, op. cit., pp. 94, 95, 1912.

ty, the Bevier was of widest extent. Included in the estimates also was 10,000,000 tons in basins and pockets, of uncertain value. Excluding the latter and re-estimating reserves at 61 per cent of the acreage assumed in Hinds' estimates, the original tonnage was about 506,000,000 tons. Of this tonnage, approximately 1,750,000 tons have been recovered in mining. It is possible that an equal amount has been lost in mining. Thus, it is likely that more than 3,500,000 tons of the most readily recoverable coal should be subtracted from original reserves. Present potential reserves in the county, on this basis, are little more than 500,000,000 tons, less than 60 per cent of the tonnage estimated by Hinds.

Recent studies of recoverability indicate that mining operations in the past have yielded only about 50 per cent of the coal originally present in an area.[300] Thus computed, only about 250,000,000 tons of coal are available from Boone County.

Only that portion of the reserves which can be mined by stripping methods will be mined on a commercial scale in the near future. Prospect drilling in parts of the county in recent years has proved some coal to be minable by stripping. Prospecting has been done by private interests and data are therefore not available for publication.

For those interested in computation of coal tonnage where outcrops or drillings provide information, the following suggestions are made. Bituminous coal is commonly assumed to have a specific gravity of 1.32. On this basis an acre foot of coal contains 1800 tons. Thus, an acre underlain by a coal bed three feet thick contains 5400 tons. Tonnage of bituminous coal is computed by some agencies on different bases. The Illinois Geological Survey computes an acre foot at 1770 tons or a specific gravity of 1.3. In Indiana, Ashley computed tonnage at 1560 tons per acre foot or a specific gravity of 1.15. Kansas reserves have been computed at 1500 tons per acre foot or a specific gravity of 1.1.

Strip mining engineers in computing coal reserves commonly estimate tonnage on a recovery basis rather than on the total coal contained in a bed. Some use a factor of 110 tons per acre inch which is 1320 tons per acre foot. This figure is a most conservative one for this method of mining.

[300]Averitt, Paul, and Berryhill, L. R., Coal resources of the United States: U. S. Geol. Survey, Circ. 94, p. 8, 1950.

CLAY

The eastern portion of Boone County is in the western part of the northern fire clay district of Missouri.[301] Much clay is present in the lower part of the Cherokee section, particularly the Cheltenham formation which is discussed in an earlier part of this report. In some localities, as previously noted, the Lagonda formation contains a clay-shale which is used for brick and tile manufacture. Although the Cheltenham clay and the Lagonda shales are widespread over the northern part of the county they have not been used commercially on a very large scale.

Wheeler in 1896[302] reported three brick plants in operation in the county. Two of these were at Centralia and one at Columbia. About 1910, there were two plants at Columbia, one, the Fay Brick Plant, was on Hominy Creek about 1½ miles southeast of Columbia in the NW¼SW¼ sec. 17, T. 48 N., R. 12 W. The other, the Edwards Brick Company, was at the present site of the Columbia Brick and Tile Company plant. Tarr[303] reported that clay was being mined only at Columbia, but stated that common brick had been made at Sturgeon and Centralia "years ago" and "locally at several places in the county, 50 and 60 years ago".

The Fay plant mentioned above was established in the early 90's and obtained clay from remnants of a clay "pocket" near the top of the south bank of Hominy Creek.

The present site of the Columbia Brick and Tile Company was first used in brick manufacturing in the late 1890's because of the close association of the clay and the Bevier coal. The coal was mined and used for fuel in the kilns. The coal supply was essentially exhausted many years ago, but small amounts are still being recovered as it is uncovered by the removal of the overlying clay-shale.

The shale above the Bevier coal, that is used in this plant, is widespread over the northern part of the county but is not persistent in its clay content. In some areas it is sandy and fairly high in iron. However, it seems quite likely that it could be used for brick and tile making in other localities if needed.

The Cheltenham clay is exposed in many places where the Burlington-Cherokee contact is at the surface and probably could be utilized if needed. A few of the best exposures of this clay are listed

[301]McQueen, H. S., Geology of the fire clay districts of east central Missouri: Missouri Geol. Survey and Water Resources, 2d ser., vol. 28, p. 3, 1943.

[302]Wheeler, H. A., Clay deposits: Missouri Geol. Survey, vol. 11, p. 509, 1896.

[303]Tarr, W. A., unpublished data, about 1923.

here: along the St. Charles road on the south line of sec. 8; along the Fulton Road in the west-central part of sec. 16; along the south bank of Grindstone Creek in sec. 15; on the South Fork of Grindstone Creek in the NE¼ sec. 22; all in T. 48 N., R. 12 W.; and in the south half of the NW¼NW¼ sec. 33, T. 50 N., R. 13 W.

Clay is present in the Loutre formation of Boone County, but because of its high content of iron, calcium, and alkali, this clay has a very low fusion point. It is generally referred to by the miners as the "poison clay".

A few analyses of clays from Boone County are given here.

Chemical Analyses of Representative Clays from Boone County

	1	2	3	4	5	6
Ignition loss	13.56	11.15	6.19	12.30	10.58	10.34
Silica (SiO_2)	45.55	56.46	64.15	55.22	59.03	56.61
Alumina (Al_2O_3)	37.03	26.46	14.96	26.88	25.99	26.96
Iron (Fe_2O_3)	0.55	1.82	6.26	2.52	1.72	2.84
Titania (TiO)	2.19	1.48	0.92	1.60	1.35	2.10
Lime (CaO)	0.76	0.27	2.50	0.77	1.21	0.09
Magnesia (MgO)	0.32	0.40	1.39	0.10	0.05	0.05
Soda (Na_2O)	0.28	ND	0.72	0.20	0.16	0.24
Potash (K_2O)	0.64	ND	2.89	0.66	0.32	0.70
P_2O_5			0.45	0.34	6.20	0.10
SO_3 (water soluble)			0.04	0.28	0.23	0.03
S (includes S from sulphates insoluble in water)			0.10	0.03	0.04	0.03
Manganese (MnO)			0.04	0.006	0.006	0.06
	100.88	98.04	100.67	100.91	100.84	100.15

1. Flint fire clay. SE¼SW¼ sec. 17, T. 48 N., R. 12 W. (from McQueen, p. 47, 1943)
2. Plastic clay, Columbia Brick & Tile Company, NE¼SW¼ sec. 8, T. 48 N., R. 12 W., (from McQueen, p. 64, 1943)
3. Lagonda clay shale, Columbia Brick & Tile Company, (Tarr, unpublished data)
4. Fire clay, W. M. Miller pit, east of Columbia (Tarr, unpublished data)
5. Fire clay, St. Charles road, sec. 8, T. 48 N., R. 12 W., (Tarr, unpublished)
6. Flint fire clay, Schwabe Place, NE¼ sec. 22, T. 48 N., R. 12 W., (Tarr, unpublished data)

Note: Sample number 5 is noted "Cone 28-2975°"
Samples 3, 4, and 5 were reported upon by Thornberry (1925, p. 38)

LIMESTONE

Limestone is quarried and used for road surfacing, concrete aggregate, agricultural limestone, building stone, and rock wool. In earlier years some lime was manufactured, but this industry has been discontinued.

Most of the rock quarried in the county is from the Burlington, but the Chouteau and Callaway are also used.

Burlington limestone.—For many years this limestone was the only one quarried and used commercially in the county. It has been well exposed at many places by stream erosion and these exposures provide an abundance of good quarry sites.

The Burlington is composed dominantly of crinoid stems and other fossils, and for the most part, is a very pure limestone.

The most troublesome impurity in the rock is chert which is present in considerable quantity. It occurs most commonly in distinct nodules and lenses parallel with the bedding planes and not as finely disseminated particles. Thus it is possible for much of the chert to be easily sorted out and discarded. For ordinary road surfacing, or for asphaltic concrete, the presence of the chert is not objectionable. However in concrete, made with Portland cement, the chert reacts with the alkaline cement to form a siliceous gel. The gel by the imbibition of water causes osmotic pressures to accumulate and these cause distention and rupture of the concrete surrounding the chert particles. The result is cracking and general deterioration of the concrete. Chert is also undesirable in agricultural limestone because it contributes nothing to the fertility of the soil. Because of its hardness, chert causes excessive wear and breakage of crushing and grinding equipment.

Other impurities in the Burlington are pyrite, sphalerite, and barite, all of which are present only in minor quantities. The Burlington contains little sand or clay.

The Burlington limestone has a relatively high crushing strength and is very satisfactory as building stone. It has been used in construction of the major portion of the buildings on the "White Campus" of the University and in many other buildings in Columbia. The beds range from a few inches to 6 feet in thickness, but in most places the bedding planes are not well developed, and dimension blocks are not as easily obtained as they would be if the bedding were better developed. Stylolitic zones are common in portions of the Burlington and detract slightly from its value as dimension stone, but do not prevent its being used.

Characteristically the limestone is light gray when fresh and weathers to darker shades of gray. Some blocks contain ferruginous material and weathering produces a reddish-yellow stain.

Tarr[304] tested the compressive strength of the Burlington limestone in Boone County and obtained the following results:

Pressure applied parallel to stratification . . . 2325 lbs. per sq. in.

Pressure applied normal to stratification . . . 20,000 lbs. per sq. in.

He also published reported chemical analyses as follows:

	1	2
SiO_2	0.178	0.429
Al_2O_3	0.062	0.057
Fe_2O_3	0.280	0.170
$CaCO_3$	98.688	98.393
$MgCO_3$	0.976	1.077
MnO	0.335	0.555
Phosphorus as P_2O_5	0.0171	0.0117
P	0.0075	0.0051
S	.058	0.067
	100.6016	100.7648

1. From quarry at south end of College Avenue, Columbia, Missouri.
2. From quarry at south end of Edgewood Avenue, Columbia, Missouri.

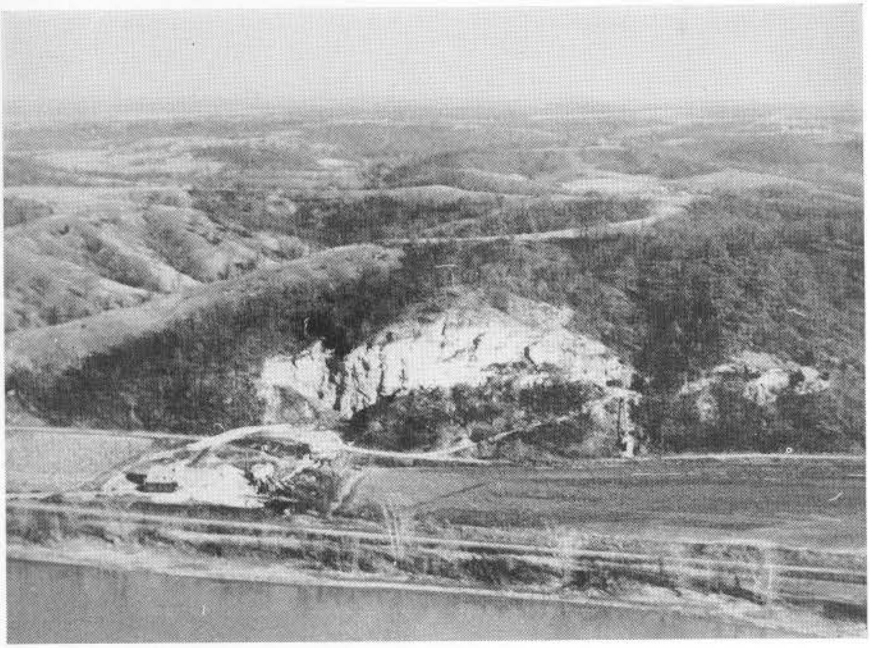
The only three quarries in operation at present are: Boone Quarries (formerly known as J. N. Fellows Quarry) at the south end of College Avenue, Columbia, Missouri, NW¼ sec. 19, T. 48 N., R. 12 W.; City Quarry (N. R. Garrett, operator) NW¼ sec. 2, T. 48 N., R. 13 W.; and Dodds Quarry, near Riggs, SE¼ sec. 27, T. 51 N., R. 13 W.

Many Burlington quarries have been opened and later abandoned. Among some of the better known ones are the following: Old Spencer-Whitlow Quarry at the south end of Edgewood Avenue, Columbia, Missouri, SE¼ sec. 14, T. 48 N., R. 13 W.; a large quarry was at one time operated at the east end of Wilson Avenue, Columbia, Missouri; east of Route 63, about 5½ miles north of Hinton, NE¼SE¼SW¼ sec. 12, T. 50 N., R. 13 W., and E½SE¼NE¼ sec. 11, T. 50 N., R. 13 W.; along M-K-T Railroad 0.8 mile NW of Huntsdale, SE¼ sec. 27, T. 48 N., R. 14 W.; Cree's Quarry, NW¼NE¼ sec. 13, T. 46 N., R. 13 W.; and several small quarries have been operated along Bear Creek north and northeast of Columbia.

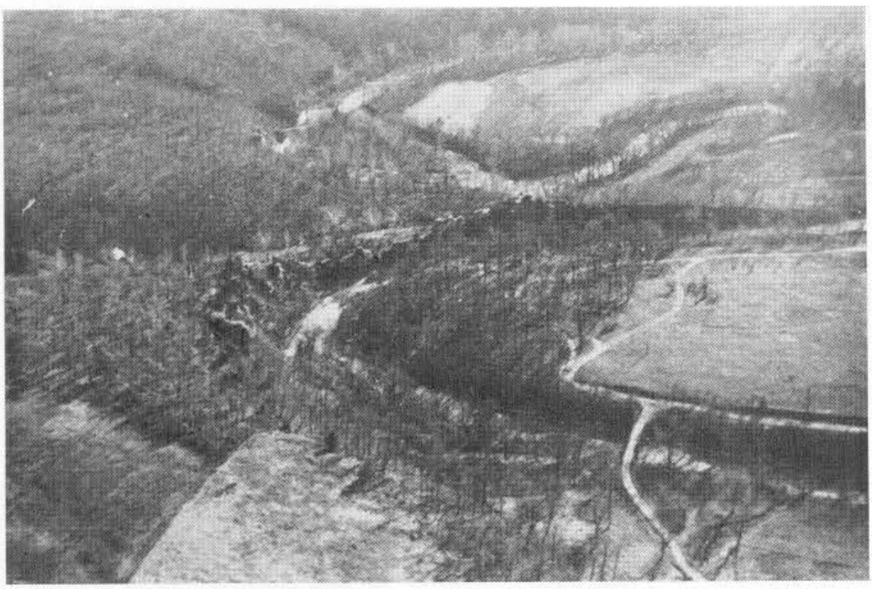
Chouteau limestone.—The Chouteau limestone has been quarried in two localities in the county. One of these, now abandoned, is in the SW¼SW¼ sec. 28, T. 50 N., R. 12 W. The rock quarried here

[304] Tarr, W. A., unpublished data.

Plate XI



A. Aerial view of rock-wool plant and quarry at Easley, sec. 3, T. 46 N., R. 13 W. Quarry face exposes Chouteau and Burlington limestones.



B. Aerial view of Pinnacles, SE¼ sec. 12, T. 50 N., R. 13 W. This erosion remnant is of Burlington limestone.

was used for road surfacing. The other, at Easley, is currently in operation (plate XI A).

The original Easley quarry was opened by the Federal Government many years ago to obtain rock for construction of improvements along the Missouri River, and both the Burlington and the Chouteau beds were quarried. This particular site has been abandoned, and a new tunnelling underground quarry has been developed immediately to the south to supply the rock wool plant. The upper 21 feet of the Chouteau formation is quarried.

Callaway limestone.—The Callaway limestone, despite its relative abundance in the county, has been quarried at only two places. One of these, abandoned in 1950, is on the east side of U. S. Highway 63, in the NW¼NW¼ sec. 24, T. 45 N., R. 12 W. The other, opened in 1951, is about one-quarter mile to the east, near the center of the NE¼NW¼ of the same section. The new quarry is being operated with the same machinery used in the older one.

The abandoned quarry has been mentioned in the literature as the "Penitentiary Quarry" because it was once operated by the State Prison, but for several years prior to abandonment, it had been under private ownership. In this quarry about 40 feet of Callaway limestone is exposed. The rock is, for the most part, a very dense to sub-lithographic grayish brown to light yellowish gray limestone containing numerous calcite veinlets. It is sparsely fossiliferous. Some beds of this quarry contain as much as 15 per cent magnesium carbonate. The rock quarried is used for concrete aggregate, road metal, agstone, and agricultural limestone.

In 1949 the Bushberg sandstone and the lower beds of the Chouteau were exposed in the uppermost part of the quarry face. However, by the summer of 1950 the face had been worked northward toward a lower slope of the hill where these beds were not preserved. Exploratory drilling in the summer of 1950 revealed that the Callaway here is immediately underlain by the St. Peter sandstone. This site was abandoned because attempts tn enlarge the quarry to the northwest revealed an abundance of solution cavities which make quarrying operations difficult and expensive.

The new site is on the next hill to the east and the rock so far uncovered is very similar to that of the upper part of the old quarry.

Pennsylvanian limestones.—Some of the numerous limestones in the Pennsylvanian in the county are suitable for use as crushed rock, but they are not used because of the greater abundance, greater thickness, and greater purity of the Devonian and Mississippian limestones.

ROCK WOOL

Rock wool is a light fluffy material used for heat insulation. It is made by melting an impure limestone and feeding the melt into a blast of air or steam under pressure. The result is a mass of fibrous or hairlike particles. This mass is fireproof and is not subject to mildew, rot, or attack by vermin. It is widely used as insulation in residential buildings.

A rock suitable for rock wool manufacture is a limestone with a carbon dioxide content of 20 to 30 per cent and a sufficient amount of silica to combine with the calcium and magnesium oxides formed during the heating. The upper 21 feet of the Chouteau in the Easley area is such a rock.

McQueen and Aid (1937)[305] made detailed investigations of the rock-wool possibilities along the M-K-T Railroad in western Boone County. They sampled and analyzed the upper part of the Chouteau (called Sedalia in their report) in the vicinity of Easley and McBaine. Although all the detailed results of this study will not be reproduced here, the chemical analyses of these beds is reproduced in the following pages.

The beds used for rock wool are also exposed in an old quarry about one mile south of Wilton, but they have not been used there for rock wool.

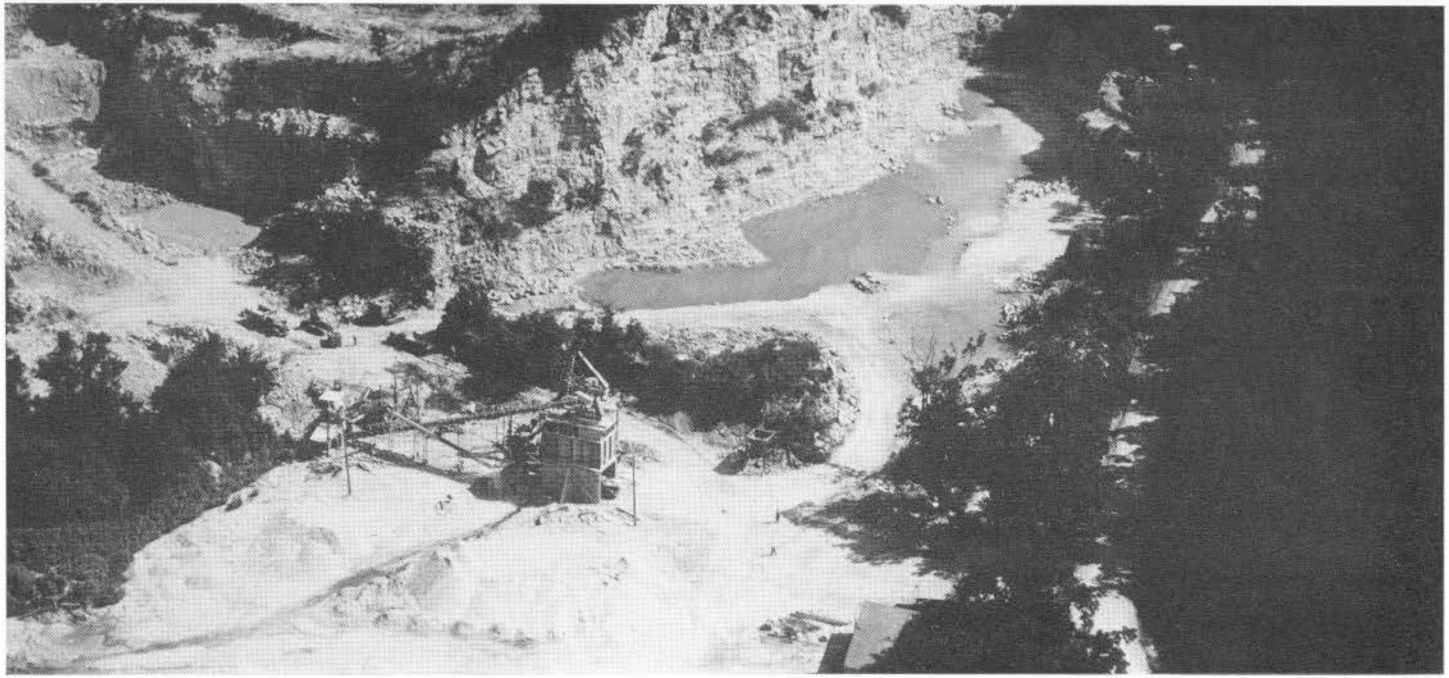
CEMENT

The manufacture of Portland cement requires limestone and shale in the ratio of three parts of the limestone to one of shale. Some argillaceous limestones contain considerable amounts of clay material and may be used alone or with very little shale added. This is true of the Blackjack Creek limestone which has been called the "cement rock" in many reports of the early writers.

In the area northwest of Brown's Station, where the Cherokee shale and the Fort Scott limestone occur in close proximity, these beds are suitable for cement manufacture. However, they are present only in quantities that would support a small scale operation

[305]McQueen, H. S. and Aid, Kenneth, Rock wool resources in central Missouri: Missouri Geol. Survey and Water Resources, 59th Bienn. Rept., App. II, 24 pp., 1937.

Plate XII



Quarry in Burlington limestone at south end of College Avenue, Columbia. NW¼ sec. 19, T. 48N., R. 12 W. (Courtesy Stephens College)

and under present conditions of manufacturing and marketing cement, small scale operations are not profitable.

SAND AND GRAVEL

Most of the stream beds of Boone County contain considerable quantities of sand and gravel. However, there has been very little commercial production of these materials because of the proximity to large sand and gravel producing operations on the Missouri River at Jefferson City and Boonville. Some of the coarse chert gravel has been used for road surfacing, but it is not satisfactory for concrete aggregate.

The St. Peter sandstone is quarried at Pacific, Klondike, and Crystal City, Missouri, and used in glass manufacturing. However, its limited occurrence in the county does not justify exploitation.

LEAD AND ZINC

About 1880 a small deposit of sphalerite and galena was discovered about 2½ miles northwest of Wilton (in the NE¼ sec. 22, T. 46 N., R. 13 W.) on a farm then owned by J. D. Calvin. A small mine was opened by Turner McBaine but was abandoned. About 1900, Burnett and McKay put down a 30-foot shaft and drove a drift about 40 feet westward under the hill. They are reported to have shipped some ore to Joplin. About 1921-22 Harrison and Bledsoe attempted to reopen the prospect and drilled a test hole to a depth of 146 feet. The test, however, showed no positive indication of ore and the site was abandoned again.

Throughout the county the Burlington and Chouteau limesones contain scattered crystals of sphalerite and galena, but there are no known occurrences of either mineral in commercial quantities.

PYRITE AND MARCASITE

Pyrite and marcasite occur in small quantities in the black shales and coals of the Cherokee, and some is scattered through the Burlington limestone. These minerals have not been produced commercially in this county.

BARITE

Occasional masses of barite, weighing up to 100 pounds, have been found in solution cavities in the Burlington limestone south

CHEMICAL COMPOSITION OF THE SEDALIA LIMESTONE

R. T. ROLUFS and J. S. BLAKENEY, ANALYSTS

(From McQueen and Aid, 1937)

Locality	Sample No.	Laboratory No.	Insol. Silica SiO_2	Insol. Residue	R_2O_3 Fe_2O_3	R_2O_3 Al_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	CO_2 (Calculated)	Moisture	Total
	0-4, Inclusive	2173	18.52	3.62	1.34		55.70	31.21	19.33	9.25	34.57	....	98.51
*A	5-9, Incl.	2174	23.36	5.60	1.66		51.41	28.86	19.39	7.85	31.19	....	98.52
	10-13, Incl.	2175	39.32	8.60	1.86		33.00	18.49	15.40	7.37	22.54	....	98.18
	0-4 Incl.	2177	37.50	9.10	2.84		20.39	11.44	29.78	14.26	24.50	....	99.61
*C	5-7, 8-9	2178	34.98	7.52	1.90		27.76	15.57	27.64	13.22	26.62	....	99.80
	10-11, 12-14	2179	26.96	5.68	1.32		40.09	22.49	25.69	12.30	31.02	....	99.74
	0-4, Incl.	2189	18.32	7.50	2.96		48.42	27.16	22.23	10.60	32.88	....	99.43
*E	5-9, Incl.	2190	32.78	3.64	2.04		42.64	23.92	18.53	8.88	28.99	....	99.63
	10-14, Incl.	2191	25.90	6.12	2.00		39.68	22.26	25.69	12.30	30.84	....	99.39
	15-20, Incl.	2192	27.20	7.94	2.12		39.54	22.18	22.84	10.93	29.30	....	99.64
	0	2108	6.74	2.46	.50	1.26	77.96	43.95	9.78	4.68	39.27	.23	99.03
	1	....	7.46	2.48	.43	1.63	74.56	42.03	13.38	6.40	39.76	.15	100.09
	2	....	12.12	3.50	.50	2.33	64.39	36.30	16.23	7.76	36.77	.16	99.23
*N	3	....	15.96	4.64	.70	2.80	48.62	27.41	25.66	12.28	34.76	.20	98.58
	4	....	16.90	4.60	.59	3.25	46.93	26.45	25.89	12.38	34.14	.21	98.37
	5	....	23.36	4.82	.59	4.07	47.80	26.94	17.38	8.31	30.08	....	98.02
	6	....	29.52	5.74	1.12	1.98	38.42	21.66	21.93	10.49	28.33	....	98.71

	7	....	45.40	8.10	1.03	2.07	26.36	14.86	16.03	7.67	19.95	....	98.99
	8	....	10.76	2.80	.75	3.27	65.84	37.11	15.21	7.27	36.88	....	98.63
	9	....	27.26	5.12	.72	2.14	40.56	22.86	23.22	11.10	29.95	....	99.02
*N	10	....	24.02	4.86	1.21	2.15	39.24	22.12	26.81	12.82	31.24	....	98.29
	11	....	21.76	4.24	.81	1.63	42.19	23.78	28.05	13.41	33.19	....	99.21
	12	....	30.98	4.54	.74	1.24	37.55	21.17	23.79	11.38	28.92	....	98.84
	13	....	28.02	5.20	.78	2.28	38.79	21.87	23.50	11.24	29.31	....	98.57
	14	....	31.80	5.30	.85	2.33	34.50	19.45	23.89	11.42	27.63	....	98.67
	15	....	34.50	5.60	.85	2.51	34.50	19.45	20.16	9.64	25.69	....	98.12
	16	....	28.20	4.96	.85	2.25	38.79	21.87	23.29	11.14	29.20	....	98.34
	17	....	27.14	5.54	.93	1.53	38.80	21.87	23.49	11.23	29.32	....	97.43
	18	....	21.82	4.34	.64	2.44	43.17	24.33	24.66	11.79	31.85	....	99.46
	19	....	15.62	2.68	1.07	3.57	44.85	25.28	29.76	14.23	35.25	....	97.57
	9	2112	34.82	5.88	.72	.84	33.53	18.79	22.78	10.89	25.93	.00	99.29
	10	....	25.02	4.18	.57	1.45	47.04	12.36	20.50	9.80	31.38	.15	99.29
	11	....	20.68	4.12	.64	1.38	42.90	24.04	29.03	13.88	34.01	.16	99.27
	12	....	24.34	4.50	.67	1.09	41.48	23.24	26.94	12.88	32.29	.11	99.71
	13	....	27.10	5.34	.86	.60	39.69	22.24	24.68	11.80	30.33	.14	99.10
	14	....	27.40	5.20	.64	1.30	38.62	21.64	26.71	12.77	30.92	.14	100.78
*M	15	....	22.62	3.98	.64	1.40	44.51	24.94	26.67	12.75	33.48	.13	100.48
	16	....	32.44	4.94	.72	2.16	35.94	20.14	22.07	10.55	27.42	.13	99.32
	17	....	34.26	5.62	.64	1.00	34.69	19.44	23.20	11.09	26.77	.16	99.02
	18	....	33.14	5.84	.79	.95	35.14	19.69	25.08	11.99	27.56	.16	99.75

*See p. 128 for description of locality.

CHEMICAL COMPOSITION OF THE SEDALIA LIMESTONE —*Continued*

	Sample No.*	Laboratory No.	Insol. Silica SiO_2	Insol. Residue	R_2O_3 Fe_2O_3	R_2O_3 Al_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	CO_2 (Calculated)	Moisture	Total
	19	....	31.52	5.78	.64	.88	36.21	20.29	23.93	11.44	29.01	.12	100.84
	20	....	31.56	5.74	.68	1.36	36.21	20.29	24.66	11.79	28.41	.14	100.14
*O	0-4, Incl.	2123	12.18	2.82	.72	.48	62.63	35.09	20.70	9.90	38.33	....	99.53
	5-6-7-9-10	....	30.10	5.04	.61	1.51	38.62	21.64	23.61	11.29	29.30	....	99.49
	11-16, Incl.	....	26.70	3.42	.72	.56	42.19	23.64	26.40	12.62	32.33	....	99.99
	17-20, Incl.	....	43.84	7.48	.74	1.38	28.72	16.09	17.10	8.18	21.55	....	99.26
*S	0-4, Incl.	2123	10.84	2.88	.89	.75	66.02	36.99	17.96	8.59	38.40	....	99.34
	5-6-7-8-10	....	29.52	5.14	.82	1.16	38.25	21.49	24.41	11.67	29.60	....	99.40
	11-15, Incl.	....	29.98	5.98	.79	.85	39.30	22.02	22.61	10.81	29.08	....	99.51
	16-20, Incl.	....	25.98	5.00	1.07	1.91	41.08	23.02	24.48	11.71	30.83	....	99.52
	21½-22½, Incl.	....	28.30	4.92	1.14	1.04	37.82	21.19	26.25	12.55	30.33	....	99.47
*U	5-9, Incl.	2208	29.78	4.82	1.96	.92	38.44	21.54	24.75	11.83	27.97	.02	100.67
	10-14, Incl.	....	25.26	4.72	2.55	1.22	39.33	22.04	27.27	13.04	31.48	.02	100.37
	15-20, Incl.	....	32.20	5.28	.99	1.42	35.23	19.74	24.52	11.72	27.91	.02	99.66
*Y	1-6, Incl.	2123	11.78	2.86	.74	2.38	56.64	31.74	25.01	11.96	37.95	....	99.41
*X	0-4, Incl.	....	12.90	3.12	1.0	.70	50.44	28.26	31.06	14.85	38.36	.08	99.30
	5-9, Incl.	....	20.22	4.08	1.07	.57	44.30	24.83	29.14	13.93	34.64	.07	99.45
	10-14, Incl.	....	34.74	4.86	1.07	.69	34.38	19.27	23.69	11.33	27.46	.10	99.53
	15-19, Incl.	....	25.54	4.56	1.07	.77	41.35	23.17	26.38	12.61	31.92	.11	99.78

	20-22, Incl.	....	29.42	4.70	1.00	.40	36.37	20.38	27.36	13.08	30.24	.32	99.57
	0	2116	4.40	1.26	.36	.68	85.27	47.78	7.37	3.52	41.34	....	99.34
	1	....	7.02	2.00	.64	.48	71.41	40.01	17.88	8.55	40.72	....	97.43
	2	....	9.86	3.02	1.22	.74	60.04	33.64	24.57	11.75	39.22	....	99.45
	3	....	17.84	4.20	1.29	1.35	46.37	25.98	29.16	13.94	35.61	....	100.22
	4	....	16.06	4.06	1.09	1.45	47.37	26.54	29.32	14.02	36.13	....	99.35
	5	....	12.40	3.60	1.14	1.52	53.97	30.24	27.76	13.27	38.22	....	100.39
	6	....	15.06	3.40	1.00	2.38	48.46	27.15	28.92	13.83	36.39	....	99.22
	7	....	25.92	4.44	1.02	.82	43.08	24.14	24.23	11.59	31.58	....	99.51
	8	....	29.10	5.34	1.02	.70	38.17	21.39	25.16	12.03	29.91	....	99.49
	9	....	35.94	5.98	.92	.14	33.27	18.64	22.98	10.99	26.62	....	99.23
*W	10	....	34.96	6.62	.80	2.26	32.64	18.29	22.09	10.56	25.88	....	99.37
	11	....	42.38	7.24	.89	.91	27.64	15.49	20.13	9.63	22.65	....	99.19
	12	....	51.72	7.62	1.07	1.01	22.83	12.79	15.31	7.32	18.03	....	99.56
	13	....	36.16	5.36	.89	1.87	32.82	18.39	22.37	10.70	26.10	....	99.47
	14	....	21.08	3.92	.84	.84	46.30	25.94	26.44	12.64	34.16	....	99.42
	15		Missing					Missing				Missing	
	16	....	25.04	4.70	.79	.77	41.74	23.39	26.27	12.56	32.06	....	99.31
	17	....	15.72	3.96	1.14	1.46	49.42	27.69	28.30	13.53	36.50	....	100.00
	18	....	14.52	2.62	1.17	1.87	50.13	29.08	29.75	14.23	37.56	....	100.06
	19	....	19.54	3.88	1.06	1.38	45.76	25.64	27.90	13.34	34.68	....	99.52
	20	....	28.44	4.96	.92	2.12	36.66	20.54	27.09	12.95	30.26	....	100.19

*See p. 128 for description of locality.

°

A, M-K-T Railroad, Milepost 156-15, Sec. 36, T. 46 N., R. 13 W.
C, M-K-T Railroad, Milepost 159-0, Sec. 22, T. 46 N., R. 13 W.
E, M-K-T Railroad, Milepost 160-19, Sec. 10, T. 46 N., R. 13 W.
M, M-K-T Railroad, Milepost 162-3, Sec. 3, T. 46 N., R. 13 W.
N, M-K-T Railroad, Milepost 162-7, Sec. 3, T. 46 N., R. 13 W.
O, M-K-T Railroad, Milepost 164-7, Sec. 28, T. 47 N., R. 13 W.
S, M-K-T Railroad, Milepost 165-19, Sec. 20, T. 47 N., R. 13 W.
U, M-K-T Railroad, Milepost 166-18, Sec. 20, T. 47 N., R. 13 W.
Y, M-K-T Railroad, Milepost 166-32, Sec. 18, T. 47 N., R. 13 W.
X, M-K-T Railroad, Milepost 168-3, Sec. 7, T. 47 N., R. 13 W.
W, M-K-T Railroad, Milepost 168-30, Sec. 7, T. 47 N., R. 13 W.

of Columbia. However, this material has not been found in sufficient quantity, to merit consideration for commercial production.

OIL AND GAS

Many wells have been drilled in this county, a few as oil prospects, but none has produced oil or gas. It cannot be stated definitely that oil or gas are absent in commercial quantities, but the available geologic data are not encouraging for further exploration.

GROUND WATER

BY

JOHN G. GROHSKOPF

Most wells in Boone County obtain their supply of water from the Mississippian limestones (Burlington and Chouteau), and the underlying Ordovician (Canadian of Ulrich) dolomites. Along the Missouri River, the wide flood plain may be depended upon for large yields from the water-bearing alluvial sands and gravels which attain thicknesses of as much as 100 feet. In the upland areas of portions of the county glacial sands and gravels are present, but as a general rule the glacial deposits in Boone County are not good aquifers. Private wells drilled in the southern two-thirds of the county range from 200 to 450 feet in depth, and obtain yields ranging from 5 to 15 gallons per minute from the limestone and dolomite formations. In the northern third of the county, the Burlington and Chouteau are overlain by glacial drift and Pennsylvanian shale which may contain thin beds or lenses of sandstone. The combined thickness of the glacial drift and the Pennsylvanian beds reaches a maximum of approximately 250 feet. The Pennsylvanian strata and the glacial drift generally do not yield very much water. However, their presence over the underlying limestones and dolomites requires correspondingly deeper wells.

In the northern third of the county, the St. Peter sandstone is a continuous deposit beneath the limestones at depths ranging form 450 to 550 feet. Where the St. Peter sandstone has an appreciable thickness, it may yield from 15 to 25 gallons of water per minute.

Wells drilled from 1,000 to 1,400 feet in depth may be depended upon to produce several hundred gallons per minute from the Ozarkian (of Ulrich) dolomites. Such wells are the source of municipal and industrial supplies at Centralia and Columbia.

All deep wells of record in Boone County produce fresh water, but at Huntsville and Moberly, in Randolph County, the St. Peter and older formations yield sulpho-saline water. At Fayette, in Howard County, the Mississippian and older rocks also yield sulpho-saline water. The chemical character of the ground water in seven selected wells is presented in the following table:

Chemical analyses of water from wells in Boone County.

Analyses by the State Division of Health unless otherwise noted.

(Quantities are in parts per million)

Well No.*	1	2	3	4	5	6	7
Depth in Feet	1338.	1200.	304.	933.	460.	526.	1505.
Alkalinity (total)	327.0	291.0	285.0	309.7	467.0	314.0	294.0
Bicarbonates (HCO_3)	397.3	354.7	347.7	377.7	569.5	383.0	358.0
Iron (Fe) total	0.14	0.1	0.2	0.23	0.10	0.18	1.2
Sodium and Potassium (Na)	80.9	48.8	25.8	51.9	44.7	107.0	48.3
Calcium (Ca)	70.2	56.3	66.3	60.0	94.7	48.1	60.7
Magnesium (Mg)	33.7	26.6	29.1	27.8	58.7	28.3	28.6
Sulfates (SO_4)	75.7	32.1	20.0	32.7	68.7	80.2	32.1
Chlorides (Cl)	53.8	33.0	16.9	19.1	12.4	40.3	32.9
Total Dissolved Solids	609.0	410.0	374.0	488.0	580.0	543.0	527.0
Loss on Ignition	188.0	127.0	140.0	143.0	147.0	76.0	193.0
Total Hardness ($CaCO_3$)	314.0	250.0	285.0	264.0	477.4	236.3	269.0
Carbonate Hardness ($CaCO_3$)	314.0	250.0	285.0	264.0	467.0	236.3	269.0
Non-Carbonate Hardness ($CaCO_3$)	0	0	0	**N.D.	N.D.	N.D.	0

*No. 1, City of Centralia, Well No. 2 (Treated by aeration and chlorination)
No. 2, University of Missouri, Well No. 3 (West well)
No. 3, State Prison tomato farm well near Claysville but in Callaway County.
No. 4, Central Dairy Company well at Broadway and Hitt Streets, Columbia. Analysis by Missouri Geological Survey and Water Resources (R. T. Rolufs, analyst)
No. 5, City of Ashland well, analysis by Missouri Geological Survey and Water Resources (R. T. Rolufs, analyst)
No. 6, Harrisburg Consolidated School well. Analysis by Missouri Geological Survey and Water Resources (R. T. Rolufs, analyst)
No. 7, City of Columbia well No. 10. Sample taken when well was at depth 1200 feet.
**N.D.—Not Determined.

The City of Columbia water supply is obtained from four deep wells, three of which are situated in a small area adjacent to the water and light plant and the other approximately one-half mile to the northeast. The average depth of the better wells is approximately 1,200 feet, or through the Gunter sandstone; and the yield ranges from 300 to 1,000 gallons per minute. Pumping of excessively large quantities of water from the small area has caused mutual interference among the wells, which has resulted in a lowering of the water level and an apparent decrease in yield. Lowering of the pumps has not been a permanent remedy for this condition, but the acute demand for increased quantities of water has not permitted pumping of the wells at lower rates. Acidization and deeper drilling may be a partial solution to the problem as indicated by the performance of City of Columbia well No. 10 after such procedures.

Well No. 10, when tested at depth of 1,200 feet in the Gunter sandstone, yielded 240 gallons per minute. After being deepened to a depth of 1,505 feet, and into the Potosi dolomite, this well showed an increase in yield to 360 gallons per minute. Treatment of the well with 4,000 gallons of hydrochloric acid when the well was 1,505 feet in depth further increased the yield to 850 gallons per minute, or an increase of 136 per cent. In addition to acidization and deeper drilling, consideration should also be given to wider spacing of any additional new wells.

Selected logs representative of typical wells drilled in the county are given in the appendix.

APPENDIX I

SELECTED LOGS OF TYPICAL WELLS OF BOONE COUNTY

Log of the Dr. Jess E. Dixon well. Location: NE¼NW¼SW¼, sec. 12, T. 50 N., R. 13 W. Elevation: 821 feet. Completed in 1939 by A. D. Donner of Columbia, Missouri. Missouri Geological Survey no. 5731. Samples studied by J. Grohskopf.

	Thickness Feet	Depth Feet
Pleistocene System		
Undifferentiated; silt, sand and clay	20	20
Mississippian System		
Osagean Series		
Burlington-Keokuk formation		
Limestone, very cherty	90	110
Kinderhookian Series		
Chouteau group		
Dolomite, slightly silty	25	135
Limestone	110	245
Devonian System		
Limestone	50	295
Sand and limestone	35	330
Sandstone (may be St. Peter)	12	342
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly sandy	10	352 Total Depth

Completion data

Casing: 95 feet of 6¼ inch, 23 feet of 5 inch set at 264 feet.
Static water level: 180 feet.
Yield: Not determined.

Log of the Jack Grey well. Location: SW¼NW¼NW¼, sec. 5, T. 48 N., R. 13 W. Elevation: 595 feet. Completed in 1940 by A. D. Donner of Columbia, Missouri. Missouri Geological Survey, no. 6268. Samples studied by J. Grohskopf.

	Thickness Feet	Depth Feet
Pleistocene System		
Undifferentiated; clay, sand, and silt	60	60
Mississippian System		
Kinderhookian Series		
Chouteau group		
Limestone, slightly cherty	40	100
Devonian System		
Limestone, non-cherty	31½	131½ Total Depth

Completion data

Casing: 70 feet 9 inches of 6¼ inch.
Static water level: 11 feet.
Yield: 30 gallons per minute.

Log of the Frank Russel, No. 1 well. Location: SW¼SW¼SE¼, sec. 20, T. 49 N., R. 11 W. Elevation: 876 feet. Completed in 1940 by A. D. Donner of Columbia, Missouri. Missouri Geological Survey no. 6345. Samples studied by J. Grohskopf and E. McCracken.

	Thickness Feet	Depth Feet
Pleistocene System		
Undifferentiated; silt, sand, clay, and gravel .	75	75
Mississippian System		
Osagean Series		
Burlington-Keokuk formation		
Limestone and dolomite very cherty .	110	185
Kinderhookian Series		
Chouteau group		
Dolomite, slightly silty	17	202
Limestone, some chert	68	270
Kinderhook? group undifferentiated		
Shale, gray	5	275
Devonian System		
Limestone, sandy	70	345
Ordovician? System		
Middle? Series		
St. Peter? formation		
Sandstone and dolomite, some chert .	25	370
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly cherty and sandy .	110	480 Total Depth

COMPLETION DATA

Casing: 139 feet of 6¼ inch and 96 feet 5 inches of 5 inch, set at 230 feet.
Static water level: 260 feet plus or minus.
Yield: 10 gallons per minute, 140 feet of drawdown.

Log of the Roy Jones well. Location: SW¼SE¼NE¼ sec. 1, T. 48 N., R. 13 W. Elevation: 670 feet. Completed, June 14, 1940, by A. D. Donner of Columbia, Missouri. Missouri Geological Survey no. 6312. Samples studied by J. Grohskopf and E. McCracken.

	Thickness Feet	Depth Feet
Mississippian System		
Osagean Series		
Burlington-Keokuk formation		
Limestone, dolomitic and cherty	105	105
Kinderhookian Series		
Chouteau group		
Limestone, slightly silty and dolomitic	25	130
Limestone, slightly cherty	80	210
Kinderhook? group		
Shale, gray	10	220
Chattanooga?-Grassy Creek formation		
Shale, black, fissile spore bearing	7	227

	Thickness Feet	Depth Feet
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly cherty and sandy .	78	305 Total Depth

COMPLETION DATA

Casing: 9 feet 7 inches of 8 inch and 30 feet 9 inches of 5 inch.
Static water level: Not determined.
Yield: 15 gallons per minute.

Log of the Sam Dalton, No. 1 well. Location: Center sec. 19, T. 48 N., R. 12 W., one mile south of Columbia on U. S. Highway 63. Elevation: 720 feet. Completed in 1940 by W. C. Schnell of Boonville, Missouri. Missouri Geological Survey no. 6519. Samples studied by J. Grohskopf and E. McCracken.

	Thickness Feet	Depth Feet
Mississippian System		
Osagean Series		
Burlington-Keokuk formation		
Limestone, cherty	120	120
Kinderhookian Series		
Chouteau group		
Dolomite, silty	20	140
Limestone, dolomite	75	215
Bushberg formation		
Sandstone and limestone, glauconitic .	5	220
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly cherty and sandy .	120	340 Total Depth

COMPLETION DATA

Casing 46 feet of 6¼ inch.
Static water level: 200 feet.
Yield: 15 gallons per minute, 10 feet of drawdown.

Log of the Jim Burke, No. 1 well. Location: center sec. 1, T. 48 N., R. 15 W., ½ mile north of Rocheport, Boone County. Elevation: 590 feet. Completed in the fall of 1937 by W. C. Schnell of Boonville, Missouri. Missouri Geological Survey no. 4528. Samples studied by J. Grohskopf.

	Thickness Feet	Depth Feet
Old well, no record	40	40
Mississippian System		
Osagean Series		
Burlington formation		
Limestone, slightly cherty	45	85
Kinderhookian Series		
Chouteau group		
Limestone, dolomitic slightly silty ...	35	120
Limestone, slightly cherty	65	185

	Thickness Feet	Depth Feet
Devonian System		
Limestone and dolomitic limestone slightly sandy	35	220
Ordovician? System		
Middle Series		
St. Peter? formation		
Sandstone, re-worked Cotter chert	10	230 Total Depth

COMPLETION DATA

Static water level: 15 feet.
Yield: 35 gallons per minute, 33 feet of drawdown.

Log of the Dr. Dexheimer, "Boone Acres", No. 1 well. Location: SW¼-SE¼NW¼ sec. 13, T. 51 N., R. 13 W. Completed in 1940 by A. D. Donner of Columbia, Missouri. Missouri Geological Survey no. 6331. Samples studied by J. Grohskopf.

	Thickness Feet	Depth Feet
Pleistocene System		
Undifferentiated; silt and clay	100	100
Mississippian System		
Osagean Series		
Burlington-Keokuk formation		
Limestone, cherty	85	185
Dolomite, very cherty	35	220
Limestone, little chert	20	240
Dolomite	10	250
Kinderhookian Series		
Chouteau group		
Limestone, slightly silty	12	262 Total Depth

COMPLETION DATA

Casing: 144 feet of 6¼ inch.
Static water level: 182 feet.
Yield: 20 gallons per minute.

Log of the Hallsville School, No. 2 Well. Location sec. 13, T. 50 N., R. 12 W. Elevation: Not Determined. Completed in August, 1950 by J. T. Watts of Mexico, Missouri. Missouri Geological Survey no. 11459. Samples studied by G. Shearrow.

	Thickness Feet	Depth Feet
No record	100	100
Mississippian System		
Osagean Series		
Burlington-Keokuk formations		
Limestone, cherty	95	195
Limestone and dolomite slightly cherty	65	260

Kinderhookian Series		
Chouteau group		
Dolomite, slightly silty	20	280
Limestone and dolomite	90	370
Chattanooga?-Grassy Creek formation		
Shale, black fissile spore-bearing	45	415
Devonian? System		
Sandstone	30	445
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly sandy	5	450 Total Depth

COMPLETION DATA

Casing: 147 feet of 6¼ inch.
Static water level: 55 feet.
Yield: 10 gallons per minute, 90 feet of drawdown.

Log of the Joe Brown, Bell's Lake filling station, No. 1 well. Location: center NE¼ sec. 6, T. 48 N., R. 14 W., at Bell's Lake on U. S. Highway 40. Elevation: 634 feet. Completed, April 10, 1941, by A. D. Donner of Columbia, Missouri. Missouri Geological Survey no. 6926. Samples studied by M. Hundhausen and E. McCracken.

	Thickness Feet	Depth Feet
Pleistocene System		
Undifferentiated; silt and clay	20	20
Mississippian System		
Osagean Series		
Burlington formation		
Limestone, dolomitic	10	30
Kinderhookian Series		
Chouteau group		
Limestone, dolomitic slightly silty	25	55
Limestone, a little chert	85	140
Kinderhook undifferentiated		
Shale, gray, and sandy	10	150
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, cherty and sandy	56	206 Total Depth

COMPLETION DATA

Casing: 50 feet of 6¼ inch and 40 feet of 5 inch liner.
Static water level: At ground level.
Yield: 15 gallons per minute, 50 feet of drawdown.

Log of the Lucille Merritt, No. 1 well (Also known as "The Farm", "Gateway Inn", and "Fair Oaks"). Location: SW¼NE¼NE¼ sec. 30, T. 48 N., R. 12 W., on the west side of U. S. Highway 63 south of Columbia. Elevation: 761 feet. Completed in 1940 by W. C. Schnell of Boonville, Missouri. Missouri Geological Survey no. 6527. Samples studied by J. Grohskopf and E. McCracken.

	Thickness Feet	Depth Feet
No record	60	60
Mississippian system		
Osagean Series		
Burlington-Keokuk formations		
Limestone	100	160
Kinderhookian Series		
Chouteau group		
Dolomite, slightly silty	15	175
Limestone, dolomite	65	240
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly cherty and sandy	184	424 Total Depth

COMPLETION DATA

Casing: 185 feet of 6¼ inch.
Static water level: Not determined.
Yield: "Strong",-driller.

Log of the University of Missouri, Dairy well. Location: NE¼NW¼SW¼ sec. 18, T. 48 N., R. 12 W., (near the corner of Rollins and South Williams Streets). Elevation: 733.83 feet. Completed in October, 1948 by Layne-Western Company of Kansas City, Missouri. Missouri Geological Survey no. 5087. Samples studied by J. Grohskopf and E. McCracken.

	Thickness Feet	Depth Feet
Mississippian System		
Osagean Series		
Keokuk-Burlington formation		
Limestone, cherty	105	105
Limestone, dolomitic	75	180
Kinderhookian Series		
Chouteau group		
Limestone, dolomitic slightly silty	20	200
Limestone and dolomitic limestone	70	270
Devonian System		
Limestone, slightly sandy and shaly	30	300

Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly cherty and sandy	165	465
Jefferson City formation		
Dolomite, cherty, thin sandstones	195	660
Roubidoux formation		
Dolomite, cherty	40	700
Dolomite, sand and chert	10	710
Dolomite, very cherty	45	755
Gasconade formation		
Dolomite, non-cherty	40	795
Dolomite, very cherty	200	995
Gunter member		
Sandstone and dolomite	20	1015
Cambrian System		
Upper Series		
Eminence formation		
Dolomite, slightly cherty	160	1175
Potosi formation		
Dolomite, siliceous, quartz druse	28	1203 Total Depth

COMPLETION DATA

Casing: 450 feet of 12 inch, set in cement.
Static water level: 202 feet.
Pumping water level: at 400 gallons per minute, 230 feet
at 500 gallons per minute, 245 feet
at 600 gallons per minute, 255 feet
at 700 gallons per minute, 295 feet
at 800 gallons per minute, 313 feet

Log of the Panhandle-Eastern Pipe Line Company, No. 1 well. Location: NE corner NW¼, sec. 10, T. 50 N., R. 11 W., 5½ miles east of Hallsville. Elevation: 879 feet. Completed in June, 1936 by Sewell Well Company of St. Louis, Missouri. Missouri Geological Survey no. 3667. Samples studied by J. Grohskopf and E. McCracken.

	Thickness Feet	Depth Feet
Pennsylvanian System		
Desmoinesian Series		
Cherokee group		
Sand, and buff to red shale	90	90
Mississippian System		
Osagean Series		
Burlington-Keokuk formation		
Limestone, cherty	85	175
Limestone, dolomitic, very cherty	45	220

Kinderhookian Series		
Chouteau group		
Limestone, dolomitic slightly silty ..	25	245
Limestone, slightly cherty	85	330
Chattanooga?-Grassy Creek? formations		
Shale, black, fissile, spore bearing ...	30	360
Devonian System		
Sandstone, greenish cast	10	370
Limestone, sandy	40	410
Ordovician? System		
Middle? Series		
St. Peter? formation		
Sandstone	25	435
Lower Series		
Cotter formation		
Dolomite, slightly cherty and sandy ..	285	720
Jefferson City formation		
Dolomite, cherty and sandy	200	920
Roubidoux formation		
Dolomite, cherty, and sandstone	110	1030
Gasconade formation		
Dolomite, non-cherty	105	1135
Dolomite, very cherty	125	1260
Gunter member		
Sandstone and dolomite	15	1275
Cambrian System		
Upper Series		
Eminence formation		
Dolomite, slightly sandy	25	1300 Total Depth

COMPLETION DATA

Casing: 394 feet of 10 inch.
Static water level: 220 feet.
Yield: 200 gallons per minute, 6 feet of drawdown.

Log of the City of Columbia, No. 10 well. Location: NW¼SE¼SW¼ sec. 6, T. 48 N., R. 12 W. Elevation: 782 feet. Completed in June 1947 by Layne-Western Company of Kansas City, Missouri. Missouri Geological Survey no. 9527. Samples studied by A. Ostrander and E. McCracken.

	Thickness Feet	Depth Feet
Pleistocene System		
Undifferentiated; silt, sand, and gravel	65	65
Pennsylvanian System		
Desmoinesian Series		
Cherokee group		
Shale, gray, calcareous	5	70
Shale, gray to pink	10	80

Mississippian System		
Osagean Series		
Keokuk-Burlington formation		
Limestone, cherty	125	205
Limestone, dolomitic	40	245
Kinderhookian Series		
Chouteau group		
Dolomite, slightly silty	20	265
Limestone, slightly cherty	70	335
Devonian System		
Limestone, slightly cherty	25	360
Ordovician System		
Lower Series		
Cotter formation		
Dolomite, slightly cherty and sandy	150	510
Jefferson City formation		
Dolomite, cherty, thin sandstones	235	745
Roubidoux formation		
Dolomite, cherty	35	780
Sandstone and cherty dolomite	20	800
Dolomite, very cherty	40	840
Gasconade formation		
Dolomite, non-cherty	45	885
Dolomite, very cherty	225	1110
Gunter member		
Sandstone and dolomite	30	1140
Cambrian System		
Upper Series		
Eminence formation		
Dolomite, slightly cherty	160	1300
Potosi formation		
Dolomite, siliceous, quartz druse	205	1505 Total Depth

Completion data

Casing: 100 feet of 26 inch surface pipe, 500 feet of 20 inch grouted with 600 sacks of cement.

Hole sizes: 19 inch to 600 feet, 15 inch below 600 feet.

Static water level and yield: At depth 1200 feet, 343 feet, 240 gallons per minute.

At depth 1505 feet, 350 feet, 360 gallons per minute, approximately 100 feet of drawdown. After acidizing with 4000 gallons of hydrochloric acid; static water level 350 feet. 850 gallons per minute, approximately 100 feet of drawdown. The increase in yield due to acidizing was 136 per cent.

Log of the Harrisburg Community School well. Location: Center sec. 11, T. 50 N., R. 14 W. Elevation: 840.5 feet. Completed in 1937 by W. C. Schnell of Boonville, Missouri. Missouri Geological Survey no. 4354. Samples studied by J. Grohskopf

	Thickness Feet	Depth Feet
No record	155	155
Mississippian System		
Osagean Series		
Burlington-Keokuk formation		
Limestone, cherty	120	275
Limestone, dolomitic	70	345
Kinderhookian Series		
Chouteau group		
Limestone, dolomitic slightly silty	20	365
Limestone and dolomite	110	475
Devonian System		
Limestone	51	526 Total Depth

COMPLETION DATA

Casing: 180 feet of 6¼ inch.
Static water level: 160 feet.
Yield: Could be bailed dry, sulphur odor.

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