MISSOURI BUREAU OF GEOLOGY AND MINES.

E. R. BUCKLEY, PH. D., Director and State Geologist.

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THE

Geology of Miller County

BY

SYDNEY H. BALL AND A. F. SMITH.

WITH AN INTRODUCTION BY

E. R. BUCKLEY.

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BOARD OF MANAGERS.

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LETTER OF TRANSMITTAL.

BUREAU OF GEOLOGY AND MINES,
ROLLA, MO., November 1, 1903.

To the President, Governor A. M. Dockery, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen—I have the honor and pleasure to transmit to you a report on the Geology of Miller county by Sydney H. Ball and A. F. Smith.

The field work for this report was done during the winter of 1901-'02 and during the spring and early summer of 1902. Mr. Ball did the field work on the north side of the Osage river and Mr. Smith did the field work on the south side. Mr. Francis B. Laney mapped the northern twenty-five square miles of township 39 north, range 15 west, and assisted Mr. Smith during a part of the field season. Owing to the very much generalized character of the United States topographic maps of this area, they could not be used as a basis for the geological mapping. Consequently the work has been based mainly upon elevations obtained from the surveys of the Missouri Pacific and Chicago, Rock Island & Pacific Railways. All elevations, beginning with a known elevation, were made with aneroid barometers. The repeated use of these instruments at different times was often necessary to insure a reasonable degree of accuracy. The elevations were obtained at many places along the different contacts between the formations; at nearly all road and stream crossings; and at mines, prospects, quarries and other points of economic interest.

The mapping was done by traversing on foot or horseback, distances being obtained by pacing and directions by using a Gurley's "Geologist's Compass." Starting at a known section corner, the direction which it was wished to pursue was obtained by the compass and indicated on the field sheet by the use of a protractor. The distance to the second station was then determined by pacing and its position, with respect to the first station, was indicated by a dot on the field sheet. Changes in the direction traversed were shown by the bearing of the compass and these were plotted by aid of the protractor on the field sheets. By a careful adherence to this plan of working the men always knew their location with sufficient accuracy for geological mapping.

The work for any day was usually so planned as to include certain known locations, such as section corners, quarter posts or points previously located, upon which the work could be checked. Necessarily, in the very hilly parts of the county where short sights were necessary and uniform pacing impossible, small errors were made. But by constant checking on known points these were minimized to such an extent that they are not apparent on the general geological map.

Owing to the fact that the contacts follow very closely the drainage lines, the valleys and ravines were everywhere traversed from head to mouth. The gulches not over a fourth of a mile long were, as a rule, sketched in, their direction being obtained by the compass. Where the contact followed close to the top of a ridge, the ridge, as well as the valley, was traversed in order to locate definitely the contacts.

In this manner every section of land in the county was traversed, and outcrops of rock, mines, prospects, soils, clays and every indication of minerals or ores was noted and recorded in the field note-books. Special attention was given to the mines and the body of the report contains accurate descriptions of all the important mines and prospects in the county.

I remain very respectfully,

Your obedient sir,

E. R. BUCKLEY,

Director and State Geologist.

ACKNOWLEDGMENTS.

Dr. E. M. Shepard, both in the field and office, has contributed his time and experience to assisting in working out the Cambro-Ordovician succession. The authors are also under deep obligations to Mr. Bailey Willis, Chief of the Stratigraphic Department of the United States Geological Survey, for time spent in the field, verifying the results of the field work. Thanks are also extended to the Chicago, Rock Island & Pacific Railroad for location maps and profiles and transportation, and to the Missouri Pacific Railroad for transportation.

The Bureau has had the hearty co-operation of every citizen of Miller county and to all these are due the thanks of this department.

To Dr. W. S. Allee, of Olean, Messrs. L. N. Musser, Mord McBride, George Swanson, George Williams and Judge J. G. Lurton, the Bureau is especially indebted for numerous courtesies extended to the assistants while carrying on the field investigations.

E. R. BUCKLEY,

State Geologist.

INTRODUCTION.

During the administrations of Swallow, Broadhead and Pumpelly reconnoissance surveys were made of forty-nine counties in the State. When Winslow took charge of the Bureau in 1889, sheet reports were substituted for county reports, and during the Winslow-Keyes administrations one entire county and parts of fourteen counties were surveyed, mapped and reported upon in this manner. During the administration of Gallaher, from 1897-1901, no additions were made to the county or sheet reports.

When the field work on the present report was begun in November, 1901, there were 49 counties, for which reports and maps had never been issued; there were 49 counties for which general reconnoissance reports had been published; one for which a complete detailed report had been published; and twenty parts of counties for which detailed reports had been published. It is the present plan to survey and report in detail upon the 49 counties for which no reports have been published, as rapidly as possible, after which the counties, of which reconnoissance reports, alone, have been issued should be re-surveyed. It is intended to survey the counties in as great detail, as though the work were under the immediate supervision of the U. S. Geological Survey.

GENERAL PLAN FOR COUNTY REPORTS.

County reports are issued in preference to sheet reports, because they serve better the interests of the public. It appears that in State survey work the unit chosen must be one which is recognized by the mass of the people. This unit is the county.

Miller is one of three counties which have been surveyed since November, 1901. It is one of the most centrally located of the counties of the State and constitutes a very desirable point from which to begin the systematic stratigraphical work, which it is intended to continue into all parts of the State.

The general plan is to extend the county surveys to the southwest, southeast, northeast and northwest, thereby connecting with the surveys of the lead, zinc and coal fields of the State. A detailed survey of two rows of counties extending diagonally across the State will give that, which we do not have today, a clear idea of the detailed stratigraphical succession of Missouri. This report is the first of a new series of county reports and the geology—stratigraphic, economic and structural—is all discussed in far greater detail than it is thought will be necessary for the remaining counties.

TEXT OF THE REPORT.

An intelligent discussion of the econmic resources of a county must be based upon a careful detailed survey, by which the stratigraphy and structure are both worked out. For this reason, the reader will find that a greater part of this report is devoted to a discussion of the rock formations and their structures as observed in this county.

There may be some criticism of this report on the ground that the discussion of the geology is entered into in too great detail. There may appear to the reader to be an unnecessarily large number of sections and other illustrations. However, it is thought that, owing to the location of the county, which is in the midst of the Ozark region, and embodying, as it does, a typical section of the Cambro-Ordovician stratigraphy of Missouri, the detailed discussion may be justifiable.

This is the second county of the Ozark region for which a very detailed survey has been made. It is not surprising, therefore, to find that in some particulars the stratigraphical succession does not correspond with the published results of the earlier reconnoissance surveys. It has been necessary to subdivide the Cambro-Ordovician formations, in the field, differently from the earlier geologists.

In 1871 the Bureau published a reconnoissance report on Miller county by F. B. Meek, in which the author recognized outliers of Burlington limestone and Coal Measure shale and a series of Cambro-Ordovician formations beginning at the top with the first or "Saccharoidal" sandstone and continuing down to the Fourth Magnesian limestone, making in all, three sandstone formations—"First," "Second" and "Third"—and three magnesian limestone formations—"Second," "Third" and "Fourth."

Through the work of the present survey, a part of the exposures of the so-called Saccharoidal and Second sandstones have been shown to be Carboniferous. At least a sandstone has been found in this county which carries inclusions of Burlington limestone and rests unconformably above it. A sandstone is also found which contains fragments of shale and is at times interlaminated with, or grades into shale of Coal Measure age. There are, however, large isolated masses of sandstone which have been considered a part of the Upper Carboniferous and which have been so indicated on the geological map, which in themselves give no evidence of their age, other than that they are post-Second Magnesian limestone (Jefferson City). These may be a part of Swallow's Saccharoidal or First sandstone which at Pacific shows the same marked unconformity which is exhibited in this county.

In Miller county, however, there is very little tangible evidence to show whether this sandstone is Swallow's First sandstone or Carboniferous. The manner of its occurrence and the character of its weathered surface lead Messrs. Ball and Smith to the conclusion that in all probability these sandstone "blocks" correspond to the Graydon sandstone of Green county which is of known Carboniferous age. However, there are two noticeable differences in the Graydon sandstone of Greene county and that of Miller county, which must not be overlooked. First, the Graydon sandstone of Greene county contains remains of plant life which are positively Carboniferous, while the Graydon sandstone of Miller county, except where it is associated with the shale or coal pockets, contains no plant remains or other fossils. In the larger, more conspicuous blocks of sandstone they are altogether wanting. Second, the Graydon sandstone of Greene county is usually micaceous, while that of Miller county contains no mica whatever. This, however, in Miller county is true of the sandstone which, from the fossil content, is known to belong to the Coal Measures. These conditions lead me to believe that a part, and possibly a large part, of the sandstone which has been mapped as Carboniferous may belong to the First or Pacific formation. If this is the case, it becomes necessary to recognize two sandstones for that mapped as Graydon, one of which belongs positively to the Coal Measure period, as shown by the work of Messrs. Ball and Smith, and the other of which belongs to the Pacific formation. The textural similarity of the two sandstones and the absence of paleontological evidence leaves one without any positive means of separating the two.

The geological mapping of Moniteau county has shown that nine-tenths of the sandstone, corresponding to that which is here mapped as Graydon, occurs outside of the area which is underlain with Carboniferous limestone. The blocks of sandstone in the Cambro-Ordovician area are very abundant while in the area which is mainly underlain with Burlington limestone they are very scarce. These general field relations give further evidence that a greater part of the sandstone mapped as Graydon in Miller county is actually the First or Pacific sandstone.

Where the early geologists recognized a single bed of sandstone known as the Second sandstone between the Second and Third Magnesian limestones, Messrs. Ball and Smith have mapped a complex formation consisting of intercalated beds of sandstone, limestone and chert.

This complex, which has been named the St. Elizabeth formation, includes all of the so-called Second sandstone and parts of the Second (Jefferson City), and Third (Gasconade), Magnesian limestone formations. Ball and Smith found that in some places the sandstone has a development of from six to fifty feet over a sufficient area to warrant distinguishing and mapping it as a member or lentil in the St. Elizabeth formation. On the map all of these lenses have been called the Bolin Creek sandstone although, as stated in the report, it is not known that they all constitute a part of the same horizon. In fact, in some instances the evidence gathered by Mr. Smith indicates that such is not the case. However, this name has been made to apply to any of the several sandstone lenses occurring in the St. Elizabeth formation in Miller county.

It has been suggested by some that the Gasconade, St. Elizabeth and Jefferson City formations might be considered as a single formation, and that the sandstone lenses be mapped as members of this formation. I believe, however, that in the light of the present knowledge of Miller county such a generalization would not be in accord with the present conception of stratigraphic mapping. As will be seen by carefully reading that part of the report relating to the St. Elizabeth formation, there is abundant ground, lithologically, economically and physiographically for differentiating this as a distinct formation.

The thinness and lithological characteristics of the beds comprising the Cambro-Ordovician series, in this region, leads to the thought that there must have been periods of long duration, during which this part of the country was at or near base level. Apparently this portion of the continent, for a long period, was subject to only such minor oscillations as were necessary to keep it submerged or near base level. The sandstone lenses, the "Cotton" rocks, the dolomite—all with more or less cross bedding, ripple marks and sometimes conglomerates at their base—give substantial proof that these were the prevailing conditions in Miller county during Ordovician time.

The limestone mapped in this report as Upper Burlington includes several outcrops of limestone which evidently belong to the Chouteau as defined by Swallow. These areas, however, were so small and their relation to other formations so obscure that very little can be said about them.

The Lower Burlington, as defined by Keyes, Shepard and others, is apparently absent in this county, unless certain of the Chouteau like beds mentioned above should be classified as such.

The Upper Burlington is easily identified in this county by the great abundance of fossil crinoids which it contains. It is widely distributed and gives evidence of having at one time overlain the entire county.

One of the most interesting formations discussed in this report is the so-called Saline Creek Cave-Conglomerate which outcrops in numerous isolated areas throughout the county. This formation is described in the following pages and mapped as belonging to the Coal Measures. It would be more nearly correct to map them as post-Ordovician in so much as they have been formed both prior to and following the Coal Measure period. It is thought that some of the "Cave-conglomerate" deposits may be very recent. There is evidently no way to determine their age and consequently they have been mapped in the Coal Measure formation.

Provisionally the Gunter sandstone has been considered the basal formation of the Ordovician. The unconformity existing between this formation and the Proctor limestone is the most striking of any in the county, below the Jefferson City formation. However, until paleontological evidence is obtained, this separation must be uncertain.

The unconformity between the Coal Measure strata and the older formations, which clearly exists in this county, may not continue beyond the marginal portion of the Coal Measure area. This unconformity, however, appears to be well defined in the area included in this report.

All the evidence gathered by Messrs. Ball and Smith points to the secondary origin of most of the chert. Certain beds which are almost co-extensive with the formations are spoken of as probably being original. By this it is not meant that the chert was originally laid down as we find it today, but that a considerable part of the silica comprising these beds was deposited at the time the sediments were laid down—either mechanical, in the shape of animal remains, or chemically, as a precipitate. It is thought that in any case it is simply a matter of percentage and that most cherts are original, in that they are formed around nuclei of silica and that most cherts are secondary in so far as they have received accretions since the original nuclei were deposited.

The chapter in which the economic products are discussed is clear, concise and complete. There has been no attempt to embellish the descriptions, and it is thought that any one who cares to investigate the mines or quarries will find conditions as represented in this report.

Very little is said by the authors about the possible mineral content of the Proctor limestone. It outcrops in only a few places and no drilling has been done to determine the nature of the formation beneath the surface. It cannot be foretold whether or not ore bodies occur in this formation, but if the rock has characteristics similar to those of the Bonne Terre limestone which occurs in the southeastern part of the State one would be justified in prospecting.

It is thought that the value of the soils in this county have been, in many instances underrated. Much of the wild land is well watered with springs and creeks; it supports a luxuriant growth of blue grass; and is unexcelled for grazing.

E. R. BUCKLEY,
State Geologist.

CHAPTER I.

PHYSIOGRAPHY.

INTRODUCTION.

The Ozark plateau includes that portion of Missouri south of the Missouri river, the northern part of Arkansas and small portions of Kansas, Illinois and Indian Territory. This plateau has an area of approximately 75,000 square miles, and has the shape of a low, flat dome extending approximately 500 miles east and west and 200 miles north and south. On all sides the Ozark plateau is hemmed in by lowlands: to the east and southeast lie the gulf plains, to the south the Arkansas valley, and to the west and north the prairie plains. The elevation of the region, which is in some places 2,100 feet, together with its dome-like structure, are in sharp contrast with the surrounding level plains, making the plateau a distinct topographic unit.

Miller county is located in that part of the Ozark plateau known as the Salem Upland* which occupies, in a general way, the southeast quarter of the State with the exception of the lowland area along the Mississippi river. The Osage, the Gasconade, the Meramec and the Current rivers flow through this upland area.

The interdependence of the geology and topography of a region makes a knowledge of both very necessary for a thorough understanding of either. So it happens that a knowledge of the geology of Miller county is essential to an understanding of the topography. Broadly stated, Miller county is an area of horizontal rocks, as a result of which the physiographic features are simple compared with those of a steeply folded area. The formations are of wide areal distribution, and consist mainly of dolomite interlaminated with chert and sandstone. They are comparatively uniform in composition and hence in durability. However, the broken chert at the base of the St. Elizabeth formation, on account of its less solubility and greater resistance to erosion, forms in places an escarpment of twenty feet.

At one time a considerable part of Miller county was covered with soft shale of Coal Measure age. The ease with which these rocks are eroded controlled in a large measure the location of the present stream

*Marbut, surface features of Missouri. Mo. Geol. Sur. Vol. VIII, 1896, p. 56.

channels. This, however, ceased to be an important factor after the removal of the shales from above the present level of the stream channels. The areal extent of the Coal Measure pockets in a number of the valleys in the northern part of the county is indicated by a flat basin the limits of which are defined by the rugged topography of the surrounding Cambro-Ordovician rocks.

The trenching of the land has been accomplished in two ways—by mechanical erosion and solution. The agents of mechanical erosion which have been most active are sudden changes in temperature, freezing water, vegetation, rain and stream erosion.

Solution in conjunction with these mechanical agents of erosion, has been unusually active. The most striking evidences of solution are the caves, sinks and cirque-like heads to the gulches. In a less noticeable manner solution has also lowered the level of the country by removing minute quantities of rock from all parts of the formation above the level of ground water. A large part of the underground water issues from the ground as springs which feed the tributaries to the Osage river. All the mineral matter in solution, except a small part which is deposited as travertine on the cliffs, is carried out of the county and into the large rivers which eventually empty into the ocean. As there have been several topographic cycles, so have there been several cycles of solution, as shown by the deposition of the Coal Measure shales and coal in basins which can only be accounted for by pre-Coal Measure solution.

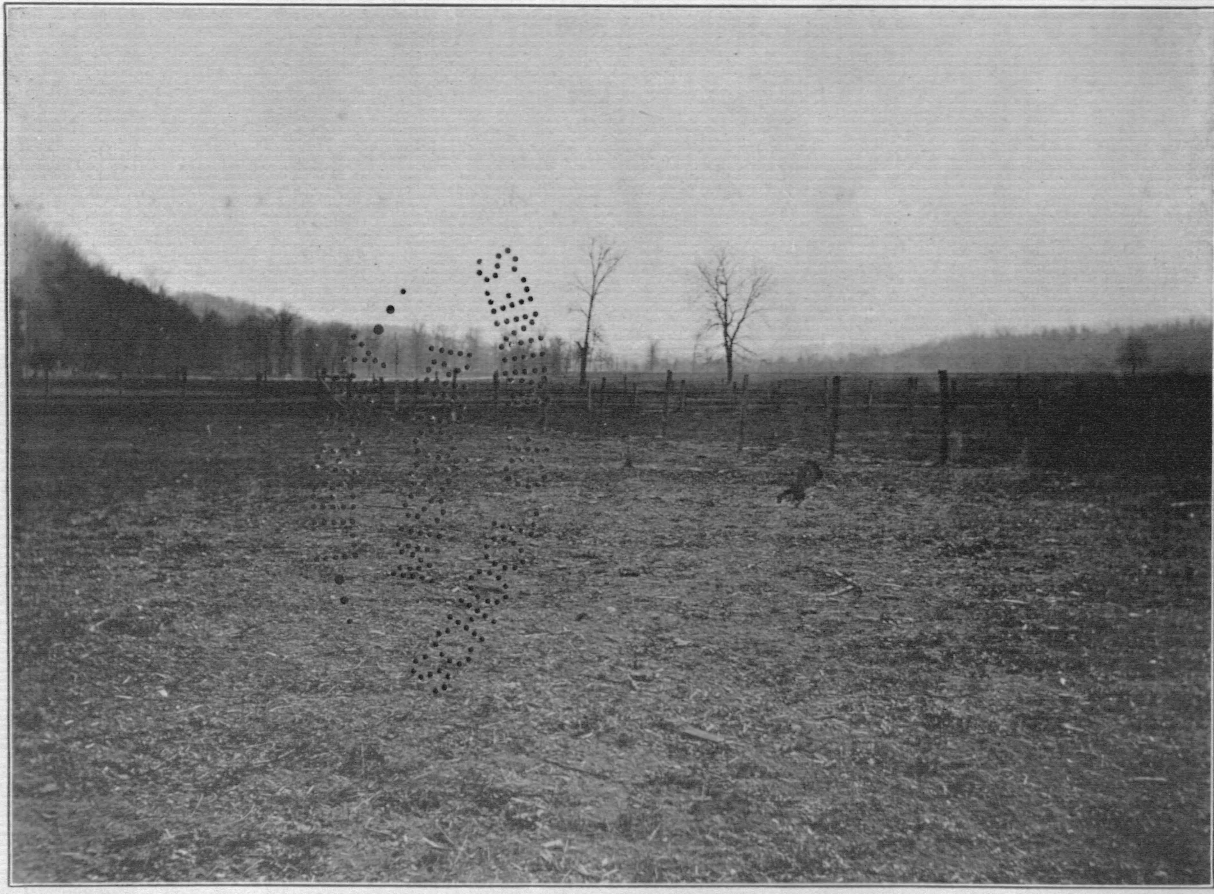
TYPES OF SURFACE RELIEF.

The surface of Miller county can, both physiographically and economically be divided into (1) alluvial plains, (2) hilly areas, and (3) table lands.

ALLUVIAL PLAINS.

The alluvial plans include what are known as the bottom lands, or those portions of the county which are covered by the water of the Osage river during periods of flood. With these should be included the bottom lands of the U-shaped tributary valleys. The area thus defined embraces not only the flood plains of the Osage river and its tributaries, but also a narrow strip of land along many of the secondary stream channels.

The total area of these valley tracts is about thirty-five square miles, of which twenty-six are a part of the flood plain of the Osage river. In the western part of the county the elevation of the flood plain varies from 545 to 580 feet above sea level. In the eastern part, owing to the



FLOOD PLAIN OF THE OSAGE RIVER.

fall in the Osage river, the flood plain ranges from 515 to 550 feet above sea level.

The alluvial plain is a comparatively level tract of land, extending from bluff to bluff on either side of the river, and in some instances continuing a short distance up the tributary streams. The level surface of the plain is interrupted at intervals by irregular depressions and elevations. The depressions consist of the widening channels of the Osage river and its tributaries; of ox-bows, which form boggy marshes; and of secondary river channels, occupied only during periods of very high water.

The elevations consist of isolated limestone hills which, from their position, might appropriately be called monadnocks. The most conspicuous of these is located in the flood plain of Tavern creek, in the S. E. ¼ of sec. 22, T. 41 N., R. 12 W. The south and east sides of this hill are precipitous, having a vertical escarpment 100 feet high. The slope on the north and west sides is gradual. The beds on the north side of the hill dip 8 degrees west-northwest, while on the south side they dip slightly east-southeast, forming a gentle anticlinal fold, with a northeast-southwest axis. During high water this hill, which comprises about forty acres of land, is almost completely surrounded by water. This hill consists mainly of Gasconade limestone, although capped with beds of the St. Elizabeth formation. The evidence is clear that at different times Tavern creek has flowed on all sides of the hill.

On the other side of Tavern creek, opposite this hill, is a smaller hill, having an elevation of fifteen feet. A third is located in the Osage river valley, in the S. W. ¼ of sec. 24, T. 41 N., R. 13 W.

From these completely detached hills in the alluvial plains to the flat topped ridges of the hilly country, there is every gradation. In secs. 10 and 11, T. 40 N., R. 12 W., Tavern creek makes a long horseshoe bend, into which extends a finger-like ridge, a half a mile long and from fifteen to forty feet high with a low gap near the middle. The full strength of the current impinges against the ridge at the gap and it will be but a brief time, geologically, before it is cut through, leaving a monadnock where there is now a ridge.

The Osage river, on the whole, is widening its channel and not cutting it deeper. In many places soil, sand and gravel are being brought in and the flood plain is being built up. During the periodical overflows the stream has been known to deposit, locally, five-eighths of an inch of sediment on the bottom lands.

The valleys of the tributary streams, above the flood plains, are U-shaped. In the lower reaches of the stream the valleys are greatly depressed, but near the source the width gradually decreases until they merge insensibly into V-shaped valleys. The V-shaped valleys, with their rugged sides and thin soil, belong, topographically, to the hill country.

The largest and most important tributaries of the Osage river from the north are the Saline and Little Gravois. The latter is the smaller and the sides of the valley in which it flows are, on the whole, somewhat less bold and rugged. The back water has been known to extend up the Little Gravois two and one-half miles from its mouth, while the U-shaped portion of the valley extends about three miles farther, to a point about 100 feet higher in elevation than the extreme high water. In 1895 the back water extended up the Saline three miles to a point above its junction with the northernmost Little Saline. In 1885 the back water of the Osage river extended up the northernmost Little Saline for half a mile. The U-shaped portion of the valley of the Saline extends west from this fork about six miles, rising in this distance 120 feet. On Cub and Gum creeks the back water extends for less than a mile from their mouths, while the U-shaped valley is somewhat longer.

Tavern creek, which enters the Osage from the south, is the most important tributary of the Osage in Miller county. The flood plain of the Tavern extends from its mouth to a point a mile northeast of St. Elizabeth and in its lower reaches is from one-fourth to three-eighths of a mile wide. The valley is skirted on one side by precipitous bluffs and on the other by hills having much gentler slopes. The height of these hills diminishes as the head of the valley is approached. In the U-shaped portion of the valley they have an average height of from 100 to 150 feet. The U-shaped portion of the valley extends from within eight miles of the Osage river to within seven miles of the county line, where it passes gradually into the V-shaped valley.

Barren and Brushy forks are the chief tributaries of the Tavern. The former, although the longer of the two, has the narrower valley and is hemmed in by much rougher topography. One of the broadest parts of the valley of Brushy fork is about two miles from its head, where it is wider than in any other part, except along the lower reaches.

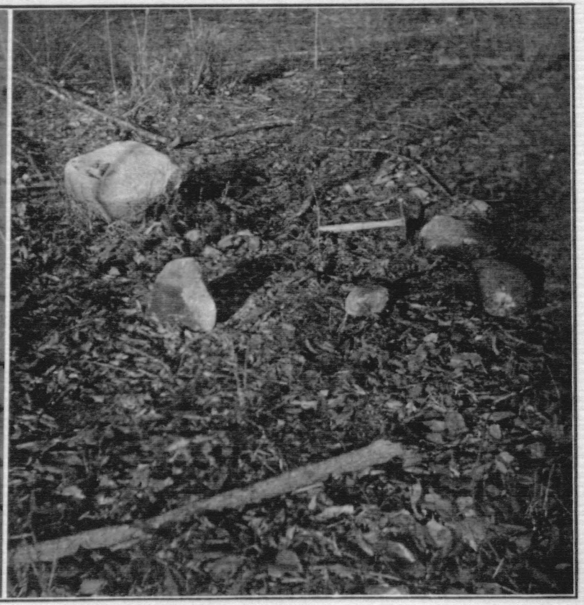
Besides Tavern creek, Sugar, Humphrey, Panther, Coon, Dog and Bear creeks are tributaries of the Osage river from the south. The backwater on Sugar creek extends about a mile from its mouth. On Dog and Humphrey creeks the back water extends half a mile.

The Auglaise, one of the most important tributaries of the Osage river, flows through the southwestern part of Miller county for several miles. Its valley throughout this distance is of the U-shaped type.

1.

1. MUDCRACKS IN OSAGE RIVER ALLUVIUM.

2.



2. GLACIAL BOULDERS ALONG DOG CREEK.

THE HILLY OR BROKEN COUNTRY.

The hilly or broken country covers about 480 square miles, nearly four-fifths of Miller county. It comprises all of the county with the exception of the prairie land in the northern part and the many pronged bottom land of the interior. In the northern part of the county the elevation varies from that of the alluvial plain of the Osage river to that of the prairie with which it merges at an average elevation of 920 feet above sea level. In the southern part of the county, the hilly country attains an elevation of 1050 feet.

The hilly country may be conveniently divided into "ridges" and "brakes." The ridge land comprises irregular areas of table land of which considerable is tillable. None of the land included in the "brakes" is level and very little is suitable for cultivation.

The cliffs, which form an escarpment on one side of the Osage river, vary from fifty to two hundred and fifty feet in height, and are often vertical or even overhanging. The latter are especially apt to occur where a gentle fold has brought a broken chert ledge of the Gasconade limestone above the water level. During the deformation of this region, the chert beds, on account of their brittle nature, were more closely jointed than the dolomite. So abundant are these fractures, that blocks one-half inch to two inches on an edge are very common. Weathering loosens, displaces and removes these small polygonal blocks more rapidly than it does the dolomite. In consequence their presence is everywhere indicated by niches and undercut cliffs. The steepest cliffs are inaccessible and treeless, except for a rim of firs about their summits. Cedar bluff, down the river from Tuscumbia, is an unusually beautiful conifer-crowned bluff.

Upon leaving the main streams, and passing up one of the innumerable side valleys, one finds himself in the so-called "brakes." Most of the year these minor valleys are dry. During the rainy season, however, the channels are often raging torrents. The creek beds are covered with fragments of sub-angular chert and some dolomite.

On either side the timbered slopes rise with almost cliff-like steepness, and one can scarcely divest himself of the idea that he is in a mountainous country. The main valley sends off side valleys and these in turn are the trunk channels of smaller valleys, which in turn send off countless smaller ones. The subdivisions of this dendritic drainage are almost infinite. Near the heads of the valleys frequently occur ledges of dolomite which extend across the stream channel, resulting in the formation of miniature waterfalls after every rain. When one climbs the walls leading out of a valley he finds himself suddenly on the top of a flat ridge.

The suddenness with which some of these valleys end is surprising. The termination is frequently a horseshoe or cirque-shaped depression with steep sides, usually covered with a rough talus of dolomite, flint and sandstone blocks. These steep slopes enclose at least three-fourths of a somewhat conical depression imparting to the topography a cirque or horseshoe-like outline as is clearly shown on the general geological may, especially in the vicinity of the Osage river. This peculiar topographic feature originates in two ways; first, as a result of combined solution, erosion and sapping of heavy beds of dolomite which underlie a considerable thickness of closely jointed chert; second, from sink-holes, caves and caverns which were probably connected with the main valley by underground galleries. As solution and underground erosion removed more and more of the dolomite from beneath the roofs of these channels they have gradually fallen in, making long narrow valleys with crescentric, sink-line heads.

The narrow gorge of the stream flowing from Klinner's cave in the S. W. ¼ of sec. 11, T. 41 N., R. 15 W., shows one of the earlier stages in the formation of a cirque like valley head by this process. Here a part of the gallery has fallen in while the sink or cave still remains.

The first is the more common origin and probably accounts for at least three-fourths of the so-called "cirque-shaped" valley heads.

The heavy dolomite beds of the Gasconade limestone lie immediately underneath the insoluable chert of the St. Elizabeth formation. As erosion cut back along the joint planes, the dolomite was removed in solution from beneath the thick, broken chert beds, allowing huge blocks to fall into the valley. Each fall exposed a greater surface to solution, until finally the lateral sapping becoming more important than the back cutting at the valley head, resulted in the formation of the cirque-like heads.

A very interesting sink-hole, which will soon become a cirque valley head, is located in the N. E. ¼ of sec. 18, T. 40 N., R. 14 W. It measures 75 feet north and south, 50 feet east and west and is 35 feet deep. Inside of this main sink-hole is a second and deeper one which is connected with an underground channel. The north and south elongation indicates that the sink-hole has been formed along a north and south joint. The upper part of this sink is in the St. Elizabeth formation, and the lower part is in the Gasconade limestone. The cherty beds of the St. Elizabeth formation are but slightly soluble and it must have been by the solution and removal of the Gasconade limestone and the subsequent collapse of the cherty beds of the St.

Elizabeth formation that the sink-hole was formed. Although, ordinarily, the water entering the sink-hole passess underground to the gulch 100 yards south, yet during flood-time the water overflows and enters the gulch through a shallow channel which has been formed on the surface. The present head of the ravine is cirque-shaped and, eventually, solution and erosion, together, will remove the neck of land separating the gulch from the sink-hole thereby extending the length of the gulch and adding a new cirque-shaped head to the valley.

These cirque-like valley heads are typically devoloped where less than 70 feet of the St. Elizabeth formation is present.

As the souces of the main streams are approached, the branches are farther apart, and consequently the surface has fewer ravines and gorges and the ridge land is proportionately increased. Within four miles of the Osage river the streams reach the limit of their dendritic development.

The land along the Osage river is eroded, not only by the water which falls on its suface and issues from springs on the hillsides, but it is also washed by the rain and spring water of the upland or ridge country. Here, as might be expected, the surface is more hilly and the hills have the sharpest peaks. Here the "balls"* are most numerous, the soil is thinnest and the population is most sparse.

One of the striking features of the hill region is the great number of more or less flat topped hills and knobs of dolomite nearly devoid of trees, called by the citizens of Miller county "balls." Only a few scraggly hack and hawberry bushes and jack and post oaks grow on these bare knobs. In the summer they are partially covered with a scanty growth of grass, but in the winter they are bare except for the lichens, which cling to the pitted ledges and boulders of dolomite. The boulders are all residual and have resulted from weathering along the joints, many of which are from one to twelve inches wide, and from five to ten feet deep. The joints are frequently filled with a rich soil, in which the few trees and bushes noted above take root.

There are three distinct horizons in the Cambro-Ordovician strata of Miller county at which the so-called "balls" form. The two most persistent are the heavy beds of dolomite at the top of the Gasconade limestone and the massive dolomite beds of the Jefferson City formation.

The lower ball is usually only exposed on a salient heading cut between two creeks or between two steep sided ravines. It usually occurs 60 feet below the Gasconade-St. Elizabeth contact, and, as a rule, the

*A corruption of "bald," referring to the small amount of vegetation on them.

heavy beds of which it is composed are uniform, finely crystalline dolomite, somewhat more massive than those of the next "ball" above.

In some places this "ball" is separated from the one above by a rough, stony bench, and in other places the two "balls" coalesce. The upper "ball" includes all or a part of the upper 50 feet of the Gasconade limestone and is much more persistent than the lower.

Wherever erosion has been active these "balls" of Gasconade limestone are very abundant. Looking from the St. Elizabeth formation in sec. 20, T. 41 N., R. 13 W., towards the Osage river one can see a great number of these "balls" marking the remnants of former ridge land areas. After the protecting covering of sandstone and chert of the St. Elizabeth formation and the blanket or residual, clayey soil is removed, the process is, geologically speaking, rapid.

The third "ball" occurs in the Jefferson City formation. Although this ball in places is undeveloped, in others it is 125 feet high. Typical examples of this "ball" may be observed between the Republic Coal Company's mine and Aurora Springs station.

In addition to the above enumerated "balls" there is an exceptional one in the Gasconade limestone, which only occurs in the vicinity of Sycamore Spring hollow in township 40 north, range 13 west. This "ball" is made up of beds about 100 feet above the base of the formation and many feet below those of the lower "ball." The beds composing this "ball" weather with a smooth, white, roundish surface. They are exposed on the county road in sec. 31, T. 41 N., R. 13 W., and at the ends of the secondary ridges at the head of Panther creek in secs. 16 and 9, T. 40 N., R. 13 W.

The escarpment at the base of the St. Elizabeth formation terminates in a practically flat topped ridge. In places the ascent to the ridge from the middle "ball" is very gradual, due to the almost complete removal of the beds of the St. Elizabeth formation. This ridge land is the complement of the hill country and in consequence, near the river the ridges are very narrow and often broken into a great number of isloated flats extending down into the Gasconade limestone, the gaps being occupied by "balls." As these ridges continue back into the country on the north side, they increase in width until at a distance of seven or eight miles from the Osage river they predominate over the "brakes" which here constitute an inconsiderable area near the streams. On the south side of the river the ridges and "brakes" occupy about equal portions of the land. The direction and shape of these ridges are determined by the position of the adjacent streams or "hollows" and their endless ramifications. The minor ravines usually trend at right angles to the major valleys. Consequently the ridges consist of flats which diminish in size toward the main drainage lines and extend at right angles to one another. The ridges slope gradually from the "brakes" to the prairie.

Where the streams traverse the St. Elizabeth formation, the topography is gentler, the hills more rounded and the gulches less numerous and less rugged than in other parts. While this is true on the north side of the Osage river, it is more pronounced on the south side where there are greater lithological differences between the Gasconade limestone and St. Elizabeth formation.

In spite of the fact that the Jefferson City formation does not occur in the lower and more active parts of the streams, the topography is rugged, resembling that of the Gasconade limestone.

THE UPLAND AREA.

The upland area is all in the northern part of the county and is coextensive with the catchment area of the south Moreau creek and its tributaries. It embraces most of the land underlain by the Jefferson City formation north of the Osage river, with the exception of a small area in the vicinity of Mary's Home, and another along the southern edge of the upland area. These areas are drained by the tributaries of the Osage river, which have cut the land into hills and valleys tpyical of the hill country. The Jefferson City formation south of the upland, in sec. 3, T. 41 N., R. 16 W., is one mile wide; south of Eldon it diminishes in width to a few hundred yards, while at the southeast corner of township 42 north, range 14 west, and the northeast corner of the adjoining township to the south, it has widened to a belt one and a half miles wide. This upland prairie includes about 70 square miles all of which has an altitude of from 700 to 1,000 feet above sea level. The greatest difference in elevation is 300 feet. A line drawn due north from the southern edge of the upland to the county line and passing one and one-half miles east of Pleasant Mount would fall about 90 feet. In the extreme eastern part of the county from Spring Garden north, the fall is not as great.

This region is a structural plain whose inclination is determined by the monoclinal dip of the rocks to the north. The dip of the rocks and the slope of the plain are almost the same except on the uplands where the slope is not quite as steep as the dip. The streams have cut down approximately to the contact of the Jefferson City and St. Elizabeth formations.

The level surface of this ancient coastal plain has been cut and carved by the streams of the present day, most of which are tributary to the Moreau river. The channels of these streams are sufficiently deep to give to the surface of the so-called prairie, a gently rolling and in some places even a hilly aspect. In their lower reaches the creeks are bounded on one side by cliffs, occasionally 50 feet in height, and on the other by a gentle slope. Farther up the creeks the cliffs gradually die out, being replaced by the gently sloping sides of the U-shaped valley. Near their source these tributary stream channels are mere ditches in the residual soil, two to four feet deep.

The sudden change from the topography of the rough hill country with its numerous rock exposures to that of the prairie, with rounded contours and few rock exposures, must be largely ascribed to the gradient of the streams which are much steeper in the hill country. The creeks flowing into the Osage river from the south side of the divide are only from 10 to 18 miles long while the Moreau on the north side travels 45 miles from where it leaves the county to where it empties into the Missouri. Yet there is very little difference in the actual elevation of the mouth of the Moreau river and those of the tributaries of the Osage river. The gradient of the streams on the south side of the divide is much steeper than that on the north side.

The upland area was originally largely prairie. Meek's* map shows the prairie to have included at that time, parts of secs. 1, 12, 13, and 24, all in T. 42 N., R. 14 W.; secs. 21, 23, 24, 25, 26, 27, 28, 31, 32, 33, 34, 35 and 36, all in T. 42 N., R. 15 W.; and secs. 1, 2 and 12 of T. 41 N., R. 16 W. This upland area, with the exception of some of the creek bottoms and a few scattered hills, is now cleared.

SINKS, CAVES AND NATURAL BRIDGES.

The physiographic features resulting from the work of underground waters may be considered under the heads of sinks, caves and natural bridges. Although these are the most conspicuous results of solution by underground waters, undoubtedly a much larger amount of rock has been removed in solution without resulting in the formation of any of the above physical features.

Although dolomitization has been important in producing the peculiarly porous condition of the Cambro-Ordovican rocks, differential solution has been most important. Cavities in the shale and chert layers are often due to the abstraction in solution of the more souluable constituents. The solution represented by the small cavities and other openings in the rock, is far greater than that represented by sinks, caves and natural bridges.

*Reports of the Geol. Sur. of the State of Missouri, 1855-71. G. C. Swallow, State Geologist. Page 111.

SINKS.

The effect on the topography, of sinks which occur near stream channels, has already been refered to. However, when sinks occur on hill sides far above the creek level, they are often indicated by the bench and cliff profile of the hill. On the ridge land itself they appear either as shallow basins or as inverted, steep sided cones. The deeper sinks of small diameter have exactly the appearance of prospect holes except that they are minus the dumps.

Sinks are most abundant on ridge land which is underlain by the St. Elizabeth formation. In the extreme southwestern corner of sec. 19, T. 41 N., R. 13 W., in the bed of a tributary of Jim Henry creek, the water disappears underground during flood-time, reappearing as a muddy torrent in a spring on the other side of a fifty foot ridge of Gasconade limestone. In the spring of 1902 the heavy rains uncovered a sink on Albert Bell's land in sec. 15, T. 42 N., R. 15 W. This sink has a diameter of 11 feet, and drops down, almost vertically, 25 feet. terminating in an open crevice, which strikes N. 5° E. This is one of several sinks which occur in the neighborhood. All of these are in the Jefferson City formation. Three of the largest sinks in Miller county are at Blyze P. O. in the northern part of township 39 north, range 12 west. These are in the St. Elizabeth formation and are from 15 to 35 feet deep and from 50 to 125 feet in diameter. Other sinks occur near the corner of secs. 16, 17, 20 and 21 in T. 40 N., R. 13 W., and in sec. 5, T. 40 N., R. 14 W.

CAVES.

Stark's Cave.

This cave is located in the center of the north half of sec. 28, T. 41 N., R. 15 W. It is at the head of a steep gulch leading from one of the head-water streams of the Little Gravois, and is situated in the upper part of the Gasconade limestone. The mouth of the cave is 100 feet wide and from 12 to 15 feet high, and extends about a fourth of a mile into the hill. Measuring all of its ramifications it has approximately a mile of chambers, many of which are of considerable size. They are a number of tortuous passages 25 feet high and so narrow that one can scarcely traverse them. Red clay similar in every respect to the residual clay of the shallow mines, covers the floor, ankle deep. The chambers are decorated with stalactites, stalagmites and columns, some of the latter being a foot in diameter and twenty feet high. One of these columns, ten feet long and six inches in diameter, is inclined at an angle of 60 degrees to the horizon; this may be due to the depositing drop of water being constantly blown to one side by the gusts of wind which enter the cave in the same manner that inclined icicles are formed from the eaves of a roof when the wind is blowing.

Wilson's Cave.

Wilson's Cave occurs in a bluff of Gasconade limestone along Tavern creek, in the S. E. ¼ of sec. 35, T. 40 N., R. 13 W. It is chiefly interesting from the fact that one of the oldest settlers and most unique characters in Miller county was buried in a small chamber directly above the mouth of the main opening. The mouth of Wilson's cave is irregularly oval in outline, having a breadth of 75 feet and a height of 30 feet. Altogether the cave has about 150 yards of narrow, winding passages. On the bed of the stream which formerly flowed through this cave are rounded fragments of chert and dolomite. These pebbles have been rounded in part by solution and in part by the erosion of the cave stream. There is no indication that this stream is connected with the surface drainage. On the floor of the cave are many angular dolomite fragments and boulders, cemented by travertine. Some stalactites and stalagmites are present.

Beckman's Cave.

Two caves occur in the Gasconade limestone in sec. 28, T. 41 N., R. 12 W. The larger extends a quarter of a mile into the hill. A partial falling in of the roof at the entrance has formed a miniature natural bridge. The stalactites, though small and few in number, have a beautiful white color.

In the smaller cave, stalactites are very numerous. At the present time the waters are rapidly depositing a dark brown, banded travertine upon the sides of the chambers. The travertine is in places 18 inches thick. Mr. Beckman says that within his memory many chambers which were formerly passable, are now almost completely closed with travertine.

Klinger's Cave.

This cave, which is in Gasconade limestone, is located in sec. 17, T. 41 N., R. 14 W. It is situated at the head of a ravine tributary to Saline creek. The entrance is 30 feet wide and 15 feet high. Seventy-five feet from the entrance the cave widens into a charmber 40 feet broad in which water stands to a depth of from three to five feet. The bottom of this pond is covered with residual clay to a depth of 18 inches.

Miscellaneous Caves.

A number of caves of less importance occur in the following places in the county: In the S. E. ¼ of the N. E. ¼ of the S. E. ¼ of sec. 21, T. 40 N., R. 15 W.; in sec. 17, T. 41 N., R. 12 W. (the Deerhof cave); in sec. 7, T. 41 N., R. 12 W., at the mouth of Tavern creek; at the northwest corner of the S. W. ¼ of sec. 24, T. 40 N., R. 14 W., and in the N. W. ¼ of the N. E. ¼ of sec. 23, T. 40 N., R. 12 W. All these caves occur in the upper part of the Gasconade limestone.

NATURAL BRIDGES.

Only one natural bridge of any importance occurs in this county. This bridge is located near the west line of sec. 35, T. 41 N., R. 12 W. The opening underneath the bridge is 200 feet long, 20 feet high and 50 feet wide. A crevice or open joint striking east and west and penetrating the entire thickness of the roof has undoubtedly been one of the chief factors determining the location of the tunnel. Large slabs of rock have fallen from the under side of the bridge along the crevice. A few stalactites on the under side give evidence that this opening may at one time have been a cave. A small stream flows under the bridge and joins Tavern creek a short distance away.

TABLE OF ALTITUDES.

The only elevations in Miller county which have been established by leveling are the following:

Name.	Authority.	Elevation.
Aurora	M. P. R. R.	912.5
Bagnell	"	579
Cooper	"	794.50
Eldon	"	918.40
Olean	"	746
South Moreau creek at bridge of C. & R. I. R. R	C. & R. I. R. R.	817
Brush creek at bridge of C. & R. I. R. R.	"	790
Etters	"	884
Railroad at bridge over Osage river	"	610

RIVER SYSTEMS.

INTRODUCTION.

Miller county is drained by two river systems, the Osage and the Moreau. These systems differ from each other widely; first, in catchment area, the Osage drains one-sixth of the state while the Moreau drains less than one-hundredth; second, in character of water, the former, except in time of flood, being remarkably clear, while the latter is extremely muddy; and third, in the shape of the valleys, the Osage being hemmed in by precipitous cliffs and rugged hills while the Moreau is, as a rule, bounded by low, roundish slopes.

THE OSAGE RIVER.

The Osage river rises in east central Kansas and flows south and east through Missouri to the center of Miller county, where it turns rather abruptly and flows north and northeast between Cole and Osage counties into the Missouri river. The Osage river is the largest tributary received by the Missouri river in Missouri. All of Miller county, with the exception of the prairie land in the northern part, is drained by the Osage river and its tributaries.

From the western border of Miller county to Tuscumbia, the Osage river flows in a general easterly direction; from Tuscumbia to where it leaves the county, it flows in a general northeasterly direction. A straight line drawn through the county from the point where it enters to where it leaves, is less than 24 miles long, while the actual distance covered by the river, in all its windings through the county is over 40 miles. This difference is due to the system of meanders which have been developed.

In its course through Miller county the Osage river falls about 30 feet, making an average grade of three-fourths of a foot per mile. The volume of water in the stream varies greatly at different seasons. In the drought of 1901 the stream could be forded on foot at a number of places without more than wetting one's shoe tops, while in the following spring and winter the water was in places 40 feet deep. Between the 17th and 22d of December, 1895, the river rose 36 feet, completely inundating the bottom land farms, washing away fences, hay-stacks, and corn and flooding houses and stores in Tuscumbia and Bagnell which were built on the alluvial plain. On subsiding, the river left a deposit of alluvium averaging three-fourths of an inch in thickness on level ground and three or four inches in depressions. Other floods of almost equal volume are known, such as that of May 24, 1896, when the gage recorded a rise of 36 feet 4 inches.

A meandering course is characteristic, as a rule, of sluggish rivers flowing through plains. The Osage river has a well developed system of meanders, sunk from 200 to 280 feet below the surrounding ridges. Its flood plain is bounded on one side by a precipitous bluff, on the other by broken hills.

This phenomenon admits of two possible explanations: first, as Prof. W. M. Davis* holds, the Osage may be following the course of a stream

*Science, Vol. XXI, pages 226-227.

which in times past meandered over a plain as smooth as that of the Mississippi. Through a subsequent elevation of this plain, the river may have gained a considerable fall and so started an active lowering of its bed, the course of which was controlled by the old meanders.

The alternative explanation presented by Arthur Winslow,* holds that the river has sunk its courses through horizontally bedded limestones, sandstones and cherts, the meanders being the result of the rivers attempt to avoid flexures and rocks of unusual hardness.

As Dr. J. C. Branner** states in regard to the White river of Arkansas, if the first were the explanation we would expect cliffs on both sides of the river, in reality we have a cliff on but one. On the other hand it may be stated that no faulting or flexuring was noted in Miller county which would assist in explaining the phenomenon. Our work covered only 40 miles of the river's course and a question of such wide physiographic improtance should not be settled by such limited observation.

The Osage river is navigable during eight or nine months of the years in which there is an average rainfall. Much of the produce of Miller county is shipped by boat down this river. Great numbers of railroad ties are rafted down the Osage to Bagnell from Miller, Morgan, Camden and Benton counties.

That the Osage river in times past has changed its course is to be inferred from the marshy ox bows of its flood-plain. The island in the Osage river in sec. 20, T. 40 N.. R. 14 W., is reported rapidly increasing in size.

The Osage river is crossed in Miller county by only one bridge, that of the C., R. I. and P. R. R., in sec. 1, T. 41 N., R. 13 W. There are three ferries across the river, one at Bagnell, another at Tuscumbia and a third at Capps. The river, when it is not at high water, can be safely forded at Bagnell, Tuscumbia and Brockman's in sec. 30, T. 40 N., R. 14 W. Besides these there are several other places where the stream can be forded at low water.

Tributaries of the Osage River.

Besides innummerable valleys of intermittent streams, the Osage river receives as tributaries from the north, the following streams: Beginning with the most easterly; the Little Tavern, Cub, Jim Henry, Saline, Gum, Lick and Little Gravois creeks and Shut-in-branch. From the south, starting in the eastern part of the county, it receives the Sugar, Tavern, Humphrey, Panther, Coon, Dog and Bear creeks, while the

*Science, July 21, 1893, March 16, 1894.

**Arkansas Geological Survey, Vol. V, p. 7, 1892.

Auglaise—commonly called the "Glaze"—flows through the southwestern corner of Miller county, joining the Osage in Camden county.

Saline creek—Saline creek has its source one mile north and a little west of Aurora Springs station, flows approximately east and south and empties into the Osage river three miles below Tuscumbia. The mouth of the Saline is 90 feet wide and the main fork has a total length of 12 miles. The principal tributaries are the north Little Saline and the south Little Saline. With its branches this stream drains approximately 55 square miles. The main fork of the creek has a fall from the prairie land to the Osage river, a distance of 12 miles, of about 475 feet, while the north Little Saline falls 325 feet in eight miles. Each of these is equivalent to an average fall of 40 feet per mile. The saline and its tributaries are fed by springs and consequently the water is very pure and comparatively cool.

Little Gravois—Little Gravois creek heads south of Rocky Mount and flows south and east, empting into the Osage river just above Bagnell. With its tributaries it drains 45 square miles of territory. In eight miles, it has a fall of approximately 400 feet or 50 feet to the mile. The main tributaries are the Aurora Springs branch and the East branch.

The Little Tavern, Cub, Jim Henry, Gum and Lick creeks and Shut-in-branch are minature Gravois and Saline streams.

Tavern creek—The name Tavern is a corruption of the word "cavern." This stream was named "Cavern creek" on account of the many caves found in the limestone bluffs on either side. Tavern creek is the most important tributary of the Osage river in Miller county. It has its source in the northern part of Pulaski county. Entering Miller county from the south through sec. 13, T. 38 N., R. 13 W., it flows in a very winding and tortuous course in a general northerly direction, emptying into the Osage river in sec. 7, T. 41 N., R. 12 W. Tavern creek is 200 feet wide at its mouth. The distance from its mouth to where it enters the county is about 20 miles almost due south. In covering this distance the creek meanders over 40 miles, draining, with its tributaries, practically all of the eastern part of Miller county, about 200 square miles.

Among the larger tributaries of the Tavern are several streams known as Little Tavern No. 1, Little Tavern No. 2, Little Tavern No. 3, Sandstone creek, Bolins creek, Bailey and Lenox branches, Brushy and Barren forks and Clinking-beard hollow. From the county line to where it empties into the Osage river, the Tavern has a fall of 300 feet, an average of 7.5 feet per mile. The Tavern and its tributaries are fed mainly by springs. Water power could be obtained at a number of places along the stream making favorable sites for small mills.

Coon creek—Coon creek rises in sec. 21, T. 40 N., R. 13 W., flows a little north of west for one and a half miles, thence in a straight course N. 25° W. to near the northwest corner of township 40 north, range 13 west, and finally in a northerly direction, emptying into the Osage river in the southwest corner of township 41 north, range 14 west. It is five and one-half miles long.

Coon creek is the most striking example in Miller county of a stream whose course is determined by geological structure. Throughout its entire length this creek follows a synclinal trough, although it cuts across minor anticlines superimposed on the main syncline. From the mouth to near the middle of sec. 20, T. 40 N., R. 13 W., the beds on the east side of Coon creek have a dip of from 10 degrees to 60 degrees, slightly south of west while on the west side of the creek the beds are nearly horizontal or have a slightly eastward dip. From the middle of sec. 20, T. 40 N., R. 13 W., to the head of the creek the beds on the north side dip sharply to the south.

Dog creek—Dog creek rises in the northern part of township 39 north, range 14 west, flows nearly due north for two miles, then northeast five miles parallel with the Osage river, from which it is separated by a narrow belt of broken country, thence northwest for one mile, and empties into the Osage river two miles below Tuscumbia. From source to mouth it falls 400 feet, an average of 50 feet per mile. Dog creek and its tributary, Cat-tail, drain about 20 square miles.

Auglaise creek—The Auglaise, or "Glaize," as it is commonly called, is about the same size as Tavern creek. It rises in Camden county, flows in a very tortuous course through the southwest corner of Miller county, describing two large horse-shoe bends, thence in a northwesterly direction through Camden county, emptying into the Osage river in sec. 1, T. 39 N., R. 16 W.

The Auglaise has a very slight fall in Miller county. The principal tributaries, in this county, are Mill, Brumley and Rollins creeks. The catchment area of the Auglaise and its tributaries in Miller county is about 44 square miles. At Jimtown there is a small water power used to run a mill.

THE MOREAU RIVER.

The Moreau river system is north of the Osage-Moreau divide and consists of the Moreau river and its tributaries.

The Moreau river is formed by the junction of what are known as the North Moreau and South Moreau. The North Moreau and its tributaries flow through Cole, Moniteau and Morgan counties, while the

South Moreau drains a part of Cole, Morgan, Moniteau and Miller counties.

The South Moreau—The South Moreau river rises near Rocky Mount, flows north two miles to the county line, then a mile and a half through Morgan county, returning to Miller and flowing north to the Moniteau county line. At this place it leaves the county, flowing east two miles parallel to the county line and re-entering again for a distance of three miles. It has a length of sixteen miles and an average descent of sixteen feet per mile in Miller county.

With its tributaries, Blyth's fork and Brush creek, it drains about 70 sqare miles of prairie land in Miller county. The valleys in which the streams flow are characterized by gently sloping sides and few rock exposures. The gradient is gentle compared with that of the tributaries of the Osage, and in consequence the streams are much less rapid and usually laden with silt. Throughout the area there is a notable absence of good springs, which is due to the fact that the shallow valleys intercept no important water bearing strata. On Blyth's fork, at Olean, artesian wells have been obtained by drilling 50 feet, although the springs in that vicinity are mainly intermittent. The South Moreau often has a cliff 30 to 40 feet high on one side.

Blyth's fork rises one-half mile northeast of Eldon, and flows northeast, emptying into the South Moreau in Moniteau county, just north of the county line. This stream is about seven miles long, and has a fall of about 210 feet, or thirty feet per mile.

Brush creek is formed by the junction of two branches, one of which rises two miles south of Spring Garden and the other just north of Pleasant Mount. These branches flow respectively west and east to where they unite to form Brush creek which flows north.

DIVIDES.

The only divide of importance in Miller county is that which separates the Osage and Moreau river systems. This divide is a sinuous line, skirting the south edge of the prairie land. To the north toward the Moreau drainage basin the divide is convex, while to the south toward the Osage basin the curve is concave.

The altitude of the divide varies from over 1,000 feet above sea level northwest of Aurora Springs, to less than 875 feet just west of the Cole county line. The tributaries of the Osage river have a much steeper grade than those of the Moreau, and are consequently cutting back their heads faster and are encroaching upon the catchment areas of the latter. If the present conditions continue, the Saline and Little

Gravois will eventually have approximately the same gradient as the South Moreau. The tributaries of the two river systems often head within a few feet of one another, as is well illustrated by the Little Gravois and the South Moreau creeks which rise about three-fourths of a mile east of Rocky Mount.

In the N. E. ¼ of sec. 25, T. 42 N., R. 14 W., Mr. H. A. Wright dug a ditch four feet deep and 100 yards long across the divide, diverting the drainage for 75 yards, from Brush to Saline creek.

At approximately right angles to the main divide are secondary ridges upon whcih are the water sheds of the secondary streams. The ridges extending north are broad prairies, gently rolling, except near the margin where they are eroded into hills and valleys of rounded contours. The ridges extending south are wide and flat near the divide. As the "hollows" become more numerous and the main streams of greater strength, the ridges narrow. They finally become mere backbones capped in the north by the St. Elizabeth formation, and in the south by the Gasconade limestone.

THE RELATIONS OF PHYSIOGRAPHIC TYPES TO INDUSTRIAL AND SOCIAL CONDITIONS.

Tales of Spanish silver mines of bonanza richness in Miller county are without foundation. Some Spanish adventurer may have penetrated this portion of the Ozarks, but of this there is no authentic record. Of the presence of the French we have abundant proof in the names Auglaize, Gravois and perhaps Saline. The oldest inhabitants also tell of early French traders and trappers who found in the forests and along the streams ample opportunity for hunting and adventure.

The first permanent settlers were hardy mountaineers from Kentucky, Tennessee and Virginia, who found in the craggy hills and fertile valleys a portotype of their former homes. A man intent on war or the chase may disregard hills and valleys, rock strewn plains and brushy forests, but burdened with a family and household goods he will invariably enter a new land by the easiest line of travel. Thus it happened that these pioneers, half hunters and half farmers, traveling by boat, came up the Osage river and built their homes on the banks of this river and its tributaries. The mountaineer built his house by some spring, usually well up on the hillside not only to be above the malarial bottoms but also to escape the devastating floods. With an abundance of corn, fish and game, these sturdy pioneers lived in comparative ease. By the inaccessibility of their hill fastnesses, these people were largely isolated from the outside world, on account of which each settlement became self sustaining. Every farmer raised his own sheep and his wife carded, spun and dyed the wool, and wove the cloth for their garments. Cotton was also raised on nearly all of the farms. During the fall, hogs were killed and the meat cured and dried for winter's use. Deer and wild turkeys were always plentiful. After severe storms, when the gullies were washed clean, the men and women would gather galena out of the coarse gravel and smelt it by improvising furnaces out of large hollow logs. In this way they obtained lead for their bullets.

The nearest trading post was Jefferson City where pelts, furs and vension hams were exchanged for powder and other necessities, which were often packed home on the pioneer's back. As game became scarcer, necessity compelled the hill man to increase his "clearing" in order to make a living for himself and family. Neither his training nor his temperament made him a good farmer and in many instances more skillful and energetic farmers from other portions of the state supplanted him.

Other mountaineers turned their attention to stock raising, the waist-high grass of the ridge lands proving as nutritious to the cattle as it had been to the vast herds of deer before the advent of civilized man. Much of the land which is now covered with timber was at that time covered with a rich growth of prairie grass, only broken by occasional small timbered areas. In the early days the Indians and trappers yearly burned the prairie to kill the tree sprouts and incease the feeding gound for the deer. With the increase in the acreage of fenced land, the buildings became so numerous as to necessitate the discontinuance of this practice. Thus it happened that gradually the area burnt over became smaller and smaller until the discontinuance of the spring fires has allowed the underbrush and trees to cover thousands of acres of formerly valuable grazing land.

In the meantime settlers entered the upland area, quickly occupying the then easily cultivated prairie land. Soon all the desirable prairie land was under cultivation while hundreds of acres of forested bottom lands remained untouched.

Many of the inhabitants of the upland had been slave holders in their native states, and when they emigrated to Miller county they brought their negroes with them. The hill and bottom land people with their small farms could not use slave labor to advantage, while the larger acreage of the prairie farms favored their use. Thus in Miller county at the beginning of the war we note the influence of physiography on the distribution of the negro and indirectly moulding the sympathies of the people. During the war both factions were continually harassed by bushwackers, who found a safe retreat in the wild, rugged hills and valleys of the hill country. After the war, there was a considerable influx of northerners, some seeking their fortune in the "New South" and others health in the Ozarks.

The railroad tie industry in Miller county began in the early eighties, increasing each year until in 1901 the output amounted to 200,000 ties."
The tie cutting industry created a class of people who made it their only means of a livelihood. These people moved from gulch to gulch as the timber in each became depleted. Their log cabins are seen everywhere, but the owners have nearly all moved to less settled parts of Missouri or Arkansas.

Through physiographic conditions the inhabitants of Miller county are divided into two quite distinct classes. The people of the prairie and bottom lands, on account of the acreage of tillable land in their farms and the fertility of the soil, constitute a class distinct from the people of the hill country where agricultural conditions are much less favorable.

The prairie and bottom land people are better provided for in the way of transportation. The main line of the Chicago, Rock Island and Pacific Railroad skirts the southern edge of the upland, while the Bagnell branch of the Missouri Pacific traverses it from north to south.

These not only serve as outlets for produce, but as a means of communcation with the rest of the state. The steamboats serve the inhabitants of the river bottoms in a similar capacity.

The comparative value of the prairie, river bottom and hill lands is shown by the price at which each can be purchased. The prairie and bottom land bring from $15.00 to $35.00 per acre, while the hill land is worth on an average of $2 to $5 per acre. Large tracts of hill country are yearly sold for taxes, for about twenty-five cents per acre. The difference in the quality of the houses, barns and live stock of the two regions is surprising.

The broad, flat-topped ridges in the vicinity of St. Elizabeth and Iberia are remarkably productive. The people are thrifty, and much of the land is valued at from $10 to $25 per acre. The prosperity of the inland towns of Iberia and St. Elizabeth results very largely from the productiveness of the land of these tableland areas.

Among the hill people, many of the customs of the early settlers are still retained, and the speech is so filled with quaint expressions and provincialisms that it forms a vertiable patois. The hills and valleys still seem to constitute, to their minds, impassible barriers, and not infrequently persons are encountered who have never been outside of the county.

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*Estimate kindly furnished by Hon. R. S. Harvey of Eldon, Mo.

The low price of farm labor and the absence of factories have to a large extent kept the foreign emigrant out of Miller county. For this reason a high percentage of the citizens are American born. In the northeastern portion of the county there are two thrifty German settlements, the one centering around St. Elizabeth and the other around Mary's Home. Although nearly all the people of these communities are American born, they still, to a large extent, speak German.

CHAPTER II.

PROCTOR LIMESTONE.

(Fourth Magnesian Limestone of Swallow.)

AREAL EXTENT.

The magnesian limestone or dolomite of which this formation is composed is the oldest sedimentary rock exposed in Miller county. This formation has a very limited areal distribution in this county, but outcrops over considerable areas in the adjacent counties of Camden and Morgan. In Miller county it is exposed for some distance along the Osage river in the southeast corner of township 40 north, range 16 west; at Brockman's ford, midway between Tuscumbia and Bagnell; and at King's bluff, four miles below Tuscumbia. Away from the river this limestone outcrops along Humphrey's creek in the vicinity of Ramsey postoffice, and in Sycamore Spring hollow, a ravine in sec. 16, T. 40 N., R. 13 W.

THICKNESS.

The total thickness of the Proctor formation in Miller county is unknown, its greatest exposed thickness being thirty feet at Brockman's ford. Here the topmost beds are some fifty-seven feet above the river, but the lower twenty feet of the formation is covered with talus. Along the river the Proctor limestone rises precipitously, or bluff-like, while farther back in the country it is quite flat, following the gentle slope of the streams.

BEDDING.

As originally deposited the dolomite of this formation was heavily bedded, but through secondary changes these beds have been split up into several smaller ones. In places along the bluff at Brockman's ford, the beds have a thickness of ten feet, but these are in most instances split into beds from two and one-half to three feet thick. At King's bluff and in the region around Ramsey's postoffice in sec. 23, T. 40 N., R. 13 W., the beds are much thinner, averaging from six to twelve inches. The bedding planes are wavy, but not markedly so.

At King's bluff a ledge of this dolomite forms a good landing for the river boats.

WEATHERED SURFACE.

The weathered surface of the Proctor dolomite has a grayish color with occasionally a pinkish, yellowish or greenish tint. It is also rough and cavernous, being filled with small caves and pot hole-like cavities.

RELATION TO ADJACENT FORMATION.

The Proctor limestone lies unconformably beneath the Gunter sandstone. The unconformity is only exhibited in a few places, particularly along the Osage river in the western part of the county where so-called dykes of sandstone extend down into the dolomite from the overlying formation. (See plate IV.) Three-eighths of a mile west of the Miller-Morgan county line, the upper four feet of the Proctor limestone is an intra-formational conglomerate, small subangular pebbles of dolomite being imbedded in a dolomite matrix. At this place, besides the small dykes of sandstone, there are solution cavities in the dolomite, which were connected with the surface during the erosion interval, which are now filled with sandstone. At Brockman's ford and in sec. 23, T. 40 N., R. 13 W., some evidence of unconformity is noticeable. In the latter place the sandstone dykes extend into the limestone from one to two feet and are of varying widths.

TEXTURE.

The limestone or dolomite of this formation is medium to coarse grained and is both crystalline and granular, the former texture predominating. In the S. W. ¼ of sec. 23, T. 40 N., R. 13 W., the dolomite has a granular or oolitic like texture, due to little rhombs of crystallized dolomite. As a whole, the dolomite of this formation is the most crystalline of any of the Cambro-Ordovician dolomites in Miller county.

COMPOSITION.

The Proctor limestone is the least siliceous and the most calcareous of the Cambro-Ordovician series in Miller county. At Brockman's ford and Sycamore Spring hollow this limestone effervesces slightly, when treated with cold hydrochloric acid. This formation is the most arenaceous in the neighborhood of Ramsey postoffice. The limestone of this formation passes abruptly into the Gunter sandstone at the county line, but at other places the transition is more gradual.

The minerals occurring in the Proctor limestone are dolomite, calcite, quartz and limonite. Small crystals of dolomite line cavities in the limestone. White and rose colored calcite crystals, lining and filling cavities and occupying seams or veins, are espeially abundant at Brockman's ford and at King's bluff.

The Proctor limestone contains comparatively little chert. Such as was observed, occurs as irregular shaped pieces or nodules, disseminated promiscuously through the beds and not in layers. The chert is most abundant at King's bluff and near Ramsey's postoffice. A small exposure of this limestone, on the north side of the Osage river at Brockman's ford, is somewhat cherty, but, with the exception of a single bed, the formation on the south side is chertless. At King's bluff the chert nodules have been fractured and recemented with thin seams of finely crystallized quartz.

POROSITY.

The Proctor limestone is very porous. It contains numerous small, roughly oval cavities lined with crystals of calcite, quartz or dolomite. The cavities are in some places so abundant that the rock has a vesicular appearance.

COLOR.

Although varying in color, the dolomite of this formation has in general a dark bluish tinge, which helps to distinguish it from that of the other formations. Some of the beds at the Morgan county line have a grayish or pinkish tinge, while those on the north side of the river at Brockman's ford are whitish, yellowish and greenish. At King's bluff a majority of the beds have a much darker color than at any other place.

Section No. 1, Fig. 1.

On the Osage river at King's bluff in Sec. 30, T. 41 N., R. 13 W.
O-river level, (low water).
Section from top to bottom.

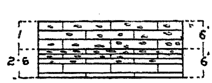


FIG. 1.

No.	Elev.	
1	6-12	DOLOMITE; thinly bedded, dark colored and slightly cherty.
2	5-6	DOLOMITE; light colored and very cherty. White and rose colored calcite fills jointing planes. A few thin seams of limonite observed.
3	4-5	DOLOMITE; coarse grained, dark colored and contains chert.
4	3-4	Similar to No. 3, also contains pockets, 2 to 3 inches in diameter, filled with calcite.
5	1-3	DOLOMITE; very dark colored, containing numerous small cavities with calcite.
6	0-1	Similar to No. 5.

CHAPTER III.

GUNTER SANDSTONE.

(Third Sandstone of Swallow.)

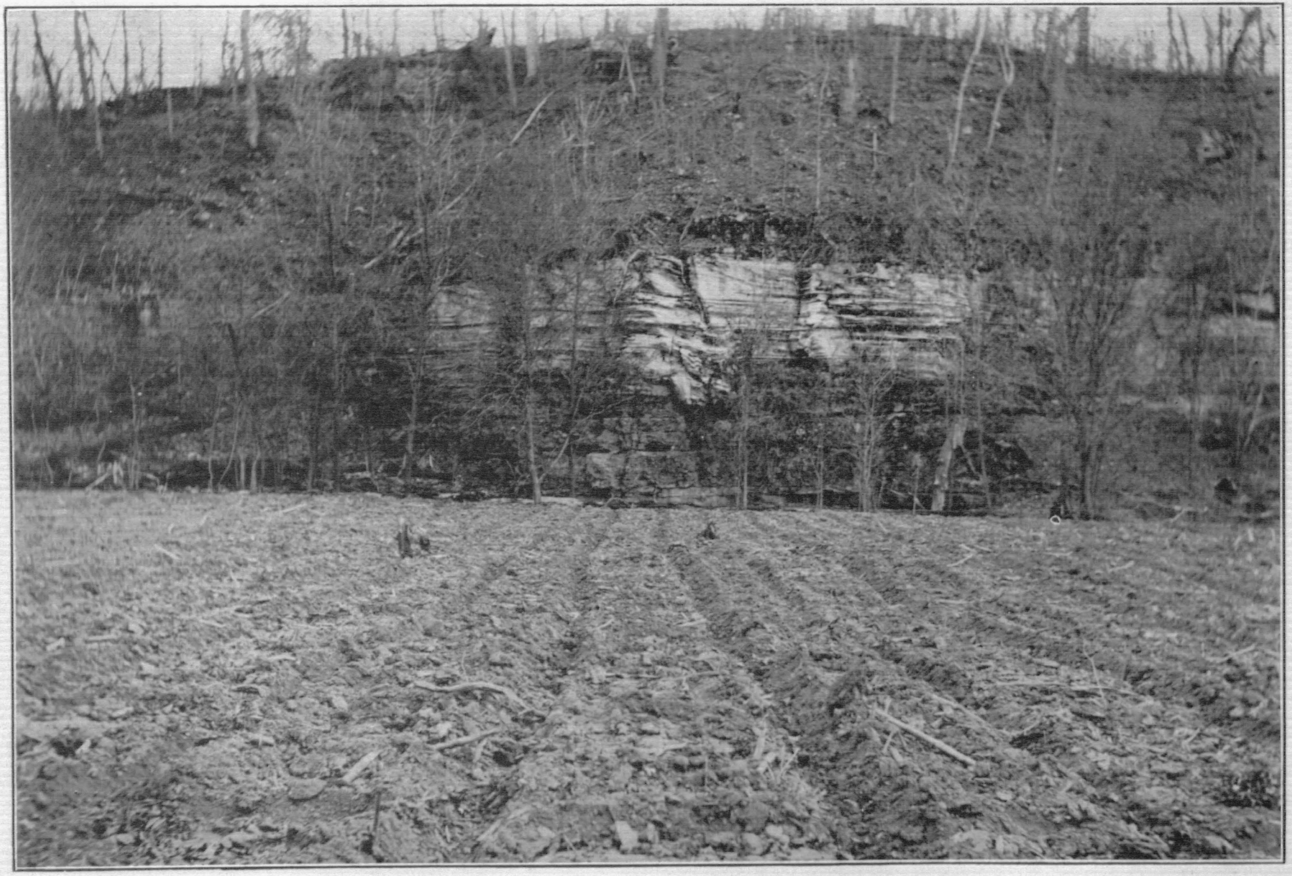
With the exception of three localities, Sandstone and Fancher hollows in secs. 8 and 7, T. 40 N., R. 13 W., and along the Osage river in sec. 28, T. 40 N., R. 15 W., the entire thickness of this formation and a part of the underlying Proctor limestone are exposed. Farther up the Osage river, outside of Miller county, this formation has a much wider distribution. In the southern part of Morgan county it is exposed in many places. It is most typically exposed on the Niangua river, at Gunter or Hahatonka springs.

THICKNESS.

In Miller county the thickness of this formation is variable, increasing and decreasing rapidly within short distances. At Brockman's ford the formation is from two and one-half to five feet thick; and in places near Ramsey, in sec. 23, T. 40 N., R. 13 W., and near the Morgan county line, it has a thickness of 12 to 18 feet. At the latter place it varies from four to seven feet in thickness. Within a quarter of a mile the thickness increases to 18 feet. The average thickness of one and one-half miles of nearly continuous exposure at this place is six feet. At King's bluff in sec. 30, T. 41 N., R. 13 W., the thickness of the formation is about five feet, and in the region around Sycamore Spring hollow the average thickness is six feet. A prospecting drill hole 120 feet deep, at the Gageville mines, passed through six feet of Gunter sandstone.

BEDDING.

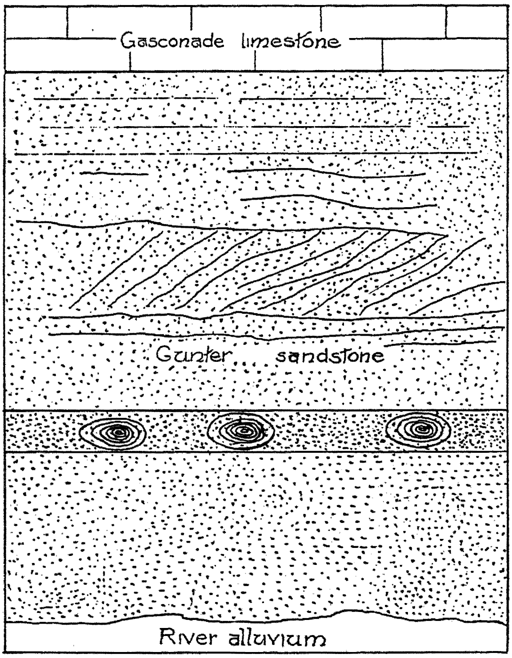
In most places along the river this sandstone outcrops in bluffs as a single bed. At Brockman's ford and King's bluff the upper two or three inches are finely laminated. Near Ramsey postoffice and in Sycamore Spring hollow the sandstone occupies the creek beds and is split into relatively thin strata. The upper and lower bedding planes of this formation are well developed, the former being smooth and regular, the latter wavy and irregular. Where the formation is rather thinly bedded ripple marks are common.



GUNTER SANDSTONE—PROCTOR LIMESTONE UNCONFORMITY.

STRATIFICATION.

Cross bedding is common in the Gunter sandstone, there being few exposures in which it does not show. The laminae of the cross bedded portions vary in dip, but are roughly parallel to each other for short distances. Near the Morgan county line a peculiar concretionary structure was noted in one of the beds of this sandstone. In this bed occurs a number of sandstone nodules having a concentric structure. These nodules do not differ from the matrix in the size or kind of grain or in the character of the cementing material. The manner of their occurrence is shown in Fig. 2.



Sandstone nodules and cross bedding in Gunter standstone on the Osage river, near the Morgan County line.

FIG. 2.

WEATHERING.

This sandstone weathers slower than the underlying and overlying limestone, for which reason it frequently forms shelf-like projections extending beyond the face of the cliffs. Where the formation outcrops near the Camden county line it forms miniature escarpments across many of the small stream channels, resulting in small waterfalls. The homogeneous character of the stone causes it to weather uniformly, producing rounded surfaces. The weathered surface usually has a light pinkish yellow color. These characteristic features easily distinguish it from the limestone formations above and below.

TEXTURE.

The Gunter sandstone varies in texture from fine to coarse grained. The usually well rounded character of the individuals is evidence that they have been well worked over by the sea and carried long distances before being deposited. At Brockman's ford the grains are fine translucent quartz of uniform size, but not well rounded. Some of the individuals have been secondarily enlarged. In places on the south bluff some of the thin layers of sandstone are composed of irregular shaped grains of sand, somewhat larger than ordinary. Near Ramsey postoffice and in Sycamore Spring hollow the sandstone shows all gradations from fine to coarse grained or saccharoidal. At King's bluff the grains have been secondarily enlarged. At the Morgan county line a pocket of coarse grained sandstone in a much finer grained matrix was observed.

COMPOSITION.

In places this formation is quite calcareous, the small quartz grains being imbedded in a matrix of calcite and secondary silica. At the Morgan county line, the sandstone is in places quartzitic and in others friable. Large water-worn pebbles were found imbedded in the medium grained sandstone. The usual cementing material is silica, but in places near Ramsey postoffice and at Brockman's ford, calcite predominates. The fresh calcareous sandstone is hard, but that which has been weathered is soft and pulverulent owing to the removal of the calcareous cement. In the south bluff at Brockman's ford the calcareous cement is most abundant in the middle of the bed, while the upper and lower parts are siliceous. In places near Ramsey the sandstone is friable, being poorly cemented with silica or iron oxide. Near the county line the sandstone is very siliceous, as shown by the little veins of silica which stand out in relief on the weathered surface. There are also a number of miniature faults with displacements of one-fourth to one-half inch.

COLOR.

The Gunter sandstone has ordinarily a white or yellow color, but near Ramsey the color is a deep brown or red.

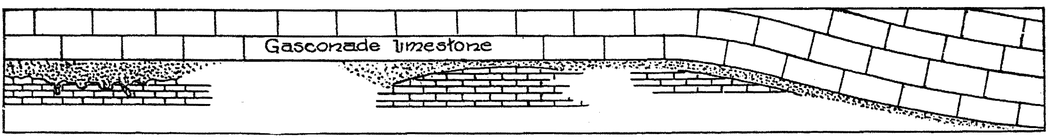
TYPICAL EXPOSURES.

This sandstone occurs in Sandstone and Fancher hollows, in secs. 17 and 8, T. 40 N., R. 13 W. With the exception of that in Fancher hollow, it occurs in the form of slabs in the bottom of the hollows and along the hillsides. These slabs lie in every position from horizontal to perpendicular. This tumbled condition of the blocks is due to both undercutting and sinks which are abundant in this locality. In Sandstone hollow there are several small sinks, and in each of them slabs of dolomite, chert and sandstone are on end. Undercutting by the streams has also been instrumental in bringing about this condition.

In Fancher hollow there is a small exposure of this sandstone in place. It is three feet thick, 150 feet long and from five to ten feet wide. A fault at this place brings the Gasconade limestone against beds of sandstone at the west end of the exposure. At the east end of the exposure the sandstone apparently passes underneath the same beds.

RELATION TO ADJACENT FORMATIONS.

The Gunter sandstone is conformable with the overlying Gasconade limestone and unconformable with the underlying Proctor limestone. (See Fig. 3.) This unconformity is not everywhere evident, as in some instances the two formations appear to be conform-



Contact of Proctor limestone and Gunter sandstone along the Osage river, near the Morgan County line.
FIG. 3.

able. The unusual thickness of this formation at the county line, 18 feet, is due to the conglomeritic sandstone filling erosion channels in the underlying limestone. The conglomerate pebbles, occurring in the so-called dykes of sandstone which penetrate the Proctor limestone, are well rounded dolomite fragments from two to twelve inches in their greatest diameter. In sec. 23, T. 40 N., R. 13 W., near Ramsey postoffice, the contact is very irregular, but none of the dykes are more than two feet deep and twelve inches thick. On the north side of the river near King's bluff, a piece of sandstone conglomerate with pebbles of well rounded white chert from one-eighth to one-fourth inch long was picked up directly beneath a bed of this sandstone, from which it was evidently derived. The Gunter sandstone grades gradually into the Gasconade limestone above.

CHAPTER IV.

GASCONADE LIMESTONE.

(Third Magnesian Limestone of Swallow.)

AREAL DISTRIBUTION.

The Gasconade limestone is the surface rock over about one-fifth of Miller county. The most typical exposures occur along the bluffs and ridges of the Osage river, which in several places has cut its channel throug the entire thickness of the formation exposing the Proctor limestone and Gunter sandstone underneath. On either side of the Osage river it also forms the lower walls of the tributary valleys, following the dendritic like net work of drainage for some distance back from the river. AlongTavern creek the formation is continuously exposed for about 38 out of the 40 miles of its length, while along Saline creek it is exposed for about 17 miles. Following as it does the drainage lines, this formation has an exceedingly irregular outline. There is one main, broad belt through which the Osage river flows. From this main belt extends numerous long, winding arms which correspond approximately to the tributary streams. Owing to the number and size of the streams south of the Osage river, at least two-thirds of the area immediately underlain by this formation is on that side.

THICKNESS.

The Gasconade limestone in this county is very uniform and constant in thickness, averaging between 240 and 250 feet.

TOPOGRAPHY.

One of the characteristic features of this formation in Miller county is the rough topography which it imparts to the surface which it immediately underlies. Rising in precipitous cliffs along the Osage river and the large tributaries, it gives a ruggedness to the scenery that has justly made the Osage valley one of the most picturesque in the State. High bluffs on either side skirt the river throughout its entire course in the county. At Capp's and just above and below Bagnell the bluffs are precipitous and especially high, having in the two latter places an elevation of about 350 feet above the river. On the opposite side of the river the bluffs and ridges rise more or less steeply, but not precipitously. The ridges near the river have narrow crests, seldom over 100 feet wide, but farther away from the river they are somewhat wider. In either case the crests are undulating and have steep slopes, covered either with chert fragments or rough rock outcrops known as "balls." Away from the river where the streams are small and quite widely separated the ridges of Gasconade limestone, with their broad bases and narrow crests rise en echelon. Here the strata outcrop continuously form the base to the top, and the two "balls" are important factors in giving to this formation the step like appearance referred to.

The two "balls" are the most striking features of this formation. They occur on nearly every ridge which is underlain with Gasconade limestone, except, perhaps, where the formation occurs at the very base of the bluffs far inland from the Osage river. They vary in size from a few square rods up to several acres, the upper "ball" being the more prominent of the two. "Balls" are best developed at the ends of the secondary and tertiary ridges.

The valleys in this formation are narrow and deep, and the majority slope rapidly from head to mouth. The heads of the valleys are rounded or cirque-like, and in some instances are wider at the head than they are farther down. The origin of these cirque-like valley heads has been discussed elsewhere in this report.

WEATHERING.

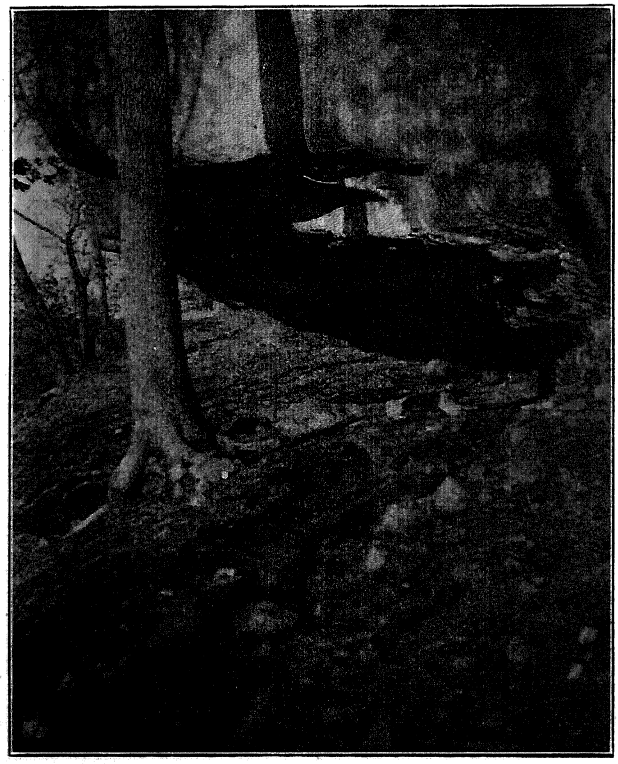
Except in the highest bluffs, the weathered surface of the Gasconade limestone has a uniform whitish or grayish color. The bluffs just above and below Bagnell, below Tuscumbia and at Capps, when viewed from a distance, have a banded appearance. The upper 75 to 100 feet has a deep reddish brown color, while 50 feet beneath is a horizon of heavy, massive beds which have a pinkish tint.

The striking variation in the color of the uppermost beds is well exhibited in secs. 30 and 31, T. 40 N., R. 15 W., in the neck of the large horseshoe bend of the Osage river in Camden county. At this place there are a great many "balls" which have a white or grayish color, while in the high bluffs along the river in sec. 31, T. 40 N., R. 15 W., these same beds are colored a deep brown. This color is due to the surface waters washing over the face of the cliff.

The pink colored, massive beds directly below the ones mentioned above often also have a streaked surface. The streaks are of a pinkish yellow color attributable, probably, to water seeping out of the overlying rocks.

Owing to the variations in the hardness and texture of the different beds, the formation, as a whole, weathers very irregularly. The heavy non-cherty beds, the cherty dolomites, and the cherts all weather differently. Both the soft, arenaceous and the hard, compact, non-cherty dolomites have smooth roundish surfaces, but bluffs of the former preserve a massive character forming low escarpments or cliffs, while the latter have a tendency to split into thin layers forming rough, angular surfaces. The greatest irregularities in form resulting from weathering occur in the dolomites containing disseminated chert. The chert being less soluble and harder than the dolomite resists more effectually solution and weathering. Thus it happens that these beds present very rough and rugged outlines. The differential weathering of cherty dolomite is well shown in Plate V.

Owing to its persistent nature the chert composes practically all of the residual boulders on the hill sides and ridges of this formation.



A recession in a bluff of Gasconade limestone on Osage river.
FIG. 4.

DIFFERENTIAL WEATHERING OF CHERTY DOLOMITE.

UNDERCUTTING.

Undercutting has occurred very extensively on all of the bluffs, chiefly at the cherty horizons. The recessions thus formed are often one-fourth of a mile long and extend back into the hill 15 or 20 feet, and are often from 20 to 30 feet high, as shown in Fig. 4. These recessions are not primarily due to erosion, but have resulted almost entirely from weathering and solution. The alternate freezing and thawing of the water contained in the numerous joints loosens the small polygonal blocks which fall away from the cliffs, being carried down by gravity.

CAVES.

Small caves and pot hole openings varying in size from a few inches up to two or three feet in diameter, are very common in the limestone along the bluffs. These are due to differences in the hardness of the rock, modified by the joints and the manner of occurrence of the chert.

COMPOSITION.

The formation is composed of beds of cherty and non-cherty magnesian limestone or dolomite, beds of chert and occasional intercalated beds of sandstone. Dolomite largely predominates.

Dolomite.—The dolomite is both crystalline and granular, the former predominating. However, the distinction between crystalline and granular in the majortiy of cases, is not very marked. The crystalline dolomite is medium or coarse grained, while the granular beds are medium grained. The medium fine grained dolomite, although occurring throughout the thickness of the formation, is particularly characteristic of the base. As a rule the heavy siliceous beds are the coarsest grained and the most completely crystalline. About 110 feet above the base of the formation are 30 feet of coarse grained and thoroughly crystalline dolomite which frequently forms a secondary cliff. The weathered surfaces of these beds are covered with small teeth like projections of dolomite crystals less than one-eighth of an inch long. The fine and medium grained crystalline dolomite does not exhibit this phenomenon.

The granular or oölitic phase of the dolomite is best shown in the railroad cuts in secs. 2, 4 and 5, T. 41 N., R. 12 W., and at Capp's bluff. The oolities are round and slightly smaller than the crystals of dolomite of which the arenaceous beds are composed.

The dolomite varies in hardness according to the amount of arenaceous material present.

A fresh surface of the Gasconade limestone usually has a whitish, grayish or pinkish white color, although some of the beds have a brown, green, grayish black or bluish tint. Many of the beds exposed in the railroad cuts in secs. 2 and 4, T. 41 N., R. 13 W., have a light chocolate color. Dolomite having the same color was observed in the northeast corner of township 41 north, range 13 west. Along the north bluff of the Osage river in the N. E. ¼ of sec. 9, T. 40 N., R. 15 W., the beds, 30 to 43 feet above the river, have either a brownish or pinkish color while those 168 to 177 feet above the river are cream colored. In the S. W. ¼ of the N. W. ¼ of sec. 19, T. 40 N., R. 14 W., in a high bluff along the river occurs a one foot bed of greenish colored dolomite. In this same bluff, at an elevation of 65 to 79 feet above the river, the beds have a grayish black color. While the bluish tinge is more characteristic of the dolomites of the Proctor limestone, yet this color occasionally occurs in beds of the Gasconade limestone. With the exception of the massive arenaceous beds about 110 feet above the base of the formation none of the beds have persistent colors. A bed which, at one place is brown may be white or gray a half a mile away. The coloring is due to the percentage of iron, and is usually very local.

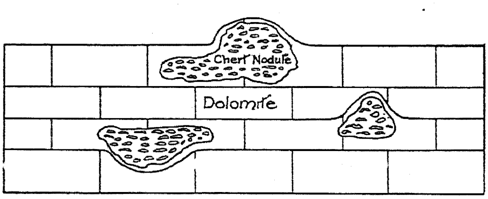
When the Gasconade limestone was being deposited the waters of the ocean were shallow and fluctuating in depth. Evidences of this are numerous. Cross-bedding is beautifully shown in an outcrop east of the middle of the S. E. ¼ of sec. 33, T. 41 N., R. 14 W. A short distance southwest of this exposure is another in the west side of N. W. ¼ of sec. 3, T. 40 N., R. 14 W., which exhibits suncracks and an intraformational conglomerate. The suncracks are about one inch apart and are filled with pink dolomite. The pebbles in the intraformational conglomerate are a coarse grained, gray dolomite the same as that in which they occur. They are elongated, rather flat and have roundish edges. The freshly broken beds do not exhibit very well this conglomerate, but, on the weathered surface, it stands out very prominently. Suncracks also occur in an exposure in the N. E. ¼ of sec. 1, T. 40 N., R. 14 W. An intraformational conglomerate bed was observed in the S. W. ¼ of sec. 1, T. 40 N., R. 13 W.

Cherts.—Practically the only variation in the composition of the Gasconade limestone is in its cherty content. The chert occurs, either bedded or in irregular pieces, masses or nodules disseminated through the dolomite beds. It is most typically exposed along the bluffs in the thin beds of dolomite, cherty dolomite and chert, known as the chert horizons.

The cherts of this formation are very grained and almost amorphous. With the exception of the concretionary lenses and nodules, they are somewhat porous, occasionally vesicular. Small drusy cavities, the walls of which are covered with small quartz crystals, are common. Occasionally one finds a cavity in which the crystals are dolomite. All except the very thin beds are so badly fractured that they have a brecciated appearance.

Although at every locality there are a number of different beds of chert in the formation, but few of these can be traced continuously over any considerable area. In townships 40 and 41, range 13, wherever the beds have been sufficiently elevated above the streams, there is exposed a bed of white brecciated chert from two to three feet thick, which is 20 feet above the Gunter sandstone. This bed is well exposed near King's bluff in sec. 30, T. 40 N., R. 13 W., and above the Gunter sandstone near Ramsey P. O. In the western part of the county where the Gunter sandstone outcrops, this chert bed is absent.

In the region around Tuscumbia and Brockman's ford, on both sides of the river, near the upper contact, there are very porous, vesicular beds of yellowish to brownish colored chert from one to two feet thick, which so closely resembles Smithsonite or "Dry bone" that they are commonly mistaken for this by the people of Miller county. These beds are well exposed on the hill across the river from Tuscumbia, along the Iberia-Tuscumbia road. This "bone" chert occurs along the Little Saline in sec. 30, T. 41 N., R. 14 W., and in the railroad cuts in secs. 3 and 4, T. 41 N., R. 12 W. Two rather persistent beds occur at the base of the upper "ball" in the eastern part of the county. The first bed is from two to two and a half feet thick and has a white brecciated appearance. The second bed has about the same thickness but has a black color. In a bluff on the east side, where the Osage river leaves Miller county, there is a very peculiar bed of white chert which contains nodules of banded black chert. These nodules are sometimes geodes which are lined on the inside with quartz crystals.

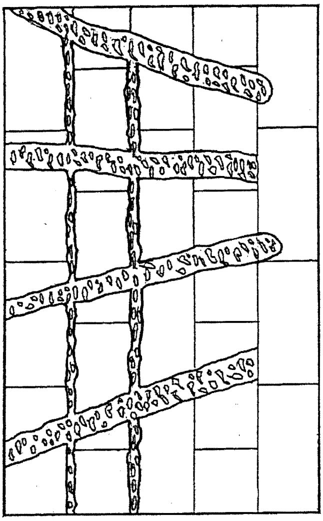


Chert in Gasconade limestone.
FIG. 5.

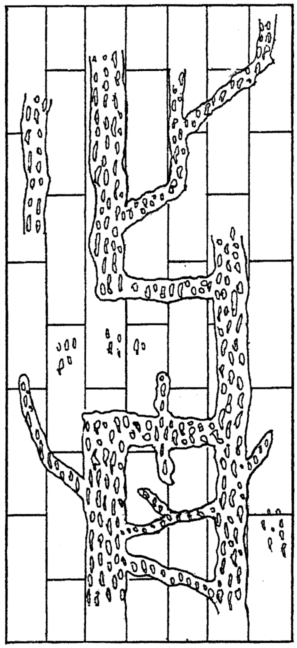
The nodular cherts occur mainly in the chert horizons and are well exhibited in the bluffs on the Osage river in the N. E. ¼ of sec. 9, T.

40 N., R. 15 W., at Tuscumbia, at the Hackney "chalk" or "silica" bank in sec. 36, T. 41 N., R. 14 W., and in the "silica" bank in sec. 14, T. 40 N., R. 14 W.

Near the Stevens mines, in secs. 24 and 25, T. 40 N., R. 14 W., and in a ravine in sec. 35, T. 40 N., R. 15 W., there are unusual occurrences of isolated, roughly nodular or lens like masses or pockets of chert in dolomites. These lens like masses or pockets are from a few inches to a foot thick and a few inches to three feet in diameter. Lead and zinc ores and barite are associated with these cherts. Figs. 5, 6, 7 and 8 show the typical manner of occurrence of chert in this formation.



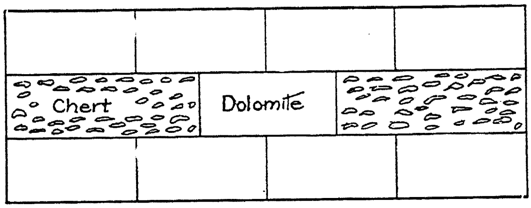
Chert in Gasconade limestone.
FIG. 6.



Chert in Gasconade limestone.
FIG. 7.

The disseminated chert occurs most commonly in small irregular pieces in the dolomite. Sometimes it is very sparingly present, while again the bed may be over there-fourths chert. The most characteristic disseminated chert occurs in the chert horizons. A great part of the chert is secondary and in these horizons, although very constant in position, varies in thickness. Across the river from Bagnell a cherty horizon which occurs beneath massive dolomitte beds decreases in thickness from 12 to 3 feet in a little over a mile.

The chert of the Gasconade limestone has a white, grayish yellow, bluish-white, or black color. In the upper part of the formation the chert is ferruginous and brighter colored. The black chert is more abundant in the eastern and southeastern part of the county. The oölitic chert, which is always black or bluish black, was only observed south of the Osage river.



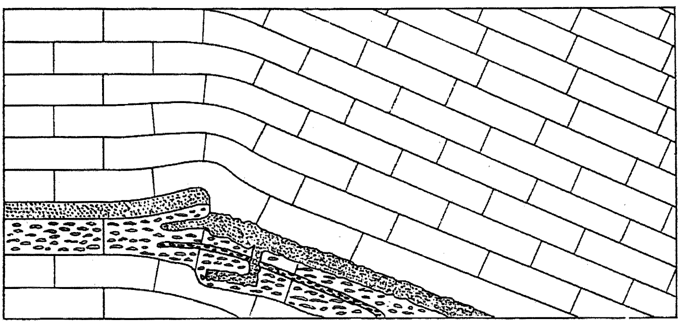
Chert in Gasconade limestone.
FIG. 8.

Intercalated Sandstone.—Several intercalated sandstone beds or lenses were observed in the Gasconade limestone south of the Osage river. In the bluff in the middle of sec. 27, T. 41 N., R. 12 W., in the upper part of the formation, there is a bed of very calcareous sandstone a few inches thick, which could be followed only a short distance.

Most of the intercalated beds are in the northwest corner of township 39 north, range 12 west, the northeast corner of township 39 north, range 13 west, the southeast corner of township 40 north, range 13 west and the southwest corner of township 40 north, range 12 west. There are two horizons, apparently, at which these intercalated beds occur. One horizon is 60 to 70 feet below the Gasconade-St. Elizabeth contact, and the other is in a lower part of the formation. The bed at the latter horizon was only observed in the vicinity of Wilson's cave in sec. 35 T. 40 N., R. 13 W. This bed is two feet thick, is composed of well rounded, medium sized grains, and exhibits well developed cross bedding. It is exposed at several places along the Tuscumbia-Iberia road and along the bluffs of Tavern creek. There is a general southwest dip at this place which carries the sandstone beneath the creek less than a half a mile below the cave. The lower contact of the sandstone bed is somewhat wavy.

The lenses of sandstone in the upper horizon are exposed at the township line one-fourth of a mile southeast of Wilson cave; along Tavern creek in secs. 1 and 12, T. 39 N., R. 13 W.; in sec. 6, T. 39 N., R. 12 W.; in the ravines in secs. 5 and 6, T. 39 N., R. 12 W.; and in a ravine in sec. 32, T. 40 N., R. 12 W. At the first place mentioned above, the sandstone is 15 inches thick but is not exposed for any considerable distance.

Along Tavern creek in township 39 N., R. 13 W., it is exposed from near the southeast corner of the N. E. ¼ of the N. E. ¼ of sec. 12 to near the northwest corner of the E. ½ of lot 1, N. E. sec. 1. At one place for a distance of 500 feet at the section line between 1 and 12, it pinches out entirely. To the north and south of this place it thickens gradually until it is about three and a half feet thick. Its maximum thickness is four and a half feet. This bed is composed of roundish, translucent grains of quartz, cemented in the upper and lower portions with a calcareous cement. Both contacts in places are wavy and irregular but more particularly the lower one from which many small dikes extend into the underlying limestone. One-fourth of a mile north of where the bed pinches out, there is evidence of an unconformity, as shown in Figure 9. Cross bedding is very common in this sandstone bed.



Intercalated sandstone bed in Gasconade limestone in Sec. 1, T. 39 N., R. 13 W.
FIG. 9.

Across the Tavern, on the north bluff, the same lens of sandstone is exposed as a bed from two and a half to four feet thick, extending from the middle of the E. ½ of the S. E. ¼ to the middle of the N. E. ¼ of the S. E. ¼, sec. 6, T. 39 N., R. 12 W. The eastward extension ends abruptly while to the westward the bed is carried beneath the river by a small flexure. Back from Tavern creek flexuring again brings the sandstone to the surface in the same section. This same bed or lens is again exposed in hollows in sec. 5, T. 39 N., R. 12 W., and sec. 32, T. 40 N., R. 12 W. The upper and lower surfaces are somewhat wavy.

Two intercalated beds were noted in a bluff of Gasconade limestone on Auglaize creek near the center of sec. 18, T. 39 N., R. 14 W. One was from three to five inches and the other about one foot thick. They could not be traced any considerable distance.

STRUCTURE.

Stratification.—Stratification planes* are the planes along which the rocks have a capacity to part through the alternation of sediments. In the Gasconade limestone these alternations are not sharp nor numerous, and, as a result, the stratification planes are not particularly well developed.

Bedding.—Bedding* differs from stratification in that, while in the latter there is only a capacity to part, in the former actual parting has taken place. The dolomite beds of this formation, as seen in the bluffs along the river, were originally deposited in heavy, massive beds, having an average thickness of perhaps 15 to 20 feet or more. While varying somewhat in texture in different places, each bed was practically homogeneous from top to bottom, and the bedding planes were even and regular. Through secondary changes, particularly silicification, the bedding planes are now more wavy and the beds, depending primarily on whether they are exposed in balls on the hillsides or in bluffs, are much thinner. The bedding planes in fine chert are much more regular than those in cherty dolomite.

Folding.—The Gasconade limestone formation has been gently though complexly flexured and folded. Steep dips were observed in several localities. The best examples are on the east side of Coon creek, where in a number of places the strata dip 60° S. 70° W., and in the S. E. ¼ of the N. W. ¼ of sec. 30, T. 41 N., R. 13 W. where on a continuation of the same fold the beds dip 20° S. 70° W. The beds surrounding areas of Carboniferous rocks usually exhibit steep local dips.

Jointing.—The strike and dip of the joints in the Gasconade limestone were taken at several hundred places over the county, and it was found that they were very closely related to one another. The average strike of the major joints is N. 70° E. and N. 15° W. (see page 132). In the steep bluffs the joints are particularly well developed, and in the cherty horizons they are very abundant. In the cherty and hard, dense dolomites they are more numerous than in the chertless and softer arenaceous beds.

Faulting.—The largest fault observed in the Gasconade limestone is in the western part of sec. 10, T. 41 N., R. 15 W. In a branch of the Saline valley, the upper beds of the Gasconade limestone occur at the same elevation as the bottom beds of the Jefferson City formation, the two formations being separated by only four or five feet. This condition can only be accounted for by normal faulting having an east and west strike and a downthrow of 150 feet. There is no evidence that this fault continues more than one-fourth of a mile.

Along the Osage river in the north central part of sec. 10, T. 40 N., R. 15 W., is a small fault which strikes N. 55° E., and has an apparent downthrow to the east of four feet. The fault dies out in a poorly exposed "ball" 100 yards away. On the east side of a railroad cut in the N. W. ¼ of sec. 4, T. 40 N., R. 15 W., is a small normal fault which

*The buildng and ornamental stones of Wisconsin by E. R. Buckley, p. 457.

strikes approximately N. 65° W., dips 55° N. 25° E., and has a downthrow of about eight feet. Along Tavern creek in the northeast corner of sec. 8, T. 39 N., R. 12 W., occurs a large fault, having a strike of N. 55° W. The amount of upthrow to the west could not be definitely determined, but it is approximately 120 feet. The fault soon dies out, but steeply dipping beds can be traced at intervals along the direction of its strike for over a mile.

Near the line between secs. 2 and 3, T. 39 N., R. 15 W., is a fault which can be traced for a half a mile. It has a strike of N. 60° W., but the downthrow to the west could not be determined.

Brecciation.—Horizontal zones of brecciation are confined to the chert horizons in which brittle chert and siliceous dolomite occur in thin layers. Slight compressive and tensile stresses break these beds into small irregular polygonal pieces which, frequently, are recemented with silica or calcium carbonate. Brecciation in vertical zones is not common. In the S. W. ¼ of the N. W. ¼ of sec. 29, T. 41 N., R. 13 W., occur two feet of close grained brecciated dolomite, the fragments of whcih have been cemented with silica and the remaining voids later filled with calcite. On the weathered surface the quartz frequently stands out in relief resembling a growth of fungi.

RELATIONS TO OTHER FORMATIONS.

The Gasconade limestone conformably overlies the Gunter sandstone. At the contact at Brockman's ford and in the outcrops opposite King's bluff, the two formations grade into each other. At other places the contact is always represented by thin transitional beds of sandstone and dolomite.

In a very few place in the county the Gasconade limestone has the appearance of being unconformably below the St. Elizabeth formation, but there is insufficient evidence to warrant the statement that an unconformity exists between the two. The greater number of contacts show an abrupt change of sedimentation, but there is no sign of a structural break. At the places where an apparent unconformity exists the contact is somewhat wavy and occasional small, irregular dikes of sandstone from the St. Elizabeth formation extend down a few inches into the Gasconade limestone. This may be due to local oceanic conditions at the time of sedimentation, or to later solution of the limestone and settling of the overlying sand into the voids.

Small areas of Carboniferous rocks, either as beds at the surface or pockets, lie unconformably above the Gasconade limestone. The wide difference in the faunal content of these formations gives evidence of a long erosion interval between the deposition of the two.

ECONOMIC CONSIDERATIONS.

Soils.—The residual soil resulting from the decomposition of the Gasconade limestone is found in very few places and is very thin. A few small areas, perhaps two or three acres in extent, show it to be dark colored, clayey, compact and fairly productive. The transported soil, which covers this formation in the lower courses of the valleys and ravines, is more loamy and finer grained than the residual soil, being better adapted to agricultural pursuits.

Lead and Zinc.—Up to the present time the greater part of the lead and zinc ores mined in Miller county have come from this formation. Galena (PbS), lead ore, and Sphalerite, known as blends or jack, (ZnS) zinc ore, are the two most common ores. Some Smithsonite ($ZnCO_3$), and Cerussite ($PbCO_3$), have been found associated with them. To mention all the localities where traces of these ores have been found would occupy more space than is at our command. It is only necessary to say that from the county line on the west to the county line on the east and on either side of the river, wherever the Gasconade limestone is the surface rock, prospecting in hundreds of places has uncovered small deposits of lead and zinc ores. It is especially noticeable that along the larger creeks and valleys, particularly on the south side of the Osage river, in the Gasconade limestone areas, the people always manifest considerable interest in prospecting for lead and zinc ores. In the regions away from the Gasconade limestone, there is very little interest in this industry. On the north side of the river the lead and zinc ores are more widely distributed through the different formations, although most abundant in the Gasconade limestone.

Silica.—Silica, known locally as chalk, is a soft, white, porous substance closely resembling tripoli. It is a decomposition product of chert and, wherever found in commercial quantities, the chert, from which it has been derived, is secondary after dolomite. The chalk occurs almost entirely in the cherty horizons and frequently in a single specimen one will find all gradations from dolomite to chalk. It occurs in many places in the Gasconade limestone.

Iron.—A few small deposits of iron ore were found in this formation, and, on the ridges, boulders of limonite, probably residual from the overlying formation, are common. Thin veins of limonite, filling jointing planes, were observed along many of the bluffs. In the N. W. ¼ of the S. W. ¼ of sec. 13, T. 40 N., R. 14 W., are a number of boulders of limonite, and in one place in a small ravine, a bed of limonite, apparently in place, four inches thick and three feet long, was found between horizontal beds of dolomite. The limonite occurs either in solid, botryoidal or tubular masses.

Copper.—Azurite ($3CuO$, $2CO_2$, H_2O), and malachite ($2CuO$, CO_2, H_2O), the hydrous carbonates of copper, occasionally occur associated with the limonite and barite, but in such minute quantities as to be of no economic importance.

Barite.—Barite occurs in a number of places in the county and in the past has been mined and shipped. It usually occurs in crevices or pockets in the dolomite beds. Along Cattail creek, Barren fork and Bailey's branch it occurs associated with black chert either in pockets or in beds.

RESUMÉ.

The Gasconade limestone consists of beds of magnesian limestone or dolomite; chert, either bedded, nodular or disseminated; and an occasional lense of sandstone, all of which were deposited in horizontal beds in a comparatively shallow sea. During deposition the sea bottom was not altogether quiescent, and at times was, apparently, elevated locally above the surface. The parts thus elevated were slightly eroded as shown by some of the intercalated sandstone beds. The cross-bedding, which is so common in the intercalated sandstone beds and in the dolomite, at various places in the entire thickness of the formation, shows that the sea bottom was uniformily within reach of the waves, tides and currents.

A change of sedimentation, rather than a structural break, marked the close of the deposition of the Gasconade limestone. The composition and texture of the rocks of this formation have been altered, chiefly through silicification. Compressive and tensile stresses have fractured and moved the beds.

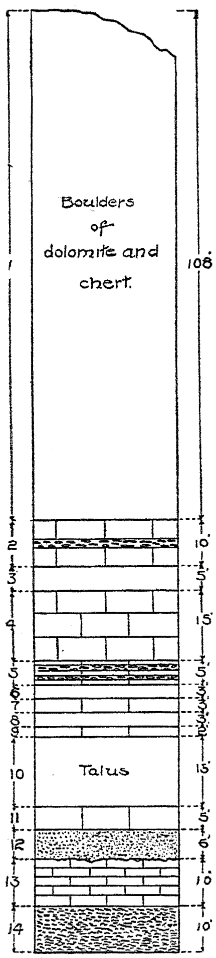


FIG. 10.

DETAILED COLUMNAR SECTIONS.

Section No. 2, Fig. 10.

On Osage River, ¼ Mile East of Morgan County Line.

No.	Elev.	
1	92-200	108 feet of boulders of DOLOMITE and CHERT.
2	82-92	Ten feet of DOLOMITE and CHERT, very much jointed.
3	77-82	Five feet unexposed.
4	62-77	15 feet of DOLOMITE, coarse grained and pinkish gray.
5	57-62	Five feet of CHERT and DOLOMITE thinly bedded.
6	54-57	Three feet unexposed.
7	51-54	Three feet of pinkish DOLOMITE, fine grained and sandy.
8	48-51	Three feet unexposed.
9	46-48	Three feet BRECCIATED DOLOMITE.
10	31-46	Fifteen feet TALUS.
11	26-31	Five-foot bed of gray DOLOMITE, rather fine grained and chertless. Lies conformably over the Gunter sandstone, the contact being somewhat wavy. Transition from Gunter sandstone to Gasconade limestone abrupt.
12	20-26	GUNTER SANDSTONE.
13	10-20	PROCTOR LIMESTONE.
14	0-10	Ten feet ALLUVIUM.

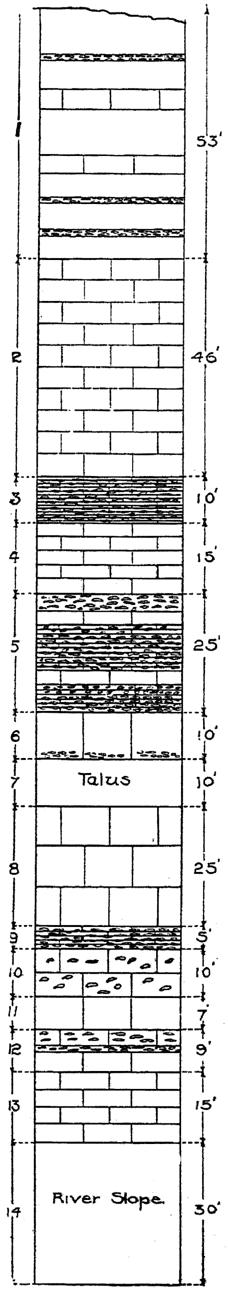


FIG. 11.

Section No. 3, Fig. 11.

East bluff of Osage river, Sec. 21, T. 40 N., R. 15 W.

No.	Elev.	
1	217-270	Fifty-three foot slope with occasional thin beds of CHERT and cherty DOLOMITE.
2	171-217	46 feet, DOLOMITE, vertical wall.
3	161-171	10 feet CHERT horizon.
4	146-161	Five three-foot beds of DOLOMITE, arenaceous and chertless.
5	121-146	25 feet, CHERT horizon. Contains an occasional thick bed of dolomite with thin layers of chert, cherty dolomite and dolomite. Undercutting has occurred at this horizon. The bedding planes are very undulating.
6	111-121	10 foot bed of DOLOMITE; the lower two feet are very cherty.
7	101-111	10 feet of TALUS.
8	76-101	25 feet of DOLOMITE, arenaceous and chertless. Heavily bedded and projects slightly out over the underlying strata.
9	71-76	5-foot CHERT horizon.
10	61-71	Two 5-foot beds of DOLOMITE, fine grained, very cherty and contains calcite.
11	54-61	7-foot bed of DOLOMITE, pitted with small cavities, often filled with calcite.
12	45-54	9 feet of DOLOMITE, CHERT and cherty DOLOMITE thinly bedded, contains thin horizontal seams of calcite.
13	30-45	15 feet of DOLOMITE.
14	0-30	River slope.

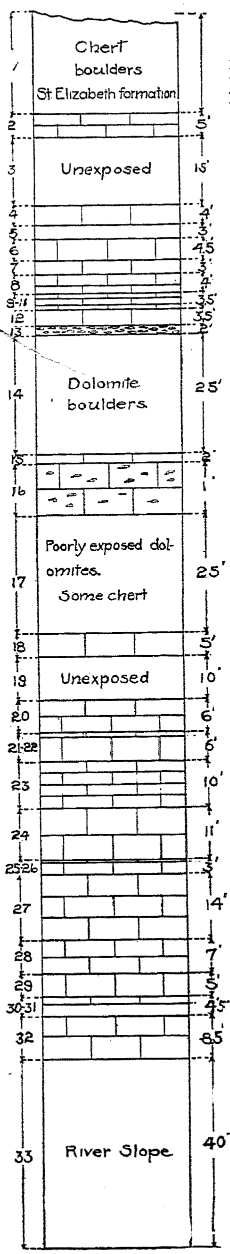


FIG. 12.

Section No. 4, Fig. 12.

The lower 195 feet of this section was made on the Osage river in the S. W. ¼ of the N. W. ¼ of Sec. 19, T. 40 N., R. 14 W.; the upper 45 feet from the west corner of Sec. 17, T. 40 N., R. 14 W.

No.	Elev.	
1	240-to	top of ridge. CHERT boulders of the St. Elizabeth formation.
2	235-240	Upper contact beds of much pitted DOLOMITE.
3	220-235	15 feet unexposed.
4	216½-220½	4 feet of medium grained DOLOMITE; grayish to rose color.
5	213½-216½	Poorly exposed.
6	209-213½	4½-foot bed of DOLOMITE. Solution has been active along this bed as shown by the small caves and cavities with which it is lined.
7	206-209	3 feet of pinkish DOLOMITE, medium grained.
8	202-206	4 feet of coarse grained DOLOMITE; light cream colored.
9	201-202	1 foot of DOLOMITE, coarse grained. Light greenish color.
10	199½-201	1½ feet of DOLOMITE, coarse grained and cream colored.
11	198½-199½	1 foot of DOLOMITE, fine grained and close jointed.
12	195-198½	3½ feet of DOLOMITE, compact and medium grained.
13	193-195	2-foot bed of CHERT which resembles dry bone.
14	168-193	25 feet of DOLOMITE boulders.
15	166-168	3 feet of DOLOMITE, medium to coarse grained and cream colored.
16	155-166	11 feet of DOLOMITE; the lower part is coarse grained and the upper part fine grained. This bed sometimes forms a sheer cliff, unjointed and massive; sometimes it is broken into several beds. It contains a few nodules of chert.
17	130-155	25 feet of DOLOMITE; beds poorly exposed, contains some "bone" chert.
18	125-130	5 feet of DOLOMITE, fine grained and gray.
19	115-125	10 feet unexposed.
20	109-115	6 feet of DOLOMITE, medium grained, much pitted and grayish.
21	108-109	1 foot of DOLOMITE, medium grained and white.
22	103-108	5 feet of DOLOMITE, medium grained and much jointed; weathers into layers one inch to one foot in thickness.
23	93-103	10 feet of DOLOMITE, medium grained and much jointed; has a pitted surface.
24	82-93	11 feet of DOLOMITE, coarse grained.
25	81½-82	½ foot of DOLOMITE, dark colored and much jointed
26	79-81½	2½ feet of DOLOMITE, medium grained and grayish, contains much calcite.
27	65-79	14 feet of black, grayish DOLOMITE; weathers with a smooth surface.
28	58-65	7 feet of DOLOMITE, medium grained, crystalline and dark colored.
29	53-58	5 feet of DOLOMITE, medium grained and contains considerable calcite.
30	51½-53	1½ feet of DOLOMITE.
31	48½-51½	3 feet unexposed.
32	40-48½	8½ feet of white DOLOMITE, fine grained.
33	0-40	River slope.

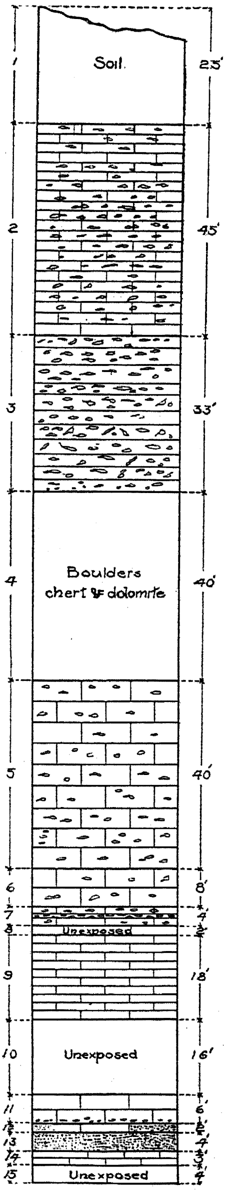


FIG. 13.

Section No. 5, Fig. 13.

On the Osage river in N. W. ¼ of Sec. 29, T. 41 N., R. 13 W.

No.	Elev.	
1	225-250	Soil.
2	180-225	45 feet of arenaceous DOLOMITE.
3	147-180	33 feet of heavy CHERT.
4	107-147	40 feet of slope covered by chert and dolomite boulders.
5	67-107	40 feet of poorly exposed beds of DOLOMITE. They contain very little chert.
6	59-67	8 feet of brown DOLOMITE, medium grained.
7	55-59	4 feet of CHERT and DOLOMITE, thinly bedded. The chert is mainly concretionary.
8	53-55	2 feet unexposed.
9	35-53	10 feet of DOLOMITE, coarse grained, bluish and thinly bedded.
10	19-35	16 feet unexposed.
11	13-19	6 feet of pinkish brown DOLOMITE, fine grained and contains a few pieces of white chert in the lower two feet.
12	11-13	2-foot bed which in some places is arenaceous DOLOMITE and in others almost pure SANDSTONE with occasional lenses of dolomite carrying small pieces of chert.
13	7-11	GUNTER SANDSTONE.
14	4-7	PROCTOR LIMESTONE.
15	0-4	Unexposed.

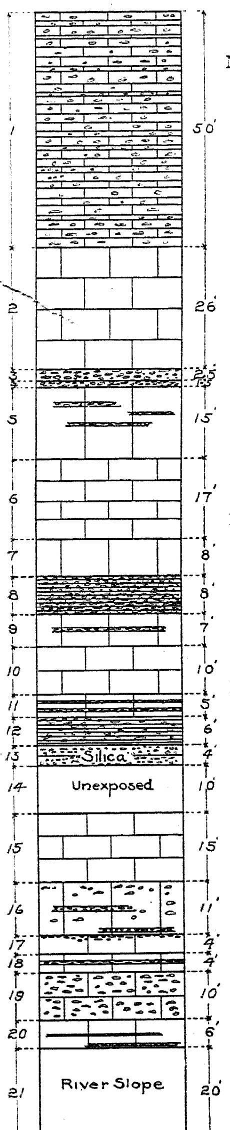


FIG. 14.

Section No. 6, Fig. 14.

Bluff on Osage river at Capps.

No.	Elev.	
1	190-240	Uppermost 50 feet is DOLOMITE of the Gasconade limestone, in beds from 6 inches to 2 feet thick. Considerable disseminated chert in these beds as well as many pockets and seams of calcite.
2	164-190	26 feet. Four beds of DOLOMITE which weather into thinner layers. Contain but little chert. Have a pitted surface.
3	161½-164	2½-foot bed of white CHERT. Varies in thickness in different places.
4	160-161½	1½-foot bed of brecciated black CHERT.
5	145-160	Massive 15-foot bed of yellowish DOLOMITE, coarsely crystalline and soft. The lower 7 feet are quite free from chert. The upper 8 feet contain numerous layers of black chert from 2 to 4 inches thick. The upper 2 feet contain much disseminated chert. The entire bed weathers with a rounded surface.
6	128-145	17 feet of poorly exposed beds of apparently light colored dolomite.
7	120-128	Massive 8-foot bed of DOLOMITE, light colored and chertless. Weathers uniformly. Pockets of calcite are common.
8	112-120	CHERTY horizon.
9	105-112	7-foot bed of buff-colored, hard DOLOMITE. Has a cherty strip through the middle.
10	95-105	Two 5-foot beds of soft, arenaceous DOLOMITE which project out over the underlying strata, forming a small shelf. Weathered surface is pink and in places is coated with travertine.
11	90-95	5-foot bed of dark colored DOLOMITE; coarse grained arenaceous. It contains three or four layers of white chert and some disseminated black chert. Numerous veins of calcite occur parallel to the bedding planes.
12	84-90	6-foot CHERT horizon.
13	80-84	Two 2-foot beds of so-called white CHALK or SILICA.
14	70-80	10 feet unexposed.
15	55-70	15 feet of light colored DOLOMITE, poorly exposed. Mostly finely crystalline and very hard. One bed two feet thick, contains numerous small spots of a material softer than the matrix. These have decomposed into a white, limelike substance giving the bed a mottled appearance. Around these spots the dolomite is coarser grained than elsewhere.
16	44-55	11-foot bed of DOLOMITE, coarse grained, light colored and arenaceous. Weathers to a rather roundish surface. Contains chert, both in thin layers and disseminated.
17	40-44	4-foot bed of DOLOMITE, fine grained, hard and compact. Upper 4 inches is very cherty.
18	36-40	4 feet of CHERT and DOLOMITE. In places the upper two feet are a solid bed of white chert.
19	26-36	Two 5-foot beds of CHERTY DOLOMITE. The chert is bluish and is intricately mixed with the dolomite. It occurs both disseminated through the bed and in layers several inches thick parallel or at right angles to the bedding. In places the dolomite grades into the chert.
20	20-26	6-foot bed of DOLOMITE, soft, arenaceous, and dark colored. Contains numerous thin seams of chert parallel to the bedding planes.
21	0-20	River slope.

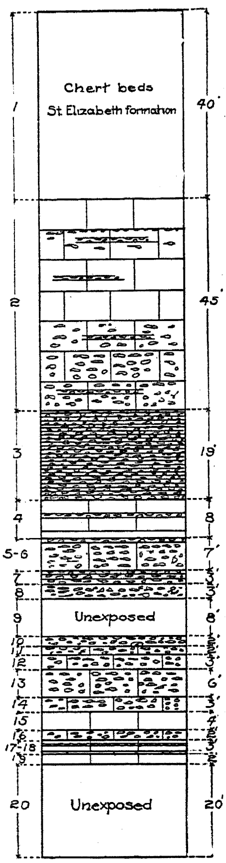


FIG. 15.

Section No. 7, Fig. 15.

On Osage river at the Osage county line.

No.	Elev.	
1	140-180	Rugged brecciated CHERT beds of the St. Elizabeth formation. Contact between Gasconade and St. Elizabeth formations not exposed.
2	95-140	45-foot cliff of massive DOLOMITE beds. The dolomite is arenaceous and contains chert, both disseminated and in layers. In the latter form it is black. With the exception of a 2-foot bed of black chert, 10 feet below the upper contact, the upper half of these beds is very free from chert.
3	76-95	19-foot CHERTY horizon, coated with travertine and limonite.
4	68-76	8 feet of alternating layers of CHERT and DOLOMITE.
5	67-68	1-foot bed of black CHERT.
6	61-67	6 feet of cherty DOLOMITE.
7	58-61	Thin layers of banded black CHERT, oolitic in places.
8	55-58	3-foot bed of CHERT.
9	47-55	8 feet unexposed.
10	45-47	2-foot bed of white CHERT containing inclusions of bluish chert, having a banded or concretionary structure. Some of the blue chert contains small cavities filled with quartz crystals.
11	43-45	2-foot bed of cherty, light colored, siliceous DOLOMITE. In places this bed is solid chert.
12	40-43	Similar to No. 11.
13	34-40	6 feet of cherty DOLOMITE.
14	31-34	3 feet of arenaceous DOLOMITE, which is split into thin layers; somewhat cherty.
15	27-31	4-foot bed of DOLOMITE, chertless, dark colored and arenaceous.
16	25-27	2-foot bed of DOLOMITE, with a five-inch layer of black chert. Considerable travertine and limonite in thin seams.
17	22½-25	Similar to No. 16. Contains disseminated white and black chert.
18	22-22½	Thin layers of DOLOMITE and black CHERT.
19	20-22	2-foot bed of fine grained, pinkish DOLOMITE.
20	0-20	Unexposed.

Section No. 8, Fig. 16.

On Tavern creek near middle of Sec. 27, T. 41 N., R. 12 W. Only the upper 82 feet are exposed.

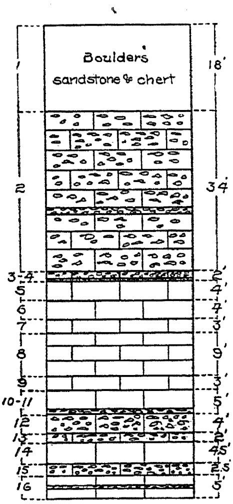


FIG. 16.

No.	Elev.	
1	82-100	18 feet of talus containing scattering boulders of sandstone and chert derived from the St. Elizabeth formation.
2	48-82	34 feet of bedded DOLOMITE, poorly exposed. Most of the beds are pitted and contain more or less disseminated white chert. 20 feet below the upper contact is a bed of white chert 15 inches thick.
3	46½-48	1½ feet of DOLOMITE; contains black chert and is arenaceous. Passes gradually into sandstone below.
4	46-46½	6 inches of SANDSTONE, medium grained; very compact and grayish. It is interlaminated with a few thin seams of blue clay. This is the only sandstone that was found in the Gasconade limestone near the river.
5	42-46	4 feet of yellow, arenaceous DOLOMITE; weathers irregularly, forming thin shaley layers.
6	38-42	Bed similar to No. 5.
7	35-38	3 feet of soft, light colored, arenaceous DOLOMITE, which splits into thin layers; considerable travertine along the bedding planes.
8	26-35	DOLOMITE similar to No. 7.
9	23-26	3 feet of DOLOMITE, fine grained, hard and having a grayish brown color.
10	19-23	4-foot bed of DOLOMITE.
11	18-19	Black CHERT.
12	14-18	4 feet of cherty DOLOMITE. The chert is black and disseminated.
13	12-14	2 feet of brecciated DOLOMITE and black chert.
14	7½-12	4½ feet of grayish DOLOMITE; fine grained and contains crystals of limonite and malachite. Travertine along the joint planes.
15	5-7½	2½ feet of brecciated DOLOMITE, containing black chert.
16	0-5	2 beds of pinkish to grayish DOLOMITE; arenaceous and weathers with an even surface. Between the two beds is a three to eight inch layer of white and black chert; some calcite and travertine.

CHAPTER V.

ST. ELIZABETH FORMATION.

(Second Sandstone (in part) of Swallow and later geologists.)

INTRODUCTORY.

Of the Cambro-Ordovician formations in Miller county, the Gasconade limestone and the Jefferson City, are well defined, easily recognizable, and markedly uniform lithologically. Each is composed of characteristic dolomites, and each contains chert, though in varying abundance, and each contains a few thin, intercalated beds of sandstone. Between these two formations is a complex consisting of beds of sandstone, chert, quartzite, dolomite and shale, all of very uncertain thickness and areal extent. The beds of this complex formation exhibit great diversity in lithological character, thickness and manner of occurrence.

This complex has been named the St. Elizabeth because it is typically developed in the town of St. Elizabeth, Miller county. South of the Osage river the sandstone beds or lenses are sufficiently well developed over certain limited areas to warrant mapping them as a distinct member of this formation. From the typical exposures along Bolin creek in township 39 north, range 12 west, the sandstone lenses have been called the Bolin Creek sandstone.

The St. Elizabeth formation in Miller county includes Meek's 2nd Sandstone, together with beds of dolomite, quartzite, chert and sandstone, which he included either in the top beds of the 3rd Magnesian limestone (Gasconade limestone), or in the lower beds of the 2nd Magnesian limestone (Jefferson City formation). On page 121 of his report, Meek says of the 2nd sandstone: "This formation varies much, as well in thickness as in lithological characters, at different localities, being usually a fine grained regularly stratified quartzose sandstone of a light grayish brown color, but sometimes passing into a heavy bedded light gray or white sandstone. At places there is much chert in it, and at other places it seems to pass almost entirely into beds of rugged chert. I have estimated its maximum thickness in the county at 60 feet. It is evidently much thinner than this at most places." While recognizing the heavy beds of rugged chert, and including them in the Second sandstone,

*Mo. Geol. Sur. 1855-71, pp. 112-134.

his main differentiation of this formation lay in the uninterrupted succession of sandstone beds, or a single massive bed of sandstone. His second sandstone was composed mostly, therefore, of the sandstone which we have mapped as the Bolin Creek sandstone member. In this report the rugged chert beds are not included in this member, but are placed in the St. Elizabeth formation. Meek, finding masses of what we have mapped as Graydon sandstone in various places all over the county, away from the region of the Bolin Creek sandstone member, considered them to be a part of the Second sandstone, and thus reported that formation to be very persistent over the county. No heavy beds of sandstone such as he included in the Second sandstone, occur north of the Osage river. Unfortunately, the different Silurian formations were not differentiated on his map, so that the exact areal distribution of his Second sandstone is not known, although he correctly observed that the best development and greatest surface distribution was on the south side of the Osage river.

Since the Bolin Creek sandstone member has such a limited extent, and since over the entire north half and over large areas of the south half of the county, sandstone beds are so nearly lacking, some geologists, conversant with the stratigraphy of the Ordovician rocks of the Ozarks, may perhaps question the advisibility of mapping a separate formation, except where there are heavy beds of sandstone, such as were recognized by Meek. However, one who studies this area carefully must recognize a complex formation of from 70 to 120 feet, which includes a part of Swallow's "Second Magnesian" limestone, all of the "Second" sandstone and a part of the "Third Magnesian" limestone. The lithologic, economic, topographic and structural difference between the Gasconade limestone and the St. Elizabeth formation are too great to allow their being considered parts of the same formation.

Lithological Differences.—The different dolomite beds of the Gasconade limestone are very similar, being uniformly medium to coarse grained, light grayish or pinkish colored and of nearly the same porosity. The St. Elizabeth formation includes some beds of dolomite similar to those of the Gasconade limestone, but the majority are very fine grained, dense and hard. They are in fact almost novaculites, being nonporous and breaking with a conchoidal fracture. The St. Elizabeth formation also contains beds of shale and argillaceous dolomite, which never occur in the Gasconade limestone.

The cherts are much better developed in the St. Elizabeth formation, often occurring in beds from 6 to 10 feet thick. In the Gasconade limestone the chert beds are much thinner and less abundant. Aside from the Bolin Creek sandstone member, there are other intercalated beds of sandstone and quartzite in the St. Elizabeth formation.

Topographic Difference.—One of the most striking differences in the two formations is in the topography. Regions underlain with Gasconade limestone are always rough and rugged having narrow ridges with steep slopes.

Areas underlain by the St. Elizabeth formation have a much gentler topography, the ridges being flat-topped and broad, and except at the heads of the hollows the slopes are much gentler.

Economic Difference—Both formations contain barite, but the lead and zinc ores and silica or ("chalk") occur mainly in the Gasconade limestone, while the iron ores occur more generally in the St. Elizabeth formation. With the exception of the sandstone the latter formation contains no stone sutiable for building purposes, while the dolomite of the Gasconade constitutes an improtant source of building stone.

Structural Differecne.—The St. Elziabeth formation being heterogeneous, is not structurally a unit, as is the Gasconade limestone. The joints in the fine dense dolomite are much closer together and strike differently than in the heavy sandstone beds. Small flextures due to sink holes and solution are common everywhere in the St. Elizabeth formation, while in the Gasconade limestone they are less common.

Taking all of the above facts into consideration, it is thought that one is justified in mapping, in this area, the complex between the Jefferson City and Gasconade formations as a distinct and separate formation.

AREAL DISTRIBUTION.

The St. Elizabeth formation has its greatest surficial distribution on the south side of the Osage river, particularly in townships 38, 39, 40 and 41 north, range 12 west and township 39 north, range 13 west, where it constitutes about two-thirds of the surface rock. On the north side it occurs most extensively in township 41 north, ranges 15 and 16 west. In township 41 north, range 13 west it caps a wide flat ridge. Close to the river, except in township 41 north, range 12 west, it usually occurs only on the higher ridges and its areal distribution is limited.

THICKNESS.

This formation varies considerably in thickness. One mile north of Iberia it is only 70 feet thick, while in secs. 13, 24 and 25 T. 41 N., R. 16 W., the thickness is apparently 160 feet. The thickness at the latter place may appear somewhat greater than it really is, owing to the very poor exposures and the possibility of a slight dip. North of the Osage river the formation has an average thickness nearly everywhere of 120 feet, although in the vicinity of Mary's Home, it is

FLAT TOPPED RIDGE UNDERLAIN BY THE ST. ELIZABETH FORMATION.

only 80 feet. South of the Osage river the average thickness is 100 feet, varying from 70 to 140 feet. In the region around Mill creek the average thickness it between 100 and 120 feet. In the eastern part of the county, the average is between 80 and 100 feet. Along Sandstone creek the Bolin Creek sandstone member makes up about half of the entire thickness of the formation.

TOPOGRAPHY.

The areas underlain by the St. Elizabeth formation are characterized by a relatively gentle topography compared with the areas underlain by the other formations. The ridges are broad, the slopes gradual, and the crests flat and level. (See Plate VI.) Beds of rock are seldom exposed on the tops of these ridges.

The valleys conform, as a rule, to the gentle topography and have more af a U than a V shape. There is, however, an exception to this general statement in the case of the valleys and ridges along the larger streams which have cut down nearly through the entire thickness of the formation. Such valleys have almost the same shape as those in the Gasconade limestone, the bluffs being steep and precipitous. Here, however, the similarity ends for above the steep bluffs the ridges usually rise to the crest with a gradual slope.

The roundish pouch shaped heads to the valleys while very pronounced in this formation are not as much so as in the Gasconade limestone. They are often as precipitous but seldom as high or as wide.

WEATHERING.

The cherts weather similarly, but the fine grained, dense dolomites, with their very smooth rounded surfaces, weather very differently from the corresponding rocks of the Gasconade limestone. Undercutting is common at the base of the Bolin Creek sandstone member, but the recessions are not as deep as those occurring in the Gasconade limestone.

CHARACTER OF THE DOLOMITE.

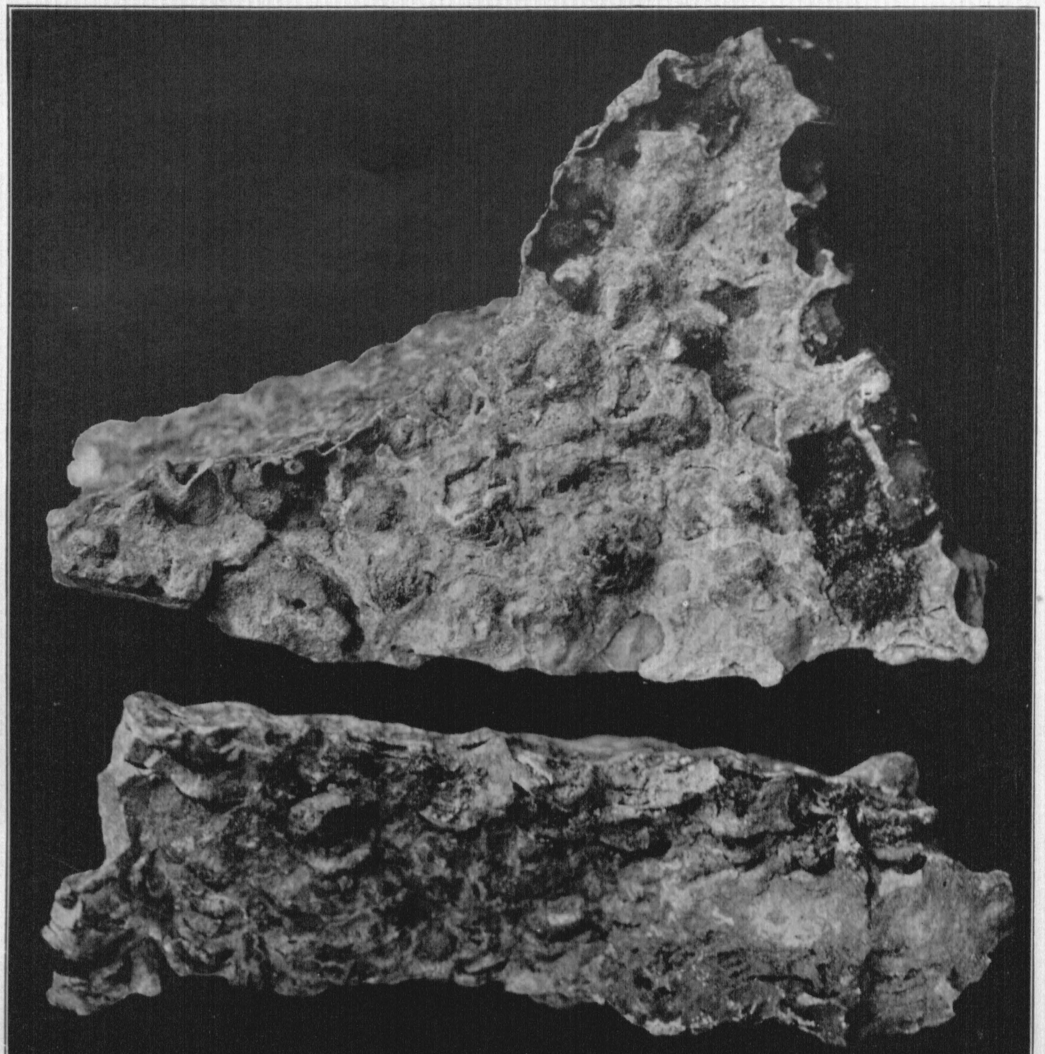
Except in townships 38, 39, 40 and 41, range 12 west, the dolomite comprises from 50 to 75 per cent. of the formation, the latter percentage holding good over nearly all the county north of the Osage river. In the townships above mentioned, the Bolin Creek sandstone, as well as the beds of rugged chert, reach their greatest development, constituting in places over 60 per cent of the formation. Though some of the dolomite is similar to that of the Gasconade formation, the greater part is very different, being especially characteristic of the St.Elizabeth formation. The characteristic dolomite is very hard, fine grained and dense, having a texture and conchoidal fracture very similar to that of the chert. These dolomite beds are from 9 to 15 inches thick, and weather to a smooth roundish surface. In many places the beds are very thinly banded. Occasional streaks one-eighth to one-fourth inch thick of clear rounded grains of sand are imbedded in the dolomite matrix. These sandy streaks are hard and weather the same as the dolomite. A very peculiar fine grained dolomite was observed in "situ" in a single place in this formation and as boulders in the Saline Creek cave-congolomerate at a number of places. The texture of this dolomite is similar to the other fine grained varieties, but the rock is more porous, having a structure which, for want of a better name, may be called "curling." This structure is shown in Plate VII. Figure 1 shows the upper surface along the bedding plane, while Figure 2 is a side view of the same specimen. This curling dolomite ordinarly has a pinkish color. This dolomite is commonly cherty, the chert being disseminated either in small irregular pieces or in nodules. Sometimes the dolomite bears the same relation to isolated lenses or nodular shaped masses of chert as does the dolomite in the Gasconade limestone, as exhibited near the Stevens mines. (See page 36.) The relation is well shown on a branch of Mill creek one-fourth mile north of Brumley.

The dolomites, which are lithologically similar, are perhaps more cherty than those of the Gasconade limestone. The cherty beds occur mainly in the lower part of the formation, while the fine grained variety occurs in the middle and upper portions where the Bolin Creek sandstone is wanting.

A very argillaceous, compact, fine grained dolomite, much softer than the ordinary fine grained dense dolomite, known as "cotton rock," occurs closely associated with the Bolin Creek sandstone, but aside from this, it has no definite horizon. The "cotton rock" is a yellowish or buff colored stone exhibiting dendritic markings. It is very thinly bedded and the strata are often separated by thin layers of shale. It is very free from chert, differing in this respect, considerably, from the cotton rock of the Jefferson City formation.

In townships 40 and 41 north, range 12 west, the upper contact beds always contain beds of fine dense dolomite and cotton rock. In township 39 north, range 13 west, the dolomite of the upper contact beds is generally coarse grained and porous, while the basal beds contain more or less cotton rock, shale and dense dolomite. On Mill creek, one-half mile below Brumley, all of the varieties of dolomite occur in the basal beds.

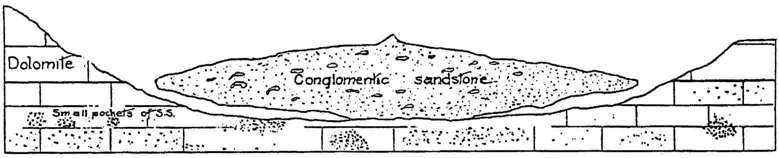
All gradations between sandstone and dolomite show in the outcrops along the creeks which flow through this formation. These beds of arenaceous dolomite usually have a bluish black color and from their weathered surface it is diffcult to say whether they are sandstone or dolo-



CURLING STRUCTURE IN DOLOMITE OF THE ST ELIZABETH FORMATION.

1. View along bedding plane. 2. Side view.

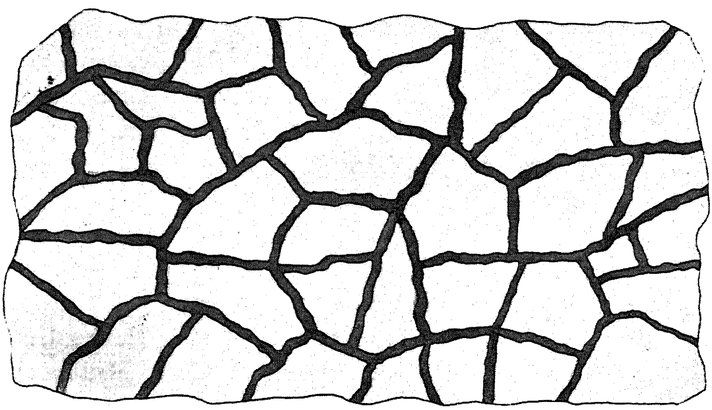
mite. In the bed of Brumley creek, in the N. E. ¼ of sec. 9, T. 38 N., R. 14 W., there is an excellent three-foot exposure of quartzose dolomite. The dolomitic phase of this bed frequently contains pockets, 2 to 3 feet in diameter, of conglomeritic sandstone. The lower portion of this bed, where it is most sandy, is also conglomeritic, containing small pebbles of water worn chert. The dolomitic part also contains chert pebbles. Above this bed, as shown in Figure 17, there is a nearly perfect lens of conglomeritic sandstone 30 feet in diameter and two and one-half



Sandstone lens in the St. Elizabeth formation.
FIG. 17.

feet thick at the center. A few feet south of this lens are dolomite beds occupying the same horizon as the sandstone lens. The grains of sand forming this "augen" are of irregular shape and size, as are also the slightly worn pebbles of black and white chert. Near this place occur several thin sandstone layers with ripple marks which strike in different directions in nearly every layer.

A bed very similar to the one just described outcrops in the bed of a small stream in the S. E. ¼ of sec. 7, T. 39 N., R. 13 W. A short distance above is a bed of light colored sandy dolomite, containing seams filled with black chert that occasionally seggregates at one place as a nodule. At other places in this bed the thin seams are apparently filled with a mud-like sandy conglomerate, the pebbles of which are broken pieces of black chert. These seams, although similar in shape to those mentioned above, are wider and somewhat more regular. (See Figure



Conglomerate chert filling suncracks in dolomite.
FIG. 18.

18.) Above this occurs a one and one-half foot bed of sandy conglomerate, such as fills the little seams in the underlying bed.

CHARACTER OF THE CHERT.

This is the most cherty of the Cambro-Ordovician formations in the county. The heavy bed or beds of rugged brecciated chert which, with few exceptions, occur at the base of the formations, are the most uniform and characteristic. In places where they attain a considerable thickness, the cirque-like heads of the hollows are especially well developed, particularly in the eastern part of the county in townships 40 and 41 north, range 12 west, and portions of township 40 north, range 13 west, and in township 40 north, range 15 west. Along the smaller streams they form a minor escarpment, which is very well displayed along the Little Gravois creek, in the western part of the county.

The beds composing this rugged chert near the mouth of Sugar creek in sec. 2, T. 41 N., R. 12 W., have a total thickness of 40 feet. Five miles west on the Osage river, at the mouth of Tavern creek, they are 30 feet thick. North of the river these rugged chert beds, except in the vicinity of Aurora Springs, form the base of this formation, and vary in thickness from 3 to 20 feet.

The rugged chert of these beds weathers to a reddish brown color, although the fresh surface is grayish white, yellow or black. The chert at the mouth of Sugar creek, is almost entirely black; three miles further south the black and white cherts occur in about equal proportions; while in the sourthern part of township 40 north, range 12 west, the chert is almost entirely black. North of the river black chert was observed.

These cherts are very porous, and usually brecciated, particularly the heavier beds. Perhaps the most characteristic chert fragments of the upper part of the formation are the cellular or honeycombed cherts. It is thought that these cherts were originally conglomerate sandstone or arenaceous dolomite which has been silicified. The weathered surface is usually whitish or pinkish colored and the fragments have roundish outlines. The pebbles which have leached out of the stone producing the cellular structure, were probably limestone, although in some instances they may have been chert.

The beds containing the honey-combed chert occur in nearly every locality, where the upper 30 feet of this formation is exposed. North of the Osage river the cellular chert occurs at the contact with the Jefferson City formation, while south of the river it is either the contact bed or within 10 feet of the contact. In two places a bed of similar chert was found about 40 feet below the top of the formation.

With the exception of a few localities, the beds of fine grained, dense dolomite are not very cherty. Where the chert is abundant it occurs either in thin layers, disseminated or in nodules. The nodular chert often occurs along the jointing planes, in which position it is nowhere found in the other Cambro-Ordovician formations of this county. The chert in the coarse grained dolomite occurs in layers, lenses and nodules as in the Gasconade limestone. Plate VIII is a photograph showing the differential weathering of chert from this formation.

Sandstone Beds.—Besides the sandstone beds of the Bolin Creek sandstone member there are other thin beds at different horizons in the formation. However, the entire thickness of these beds, if placed upon one another would not exceed a few feet. The average thickness of these beds north of the Osage river is from 5 to 7 feet. Over large areas on this side there is not a single sandstone bed exposed in the formation. Near Mary's Home, as shown in columnar section No. 25, the formation is unusually sandy, the total thickness of the sandstone beds being about 12 feet. In the western part of sec. 24, T. 41 N., R. 16 W., there is a 6 foot bed exposed. In other localities where sandstone outcrops it is usually very thinly bedded, and shows ripple marks. Fifty paces south of the half section corner between secs. 2 and 3, T. 42 N., R. 15 W., 12 feet below the upper contact occurs two and one-half feet of fine grained white sandstone, made up of layers from one-half to two inches thick. This bed grades above into a medium to coarse grained dolomite. Above this occurs one foot of sandy dolomite, which passes abruptly into a six inch bed of sandstone. The contact bed here is the cellular conglomeritic chert, or a very indurated sandstone, from which the boulders of the honey-combed chert have been derived.

South of the Osage river sandstone beds are everywhere found in the St. Elizabeth formation, although in the region up the Osage river from Tuscumbia, there is probably not more than four feet of sandstone in the entire formation, and this is seldom exposed. These thin sandstone beds, which do not belong to the Bolin Creek sandstone member, vary greatly in size of grain, color, texture and cementation, their only similarity being either their ripple marks, fucoidal markings or sun cracks. The upper few feet of the formation also frequently contain very thinly bedded sandstone and vitreous chert in nodules, similar to that in the cotton rock at the base of the Jefferson City formation. The white thinly bedded cherts are almost quartzite, being exceedingly dense and vitreous. They are sometimes oölitic, the oölites consisting of concentrically banded silica and not of sand grains.

In the bed of a small creek near the two faults in sec. 5, T. 38 N., R. 13 W., the upper contact shows no unconformity, although the upper bed of this formation is a somewhat indurated conglomeritic sandstone.

The pebbles are water worn, and are from less than one-fourth up to eight inches in diameter. They consist of white and black chert, both oölitic and non-oölitic. The beds from which the fragments were delivered could not be located.

STRUCTURE.

Stratification.—The beds of the St. Elizabeth formation are thinner than those of the Gasconade limestone. Owing to the sudden changes in sedimentation which occured during the deposition of the materials comprising this formation, the stratification planes are therefore more abundant than in the Gasconade.

Bedding.—Throughout this formtaion the bedding planes are irregular and wavy. The beds of chert and sandstone are thicker than the Gasconade limestone, but the dolomites are much thinner. None of the beds in this formation have an original thickness of more than six feet. Many of the beds of the Gasconade limestone, on the other hand, originally had a thickness of from 15 to 25 feet.

Jointing.—Owing to the variable character of the strata comprising this formation, no very definite system of jointing could be made out in the cherts and dolomites. See page 133. The chert beds are broken into very small polygonial pieces by numerous jointing planes which apparently strike and dip in many directions and at various angles. The Bolin Creek sandstone member exhibited two sets of joints striking N. 20° W. and N. 60° E. These joints vary through an angle of about 20° and occur a considerable distance apart.

Folding.—This formation is complexly flexured very much the same as the Gasconade limestone underneath. Steeply dipping beds are more common in this formation than in any other. Many of them have resulted from the falling in of the roofs of caverns due to underground solution.

Faulting.—Most of the faults of this formation are in township 38 north, range 13 west. In the N. W. ¼ of sec. 6 of this township and range, occurs a fault striking east and west which has a downthrow of approximately 50 to 60 feet to the south. In the S. W. ¼ of sec. 5, one and one-half miles southeast of the above fault, two faults occur which strike nearly at right angles to each other. In the middle of the S. W. ¼ of the N. W. ¼ of sec. 11 occurs a fault striking north-northwest which has a displacement of 120 feet with a downthrow to the southwest. On the section line between sections 13 and 14, about one-fourth of a mile north of the county line, occurs a small block fault which has lowered beds of Jefferson City limestone about 150 feet. The fault in sec. 10, T. 41 N., R. 15 W.,

DIFFERENTIAL WEATHERING OF ORDOVICIAN CHERT.

with a throw of 150 feet, has already been referred to in connection with the Gasconade limestone.

It is difficult to determine in many cases whether these faults have been due to underground solution and subsequent caving in of the roofs of subterranean caverns or whether they are due to tensile stresses by which the strata on one side of the fault have been lowered with respect to the other side. The faults occurring in this formation are described in detail in the chapter dealing with structure.

Brecciation.—The heavy chert beds occurring throughout this formation are frequently broken into small angular fragments and recemented with thin seams of limonite and quartz. The brecciation has occurred along the horizontal beds and not in vertical zones or along planes of faulting. In some of the crevices formed through solution along joint planes, pieces of rock were found cemented by various mineral substances. Such agglomerate masses are not true breccias which are formed by orogenic movements. These masses might better be called solution breccias.

FOSSILS.

The St. Elizabeth is more fossiliferous than the underlying formations. The fossils occur mainly in the chert beds, where they are present as siliceous casts.

These fossils have been referred to the paleontologist of the United States Geological Survey for determination. The results of such determination will be published at a later time.

RELATIONS TO ADJACENT FORMATIONS.

In some places there may have been a slight erosion interval between the deposition of the Gasconade and St. Elizabeth formations. The best evidence of this is found in sec. 9, T. 41 N., R. 15 W., at which place roundish boulders of Gasconade dolomite one foot in diameter occur in a bed of sandstone at the base of the St. Elizabeth formation. In some places where the bed of sandstone occurs at the base of this formation, little dikes extend into the limestone underneath. These so-called dikes may be merely solution cavities filled with sand. The contact is also often irregular and wavy.

Many of these minor discordances in bedding may be attributed to ocean scour, as was suggested by Mr. Bailey Willis of the United States Geological Survey. This being the case one is hardly justified in presuming that an unconformity exists between these formations.

In most places the St. Elizabeth and Jefferson City formations grade into each other through sandstones, conglomeritic sandstones, shales and cotton rock. The upper bed of the St. Elizabeth formation, over a considerable area, is the very cellular, honey-combed chert above referred to. The lower beds of the Jefferson City formation consist mainly of shale, cotton rock and occasional thin layers of sandstone. The same kind of nodular chert is found in the upper beds of the St. Elizabeth and the lower part of the Jefferson City formation.

In a number of places this formation is overlain with Graydon sandstone, Coal Measure shale, coal pockets and Burlington limestone. They rest unconformably above this formation and occur in a manner very similar to those above the Gasconade limestone.

ECONOMIC CONSIDERATION.

That portion of the county which is immediately underlain by this formation is primarily important for its farming and grazing lands. The broad flat-topped ridges in the eastern and southern parts of the county are excellent examples.

Lead and Zinc.—The McMillan and Crump Diggings on the north side of the river are the only mines in this formation from which any considerable amount of ore has been taken. The McMillan Diggings are reported to have produced 200,000 pounds of lead, but the output of the Crump Diggings could not be ascertained. Traces of lead and zinc occur throughout the entire formation, but the most promising horizon is near the contact with the Gasconade limestone.

Barite.—The barite occurs mostly associated with the brecciated chert. On the south side of the Osage river it was only found as float, while on the north side there are several deposits in place. Apparently there is no definite horizon at which the barite occurs.

Silica.—In some places the chert has been decomposed into silica or "chalk," but no bodies of commercial importance are known to exist in this formation.

Iron.—A large part of the iron of this county is in the St. Elizabeth formation south of the Osage river. The hematites are generally associated with the Bolin Creek sandstone member.

Copper.—Occasional green stains of copper carbonate occur in the small pieces of limonite and limestone breccia. In sec. 1, T. 40 N., R. 13 W., one mile east of Capps, a few crystals of azurite and malachite were found in small pieces of float limonite which had probably been derived from this formation. A number of pits have been sunk in search for copper, but they have all been abandoned.

RESUMÉ.

The St. Elizabeth formation comprises deposits which were laid down in a very shallow sea. The character and kind of sediment often change suddenly and the interruptions to deposition were frequent. Dolomite passes suddenly into sandstone or shale, and vice versa. The numerous changes in sedimentation are evidenced by the thinness of the beds and the numerous planes of stratification. The sun cracks and ripple marks in the sandstone, at all horizons, show that the formation was often above sea level. There is no evidence that deep sea conditions prevailed at any time.

The principal changes which have occurred since deposition are the alteration of a portion of the dolomite to chert, and the formation of secondary structures, including folding, faulting, jointing, brecciation crevices, caves and caverns.

BOLIN CREEK SANDSTONE MEMBER.

This member of the St. Elizabeth formation comprises the heavy deposits of sandstone, all of which occur south of the Osage river. The sandstone beds of which it is composed consist of lenses or lentels of varying size and thickness, and occur either as single massive beds or as a number of thinner ones in uninterrupted succession. North of the Osage river there are only one or two localities in which the sandstone of this formation attains a thickness of seven feet, and since these beds could not be traced over 100 feet they are not included in this member.

The Bolin Creek sandstone is best exposed in townships 38 and 39 north, range 12 west, where it attains its greatest development. It is typically exposed along Bolin and Sandstone creeks in township 38 north, range 12 west. Tavern creek, which flows through these townships, defines very closely the western edge of the largest and most important lens. For several miles west of the creek very few heavy beds of sandstone occur. In crossing Tavern creek from the east, in almost any locality in these townships, the change from the sandstone to the non-sandstone area is very apparent even to the casual observer. Besides the above mentioned localities this sandstone is found in township 39 north, range 13 west, along Barren and Brushy forks, and in township 39 north, range 14 west.

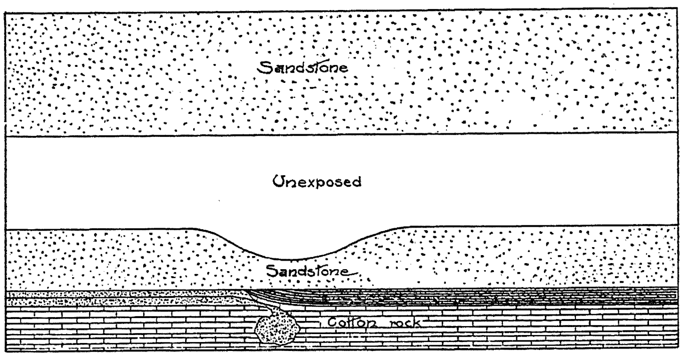
Thickness.—This member varies in thickness from one to fifty feet, the maximum thickness being along Sandstone creek in secs. 25 and 26, T. 39 N., R. 12 W. Whether this is the same lens which outcrops in townships 40 and 41 north, range 12 west, could not be definitely determined. In some places it is thought to be a different lens, inasmuch as its thickest place is from 30 to 50 feet above the base of the St. Elizabeth formation, and from 20 to 30 feet of the top. Its position with reference to the upper contact of the formation is much more constant than with reference to the lower contact. In several places in townships 40 and 41 north, this member outcrops considerably lower down in the formation than does the main lens in townships 38 and 39 north, but a majority of the exposures correspond in general to the position of the main lens.

In most parts of townships 40 and 41 north, range 12 west, and around St. Elizabeth, this member is from 10 to 18 feet thick, and occurs in the upper part of the formation just above the bed of very fine grained, dense dolomite and underneath beds of black vitreous oolitic chert. Although sometimes cherty, this member is seldom quartzitic in secs. 24 and 25, T. 40 N., R. 12 W., where it is quite thinly bedded. Two miles southwest, in sec. 33, T. 40 N., R. 12 W., the sandstone is 25 feet thick, non-quartzitic and very heavily bedded. From their position in the formation it is thought that these beds belong to the main lens. Northwest of this locality the main lens cannot be definitely recognized. From sec. 33, T. 40 N., R. 12 W., to secs. 25 and 26, T. 39 N., R. 12 W., this lens gradually increases in thickness to 50 feet. South of here, to the county line, and southwest to sec. 18, T. 38 N., R. 12 W., it again thins to about 20 feet.

The Bolin Creek member is exposed at many places along Barren and Brushy forks in township 39 north, ranges 13 and 14 west, varying in thickness from 5 to 12 feet. It is lower down in the formaton at these places than the main lens, being from 50 to 70 feet below the top of the formation. In the western part of townships 38 and 39 north, range 14 west, it occurs in the upper part of the formation, has a thickness of from 7 to 15 feet and more nearly resembles the main lens than at any of the other exposures.

Bedding.—Usually this member consists of massive beds of sandstone. This is particularly true of the main lens, which, along Sandstone and Bolin creeks, occurs frequently as a massive bed, from 20 to 40 feet thick This lens, as well as those along Barren and Brushy forks, is very homogeneous and comparatively free from chert. In townships 40 and 41 north, range 12 west, the sandstone is more heterogeneous and cherty, and the beds are much thinner.

The basal bedding planes of this member are always more or less irregular, while the others are quite smooth and regular. At the mouth of Bolin creek, just north of the center of sec. 16, T. 39 N., R. 12 W., a narrow dike two feet long penetrates the underlying cotton rock, as shown in the diagram, causing the latter to form a pronounced shelf above the sandstone dike, as shown in Fig. 19.



Irregular lower contact of Bolin creek sandstone in Sec. 16, T. 39 N., R. 12 W.
FIG. 19.

Texture.—The sandstone of this formation is composed of well rounded grains of quartz which vary considerably in size even in the same bed. For example, in a quarry in the N. E. ¼ of sec. 32, T. 41 N., R. 12 W., a three and a half foot bed, which is fine grained at the bottom, grades gradually into a very coarse grained sandstone at the top. A similar variation was observed in the main lens on Sandstone creek and at a number of other localities throughout the county.

Some of the beds have an oölitic texture. The oölites are sometimes smaller than a pin head and have nuclei of rounded, clear quartz covered by a thin white coating of silica. These oölitic beds, which are thinly laminated and usually quite indurated, are most abundant in townships 40 and 41 north, range 12 west, and at the Cannon mines in sec. 15, T. 38 N., R. 12 W.

Cementing Material.—The common cementing material of the sandstone is silica. At the Cannon mines the bottom three feet of the heavy sandstone beds are quartzite. Some heavy quartzite beds occur in sec. 25, T. 40 N., R. 12 W., and thinner beds were observed in sec. 29, T. 41 N., R. 12 W. Iron oxide is a very common cement, and occasionally the green iron silicate serves this purpose. No calcareous cement was observed in this sandstone.

Porosity.—This sandstone is very porous and naturally constitutes an important water bearing horizon. It is the source of most of the springs in the St. Elizabeth formation.

Color.—The sandstone varies in color from a pure white, yellow, deep brown or reddish brown to nearly black, depending upon the amount and character of the iron oxide present. It usually has the deepest color of the surface, in many instances having a steel black tint.

Weathering.—Where this member is exposed near the tops of the ridges it preserves its massiveness, and at the heads of the valleys or ravines forms numerous small water-falls. Where the heavy beds are exposed at the brow of a hill, they often break up into large blocks which are scarcely distinguishable from blocks of Graydon sandstone.

Sun cracks, Ripple Marks and Cross Bedding.—Sun cracks, ripple marks or cross bedding are found almost everywhere along the bedding planes of this member. In a creek bed in the S. E. ¼ of sec. 18, T. 38 N., R. 12 W., the sandstone splits into thin layers which show both ripple marks and sun cracks. In one instance the strike of the ripple marks was N. 40° E., while four feet away along the same bed the strike was nearly at right angles. In other instances the direction of the ripple marks in contiguous layers is entirely different. Fig. 20 is a photograph of a bed of this sandstone showing well defined cross bedding.

Cross bedding in Bolin Creek sandstone.
FIG. 20.

Cherty Contents.—Except in townships 40 and 41 north, range 12 west, this member is remarkably free from chert. In these townships, chert occurs either in thin layers or in small, flat pieces arranged in sheets parallel to the bedding planes. It has a white, bluish white, yellow or rarely dark color and is both oölitic and non-oölitic. Everywhere small pieces of chert are disseminated irregularly through the bed or beds comprising the main lens. In secs. 25 and 26, T. 39 N., R. 12 W., the upper part of the main lens includes a 5-foot horizon of chert, having a matrix of granular decomposed sandstone, through which small irregular shaped pieces of black and white oolitic chert are uniformily disseminated. Above and below this bed the sandstone has the usual non-cherty character. In sec. 36, T. 39 N., R. 12 W., and in township 38 north, range 12 west, this cherty bed grades into a quartzitic, brecciated chert which is not included in this member.

Summary.—From the well rounded, water-worn character of the sand grains, the ripple marks and cross bedding, it is evident that this member is a beach deposit, and was laid down uniformily near shore.

DETAILED COLUMNAR.

SECTIONS OF THE ST. ELIZABETH FORMATIONS.

Section No. 9, Fig. 21.

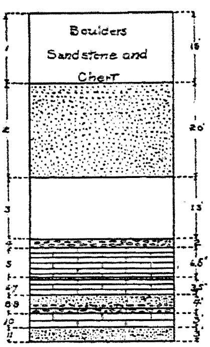


FIG. 21.

At Bray's mill, on Tavern creek in sec. 9, T. 39 N., R. 12 W. From top to bottom.

No.	Elev.	
1	55-70	15-foot slope covered with boulders of loose SANDSTONE, OÖLITIC CHERT and QUARTZITE.
2	35-55	20-foot bed of brown SANDSTONE, medium grained, which belongs to the Bolin creek sandstone member. This bed is much jointed. The most prominent sets strike N. 50° W., and N. 45° E., and are vertical.
3	22-35	13 feet unexposed.
4	20-22	2-foot bed of white CHERT, almost quartzite.
5	13½-20	6½ feet of thinly bedded, dark colored fine grained, dense DOLOMITE.
6	13-13½	6-inch bed of SANDSTONE.
7	10-13	3 feet of DOLOMITE, similar to No. 5.
8	7-10	3-foot bed of white SANDSTONE. The bottom foot contains considerable black oölitic chert.
9	6-7	1-foot bed of DOLOMITE, arenaceous and cherty, the chert being blue and nodular.
10	3-6	3 feet of pinkish DOLOMITE, fine grained and dense. Weathers with rounded surfaces.
11	0-3	3-feet contact bed of white friable SANDSTONE.

Section No. 10, *Fig.* 22.

Along Tavern creek in the S. E. ¼ of sec. 17, T. 39 N., R. 12 W., is a high bluff, the upper 80 feet belonging to the St. Elizabeth formation.

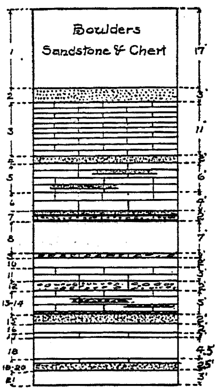


FIG. 22.

From top to bottom.

No.	Elev.	
1	63-80	17 feet covered with large boulders and blocks of SANDSTONE from the Bolin creek sandstone member, together with chert, cherty sandstone and honey-combed chert.
2	60-63	3 feet of SANDSTONE of Bolin creek member. Shows cross bedding.
3	49-60	11 feet of thinly bedded, very dense, fine grained DOLOMITE.
4	47-49	2-foot bed of very calcareous SANDSTONE. The grains of sand are clear and are bedded in a whitish matrix of much finer sand and limestone.
5	41-47	6 feet of thinly bedded, fine grained DOLOMITE and SANDSTONE.
6	37-41	4 feet of buff colored DOLOMITE, fine grained and dense.
7	35-37	4 inches of pinkish, fine grained, banded DOLOMITE; 8 inches of a white oölitic CHERT, and 1 foot of white indurated SANDSTONE, containing disseminated oölitic and white chert.
8	28-35	7 feet unexposed.
9	27-28	1-foot bed of pinkish, cherty, sandy DOLOMITE.
10	25-27	2 feet unexposed.
11	22-25	3 feet of a greenish blue, fine grained arenaceous DOLOMITE.
12	20-22	2-foot bed similar to No. 9.
13	15½-20	4½ feet of very cherty, fine grained, DOLOMITE. The chert is mostly in layers. Bottom 2 inches of this bed are made up of alternating thin laminae of white, compact dolomite and yellow, soft, sandy dolomite.
14	15-15½	6-inch bed of fine grained, pink DOLOMITE. Contains much disseminated, white banded chert.
15	13-15	2-foot bed of vitreous, oölitic, white QUARTZITE, containing disseminated white chert throughout.
16	11-13	2 feet unexposed.
17	10-11	1 foot of white, fine grained DOLOMITE. Weathers to a very smooth, roundish surface.
18	5½-10	4½ feet unexposed.
19	4 2-3-5½	10-inch bed of light colored, fairly fine grained DOLOMITE.
20	3-4 2-3	20-inch bed similar to No. 4.
21	0-3	Contact unexposed.
22		80 feet of Gasconade limestone. The upper bed is medium grained, chertless, light colored and has a pitted surface.

Section No. 11, Fig. 23.

On Tavern creek in the S. W. ¼ of sec. 1, T. 38 N., R. 13 W.

From top to bottom.

No.	Elev.	
1	85-110	25 feet of talus containing many pieces of black and white oölitic CHERT and QUARTZITE.
2	82½-85	2¼-foot bed of white, medium grained SANDSTONE.
3	81-82½	1½-foot bed of fine grained calcareous SANDSTONE.
4	78-81	3 feet of thinly bedded black oölitic CHERT.
5	77-78	1 foot of DOLOMITE. Fine grained and dense.
6	68½-77	8½ feet unexposed.
7	68-68½	6 inches of thin layers of SANDSTONE and DOLOMITE.
8	66-68	2 feet unexposed.
9	64-66	2-foot bed of white, medium grained SANDSTONE. Contains a little chert.
10	63-64	1-foot bed of fine grained, dense DOLOMITE. It is sandy and slightly cherty.
11	60-63	3-foot bed of compact, fine grained, calcareous SANDSTONE.
12	58-60	2 feet of fine grained, dense DOLOMITE, containing nodules of black chert.
13	49-58	9 feet of poorly exposed, but apparently fine grained, dense, cherty DOLOMITE; the chert is both black and white and oölitic.
14	47-49	2 feet of arenaceous DOLOMITE.
15	46½-47	6 inches of black oölitic CHERT.
16	44½-46½	2 feet unexposed.
17	43-44½	1½ feet of fine grained, dense, cherty DOLOMITE. The chert is both black and white.
18	39-43	Like No. 17.
19	36-39	3 feet, of cherty DOLOMITE.
20	32-36	4-foot bed of banded white and bluish black CHERT.
21	22-32	10 feet of DOLOMITE.
22	17-22	5 feet of bluish white, whitish yellow and black oölitic CHERT, containing a few small nodules of dolomite. The chert is all banded.
23	15½-17	1½ foot of cherty DOLOMITE.
24	15-15½	6 inches of bluish white CHERT.
25	13-15	2 feet of cherty DOLOMITE, in which whitish blue chert occurs in regular layers.
26	11-13	2 feet of brecciated black CHERT, with a little dolomite.
27	7-11	3 feet, 8 inches of banded white CHERT, secondary after dolomite, and 4 inches of dolomite. There is an occasional streak of vitreous, black chert in the mass of white chert.
28	4-7	3 feet of alternating beds of CHERT and DOLOMITE of about equal thickness. The uppermost inch is black oölitic chert, which changes gradually into white oölitic chert.
29	4-5	1 foot unexposed.
30	0-5	5-foot contact bed of indurated yellowish SANDSTONE, containing streaks of oölitic chert and green stains of iron silicate. Contact is smooth.

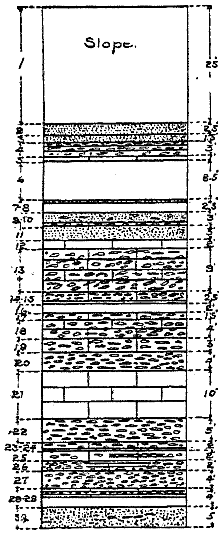


FIG. 23.

Section No. 12, *Fig.* 24.

Sec. 31, T. 41 N., R. 14 W.

From top to base of formation.

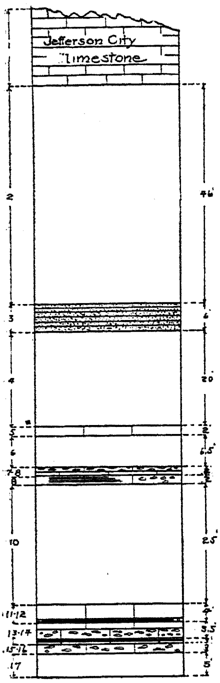


FIG. 24.

No.	Elev.	
1	125	Beds of Jefferson City limestone.
2	79-125	46 feet unexposed.
3	73-79	6 feet of white SANDSTONE in very thin layers. Bottom 5 feet is somewhat conglomeratic.
4	53-73	20 feet unexposed.
5	51-53	2 feet of DOLOMITE.
6	44½-51	6½ feet unexposed.
7	43½-44½	1 foot of cherty, fine grained DOLOMITE. Some of chert nodules have a thickness of 6 inches.
8	42½-43½	1-foot bed of soft, medium grained DOLOMITE, overlain by a thin layer of quartzite.
9	40½-42½	2 feet of thinly bedded, re-cemented, greenish and drab DOLOMITE, containing shaley partings and a little white chert. Where the rock has a green color it is most strongly cemented. Where the rock has a drab color the beds are more compact. All the bedding planes are wavy. In places the dolomite has rounded grains imbedded in the secondary cement.
10	15¼-40½	25 feet unexposed.
11	12¾-15½	3 feet 2 inches of coarse grained intensely red DOLOMITE.
12	11½-12 1-3	10 inches of closely jointed CHERT and SHALE. Barite occurs in the joints.
13	10-11½	1½ feet of fine grained, brownish gray DOLOMITE.
14	8-10	2 feet of decomposed, medium grained DOLOMITE. Secondary chert occurs in irregular lenses; some parallel to the bedding, others along the jointing planes.
15	7-8	1 foot unexposed, thinly bedded DOLOMITE.
16	5-7	2 feet of medium grained DOLOMITE, splitting, in some places, into three or four layers. Chert nodules occur either in a bed or isolated. These nodules consist of concentric black and white bands.
17	0-5	Unexposed.

Section No. 13, *Fig.* 25.

Sec. 16, T. 41 N., R. 13 W.

From top to bottom.

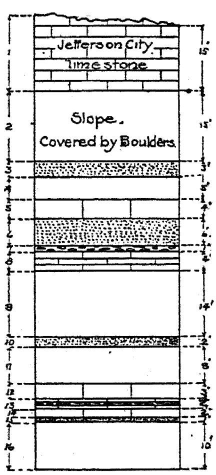


FIG. 25.

No.	Elev.	
1	80	Jefferson City limestone contact.
2	65-80	15 foot slope, covered by boulders.
3	62-65	3 foot bed of cellular, honey-combed, indurated SANDSTONE or chert.
4	57-62	5 feet unexposed. The space is covered with sandstone boulders.
5	53-57	4 feet of fine grained DOLOMITE.
6	47-53	6 foot bed of quartzitic SANDSTONE, containing many cavities. Originally this bed was apparently a conglomerate from which the pebbles have been removed.
7	46-47	1 foot bed of oölitic chert, considerably jointed and containing some calcite.
8	42-46	4 feet of fine grained, grayish DOLOMITE.
9	25-42	14 feet unexposed.
10	26-28	2 foot bed of SANDSTONE, containing small, beautifully preserved ripple marks.
11	18-26	8 feet unexposed.
12	15-18	3 feet of fine grained DOLOMITE.
13	13-15	2 feet of thinly bedded CHERT and DOLOMITE. In the chert are small rosettes of barite crystals.
14	11-13	2 feet of fine grained DOLOMITE.
15	10-11	1 foot bed of SANDSTONE, having ripple marks.
16	0-10	10 feet unexposed.

CHAPTER VI.

JEFFERSON CITY FORMATION.

AREA DISTRIBUTION.

The Jefferson City formation, so named by Winslow because it is typically exposed at Jefferson City, Missouri, underlies the higher portions of the county on both sides of the Osage river. Its areal distribution south of this river is more irregular than it is north, owing to the more broken character of the land. The main area underlain by this formation on the south side of the river comprises over one-half of townships 38 and 39, range 14 west, and two-thirds of township 38, range 13 west. Aside from this area, the formation occurs only on the tops of the higher ridges. With a few exceptions the line between townships 39 and 40 north, marks the northern extent of the Jefferson City formation on the south side of the Osage river. North of the river this formation underlies practically all of the prairie region as well as capping the broad ridge in township 41 north, range 13 west.

THICKNESS.

The Jefferson City formation has its greatest thickness in the southern part of the county where, in one place, it attains a thickness of about 200 feet. At this place there is a considerable thickness of residual cherts derived from interlaminated beds, which have been included in the formation in estimating its thickness. The greatest thickness of this formation, 150 feet, is along the county line in sec. 14, T. 38 N., R. 13 W. The average thickness of the exposed beds south of the Osage river is about 100 feet. In the eastern part the thickness is less, while in the southern and middle portions it is somewhat greater. The average thickness north of the Osage river is 60 feet, although near Eldon it is 104 feet. Meek* states that in this county it attains its greatest thickness in the northern townships, and estimates it at 150 feet. From Eldon there is a northerly dip of 30 feet per mile, which fact Meek appearently did not take into consideration. His estimate was probably based upon the different elevations at which outcrops were observed.

*Geol. Sur. Mo., 1855-71, p. 188.

This formation consists principally of beds of dolomite, containing chert nodules and in places interstratified with thin layers of chert, sandstone and shale. The dolomite is either very hard, dense and fine grained; soft, argillaceous and arenaceous as in the "Cotton rock;" or coarse, vesicular and hackly.

TOPOGRAPHY.

The Jefferson City formation underlies the gently rolling prairie land north of the Osage river, the ridge land near the village of Ullman, and the broken hill country in township 38 north, ranges 12 and 13 west in the southern part of the county.

The ridges which are capped by this formation are steeper and more precipitous on one side than on the other. The cirque-like valley heads, although occasionally present, are not nearly as numerous as in the Gasconade and St. Elizabeth formations.

In Miller county the Jefferson City formation, as compared with other formations, shows a disinclination to form cliffs, although along the Moreau creek in the northern part of the county some occur which are from 20 to 30 feet high. Along Barren forks and Mill creek, on the south side of the river, in two or three places, small cliffs are closely associated with sharp local flexures or faults. This tendency not to form cliffs is due to the ease with which the comparatively thin beds flake off, forming step-like slopes rather than precipitous bluffs.

The Jefferson City formation has a tendency to form "balls," which may occur at almost any horizon from the base to the top. In the rougher portions of the county, particularly along Brushy and Barren forks and Mill creek, the entire thickness of the formation occurs as a "ball." Some of the "balls" cover several acres, being much larger than those of the Gasconade limestone.

WEATHERING.

The manner in which the dolomite weathers is especially characteristic of this formation. The surface of the cotton rock is usually smooth and rounded. Frequently it is covered with little saucer-like depressions, resembling the prints of rain drops on sand. In many instances these are the result of the removal of small limonite concretions which occur abundantly in these beds. In some cases they may have resulted from temperature changes through which small spals were detached from the rock.

The heavy massive beds are considerably harder than the cotton rock beds and the weathered surface is rough and hackly as a result

TYPICAL WEATHERED SURFACE OF PITTED BEDS OF JEFFERSON CITY LIMESTONE.

TYPICAL WEATHERED SURFACE OF PITTED BEDS OF JEFFERSON CITY LIMESTONE.

of inequalities in the hardness of the dolomite. The pitted surface of the heavy beds of this formation differs from that of the Gasconade limestone in that the pits are uniformily deeper, broader and more irregular in shape, while the intervening ridges or projections are sharper and more uneven. The accompanying illustration, Plate IX, shows a typical weathered surface. The plate also shows the step-like manner in which the beds occur in most of the "balls."

Little geodes of white chert, lined with tiny crystals of quartz, are common in many of the massive pitted beds. They stand out prominently on the weathered surface.

The joints in the pitted beds on the south side of the Osage river are usually short and gently curved. Weathering often enlarges these seams near the surface, forming open gaping fissures.

COMPOSITION OF THE ROCK COMPRISING THE FORMATION.

Cotton Rock.—Cotton rock is an argillaceous, siliceous dolomite. It is very fine grained and dense, but relatively soft. It has an earthy or clayey texture, being neither granular nor crystalline. It usually splits with a conchoidal fracture. The color is white, gray, yellow or buff. Dendritic markings are common.

With a few exceptions in sec. 31, T. 41 N., R. 14 W., and in the eastern part of township 39 north, range 12 west, the basal beds of the Jefferson City formation are cotton rock. The cotton rock at this horizon attains its greatest thickness, 30 feet, in the northwest corner of the county. East, southeast and south of this place the thickness decreases. In the northeast corner of the county, township 41 north, range 12 west, it is not more than 10 feet thick. South of the Osage river in townships 38 and 39 north, ranges 14 and 15 west, the average thickness is from 15 to 20 feet, while further east the beds decrease until they die out entirely. Thin shaly partings are common.

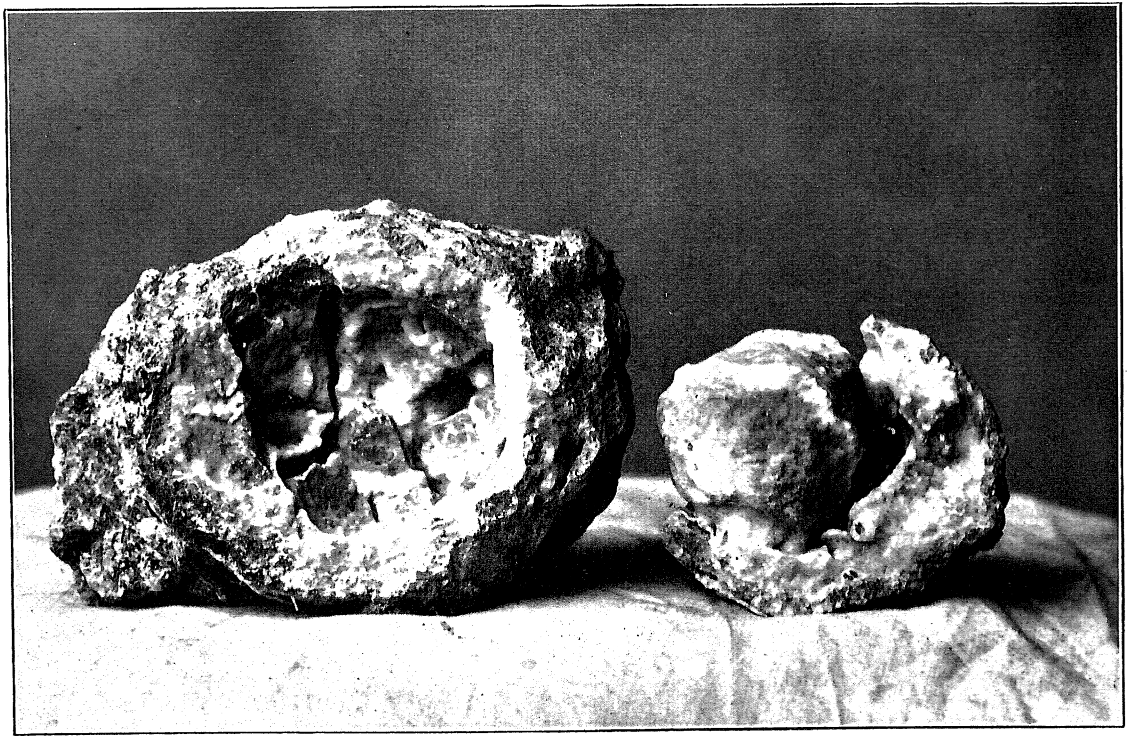
Cotton rock also occurs at other horizons throughout the entire formation. On the north side of the Osage river, and at a few localities on the south side, there is a somewhat persistent horizon of cotton rock about 45 feet above the base of the formation. The next important horizon is about 70 or 80 feet above the base, and the last is at the very top of the formation. This uppermost horizon has its greatest development in the southern part of the county. At all of these horizons the cotton rock has essentially the same characteristics. The main difference is in the quantity of chert and the manner in which it occurs.

Hackly Pitted Dolomite.—The beds of this dolomite are remarkably uniform and persistent over the entire county, giving to the formation its chief distinguishing characteristic.

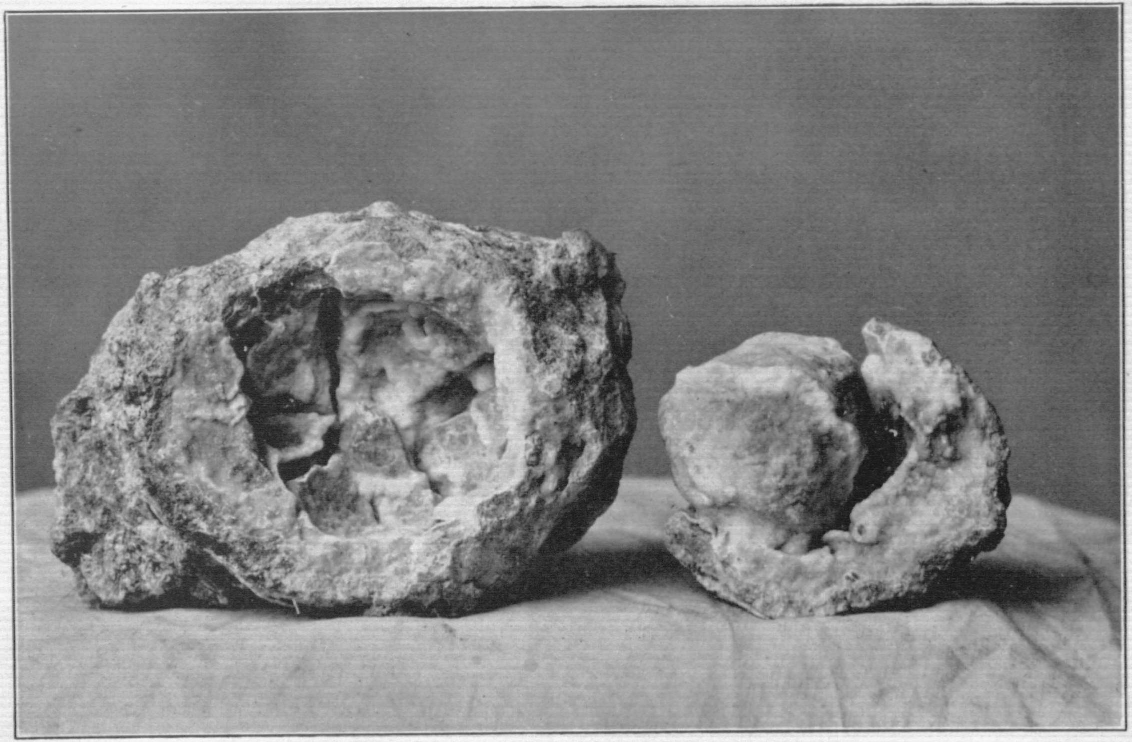
The principal variation in these beds is in the content of chert which, in some places, is very abundant and in others almost entirely absent. There is a soft, white or yellow powdery material scattered through the beds, usually in planes parallel to the bedding, which imparts a streaked or mottled appearance to the freshly exposed surfaces. The rock breaks with a hackly fracture.

Dense Dolomite.—In a few places in the county this formation contains beds of fine grained dense dolomite, such as characterizes the St. Elizabeth formation. This dolomite breaks with a conchoidal fracture and is very free from argillaceous or arenaceous material. Dolomite beds of this character occur 25 or 30 feet above the base of the formation in the S. W. ¼ of sec. 34, T. 39 N., R. 13 W., and near the base of the formation in the N. W. ¼ of sec. 6, T. 38 N., R. 13 W.

Chert.—This formation contains less chert than the Gasconade limestone or the St. Elizabeth formation. Only in the southern part of township 39 north, range 12 west, where the dolomite is associated with intercalated beds of sandstone, were heavy chert beds observed. In sections 31 and 32 of the township above referred to, and 100 feet from the base of the formation, there is a three-foot bed of black, oölitic, brecciated chert, closely resembling that of the St Elizabeth formation. The other chert beds, averaging about four inches in thickness, occur mostly in the cotton rock and sandstone horizons. The chert is black, bluish white or white and frequently oölitic. The nodular chert is entirely confined to the cotton rock horizon. In the lower horizons it sometimes forms thin layers, although it is usually in distinct nodules. The nodules are of various shapes and sizes, although usually flat. Often they are not more than one or two inches thick, eight to twelve inches long, and four to six inches wide. As a rule, the outside of all the nodules is white, while the interior may be white, yellow, brown, black or bluish. They are quite uniformily banded, and often contain a cavity lined with quartz at the center. Plate X shows a peculiar form of chert nodule occurring in this formation. In sec. 36, T. 39 N., R. 14 W., in the cotton rock horizon 100 feet above the base, the nodular cherts are cylindrical in shape and gently curved. The surface is often rough, due to innumerable tiny projections. Small irregular shaped pieces of disseminated bluish chert are common in the heavy pitted beds.



PECULIAR FORM OF CHERT NODULE.



PECULIAR FORM OF CHERT NODULE.

Sandstone.—There are a number of intercalated beds of sandstone, of varying thickness, in this formation. Except in railroad cuts and deep gullies, all but the most prominent of these beds are concealed by the way in which the dolomite beds weather. Their presence, however, is shown by numerous small fragments occurring everywhere on the slopes underlain by this formation.

The sandstone beds vary in thickness from one inch to five feet. The thin beds are most common and together make up a larger part of the entire thickness of the sandstone. However, they are so poorly exposed as to be usually overlooked. They occur at all horizons throughout the formation. Ordinarily they consist of well rounded, fine to medium sized grains of quartz, deeply stained with iron oxide. They always contain more or less nodular chert and are usually soft and friable.

There are a number of beds from one to five feet in thickness, which are relatively conspicuous. These beds vary in composition from calcareous sandstone to arenaceous dolomite. The weathered surfaces of the highly calcareous sandstone beds are somewhat rough and irregular. In color they also closely resemble the dolomite. There is a 4-foot bed of this character in sec. 7, T. 41 N., R. 15 W., in which the grains have been partly recrystallized. A very calcareous bed, two and a half to five feet thick, is persistent over much of the eastern part of township 39 north, range 12 west. It is 45 feet from the base of the formation, and its position is everywhere easily recognized by the springs which issue from it. In sec. 13, T. 38 N., R. 14 W., there is a 2-foot bed of sandstone similar to that in the upper part of the formation, and in the S. W. ¼ of sec. 30, T. 39 N., R. 12 W., there is another two and one-half-foot bed of this sandstone belonging to the lower 30 feet.

A greater part of the heavier intercalated sandstone beds are medium grained and friable; have a deep reddish brown color; and weather with rounded surfaces. A bed of sandstone of this character, having a thickness of from three inches to two and one-half feet, occurs everywhere north of the river and to a lesser extent south of the river in the lower 25 feet of the formation.

South of the east and west fault along Barren forks, in sec. 6, T. 38 N., R. 13 W., there is a bed of white friable sandstone in which the grains are well rounded. This bed varies in thickness from two and one-half to four feet, and can be traced almost continuously for about two miles up the creek from the fault. In many places it is oölitic and frequently it is cherty. Cross bedding is common. Just south of the fault the slabs broken off from this bed are so numerous that one might easily mistake them for blocks of Graydon sandstone. This sandstone outcrops in numerous places in secs. 1 and 12, T. 38 N., R. 14 W.

In the northeast quarter of sec. 9, T. 39 N., R. 13 W., two other beds of sandstone are intercalated with the dolomite of this formation. One of these beds is two and one-half feet thick; has a white, yellow or brown color and is very friable. It can be traced about a half a mile before it apparently dies out. Other intercalated sandstone beds occur in the N. E. ¼ of sec. 14, T. 42 N., R. 15 W.; in the N. E. ¼ of the N. W. ¼ of sec. 3, T. 38 N., R. 13 W.; in secs. 25 and 36, T. 39 N., R. 14 W.; in the N. E. part T. 39 N., R. 14 W., and in the S. W. ¼ of sec. 32, T. 40 N., R. 13 W.

STRUCTURE.

Stratification.—Stratification planes in this formation are a result mainly of thin laminae of shale which occur throughout the formation separating the dolomite beds from one another. With the exception of these, the changes in sedimentation are not usually abrupt. Considerable thicknesses of both cotton rock and heavy pitted dolomite show no other change in sedimentation.

Bedding.—The bedding planes are close together, five or six feet being an unusual separating distance, and beds of this thickness occur only in hackly or pitted dolomites. The average thickness of the beds of cotton rock, as ordinarily exposed, is but a few inches. Where exposed in cuts or quarries, the thickness is more variable. In quarries of cotton rock, it was noticed that near the surface the beds were from one-eighth to one-fourth inch thick, while deeper down they increased to six or eight inches. The bedding planes, particularly in the sandstone and cotton rock, are slightly wavy, having in many places discordances in bedding which have the appearance of unconformities. However, the general field relations clearly show that no unconformity exists. Mr. Bailey Willis has suggested that this discordance in bedding may be the result of ocean scour, combined with other conditions existing at the time the sediments were originally deposited.

Folding.—The beds of the Jefferson City formation are seldom perfectly horizontal, but exhibit slight local dips in addition to the general dip of the formation. Complex flexuring similar to that in the formations underneath occurs in this formation. No flexuring of importance was observed, except in the immediate vicinity of a fault, or close to some of the large masses of Graydon sandstone. South of the Osage river there are a number of flexures having an amplitude of about 100 feet.

In the northern part of the county the strata dip north 30 feet per mile.

Faulting.—The principal faults in this formation have already been mentioned in the description of the St. Elizabeth formation. In addition to these, faults were observed in township 38 north, range 13 west, and in townships 38 and 39 north, range 14 west.

Jointing.—This formation has curved jointing planes, which are not common in the other formations. These somewhat peculiar joints occur both in the cotton rock and the heavy pitted dolomite, although best developed in the former. These joints are in planes at all angles to the bedding, and occasionally result in the formation of nodular shaped pieces of rock within the beds. In the heavy pitted beds the joints are not continuous, but die out within comparatively short distances. They are so broadly curved that, south of the river, although a great number of observations were taken, no definite average strike could be determined. Along the joints in the heavy pitted beds erosion and solution are very active.

RELATIONS TO OTHER FORMATIONS.

The Jefferson City formation is conformable with the St. Elizabeth formation. In some places the transition between the two is abrupt, and in others it is gradual. Where the transition is abrupt the shale or cotton rock of the Jefferson City formation rests on a conglomeritic bed of sandstone.

The relation between this formation and the Carboniferous is similar to that between the St. Elizabeth formation and the Carboniferous. They are everywhere unconformable.

ECONOMIC CONSIDERATIONS.

Soils.—The disintegration of the dolomite, sandstone and shale of the Jefferson City formation furnishes the best soil of any of the formations in Miller county. Consequently the best farming land, outside of the river bottoms, is in the prairie country north of the Osage river. In the southern part the most productive soil is on the broad ridges and valleys underlain by the Jefferson City formation, as illustrated by the region around Ullman. Besides having a more desirable composition, this soil retains the moisture longer than that of the other formations.

Lead and Zinc.—Very little can be said of the lead and zinc ores of this formation in Miller county. They are more evenly distributed in this than in the St. Elizabeth formation, although the production has not been as large. They usually occur as float in the surface clay; as loose fragments in the crevices; as pockets or thin veins in semi-decomposed dolomite; and occasionally in the cavities of the pitted dolomite.

Barite.—Barite occurs widely disseminated throughout the formation either along joints or in small cavities of the pitted dolomite.

Iron.—Small boulders of blue specular and hard red hematite and limonite were observed among the chert and sandstone fragments on the higher ridges.

RESUMÉ.

Like the other Cambro-Ordovician formations in Miller county, the Jefferson City is essentially a shallow water formation. Evidences of this are abundant. In the railroad cut in the S. W. ¼ of the S. E. ¼ of sec. 25, T. 42 N., R. 15 W., is a bed of conglomerate one and one-half inches thick. The pebbles are chert, cotton rock and dolomite from the heavy pitted beds. In the railroad cut through this formation in the N. E. ¼ of sec. 32, T. 42 N., R. 15 W. occurs a bed of conglomerate, some of the pebbles of which are six inches in diameter. Sun cracks and ripple marks were observed in a number of places, not only in the intercalated sandstone beds where they are common phenomena, but also in the cotton rock and heavy pitted dolomite.

The Jefferson City formation, after deposition, was elevated above sea level and then subjected to erosion. This was followed by a period of submergence, during which the Pacific sandstone was deposited.

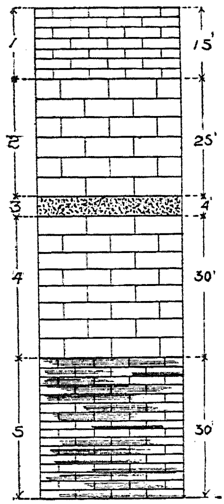


FIG. 26.

DETAILED COLUMNAR SECTIONS OF THE JEFFERSON CITY FORMATION.

Section No. 14, *Fig.* 26.

Sec. 7, T. 41 N., R. 15 W.

From top to bottom.

No.	Elev.	
1	89-104	15 feet of COTTON ROCK, exceptionally white.
2	64-89	25 feet of poorly exposed, fine grained DOLOMITE.
3	60-64	4 foot bed of SANDSTONE; coarse grained, white and somewhat calcareous. Grades gradually into the dolomite above.
4	30-60	30 feet poorly exposed. Made up of six inch to one foot beds of PITTED DOLOMITE.
5	0-30	30 feet of COTTON ROCK.

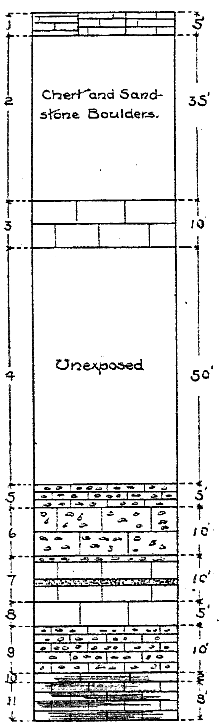


FIG. 27.

Section No. 15, *Fig.* 27.

On Tavern Creek, S. E. ¼, Sec. 13, T. 38 N., R. 13 W.

From top to bottom.

No.	Elev.	
1	145-150	5 foot "ball" of typical PITTED DOLOMITE. Scattered over this "ball" are pieces of COTTON ROCK.
2	110-145	35 feet unexposed. Many boulders of chert and sandstone. The chert is rough and brecciated like that of the St. Elizabeth formation.
3	100-110	10 feet of PITTED DOLOMITE.
4	50-100	50 feet unexposed. Slope covered with boulders of sandstone, some of which are cherty. White, disseminated chert occurs in the quartzitic sandstone.
5	45-50	5 feet of cherty COTTON ROCK, having dendritic markings.
6	35-45	10 feet of PITTED DOLOMITE, containing little druses filled with quartz and white disseminated chert.
7	25-35	10 feet of light colored DOLOMITE, and thin beds of intercalated SANDSTONE and CHERT. Springs occur at this horizon.
8	20-25	5 feet of PITTED DOLOMITE.
9	10-20	10 feet of COTTON ROCK, with dendritic markings. Contains nodules of white chert.
10	8-10	2 feet of PITTED DOLOMITE.
11	0-8	8 feet of thinly bedded, dark yellowish COTTON ROCK.

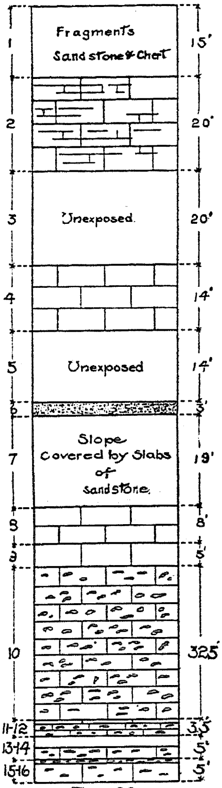


FIG. 28.

Section No. 16, Fig. 28.

At the fault on Barren forks in Sec. 6, T. 38 N., R. 13 W.

From top to bottom.

No.	Elev.	
1	150-165	15 foot slope covered with loose boulders of chert and small slabs of sandstone. Gasterapods occur in the chert near the top.
2	130-150	20 foot slope covered with boulders of PITTED DOLOMITE and COTTON ROCK, the remnants of a "ball." Many large nodules of white chert and fragments of fossiliferous chert.
3	110-130	20 feet unexposed.
4	96-110	14 feet of PITTED DOLOMITE.
5	81 or 83-96	14 feet unexposed.
6	78-81 or 83	4 feet of SANDSTONE.
7	59-78	19 foot slope strewn with slabs of SANDSTONE.
14	5-7½	2½ feet of cherty PITTED DOLOMITE.
9	46-51	5 foot bed of PITTED DOLOMITE.
10	13½-46	32½ feet of PITTED DOLOMITE, somewhat cherty. Beds are from six inches to one foot thick.
11	12½-13½	1 foot bed of PITTED DOLOMITE.
12	10-12½	2½ feet of COTTON ROCK, containing thin layers and nodules of chert. The layers of chert have a banded blue and white color. Calcite occurs along the jointing planes.
13	7½-10	2½ feet unexposed.
14	5-7½	2½ feet of chetry PITTED DOLOMITE.
15	4-5	1 foot bed of white CHERT, secondary after dolomite.
16	0-4	4 feet of thinly bedded, siliceous DOLOMITE; fine grained, dark colored and contains a few blue shale laminae and occasional white chert nodules.

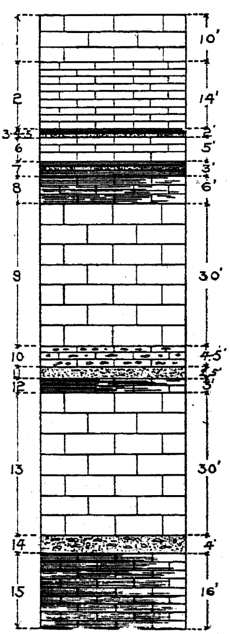


FIG. 29.

Section No. 17, Fig. 29.

Section along road leading from Brushy Forks to top of the ridge in the southern part of Sec. 14, T. 39 N., R. 14 W.

From top to bottom.

No.	Elev.	
1	120-130	10 feet of PITTED DOLOMITE. A short distance north of the road is a six inch bed of sandstone intercalated with these upper pitted dolomite beds.
2	106-120	14 feet of COTTON ROCK. Four feet from the bottom is a four inch layer of white, vitreous, oolitic chert.
3	105½-106	6 inch bed of SANDSTONE; fine grained, white and cherty.
4	105-105½	6 inches of blue SHALE.
5	104-105	1 foot bed of brown SANDSTONE. Round medium sized grain.
6	99-104	5 feet of white COTTON ROCK.
7	96-99	3 feet of thin layers of SANDSTONE and SHALE.
8	90-96	6 feet of COTTON ROCK and SHALE.
9	60-90	30 feet of PITTED DOLOMITE.
10	55½-60	4½ feet of COTTON ROCK, containing nodules of white vitreous, oolitic chert.
11	53-55½	2½ foot bed of conglomeritic SANDSTONE; the pebbles consist of small rounded fragments of chert.
12	50-53	3 feet of COTTON ROCK and SHALE.
13	20-50	30 feet of PITTED DOLOMITE.
14	16-20	4 feet of poorly exposed, thinly bedded SANDSTONE and CHERT.
15	0-16	14 feet of very thinly bedded COTTON ROCK and white SHALE.

CHAPTER VII.

PACIFIC SANDSTONE.*

(First Sandstone of Swallow.)

South of the Osage river, particularly in townships 38 and 39 north, ranges 13 and 14 west, on the tops of the highest ridges, where the dolomite of the Jefferson City formation has a development of from 100 to 150 feet, there are numerous fragments of sandstone, chert and quartzite. Although the fragments are abundant, the beds from which they were derived are exposed in very few localities. However, such as remain indicate clearly that at one time at least portions of the southern half of the country were overlain by a sandstone formation which has since been almost entirely removed. This formation, although poorly exposed, corresponds in position, manner of occurrence and lithological character to the First Saccharoidal sandstone of Swallow.

This formation is exposed in "situ," or nearly so, in four places, namely, in the eastern part of sec. 30, T. 40 N., R. 13 W.; in the southern part of sec. 26, T. 39 N., R. 14 W.; on the line between secs. 12 and 13, T. 38 N., R. 14 W., and in the N. W. ¼ of the S. W. ¼ of sec. 33, T. 39 N., R. 14 W.

In the eastern part of sec. 30, T. 40 N., R. 13 W., slabs of sandstone cap the summit of a high mound which is underlain by 100 feet of the Jefferson City formation. These slabs, which are several feet long, two or three feet wide, and six to ten inches thick, are not exactly in place, but approximately so. The unexposed portion of the mound between the cotton rock and the summit has a thickness of 30 feet. The sandstone grains are of medium size and well rounded. The stone is usually friable and in some places contains chert. The color varies from white to reddish brown. The chert is white and compact. Some of the chert fragments, although not well rounded, are apparently of fragmental origin. Slabs from the base of the formation have in places the appearance of an intraformational conglomerate. The matrix

*See introduction. There is a strong probability that some of the sandstone mapped and considered in this report as Graydon is Pacific sandstone.—E. R. Buckley.

of this conglomeritic bed consists of fine grained, sandy dolomite, in which are embedded numerous large, well rounded grains of translucent quartz and irregular shaped pieces of cotton rock similar to that of the underlying beds.

The best exposures of this sandstone observed are at the head of Mill creek. In the southern part of sec. 26, T. 39 N., R. 14 W., this sandstone has its greatest development in Miller county. It outcrops ten feet above the uppermost beds of cotton rock.

The following section shows the succession of beds:

Section 18.

No.	Elev.	
1	30	Top of hill. Unexposed slope covered with fragments of CHERT and SANDSTONE. At the very top of the ridge two pieces of fine grained dolomite resembling cotton rock were found, which may be remnants of the First Magnesian limestone, which in other localities in this state overlies the Pacific sandstone.
2	24½-30	Large blocks and slabs of rugged, brecciated, CHERT, which are nearly in place.
3	23-24½	1½ foot bed of cherty SANDSTONE. The sandstone and chert are both white.
4	18-23	Unexposed. Slope is covered with sandstone slabs.
5	13-18	2 beds of cherty SANDSTONE. *The sandstone is composed* of round grains of quartz. It has a brown or yellow color and is friable. The chert is black and oölitic. The fragments have an irregular shape and are from less than one to several inches long and from three to four inches thick. They are arranged in rows in the sandstone.
6	3-18	Unexposed.
7	2-3	1 foot bed of white SANDSTONE composed of round, medium sized grains. Shows sun cracks.
8	0-2	2 foot bed of SANDSTONE and CHERT. The bottom 8 inches is chertless. Above this is a 6 to 8 inch bed of medium grained yellowish sandstone containing a little white oolitic chert. The upper 10 inches is black, oölitic, vitreous chert.

About a half a mile southeast of this place, in a ravine in sec. 35, T. 39 N., R. 14 W., the uppermost cotton rock beds of the Jefferson City formation are covered with large boulders and slabs of this sandstone. For the most part they are identical with those described in the section given above.

The sandstone varies from fine to coarse grained, and often has a worm-eaten appearance. Along the Iberia-Brumley road, from the latter town to the ridge at the head of Mill creek, boulders of this sandstone occur at a number of places.

Near the half section corner between secs. 12 and 13, T. 38 N., R. 14 W., there are slabs of sandstone similar to that which outcrops three miles further north.
further north.

In the N. W. ¼ of the S. W. ¼ of sec. 33, T. 39 N., R. 14 W., where the Jefferson City formation has a thickness of 130 feet, there is a single two-foot bed of sandstone about 20 feet above the topmost bed of cotton rock and 30 feet below the crest of the ridge. This sandstone is coarse grained and friable and has a dull brown color. In some places it contains small white specks of decomposed chert and small angular pieces of white oölitic chert. Above this bed to the top of the ridge, are small boulders of black, brecciated, oölitic chert, resembling that found at the head of Mill creek.

RESUMÉ.

The Pacific sandstone, as it occurs in this county, is a very heterogeneous formation, apparently composed of thin beds of chert, sandstone and cherty sandstone. The sandstone and cherty sandstone resemble in their lithological characters, occurrence and position, the beds of First sandstone exposed near Graydon Springs in Polk county and described by Dr. E. M. Shepard* in his report on the geology of Greene county. In position and manner of occurrence they resemble the First or Pacific sandstone, as typically exposed at Pacific. Lithologically, however, they are entirely different.

This formation in Miller county lies unconformably above the Jefferson City formation, as indicated by the conglomerate in sec. 30, T. 40 N., R. 13 W., and also by the very different elevations, not accounted for by faulting, at which it occurs.

*Mo. Geol. Sur. Vol. XII, Part I, p. 57.

CHAPTER VIII.

LOWER CARBONIFEROUS.

THE CHOUTEAU.

At a number of localities in this county several disconnected outcrops of Lower Carboniferous limestone were observed which resemble beds of Chouteau, as described by Swallow in the early reports of this Bureau. At J. E. Sullen's quarry in sec. 26, T. 42 N., R. 14 W., for example, there are beds of shale and buff colored, siliceous limestone which differ from the rocks of the Burlington formation and resemble very much those of the Chouteau at the type locality in Cooper county. Fragments of a gray or buff, siliceous limestone, observed in the vicinity of other of the Burlington limestone outcrops, are thought to belong to the Chouteau.

The areas of probable Chouteau are, however, too limited to be represented on the geological map.*

THE UPPER BURLINGTON LIMESTONE.

GEOGRAPHICAL DISTRIBUTION.

The Upper Burlington limestone has a very limited areal distribution in Miller county. It occurs in small, isolated areas called outliers; as chert boulders and pebbles; and as chert and limestone fragments in the Saline Creek cave-conglomerate, the Coal Measure shale and the Graydon sandstone. The southern boundary of the main area of Upper Burlington limestone is about twenty miles north of Miller county.

In this county the Upper Burlington limestone outliers occur in the eastern part of township 42 north, range 15 west; in township 42 north, range 14 west; in the northeastern corner of township 41 north, range 14 west; and near the northern boundary of township 41 north, range 13 west. In these four townships there are about thirty disconnected areas of Upper Burlington limestone, most of which are less than 100 yards in their greatest diameter and cover less than four acres. The position occupied by these outliers has no relation to the present topography. They occur indiscriminately, in the valley bottoms, on the hill tops, and along the intermediate slopes.

*The identification of the Chouteau beds was made after this report was in the hands of the director.—E. R. B.

The Upper Burlington chert usually occurs in the form of residual boulders from four inches to two feet in diameter. They are more or less perfectly round, angular fragments being rare. These boulders are much more widely distributed than the limestone itself, being found in many localities in the northwestern part of the county. Two of the places where they were observered are as follows: N. E. ¼ of sec. 11, T. 41 N., R. 16 W., and the N. W. and S. W. ¼ of sec. 12, T. 41 N.; R. 16 W. Along the northern border of the county chert bouldeis are very abundant, while large portions of the surface of secs. 2, 3 and 10, T. 42 N., R. 14 W., are thickly strewn with them. In the southern part of the county, in the N. E. ¼ of the S. E. ¼ of sec. 14, T. 39 N., R. 13 W., these boulders are abundant.

Fragments of Upper Burlington chert in Graydon sandstone were observed in the center of sec. 1, T. 40 N., R. 14 W., in the S. E. ¼ of the N. E. ¼ of sec. 14, T. 41 N., R. 16 W.; in the centre of the E. ½ of sec. 8, T. 41 N., R. 13 W.; in the west centre of the S. W. ¼ of sec. 9, T. 41 N., R. 13 W.; in the north centre of the N. E. ¼ of sec. 15, T. 42 N., R. 14 W. The fragments thus far observed in the Graydon sandstone are typical flint pebbles with no traces of limestone.

In the Coal Measure shale, fragments of Upper Burlington limestone and chert have been noted in three places. At the "Little Nugget" mine near Mary's Home, numerous boulders of both limestone and chert were found imbedded in the shale throughout the entire depth of the 135 foot shaft. The limestone boulders are somewhat rounded. The carbonaceous matter of the shale has stained some of the limestone a dark gray, the fossil shells in some instances being black. In an exposure along the Chicago, Rock Island and Pacific R. R. on the line between secs. 25 and 26, T. 42 N., R. 14 W., boulders of Burlington limestone were observed in Coal Measure shale. The Coal Measure shale in the north centre of the N. E. ¼ of sec. 15, T. 42 N., R. 14 W., also contains boulders of Upper Burlington chert.

TOPOGRAPHY.

The very limited area underlain by the Upper Burlington limestone gives it very little, if any, control over the major topographic features of the county. Wherever the Upper Burlington limestone occurs the surface is rounded. Wherever the Upper Burlington chert occurs in small areas it forms steep sloped, almost perfectly conical hillocks. Typical examples of these hillocks are found in the S. W. ¼ of sec. 5, T. 41 N., R. 13 W.; just north of the centre of the N. ½ of sec. 1, T. 41 N. R. 14 W., and in the N. E. ¼ of sec. 35, T. 42 N., R. 14 W. Where the chert covers large areas the slopes are much gentler, although the summit still has a tendency to be conical. In some places the boulders form an almost continuous pavement, rendering the land too stony for farming. These hills which are largely confined to township 42 north, range 14 west are forest clad.

WEATHERING.

Good exposures of the Upper Burlington limestone are few: The ledges are usually well rounded and the rock is often obscured by soil. Loose, slab-like blocks, with rounded edges and corners are common near the outcrops.

The weathered surface of this limestone is very rough, owing to the unequal hardness of the fossils and their matrix. Frequently the matrix is almost entirely removed before the fossils have begun to disintegrate. On account of this, the surface is unusually rough.

It is difficult to determine the extent to which solution has effected this limestone. Its ready solubility has undoubtedly hastened very materially its removal from Miller county. The existing areas are too small to admit of the development of caves and sinks of any considerable size. However, it is extremely difficult to distinguish dips which may be due to possible post-Burlington folding from those connected with sink hole phenomena.

Burlington limestone showing local dip.
FIG. 30.

THICKNESS.

Dr. C. R. Keyes* says that the average thickness of the Upper Burlington limestone in Missouri is 60 feet. Dr. E. M. Shepard** states that the maximum thickness of the Upper Burlington limestone in Greene county is 240 feet. In Miller county the Upper Burlington limestone has a maximum thickness of 35 feet, in Sullen's quarry in the center of sec. 26, T. 42 N., R. 14 W. The variations in thickness, although the result, in part, of the unevenness of the surface upon which the Upper Burlington limestone was deposited, are largely due to post-Burlington erosion.

LITHOLOGICAL CHARACTERISTICS.

The Upper Burlington limestone is very pure calcium carbonate, and is composed very largely of fossils embedded in a calcareous matrix.

Color.—A fresh surface of the limestone is usually a dazzling white, although grayish, yellowish and pinkish tints are common. Weathered surfaces usually have a dark gray color.

Texture.—This limestone is completely crystalline and, as a rule, rather coarse grained. The cleavage faces of the calcite crystals, of which the crinoid stems are composed, are often a fourth of an inch broad.

Although, as a rule, the stone is course grained, beds occur which are compact and fine grained. The precentage of fossils in the stone is not constant but varies in different parts of the individual areas examined.

An exposure in the center of the N. ½ of sec. 20, T. 42 N., R. 14 W,. exhibits coarse grained stone at the south end and fine grained at the north end.

Nodules of chert occur along the bedding, jointing and stylolitic planes.

Chert.—The Upper Burlington chert varies from an extremely porous, friable variety, to one which is dense, fine grained and compact. The former, which is the more abundant, contains numerous fossils. Some of the cherts are merely a mass of silicified shells and crinoid stems or their casts. This fossiliferous chert is undoubtedly secondary after the limestone, as proven by collected samples which show every gradation between the limestone and chert.

The dense fine grained chert was only observed in the "Little Nug-

*Mo. Geol. Sur., Vol. IV, p. 30.
**Mo. Geol. Sur., Vol. XII, p. 111.

get" mine. Here it had a sharp conchoidal fracture. All gradations between the fossiliferous and dense, fine grained cherts were observed in hand specimens collected from this mine.

That these fossiliferous chert fragments are of Upper Burlington age is shown by the fossils which they contain. That they were originally limestone is shown by the partly silicified boulders which show every gradation between the Upper Burlington limestone and chert. In the outcrops of Burlington limestone the chert is found very generally along bedding, jointing or stylolitic planes.

Thin sections of partially silicified Upper Burlington limestone, examined under the microscope, show that the crinoid stems are the last to silicify. The spaces between the fossil fragments and the holes in the crinoid stems are filled with a mosaic of rather coarse grained chalcedony. The crinoid stems themselves are sometimes partially silicified, the silica being very fine grained. The most completely silicified portion of the crinoid is the interior of the stem.

The best evidence of the origin of the fossiliferous chert is shown in a railroad cut on the line between secs. 25 and 26, T. 42 N., R. 14 W., and in an exposure along the Missouri Pacific railroad three miles north of Olean.

As stated above, it is thought that the chert is mainly a metasomatic replacement, more or less complete, of the limestone. It seems most probable that the silica which replaced the limestone was derived from the underlying Cambro-Silurian formations.

Assuming that the silicification of the Burlington limestone was prior to Coal Measure times, we are compelled to believe that the underlying sandstone and siliceous dolomite were the immediate source of the silica. That silicification occurred prior to Coal Measure time is shown by the silicified fragments of Burlington chert occurring in the Graydon sandstone. Cavities in these fragments were found to be filled with sand, which argues that prior to the deposition of the Graydon sandstone the chert had become porous. Fragments of Upper Burlington chert also occur in the pockets of Coal Measure shale.

STRUCTURE.

Stratification, Bedding Planes and Jointing.—Stratification planes* are poorly developed in the Upper Burlington limestone of this county, due probably to the very uniform conditions of deposition. Weathering, however, often shows one stratum to be less fossiliferous and finer grained than another. The laminae often seem very fine, in some cases

*Building and ornamental stones of Wisconsin. E. R. Buckley, 456.

twenty being counted to an inch. Although the bedding planes are slightly wavy, no indication of cross bedding was observed. Deformation has emphasized some of the stratification planes, forming bedding planes.* The beds are, as a rule, from four to five inches thick, although in a few places from one to two feet.

Besides the bedding planes, there are two sets of joints, dipping at an angle of from 45° to 90°. The strike of the joints varies in different localities and no persistent system could be made out.

Stylolitic Partings.—Stylolitic partings, commonly known as crowfoot seams, are quite common. They occur both perpendicular and parallel to the bedding.

Folding.—As stated above, it is often difficult in places to determine whether an exposure is a part of a ledge or a part of a residual block. The beds of limestone comprising these isolated areas have, as a rule, more or less of a synclinal form. The older rocks enclosing them may or may not be flexed.

Faulting.—Only one fault was noted in the Upper Burlington limestone. This is near the center of sec. 3, T. 42 N., R. 14 W. That minor faulting has accompanied the deformation of the Upper Burlington limestone is very probable, although it has not been noted.

Fossils.—The fossils which so largely compose both the limestone and chert are beautifully preserved, showing none of the water worn characteristics ascribed to some of those of Greene county by Dr. Shepard.† Crinoids are by far the most characteristic fossils, although bryozoans, brachiopods and blastoids are common. The following is a list of Lower Carboniferous fossils collected in this area and named by Dr. George H. Giety of the United States Geological Survey:

Crinoid (undet).
Productus Burlingtonensis. (3 specimens.)
Prooductus cf Scabriculus.
Productus setigerus.
Productus sp.
Platyceras, small ind. spec.
Spiriferina subelliptica.
Spirifer Logani (3 specimens.)
Spirifer or Spiriferina indet.
Spirifer cf. pinguis Phillips, (2 specimens.)
Phillipsia tuberculata. (2 specimens).
Spirifer Keokuk (5 specimens.)
Zaphrentis sp. (6 specimens.)
Rhipidomella Burlington ensis (5 specimens.)
Athyris sp.
Rhipidomella Michelini.
Chonetes sp.
Amplexus sp. (2 specimens.)
Polypora sp.
Seminula ? sp.

*Ibid 457.
†Mo. Geol. Sur., Vol. XII, p. 120.

Athyris incrasata.
Athyris lamellosa.
Productus, small indeterminable spec. (2 specimens).
Productus punctatus. (2 specimens).
Productus cf. Gallatinensis, (3 specimens.)
Productus near scabriculus.
Syringothyris Carteri.
Platyceras sp. (3 specimens.)
Aviculopecten sp.
Fenestella cf. tenax (3 specimens.)
Fenestella, fragments, several spp.
Pentremites cf. conoideus.
Syringopora sp. (cast).
Camarophoria subtrigona.
Reticularia pseudolineata?.
Seminula subquadrata.
Glyptopora near Michelinia.
Eumetria verneuiliana?.
Fenestella several spp.
Fenestelloid.
Pentremites indeterminable.

ECONOMIC CONISIDERATIONS.

The upper Burlington limestone burns into a very execellent lime. As a rule it has too many joints to be of value as a building stone. It has been used to a small extent for foundations and the Missouri Pacific railroad has used it in several places for bridge piers and road ballast. last.

No ore has been found in the Burlington limestone of this county.

RELATIONS TO OTHER FORMATIONS.

The Upper Burlington limestone is the most easily recognizable formation in Miller county. Not only are its lithological and paleontological characters striking and constant, but it is separated from the formations above and below by distinct unconformities. The unconformity between the Upper Burlington and the Cambro-Silurian formations is everywhere clear and well defined. The Upper Burlington limestone has been observed above and in contact with both the Jefferson City and St. Elizabeth formations, while Burlington chert was found upon Gasconade limestone.

Unconformably above the Upper Burlington limestone are exposures of Graydon sandstone and Coal Measure shale. In the south central part of the S. W. ¼ of sec. 6, T. 41 N., R. 13 W., and near the center of sec. 26, T. 42 N., R. 14 W., are exposures of shale surrounded by Upper Burlington limestone. The almost constant association of Upper Burlington limestone and Graydon sandstone is very striking. There is scarcely an exposure of Upper Burlington limestone in this county which is not associated in one way or another with the Graydon sandstone.

RESUMÉ.

The reports of the early geological surveys mention numerous Upper Burlington limestone exposures in Cole,* Moniteau** and Morgan† counties. The reports of Swallow mention Burlington chert in Ozark‡ and Wright§ counties, while Winslow§§ states that "Lower Carboniferous chert" is found in Howell and Crawford counties. As a result of the present survey, Upper Burlington limestone has been located on the most elevated parts of the northeast townships of Miller county.

That the topography was rugged prior to the Upper Burlington limestone deposition is indicated by the fact that apparently undisturbed outliers occupy not only the slopes and tops of the hills, but also the north of the center of sec. 1, T. 41 N., R. 14 W., on a hill top on the Tuscumbia-Spring Garden road. At this place there is an exposure of Upper Burlington limestone having rather sharp dips. A quarter of a mile south, in the valley of a fork of Saline creek, 75 feet below, there is another exposure of undisturbed Upper Burlington limestone. The beds at this place are practically horizontal as would be expected if they were deposited in a comparatively wide valley. In a stream bed in the N. E. ¼ of sec. 35, T. 42 N., R. 14 W., Upper Burlington limestone is in contact with the Jefferson City formation. The hill slopes on either side are more than 50 feet high and at their summits, the Jefferson City formation is exposed.

The Upper Burlington limestone appears to have been laid down in a sea of moderate depth, teeming with animal life. The absence of vegetable remains and clayey matter indicates that the strata were deposited at some distance from the shore. As crinoids are usually inhabitants of a comparatively quiet sea, their presence in such vast numbers indicates the absence of strong currents. That the conditions of deposition remained undisturbed for a considerable time is shown by the constant lithological character of the limestone.

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*Report of the Geol. Sur. of the State of Missouri, including field work of 1873-4. Garland C. Broadhead, State Geologist, Jefferson City, 1874, p. 324.

**The first and second annual reports of the Geol. Sur. of Mo., 1855, Part II, page 99.

†Reports on the Geol. Sur. of the State of Missouri, 1855-71, p. 135-156.

‡Geol. Sur. of Mo., 1855-71, p. 190.

§Ibid, page 206.

§§Mo. Geol. Sur., Vol. VII, p. 439.

CHAPTER IX.

THE COAL MEASURE FORMATIONS.

The Coal Measure sediments in this area consist of conglomerate, sandstone and shale. The conglomerate is represented by certain irregular deposits of the so-called Saline Creek cave-conglomerate; the sandstone, by the Graydon formation; and the shale, by shales and clay with which coal is often associated.

The sandstone of the Coal Measure rocks has every appearance of that which has been called Graydon by Dr. E. M. Shepard,* and its relations to the other formations are very similar. For these reasons this sandstone has been called Graydon. Until the relation between the Graydon sandstone and the Coal Measure shale is more thoroughly understood the shale will be provisionally called the Coal Measure shale.

Observations in the field indicate that the Graydon sandstone, in part at least, and the Coal Measure shale are probably phases of the same formation. However, conclusive proof of this hypothesis is not at hand. As yet no large deposit of typical Graydon sandstone has been observed grading into typical Coal Measure shale.

Near the middle of lot 1, sec. 4, T. 39 N., R. 13 W., residual boulders of Graydon sandstone cover a small area underlain by Coal Measure shale. The Graydon sandstone is of the ordinary type, except that it contains numerous small inclusions of carbonaceous shale.

In the north central portion of sec. 26, T. 41 N., R. 16 W., there is a huge mass of Graydon sandstone lying on the St. Elizabeth formation. It is medium grained sandstone which upon weathering takes on a purplish cast. The stratification planes are curved and more or less disconnected. They are at times emphasized by parting planes of green, unctuous shale. In some places more firmly cemented sandstone pebbles occur in the sandstone, giving it the appearance of an intraformational conglomerate.

Three-eights of a mile northeast of Olean on the east bank of Blyth's fork there is an exposure, which is partially Graydon sandstone and partially Saline Creek cave-conglomerate. One hundred and twenty-five

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Mo. Geol. Sur., Vol. XII, p. 124.

feet from the north end of the exposure the beds of the St. Elizabeth formation dip 30° S. 20° W., and this dip increases up to the Saline Creek cave-conglomerate contact where it is 90 degrees. On the south side, the dolomite dips toward the sandstone, although less steeply. At the north end of the 250 feet intervening between the Cambro-Ordovican dolomites, there is a typical exposure of Saline Creek cave-conglomerate. At the south end Graydon sandstone conglomerate is exposed. This sandstone grades above into another containing round shale pebbles. Weathering removes these, leaving a pitted surface. In the sandstone there are also well rounded flint pebbles, several inches in diameter, similar to those occurring in the Coal Measure shale. A short distance away the shale increases until the rock becomes an arenaceous shale. This is gradually replaced by an almost pure sandstone. The mass is well joined, the following joints having been recorded: N. 55° E. (dip 65° N. 35° W.); N. 80° E. (dip 90° N. 10° W.); N. 35° W. (dip 80° S. 55° W.), and N. 40° E. (dip 65° N. 50° W.).

In the center of sec. 26, T. 42 N., R. 14 W., there is a large outlier of Burlington limestone. In the valley eroded in this limestone there is exposed a deposit of argillaceous, non-calcareous sandstone. It is fine grained and quite incoherent. The layers are from one-fourth to one-half an inch thick and dip 85° N. 22° W. The relation which this sandstone bears to the Upper Burlington limestone is not clear, although it appears to be above it. The Upper Burlington beds in this vicinity dip very little, while the sandstone stands on edge. This may be due either to faulting or to a cave in. It would probably be most satisfactory to consider this a result of solution of the limestone through which a mass of sandstone, originally situated on higher ground, has been undermined and thus allowed to slide into the valley.

Three-eighths of a mile northwest of the last mentioned deposit is an exposure of arenaceous shale, in which are thin intercalated beds of red sandstone. The sandstone beds abut against practically horizontal beds of Jefferson City limestone. Near the Jefferson City formation the bedding of the shale is disturbed, and at a moderate distance from the Jefferson City limestone the shale dips 26°, 40° S. 12½ E.

The shale and sandstone may or may not be phases of the same formation. They may have been deposited contemporaneously. There is some evidence, however, that this is not true of all the sandstone and shale. In the deposit in sec. 4, T. 39 N., R. 13 W., mentioned on page 90, the Graydon sandstone appears to be younger than the Coal Measure shale, while in the S. W. ¼ of sec. 20, T. 42 N., R. 14 W., the Coal Measure shale appears to be younger than the Graydon sandstone. At this place an excavation shows two inverted cones of Coal Measure shale four feet in diameter at the surface and five feet deep. Throughout the sandstone are small pockets of white or purplish red, unctuous shale of very fine grain. It is the usual plastic Coal Measure shale, containing some typical, well rounded chert pebbles. The contact between the shale and the sandstone is sharp. It was not shown whether these were original deposits in the sandstone or were introduced afterwards by circulating waters.

THE SALINE CREEK CAVE CONGLOMERATE.

This formation receives its name from Saline creek near whose headwaters it is well exposed. Small caves, cave galleries and open seams filled with the conglomeritic masses of this formation are scattered throughout the county, where good exposures of the Cambro-Ordovician rocks occur. They are especially aboundant near the headwaters of Saline creek and in the vicinity of the coal deposits in township 41 north, ranges 15 and 16 west.

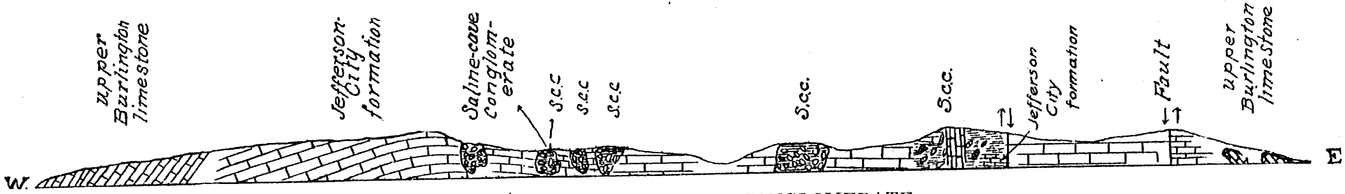
Thickness.—On acount of the manner in which this formation occurs its thickness is not the same in any two places. The thickest development observed is in sec. 27, T. 41 N., R. 12 W., where the conglomerate is at least 60 feet thick.

Origin and Lithological Characteristics.—From such evidence as has been gathered, it is believed that this formation is a cave deposit younger in age than the Burlington but older or contemporaneous with the Coal Measure formations. The conglomerate is very coarse, the boulders having in some instances a diameter of 20 feet. The large boulders, as a rule, have angular outlines, while the small ones are often well worn. The boulders are derived from all of the older formations including the Upper Burlington limestone. The matrix is either argillaceous limestone, calcareous shale, or calcareous sandstone.

Structure.—There are no indications in this formation of either stratification or bedding. Joints are extremely rare.

TYPICAL EXPOSURES.

Exposures along the Chicago, Rock Island and Pacific Railroad.—The cuts along this railroad in sec. 25 and 26, T. 42 N., R. 14 W., expose numerous pockets and joints filled with Saline Creek cave-conglomerate (see Figure 31). At these places the conglomerate is composed of arenaceous and calcareous shale in which are embedded boulders of dolomite, cotton rock and black flint from the Jefferson City formation, and limestone from the Upper Burlington. Some of the boulders are five feet in diameter.



THE SALINE CREEK CAVE CONGLOMERATE.

Saline Creek cave conglomerate. Cut on the C., R. I. and P. R. R. on line between secs. 25 and 26, T. 42 N., R. 14 W. Vertical scale, 1″=133′. Horizontal scale, 1″=266′.

FIG. 31.

Exposure along Tavern Creek.—The largest exposure of the Saline Creek cave-conglomerate observed in Miller county occurs in the center of sec. 27, T. 41 N., R. 12 W., on the road from Tavern creek to St. Elizabeth. Its length east and west, the only other obtainable dimension than its thickness, is 250 feet. It is at least 60 feet thick. The boulders include both cotton rock and pitted dolomite from the Jefferson City formation, and dolomite and sandstone from the St. Elizabeth formation. Some of the boulders have a diameter of 18 feet. The larger ones are very angular, although many of the smaller ones are well rounded. They constitute a distinctly unassorted conglomeritic mass. Portions of the deposit are made up of boulders imbedded in a bluish, sandy shale matrix. Other portions of the deposit consist of perfectly rounded pebbles one to one and a half inches in diameter imbedded in an arenaceous shale matrix. For 150 feet on either side of this conglomerate the Gasconade limestone beds dip toward it. Whether this is a filled sinkhole, a cave or the worked-over talus slope of a filled valley, it is difficult to determine. The local dips are more commonly associated with sink holes and caves than with river valleys. For this reason, the sink hole or cave origin is favored.

Ramsey.—In a cistern at Mr. James Ramsey's residence, in the N. E. ¼ of sec. 28, T. 40 N., R. 13 W.; a small crevice in the lower portion of the Jefferson City formation was followed down twenty-two feet. At a depth of 18 feet the crevice widened and at the bottom it was eleven feet across. The crevice is filled with a conglomerate of well rounded cotton rock, chert and shale pebbles from the Jefferson City formation. These pebbles are one-eighth of an inch to five inches in diameter. The matrix is an arenaceous, non-calcareous shale.

Whitaker's Shaft.—In the E. ½ of lot 6 N. E. of sec. 2, T. 39 N., R. 12 W., in the bed of a small stream, is a crevice striking N. 33° W. This enlarged joint is filled with a conglomerate with a matrix of calcareous, arenaceous shale. Some of the pebbles are well rounded, while others are angular or sub-angular.

A shaft about 125 feet S. 30° E. from this place penetrates the same deposit. Fourteen feet S. 30° E. of the shaft, the walls of the crevice come together. Beyond this bar the crevice again opens out. Northwest of the bar galena is found in the crevice, while southeast of it, blende is the ore.

The Cannon "Mines."—The Cannon "mines,' located in sec. 15, T. 38 N., R. 12 W., are sunk in a deposit of the Saline Creek cave-conglomerate. This deposit is 40 feet wide, and can be traced 500 feet N. 40° W. The main shaft, which is 73 feet deep, is said to have passed through a thin layer of blue and yellow clay, and, following a wall of the St. Elizabeth formation, it continued in Saline Creek cave-conglomerate to the bottom. The matrix is a greenish, argillaceous sandstone in which are embedded pebbles of gray, concretionary and black chert from the St. Elizabeth formation, and gray, green and brown limestone of several different varieties. Pebbles of black dolomite with small calcite druses were also noted.

The Saline Creek cave-conglomerate lies unconformably upon the Cambro-Ordovician and Upper Burlington formations, and is overlain, conformably, by the Graydon sandstone and Coal Measure shale. The Saline Creek cave-conglomerate and the Coal Measure shale grade into one another and in many cases the contact between the two is extremely difficult to determine.

GRAYDON SANDSTONE.

AREAL DISTRIBUTION.

There are about 150 separate and distinct areas of Graydon sandstone in Miller county, three-fourths of which are north of the river. All but thirty of these are found in a belt six miles wide adjacent to the Osage river. On the south side of the river, they occur most abundantly in the most southern townships.

The Graydon sandstone was deposited upon the uneven surface of the pre-Coal Measure land area. The comparatively few areas of Graydon sandstone immediately along the Osage river may be attributed to the lower level to which the Osage river and its tributaries have since eroded that part of the county. Unless the Graydon sandstone was deposited in an unusually deep canyon or gulch, erosion has removed all traces of it. Near the river the Graydon sandstone areas have a somewhat trail-like course and are called "trails of sandstone" by the inhabitants. One of these, in the N. W. ¼ of sec. 13, T. 40 N., R. 15 W., is 500 feet wide and about a quarter of a mile long. Another, passing through the northeast corner of sec. 4, T. 40 N., R. 15 W., is 100 feet wide and almost a half a mile long. A third, in the southwest part of sec. 2, T. 41 N., R. 14 W., is 35 feet wide and 250 feet long. On the highlands along the north and south borders of the county, the Graydon sandstone areas have a more or less circular or elliptical shape. This shape is a natural result of the removal of all but isolated remnants of a formation which was deposited on a comparatively level surface. If the Graydon sandstone near the north and south limits of the county had been deposited upon a surface in which the pre-Coal Measure drainage lines were as well developed as they appear to have been in the vicinity of the Osage river, it is very probable that the outliers of today in the highlands would occur in a more trail-like manner.

It appears from the distribution of these sandstone outliers that, prior to the deposition of the Coal Measure rocks, the country in the vicinity of the Osage river was more hilly and rough than the country back from that stream.

The area covered by any one of these sandstone outliers nowhere exceeds 20 acres, while some of the areas are not over 100 square feet. Topographically, the Graydon sandstone is found in every position imaginable,—on the tops and slopes of the hills and in the valley bottoms.

TOPOGRAPHY.

On account of their small size, the Graydon sandstone areas have very little effect upon the major topographic features, although they have had a marked local influence. The sandstone weathers into large, rounded blocks of narrow pinnacles usually with rounded surfaces, although in places they are somewhat craggy.

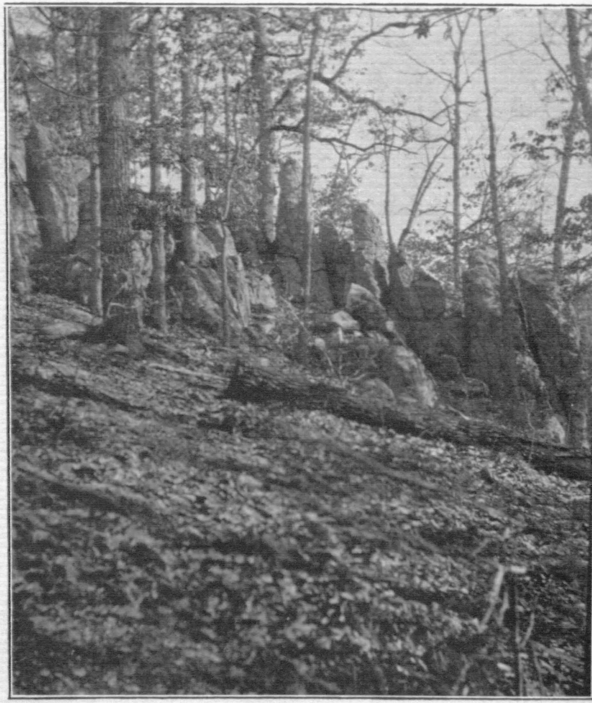
THICKNESS.

Occurring as it does in isolated, closely circumscribed areas, the original thickness of the Graydon sandstone in this county cannot be determined. In many places it is now only a foot thick, but in others, as in the N. W. ¼ of sec. 13, T. 40 N., R. 15 W., it has a thickness of at least 75 feet. Probably the thickness at this last place was originally 150 feet. If this Graydon sandstone is a continuation of that in the northern part of the county, in places the thickness must have been at least 500 feet.

WEATHERING.

The loose blocks are, as a rule, more or less rectangular in shape, due to the well developed systems of joints. By differential weathering, small cave-like recessions, and even small natural bridges are formed. Unequal distribution of the iron oxide cement causes unequal weathering, which results in the formation of the peculiar pits and rings which show conspicuously on the weathered surface.

The surface of much of the sandstone is marked with cracks averaging one-half an inch in depth and one-fourth of an inch in width. In places these cracks intercept one another at right angles, both dying out within a space of from six to twelve inches; at other places they cross at such angles as to form a rough polygon with slightly curved faces. In some places these polygons are almost perfect hexagons. The largest polygons are eight inches and the smallest are an eighth of an inch in



1.

JOINTING IN GRAYDON SANDSTONE.

2.

POLYGONAL MARKINGS ON WEATHERED SURFACE OF GRAYDON SANDSTONE.

diameter. Plate XI., Figure 2 is a photograph of a small sandstone boulder, showing these markings.

That these are not impressions of sun cracks is proved by the fact that they occur along jointing as well as bedding planes. While some of these impressions may possibly be due to weathering along joints, we believe that such cases are rare. It is thought that they are probably due to stresses caused by sudden changes in temperature. Where the case hardened surface of a Graydon sandstone block is struck with a hammer, cracks having a similar outline are formed. A sudden alternation of heat and cold would undoubtedly produce the same effect. When once a crack is produced, the further widening would be merely a question of time.

LITHOLOGICAL CHARACTERISTICS.

The Graydon sandstone is composed of fine to medium grained, well rounded quartz sand. The individuals are cemented by quartz and iron oxide. The grains are often secondarily enlarged. The sandstone varies greatly in coherence, it being in some places quartzitic and in others so friable as to be easily crushed between the fingers. The quartzite is usually a local phase of the less indurated sandstone.

Iron oxide often occurs in the Graydon sandstone in more or less parallel layers along joint or fault planes. Limonite concretions, one-fourth to eight inches in diameter, are very characteristic of some exposures. The largest concretions were observed in the S. W. ¼ of sec. 29, T. 41 N., R. 15 W., where they are strewn abundantly over the valley slope.

This sandstone is often conglomeritic. The pebbles are either rather large and sparse or small and very numerous. The coarse conglomeritic phase of this sandstone occurs in the center of sec. 1, T. 41 N., R. 14 W., in the S. E. ¼ of sec. 14, T. 41 N., R. 16 W., and in the N. E. ¼ of sec. 35, T. 42 N., R. 14 W. The second phase of the conglomerate is well developed near the base of nearly all the larger exposures.

The lithological characteristics of this formation are as constant as those of the Burlington limestone or any of the other well differentiated formations in the county.

STRUCTURES.

Bedding.—The typical Graydon sandstone is altogether lacking in stratification and bedding planes. Its massive structure is one of its most striking characteristics. However, in the southwest corner of the outcrop in sec. 13, T. 40 N., R. 15 W., beds 1½ feet thick were noted. Other outcrops having bedding planes are located in the north center of sec.

19, T. 42 N., R. 15. W., in the S. W. ¼ of sec. 7, T. 41 N., R. 15 W., and in the west center of sec. 26, T. 41 N., R. 16 W. Cross-bedding was observed, but it is not characteristic.

Jointing.—The sandstone is broken into polygonal blocks by well developed systems of joints. Each sandstone area seems to possess its own system of joints.

Faults.—Faults of any importance were not observed in the Graydon sandstone. However, considerable readjustment has taken place in the formation, and doubtless many minor faults exist. Although slickensided boulders are comparatively common, slickensides, in situ, were observed in but four instances. Two occur in an outcrop in the N. E. ¼ of sec. 15, T. 42 N., R. 14 W., (dipping 60° N. 35° W. and 50° N. 25° E.), and two in the type exposure in the N. W. ¼ of sec. 13, T. 40 N., R. 15 W. The latter two dip 90° and strike north 10° E. or practically parallel to the long direction of the outlier. This would indicate that the easiest direction of relief was at right angles to the resistant dolomite beds against which the sandstone abuts.

FOSSILS.

No fossils were found in this formation.

ECONOMIC.

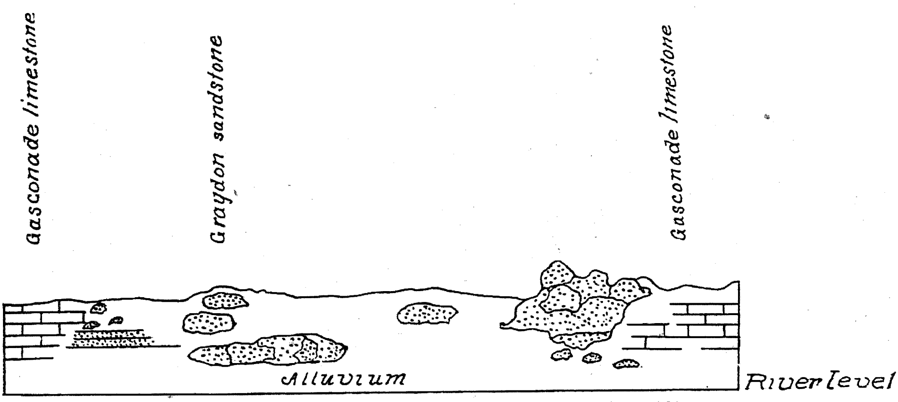
Sandstone is regarded as a rock in which lead and zinc ores are unlikely to occur and in Miller county there is no exception to this rule. The crushed sandstone has been used locally in plaster and was utilized to a small extent in the concrete used for the bridge abutments along the Chicago, Rock Island & Pacific Railroad. The sand is free from impurities, but unfortunately the grains are, as a rule, too round for use in concrete. Some of the sandstone is snowy white, but the quantity is too uncertain and the danger of striking a joint along which iron has infiltrated too great to warrant the quarrying of it for the manufacture of glass. It does not possess the necessary clay film, and is too coarse to be used as a moulding sand.

RELATIONS TO OTHER FORMATIONS.

In difficult places immediately underlying hte Graydon sandstone there have been observed, besides the Saline Creek cave-conglomerate, the Gasconade limestone, the St. Elizabeth and Jefferson City formation and the Upper Burlington limestone. That the sandstone is unconformable with the last four formations is indicated by the variety of the underlying rock; by the valley-like depression in which the Graydon sandstone so often occurs; and by the pebbles of older rocks which occur in the conglomeritic phase. In four localities the actual contact with the underlying formations has been obesrved. Two of the exposures show the sandstone resting on the Jefferson City formation, and two on the St. Elizabeth formation. In each of these places the base of the sandstone is conglomeritic. In places the Saline Creek cave-conglomerate appears to underlie it conformably, in others unconformably.

TYPICAL EXPOSURES.

The Adcock Exposure.—The Adcock exposure is located in the N. W. ¼ of sec. 13, T. 40 N., R. 15 W. It is situated on the side of a small gully leading from the Osage river. It is 500 feet wide from east to west, and about one-fourth of a mile long from north to south. Fig. 1, Plate XII., is a general view taken from the river bottoms, and Fig. 2 is a near view. Figures 32 and 33 are sections east and northeast across it. The Gasconade limestone outcrops within three feet of the sandstone, and on either side the beds are horizontal. The sandstone outcrops above the surface in huge blocks and masses some of which are twenty feet high. The sandstone is mostly medium grained, although in places conglomerate pockets are numerous. The pebbles in these pockets are from ¼ of an inch to 4 inches in diameter and are beautifully rounded. The chert pebbles have been derived from the concentrically banded chert of the St. Elizabeth formation, and from the secondary chert of the Gasconade limestone.



Graydon sandstone. Adcock exposure. 1"=400'.
FIG. 32.

The markings due to differential weathering are common. The exposed surfaces are stained red with iron oxide, although the mass of the stone is light colored.

The stone in this outcrop has very few stratification planes. Bedding planes occur in the southwest part of the exposure. The joints are prominent, the following being a list of the most conspicuous sets: strike E. and W.,—dip 65° N.; strike N. W.-S. E.,—dip 75° S. 45° W.; strike N. 75° E.,—dip 6° N. 15° W.; strike N. 15° E.,—dip 80° S. 75° E.; strike N. 68° W.,—dip 78° S. 22° W.; strike N. 70° E.,—dip 17° S. 20° E.; strike N. and S.,—dip 25° W. Slickensided surfaces having a strike of N. 10° E. were noted. Cross-bedding and ripple marks were observed in several places.

The Manning Exposure.—In Mr. George Manning's yard in the S. E. ¼ of sec. 7, T. 42 N., R. 15 W., is a depressed dome-shaped mass of Graydon sandstone 25 feet in diameter and four feet high. Other exposures of the sandstone occur in this vicinity, covering an area 750 feet long and 100 feet wide.

Cub Creek Exposure.—In a valley in the S. E. ¼ of sec. 23, T. 41 N., R. 13 W., 55 feet below the contact of the Gasconade limestone and the St. Elizabeth formation, are two exposures of Graydon sandstone, separated from each other by a rib of Gasconade limestone 5 feet wide. The major exposure, trending northwest is a fourth of a mile long and 200 feet wide, while the minor, trending N. 15° E., is 150 feet long and 10 feet wide. One of the sandstone exposures shows minor faulting with displacements of from ¼ to ½ of an inch.

Dog Creek Exposure.—On Dog creek, near the middle of sec. 1, T. 40 N., R. 14 W., the Graydon sandstone is again typically developed. Isolated boulders eight inches in diameter occur in the sandstone. A boulder of Upper Burlington chert, which apparently had weathered out of the sandstone, was found near the exposure.

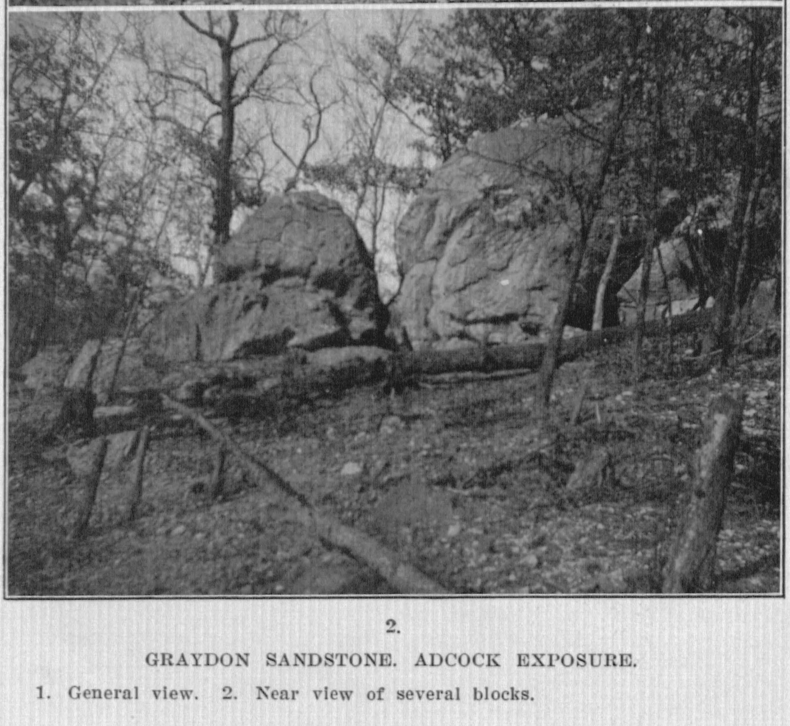
The Mill Creek Exposure (See Fig. 34).—The main mass of Graydon sandstone in the N. E. ¼ of the N. W. ¼ of sec. 33, T. 39 N., R. 14 W., has the shape of a crescent, being 375 feet from tip to tip. In cross section it is 75 feet broad at the base and four feet at the apex. It is surrounded on the east, south and west by outcrops of Jefferson City limestone. At the east end the Jefferson City formation has weathered away close to the Graydon sandstone and, in consequence, the latter formation stands out in bold relief. The sandstone close to the Jefferson City formation is quartzitic. To the east of the main exposure for 400 feet is a broken trail of Graydon sandstone boulders striking N. 60° E.

COAL MEASURE SHALE.

GEOGRAPHICAL DISTRIBUTION.

As in the case of the Graydon sandstone, the outliers of Coal Measure shale occur mainly on the north side of the Osage river. About 60 isolated areas were located on the north side, while but 20 were observed

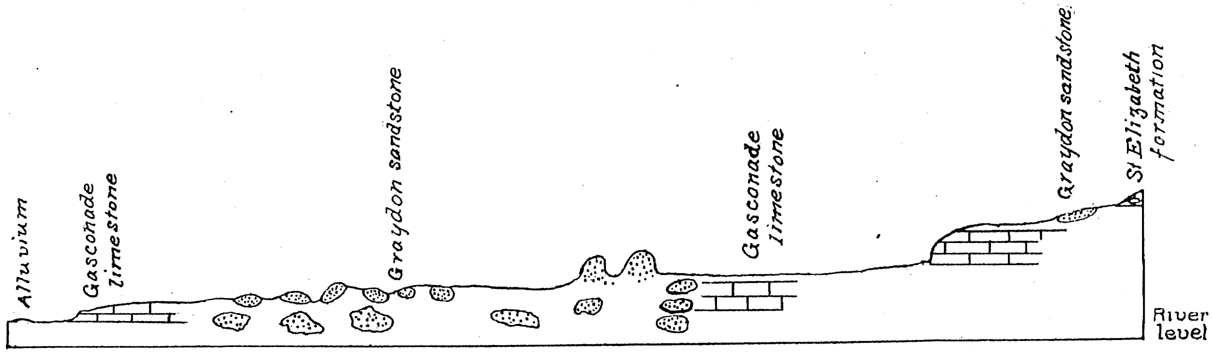
1.



2.

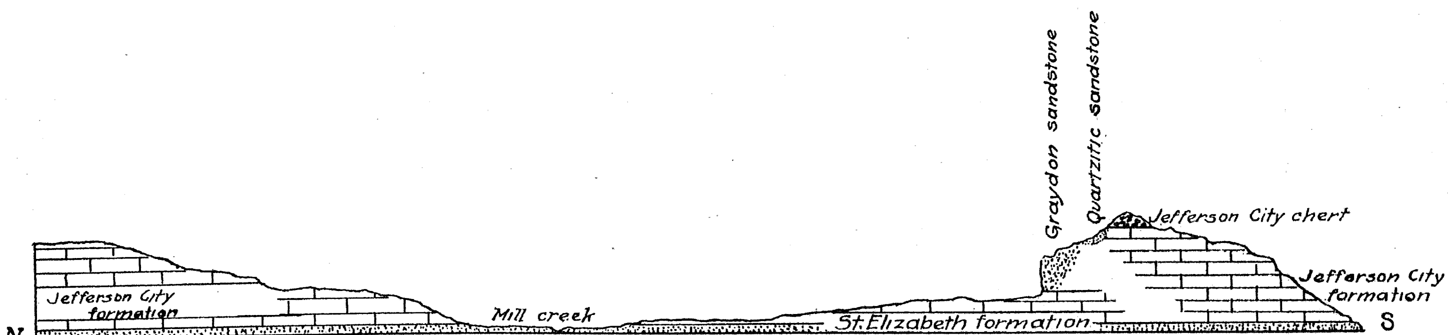
GRAYDON SANDSTONE. ADCOCK EXPOSURE.

1. General view. 2. Near view of several blocks.



Graydon sandstone. Adcock exposure. Horizontal scale, 1″=800′. Vertical scale, 1″=800′.

FIG. 33.



Graydon sandstone. Mill creek exposure. Horizontal scale, 1″=400′. Vertical scale, 1″=800′.

FIG. 34.

on the south side. These shale pockets are also more numerous away from the river than they are near it. On the north side they are especially abundant in the "brakes" just south of the Osage-Moreau divide between the west side of sec. 4, T. 41 N., R. 15 W., and the Morgan county line. Here, in an area of approximately four square miles, nearly one-half of the shale areas are located.

All of these areas are small, the largest not having a diameter of more than 700 feet. The pockets are situated on the tops of hills, along the slopes and in valley bottoms, with no regard for the present topography.

TOPOGRAPHY.

The small size of the areas of Coal Measure shale, composed, as they are, of soft rocks, have very little effect, except locally, upon the topography.

THICKNESS.

The Coal Measure shale was only observed in places where it had been protected by the resistent dolomite of the Cambro-Ordovician formations. On account of this it was impossible to make a satisfactory determination of its thickness. The shaft of the Sight Me Prospect passed through 150 feet of shale, the greatest thickness known in the county. There is no way of knowing how many feet deeper the shale extends or how many feet have been removed by erosion from the present surface of the deposit. Furthermore, faulting and flexing of the beds in these pockets have undoubtedly exaggerated their actual thickness. This shale may originally have been five hundred or more feet thick.

WEATHERING.

The weathered zone is usually less than six feet deep. In many cases weathering has extended less than a foot below the surface. Upon the exposure to the atmosphere the black shale changes to a rusty brown while the green becomes bleached. When badly decomposed, the shale is, in places, difficult to distinguish from the residual clays of the Cambro-Ordovician formations.

LITHOLOGICAL CHARACTERISTICS.

The Coal Measure shale is extremely variable in composition and texture. In some places it is a pure shale, in other places a slightly argillaceous sandstone, and in others it is an extremely calcareous shale. The carbonaceous content varies greatly. In some places there is practically no carbonaceous material in the shale, while in other places the shale is sufficiently carbonaceous to burn readily.

Cannel coal, which is a shale containing a very high percentage of carbonaceous material, was observed in five different localities in the county.

R. B. Snyder reports three feet of cannel coal at a depth of 19 feet in a well on the S. E. ¼ of sec. 2, T. 41 N., R. 16 W. (Sec. 19, Fig 35.)

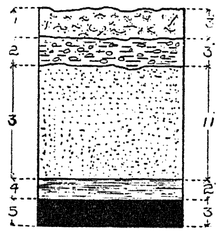


FIG. 35.

A similar coal seam is reported from the well at the school house in the center of sec. 11, T. 41 N., R. 16 W. In the south center of the N. W. ¼ of the N. E. ¼ of sec. 3, T. 41 N., R. 16 W., on land owned by Mr. Joseph Cotton, twelve to fourteen feet of cannel coal was passed through at a dept of 8 feet. (Sec. 20, Fig. 36.) In the S. W. ¼ of the N. W. ¼ of sec. 3, T. 41 N., R. 16 W., cannel coal is exposed for 100 feet along a small stream. In two prospect holes on the hill side north of this outcrop, the same grade of coal was encountered.

Cannel coal is exposed in the bed of a small stream in the center of the W. ½ of the S. W. ¼ of sec. 2, T. 41 N., R. 16 W. (See Fig. 37.)

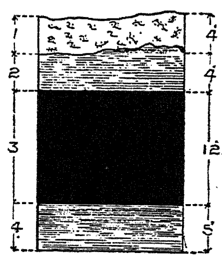
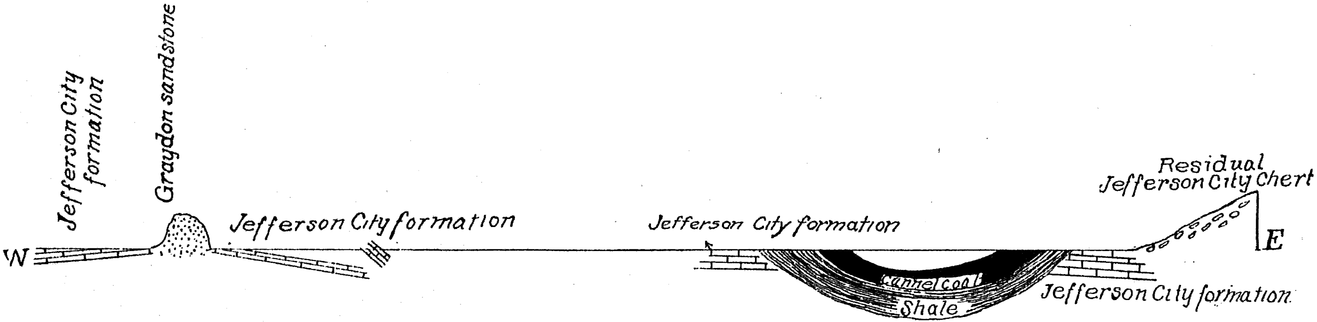


FIG. 36.

It is underlain by above 50 feet of shale. At this place there is exposed every gradation between typical shale and cannel coal. Nodules of iron pyrites with their long dimensions parallel to the bedding planes are common. A 40-foot shaft at this place is entirely in cannel coal with the exception of 1½ feet of carbonaceous shale. Near the center of sec. 11, T. 41 N., R. 16 W., cannel coal is reported to have been struck at a depth of 48 feet.

As a rule the nearer one approaches the contact with the underlying formation the more conglomeritic the shale becomes. The shale



Section across a small stream in the S. W. ¼ of sec. 2, T. 41 N., R. 16 W. Horizontal scale, 1″=400′. Vertical scale, 1″=800′.

FIG. 37.

which occurs in joints and small crevices in the Cambro-Ordovician rocks is almost invariably conglomeritic and usually of a sandy type. The differentiation of the Saline Creek cave-conglomerate and the lower beds of the Coal Measure shale is often extremely difficult. The two grade into each other.

STRUCTURES.

Bedding.—Usually the stratification planes of the Coal Measure shale are obliterated or obscured by slickensides, although in a number of instances, they were strongly developed. The shale which accompanies the cannel coal at Julius Cotton's prospect in the center of the W. ½ of the S. W. ½ of sec. 2, T. 41 N., R. 16 W., splits parallel to the bedding into thin plates one-fourth to one inch thick.

Folding.—In some places the shale beds have apparently been flexed or folded, as shown by the steep dips. However, unless the beds are unusually well exposed, it is difficult to determine whether these dips are due to folding, faulting or undermining by solution and subsequent settling.

Faulting.—Faulting with measurable throw was not observed. That most of the pockets have been subjected to stresses of some kind is shown by the complex slickensided surfaces so common in the shale. The brecciation and the scratched and polished surfaces of some of the limestone and sandstone boulders in the "Little Nugget" mine is also evidence. (See Plate XIII.) These boulders, which are mainly cotton rock, are more or less subangular and are scratched and grooved, in places, to a depth of an eighth of an inch. They bear a striking resemblance to the striated limestone of the glaciated region. The scratches have evidently resulted from the rubbing of the hard chert fragments against the soft cotton rock.

SINK-HOLE DEPOSITS.

The more or less circular form of some of the shale deposits and their great depth in proportion to their areal extent has been referred to above. This combined with the disturbed condition of the beds of the Jefferson City and other formations in the vicinity has lead to the belief that these shale pockets are of sink-hole origin.

FOSSILS.

Fossils are common in the Coal Measure shale. Fossil wood, poorly preserved, was found in the Coal Measure shale in sec. 2, T. 41 N., R. 14 W., near the Loveall diggings. A fern impression was collected from shale in the N. W. ¼ of the N. E. ¼ of sec. 3, T. 41 N., R. 16 W., at the Joseph Cotton zinc prospect. At McClure's zinc mine, beautifully preserved fossil nuts were found and presented to the Bureau by Dr. Thomas R. Thornton of Lees Summit. A petrified log is said to have been found in the "Little Nugget" mine. Fossil shells are common in the limestone at the Republic coal mine.

The fossils collected were submitted, through the Director of the United States Geological Survey, to Dr. G. H. Giety and Dr. David White for determination. Their report showed the following invertebrates and fossil plants in the collection. These species indicate the geological age to be rather early in the Coal Measures.

PLANTS.

Exogenous wood.
Neuropteris rarinervis.
Plant fragments.
Calamites sp. indet.
Trigonocarpon Dawesii.

ANIMALS.

Pleurotomaria sp. indet.
Productus semireticulatus (4 specimens).
Productus cora (2 specimens).
Spirifer cameratus (3 specimens).
Spirifer sp.
Spirifer rockymontanus.
Seminula subtilita (3 specimens).
Chonetes flemingi.
Pleurotomaria sp.
Derbya crassa.
Marginifera wabashensis (3 specimens.)
Fusulina sylindrica.

ECONOMIC CONSIDERATIONS.

Both cannel and bituminous coal are associated with the Coal Measure shale. Where the shale is pure and sufficiently abundant, it constitutes a valuable material for the manufacture of brick. Gypsum and barite occur in the shale, but neither is present in commercial quantities. Iron pyrites occurs abundantly throughout the shale, although never in commercial quantities. Zinc blende and galena are widely distributed through the formation.

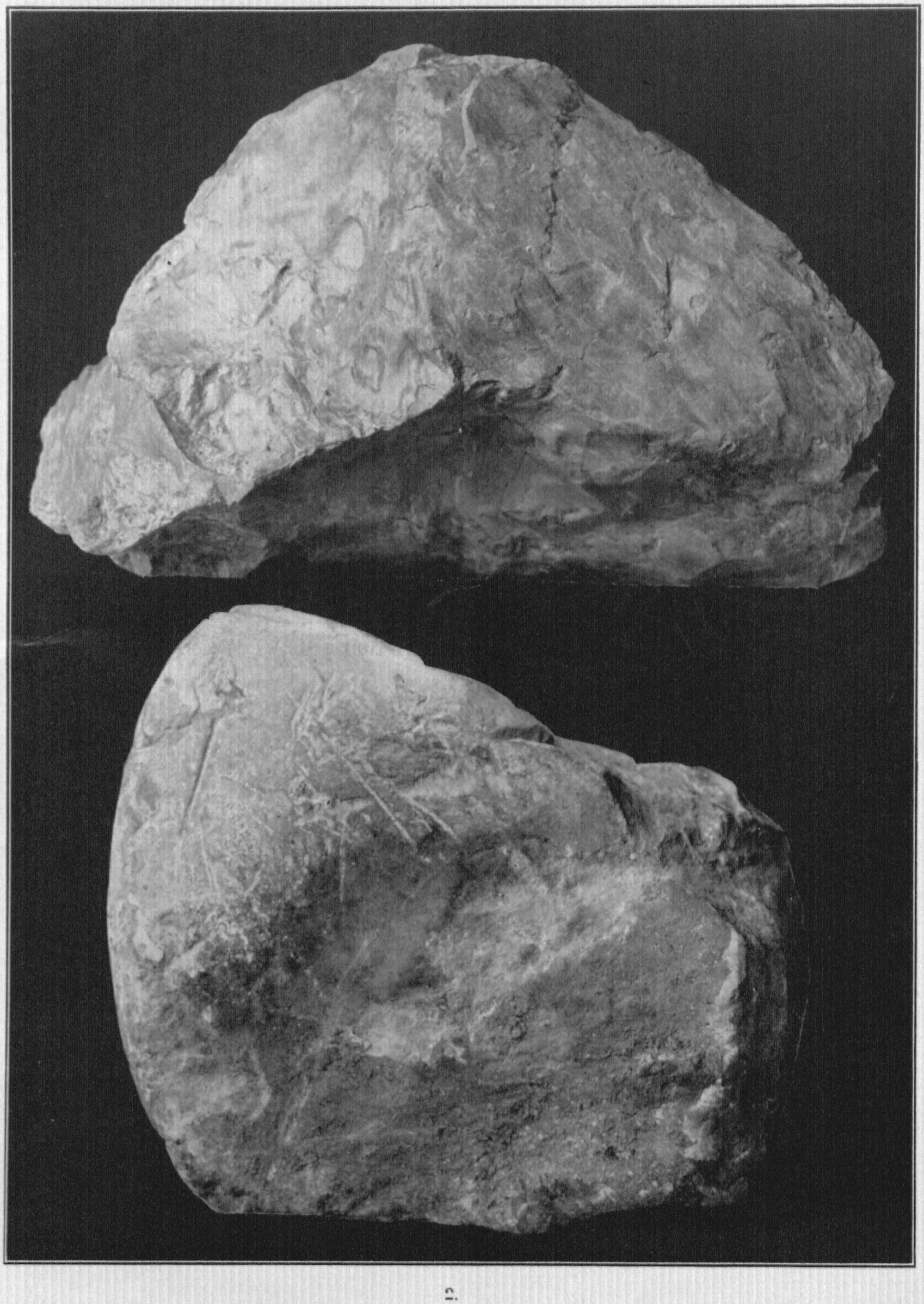
RELATIONS TO OTHER FORMATIONS.

The Coal Measure shale is underlain by the Saline Creek cave-conglomerate, the Upper Burlington limestone, Jefferson City and St. Elizabeth formations and the Gasconade limestone. It lies conformably upon the Saline Creek cave-conglomerate and unconformably upon the other formations.

TYPICAL EXPOSURES.

The Little Nugget Mine.—The type locality of the Coal Measure shale in this county is in the S. E. ¼ of the N. W. ¼ of sec. 15, T. 41

1.



2.

1. SHALE SHOWING SLICKEN SIDES.
2. BOULDER OF FAULTED LIMESTONE SHOWING PLANNING AND SCRATCHING.

N., R. 13 W., one-fourth of a mile east of Mary's Home. The shale is not exposed at the surface and the knowledge of the formation has been obtained entirely from the shafts and dumps of the Little Nugget mine.

The shaft, which is farthest south, shows that the shale deposit is enclosed, in part at least, by Upper Burlington limestone. As nearly as can be estimated, this shale covers an area of two acres and is at least 135 feet deep. From comparisons with similar deposits elsewhere there is no hesitancy in saying that this deposit fills a pre-Coal Measure sink hole.

At the bottom of the main shaft there is a greenish gray, fine grained shale, containing variable percentages of calcium carbonate and quartz sand. Many boulders and pebbles of St. Elizabeth sandstone, banded and oölitic chert and dolomite, Jefferson City dolomite and cotton rock, and Upper Burlington limestone and chert are embedded in this shale. The boulders, some of which are five feet in diameter, are mostly angular, although some are well rounded. The small pebbles are all smooth and apparently water worn. Charcoal-like vegetable matter is widely and abundantly disseminated through the shale. In the shaft at a depth of between 80 and 90 feet, it is reported that a log was found which extended across one corner of the shaft.

The shale is broken into small roundish, polygonal or lense shaped masses which are slickensided on nearly every surface. The shale wraps itself very closely around the boulders and usually shows considerable movement. The chert and dolomite boulders are usually slickensided. A trail of small angular fragments extends away from some of the sandstone boulders, apparently a result of drag.

Calcite, barite, galena and blende occur in the dolomite, chert, shale and sandstone.

Sight Me Prospect.—The Coal Measure pocket upon which the Sight Me Prospect is situated, is located on a branch of the South Moreau 300 yards north of the center of sec. 6, T. 41 N., R. 15 W. This pocket covers an area of approximately two acres and is at least 156 feet thick. The shaft, which is 156 feet deep, is reported to have passed through the beds shown in the accompanying section.

Section 21.

No.	Depth.	
1	0-8	8 feet, soil.
2	8-70	62 feet, carbonaceous shale.
3	70-156	86 feet, "boulder formation."

From an examination of specimens on the dump it is evident that both the shale and boulder formation belong to the Coal Measure formations. Scattered here and there in the dark shale are small lenses of white clay and chert. Some of the lenses have been elongated and fissured parallel to the bedding and subsequently black carbonaceous material has infiltrated into the cracks. The shale is wrapped in concentric layers around the pebbles of chert and dolomite.

The Son Prospect.—The shale pocket, in which this prospect is situated, is in the center of the S. E. ¼ of sec. 19, T. 41 N., R. 15 W., on John Son's farm. The following section gives the succession of beds at that place.

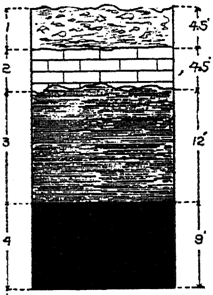


FIG. 38.

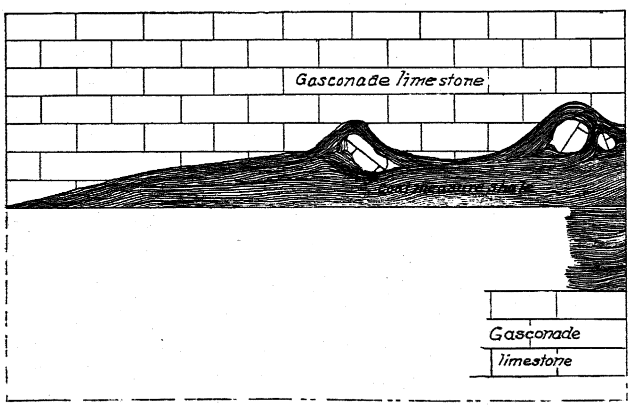
Section 22, *Fig.* 38.

No.	Depth.	
1	0-4½	4½ feet, yellow clay with flint fragments.
2	4½-9	4½ feet Gasconade limestone, destitute of flint.
3	9-21	12 feet Coal Measure shale.
4	21-30	9 feet Coal (reported).

The shale at this place is much like that at the Sight Me Prospect. A strong flow of water was encountered upon drilling in this pocket, which indicates that the deposit is not very thick. The contact between the overlying Gasconade limestone and the shale is unconformable, the latter protruding irregularly into the dolomite.

At the surface, this shale pocket is less than 50 feet wide while 20 feet below the surface it is over 150 feet in diameter. A deposit of this shape can only be accounted for by supposing the materials to have been deposited in a pre-Coal Measure cave or sink-hole.

The Gageville Mines.—In the main shaft of the Gageville mines in the S. W. ¼ of the N. E. ¼ of sec. 14, T. 41 N., R. 14 W., ten feet



Contact of the Gasconade limestone and Coal Measure shale at the Gageville "Mines."
FIG. 39.

of Coal Measure shale was passed through at a depth of 52 feet. Two feet of shale was again encountered in a prospect hole 125 feet, S. 25° W. of the main shaft. In the bottom of the gulch, southwest of the main shaft, Coal Measure shale was again encountered in the prospect hole.

The contact of the shale and Gasconade limestone, although in a general way parallel to the bedding planes of the dolomite, is very irregular. This is especially well shown in the drift connecting the air shaft with the main shaft. Figure 39 shows the relation of the shale to the overlying formation.

The shale in the main shaft is intensely slickensided. Some of the dolomite near the shale is considerably brecciated, while it is all greatly decomposed. Above the shale unusually rich ore was found (see page 171).

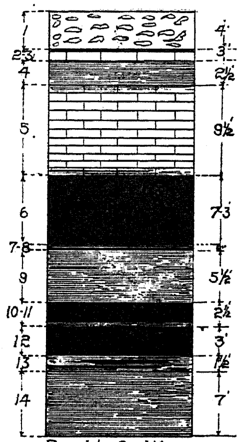
The shale in the drift and at the first prospect apparently fills the gallery of a cavern, alternately thinning and thickening. Whether or not the shale in the gulch was at one time connected with that in the hill it is impossible to say.

The Republic Coal Mine (abandoned).—The Republic coal mine, formerly known as the Barnard Coal Bank, is located in the N. W. ¼ of the S. E. ¼ of sec. 7, T. 41 N., R. 15 W. The shale pocket in which this mine is located occupies a basin in the Jefferson City formation and has dimensions of approximately 200 feet north and south and 250 feet east and west.

At this mine the succession of the Coal Measure shale from top down is as follows:

Section 23, Fig. 40.

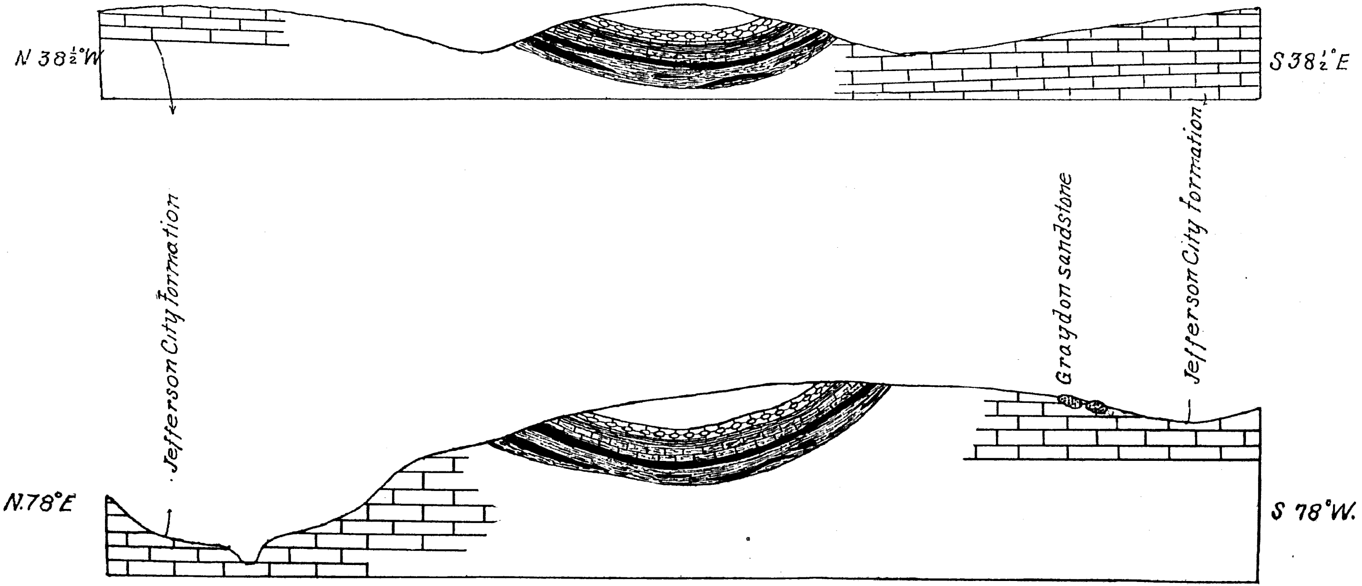
No.	Elev.	
1	0-4	4 feet variously colored chert having a conchoidal fracture. Decomposed in places. The lowest one foot is especially fossiliferous, crinoids and brachiopods predominating.
2	4-4¼	½-3 inches yellow calcareous shale.
3	4¼-5¼	1 foot limestone; yellowish when weathered, dark gray when fresh; rather fine grained and contains a few coarse calcite crystals. A few brachiopods were observed.
4	5¼-7¾	2½ feet finely fissile shale, yellow to black when fresh. Very calcareous and contains very little sand. Small nodules of limonite, the alteration product of iron pyrites, are common.
5	7¾-17½	9½ feet argillaceous limestone. The lower foot and a half is virtually a calcareous shale. This becomes increasingly carbonaceous with depth, grading into the coal below. A well rounded boulder two feet long and one and a half feet thick composed of a blackish gray limestone closely resembling No. 3, was found embedded in these shales. Fossils are abundant in this member. Small pieces of a charcoal-like substance are scattered irregularly through the limestone, especially near the base.
6	17¼-24½	7 feet 3 inches bituminous coal. Rather soft and very light. Three feet six inches from the bottom of the coal is a shaley parting, varying from six inches to one foot two inches in thickness. There are numerous other smaller pyritiferous shale lenses, two to three feet long and one to two inches thick throughout the coal seam. The shale is considerably slickensided. The coal is closely jointed. Occasional thin sheets of zinc blende occur parallel to the long diameter of the shale lenses. Thin films of gypsum occur abundantly along the jointing planes.
7	24½-24¾	2 inches very carbonaceous shale, rather sandy in places.
8	24¾-25	4 inches bituminous coal.
9	25-30½	5½ feet arenaceous, carbonaceous shale. In places this shale encloses lenses of sand about four feet long and two inches thick. Well rounded boulders, from 3 to 6 inches in diameter, are of frequent occurrence. Some of the larger slickensided surfaces shine under a lamp like huge mirrors. Others are complex and wavy.
10	30½-32½	2 feet bituminous coal and shale lenses.
11	32½-33	6 inches shale like No. 9.
12	33-36	3 feet bituminous coal.
13	36-37½	1½ feet shale interbedded with layers of impure, bituminous coal. Lenses of coal are also abundant.
14	37½-45	7 feet intensely slickensided shale.



Republic Coal Mine

FIG. 40.

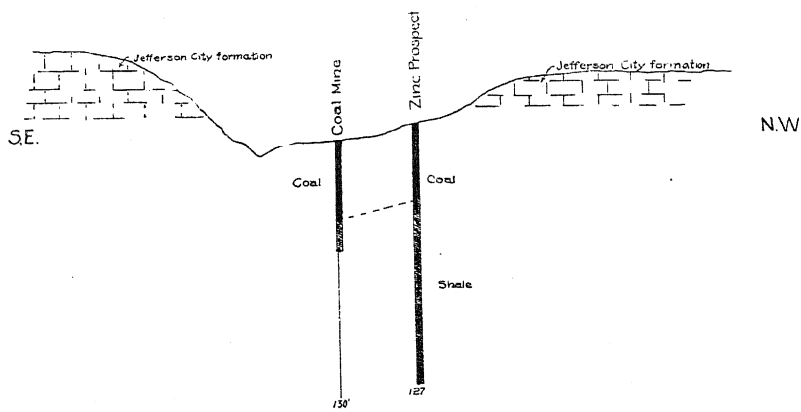
A section made 30 feet west of the above shows very much less coal. The coal is replaced horizontally by shale. (Figs. 1 and 2, Plate XIV. are sections across this mine.)



CROSS SECTIONS REPUBLIC COAL MINE.

The McClure Prospect.—The shale pocket in which the McClure prospect is situated, it at the head of a cirque-shaped valley in the S. E. ¼ of the S. W. ¼ of sec. 12, T. 41 N., R. 16 W.

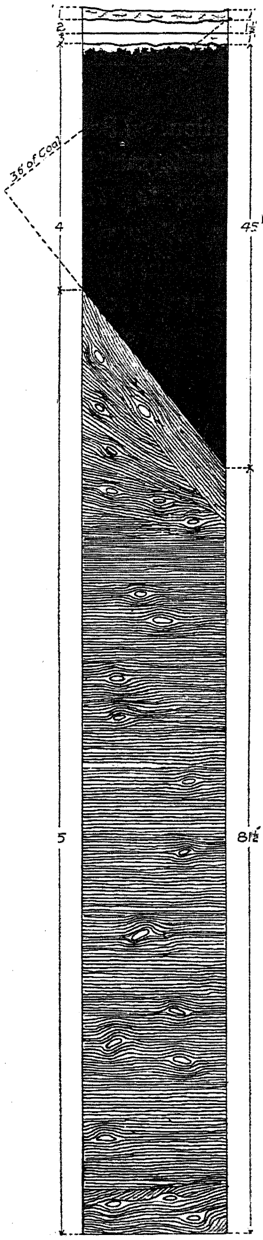
This pocket of shale lies in the Jefferson City formation. (See Fig. 41.) Horizontal beds of dolomite of the Jefferson City formation are exposed 125 feet northeast of the shaft in the steam bed 125 feet N. 20° E., and 175 feet S. 20° W. The valley slopes on either side are so steep that it is scarcely probable that shale underlies them. The deposit at this place is a cylinderical mass of Coal Measure rocks, less than 275 feet in diameter and about 130 feet thick. This shale was undoubtedly deposited in a sink-hole.



Cross section of McClure prospect. Horizontal scale, 1″=200′.

FIG. 41.

The following is a columnar section showing the succession of beds from top to bottom:



Section 24, Fig. 42.

No.	Elev.	
1	0-1	1 foot soil.
2	1-2½	1½ feet yellowish, decomposed coal.
3	2½-3½	1 foot brown partially decomposed coal, much jointed.
4	3½-48½	45 feet bituminous coal, much jointed. The coal dips 50° S. 60° W., making the actual thickness of the bed of undecomposed coal 32 feet. The coal contains pyritiferous shale lenses six inches thick and eight feet long. Gypsum and zinc blende occur in the coal. In places the coal seams are quite sharply folded into minor anticlines and synclines. Slickensides are common, but no faults of measurable displacement were observed.
5	48½-130	81½ feet mainly shale. On the east side in the bottom of the shaft the rock is much harder and consists of a conglomerate with a matrix of sandy, calcareous shale. The strong flow of water struck in a drill hole at 126 feet indicates that the limit of the shale had been reached At the bottom of the shaft on the west side, normal black and green Coal Measure shale occurs.

FIG. 42.

The Shelton Prospect.—The shale pocket in which the Shelton prospect is situated is 125 feet southwest of the center of sec. 11, T. 41 N., R. 16 W., on the edge of the prairie. A shaft 49 feet deep passed through 6 feet of bituminous coal 32 feet from the top, and a one-foot bed of cannel coal at the bottom.

An interesting modification of the coal is found in the S. W. ¼ of the S. E. ¼ of the S. E. ¼ of section 3, T. 41 N., R. 16 W., on Mr. Shelton's land. At this place a small trench in a gully exposes a bank of coke. Not only has the coal been coked, but the shale associated with it is also baked to a red and purple cinder-like mass. Pieces of the shale are incipiently fused. On all sides dolomite beds of the Jefferson City formation surround the pocket, which is about 200 feet in diameter.

The coal was doubtless ignited by forest fires or possibly by spontaneous combustion, and, due to natural conditions, was coked. No record could be found that the coal had ever been on fire. The coking may have occurred prior to the settlement of this county by the white man.

In April, 1897, the forest in the vicinity of McClure's coal bank was burned over. The coal in the bank caught fire and burned until September. When the fire was extinguished a portion of the coal was found to have been coked.

The Knowall Prospect.—In the S. W. ¼ of the S. E. ¼ of sec. 31,

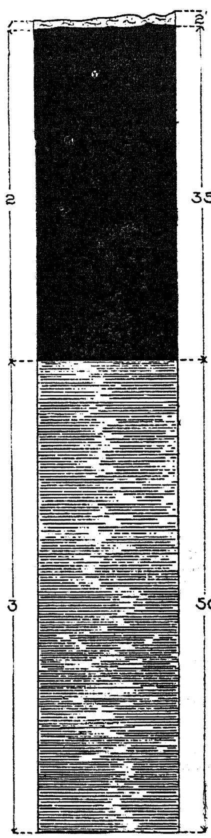


FIG. 43.

T. 42 N., R. 15 W., Mr. H. M. Knowall sunk a shaft 85 feet deep, the upper 35 feet of which was in coal, and the remainder in shale (see Fig. 43). Zinc blende occurs in the shale. A shaft 100 feet south of this one passed through an unrecorded thickness of coal, which is said to have been horizontally bedded. To determine the extent of the deposit, four drill holes were put down, one situated 250 feet N. 40° W., another 400 feet N. 65° E; still another 400 feet S. 60° E., and the last 300 feet S. 25° W., from the main shaft. Coal was not found in any of them.

The Scott Shaft.—A prospect shaft, put down on the farm of Messrs. B. A. and E. A. Scott in the S. E. ¼ of S. E. ¼ of sec. 11, T. 42 N., R. 15 W., passed through 10 to 12 inches of bituminous coal at a depth of 26 feet.

It is reported that four feet of coal was discovered in a drill hole 200 feet southwest of this shaft.

The Spaulding Prospect.—In the S. E. ¼ of sec. 2, T. 41 N., R. 14 W., in a dry branch, there is a shale pocket in which Mr. Edward Spaulding sunk a shaft. The following beds were passed through:

Section 25.

No.	Elev.	
1	0-5	5 feet pyritiferous shale with more or less coal in small lenses.
2	5-22	17 feet bituminous coal and shale interlaminated—about half coal and half shale. A 2 foot vein of coal, carrying blende and pyrite, was encountered.

Southeast of the center of sec. 2, T. 41 N., R. 14 W., on the St. Elizabeth formation is a small Coal Measure shale pocket in which a few inches of coal were found at a depth of 15 feet.

The Garner Well Section.—In 1875 Mr. T. B. Garner, of Iberia, struck a thin seam of coal in a well at a depth of 23 feet, and at 53 feet the drill passed through a 6½ foot seam. Yellow clay is reported both above and below the coal. Some iron pyrites and gysum were found. The coal is a bright, very oily-looking, bituminous coal. An analysis gave:*

Moisture expelled at 218 degrees F.	1.324
Volatile matter at red heat	25.784
Fixed carbon	52.445
Ash	20.447
	100.00
Sulphur in ash	5.810
Total coke	72.912

Color of ash, grayish pink.

*We are indebted to Mr. Garner for this analysis. Analyst Prof. Chas. P. Williams, Missouri School of Mines. Analysis performed in 1873.

Miscellaneous Outcrops.—In the south center of sec. 11, T. 38 N., R. 14 W., on a creek bank are four pits, sunk twenty-five years ago, from which coal was obtained. In the creek bed a thin seam of coal, dipping 15° S., 45° E., outcrops.

Meek* states that coal occurs in the W. ½ of lot I, N. E. of sec. 4, T. 39 N., R. 13 W. At this place on Mr. Wait's land, on the top of a high ridge, are several small pits now almost entirely filled. On the dump are bits of very black, carbonaceous shale or impure cannel coal. The pocket is 150 feet long, 50 feet wide, being enclosed by dolomite beds of the Jefferson City formation.

THE UNDIFFERENTIATED JEFFERSON CITY FORMATION COAL MEASURE SHALE AREA.

This area lies in the west center of the county along the junction of the prairie land and the "brakes." It is a country of rounded hills and valleys, which, compared to those of the southern portion of the "brakes," are low and gently sloping. Along the streams are exposures of the Jefferson City formation and Coal Measure shale. All but the stream beds and some few "balls" are covered with flint fragments. Many of these are of oölitic chert from the Jefferson City formation, others are from the cherts above the coal, while still others are the well rounded cherts so characteristic of the Coal Measure shale.

While 99 per cent. of the area is underlain by the Jefferson City formation, there are certainly concealed pockets of Coal Measure shale, and for this reason, the area has been mapped separately. In going over the area, it is utterly impossible to tell whether Jefferson City or Coal Measure rocks underly the surface.

THE DEPOSITION OF THE COAL MEASURE ROCKS.

After the Upper Burlington limestone had been laid down the land was elevated above the sea. That this elevation was considerable is shown by the fact that solution and mechanical erosion produced sink-holes, the bottom of which are at least 25 feet below the present water level. The fact that solution, except under unusual circumstances, is not active below the level of ground water, leads one to conclude that these sink-holes were formed when the rocks were in the belt of weathering.†

Coincident with the elevation of the land above the sea, valleys were carved and sink-holes formed. The importance of solution in shaping

*Report on the Geol. Sur. of the State of Missouri, 1855-1871, p. 118.

†Van Hise. "Some principles controlling deposition of Ores." Genesis of ore deposits. Am. Inst. of Min. Eng., p. 327.

the pre-Coal Measure topography was doubtless much greater than at present. The surface rock was the pure Upper Burlington limestone upon which solution must have acted with unusual rapidity. At the present day, the country underlain by Upper Burlington limestone is characterized by numerous caves and sink-holes. Greene county, Missouri, is a striking example.* Sinks were formed in the various underlying members of the Cambro-Ordovician series, as well as in the Upper Burlington limestone. That the dolomites of the Cambro-Ordovician series are in a measure favorable to the formation of sinks is shown by the sink-holes, which occur in them to-day. Some, perhaps many, sink-holes were formed in the dolomites after the Upper Burlington limestone had been locally removed. During the formation of these sinks varous sized boulders fell from the overhanging sides. These boulders with the sand and clay washed in from the surface and limestone deposited by the cave waters formed the Saline creek cave-conglomerate. While many of the Saline creek cave-conglomerate deposits are older than those of the Coal Measure shale, it is probable that others are contemporaneous.

That this erosion interval was of considerable duration is shown by the removal of the greater part of the Upper Burlington limestone, and by the character of the Upper Burlington chert boulders which occur in the Graydon sandstone and Coal Measure shale. These chert boulders show that the metamorphism of the limestone to chert occurred prior to the deposition of the Coal Measure strata.

Following the erosion interval the land was depressed until finally the Ozark region, with the possible exception of the St Francois Mountains, were either a coastal plain or below sea level. Miller county seems to have been on the coast, being alternately above and below the sea. It was a period of slow and at times intermittent depression and elevation. At this time it is inferred that almost, if not quite, all of Miller county was submerged. Loose material which lay in the immediate vicinity of the sinks was washed into them, forming the cave-conglomerate above mentioned. The boulders are noticeable local in their origin and too large to be handled by any but the strongest streams, demanding a declivity which the inferred pre-Coal Measure topography was insufficient to afford. Moreover, the softness of the cotton rock of the Jefferson City formation and the limestone of the Upper Burlington formation precludes the possibility of transportation for any considerable distance.

It seems generally true that the more arenaceous shales are located either on the St. Elizabeth formation or upon arenaceous beds of the Jefferson City formation. The composition of the shale of various pockets

*E. M. Shepard, Mo. Geol. Sur., 1898, Vol. XII, part I, p. 33.

corresponds in a general way with the composition of the present residual soil of these formations.

The carbonaceous material in the shale was probably partially in the soil, although the larger part seems to have been washed in from the neighboring hillsides. In places the shale contains such a high percentage of vegetable matter that it forms cannel coal.

The immense amount of vegetable matter required to make the thick beds of coal can be best appreciated when it is understood that one foot of coal is calculated to represent 15 feet of peat. In other words the 32 feet of coal at McClure's mine represents a peat deposit of 480 feet.

That the conditions of deposition were very local is indicated by the fact that pockets but a few miles apart apparently have an entirely different succession of beds.

In places the region seems to have been beneath the sea, and the streams from the land to the south and southeast brought in immense quantities of sand which was later consolidated forming the Graydon sandstone.

The pre-Coal Measure drainage must have been practically the same as it is to-day, else there would be more exposures of Graydon sandstone in the elevated parts of the county. The sandstone is taken into solution very slowly by circulating waters and, when protected from corrosion by the surrounding dolomite, it is very persistent. This is evidence that the old stream-channels were deeper that those of the present day, even in the vicinity of the Osage river.

Both sandstone and shale occur on almost the highest elevations in Miller county, and there is no doubt but that at the close of this period the entire county was overlain with shale and sandstone, which in some places must have been at least 500 feet thick. That a continuous sheet of coal at one time covered this county seems improbable.

The Saline creek cave-conglomerate is in a general way the oldest Coal Measure rock, the shale itself next, and the sandstone the youngest. However there are many exceptions to this rule. It may very well be that the sandstone belongs to two, three or more separate depressions of the land, and that the shale and sandstone were being deposited at the same time in different parts of the county. That the sea in which the sandstone was laid down was shallow is proved by the cross bedding and sun cracks.

The Graydon sandstone of Miller county occupies channel-like depressions which can best be explained by erosion. Both shale and sandstone occur in the joints and crevices of the Cambro-Ordovician rocks.

Since these indications of low water deposition occur at the very base of the Graydon sandstone as exposed in Miller county, we must conclude that the depression was gradual and that shallowing through deposition kept pace with depression. The first sandstone beds were doubtless deposited in estuaries which by continued depression widened until the whole county was submerged.

In speaking of the Coal Measure coal deposits Swallow* states "these abnormal deposits are found in ravines and cavities of denundation in the rocks of all ages from the Archimedes limestone down to the Calciferous sandrock." Meek** states that those of Moniteau county (the adjoining county on the north) are due to the filling of depressions in the older rocks and also to the slipping of masses of Coal Measure rocks from the surrounding hill tops. Winslow*** suggests ravines and sink-holes as the places of deposition.

All the more striking coal and shale deposits seem to occur in basin-like depressions. These vary in shape from the comparatively gently sloping Republic Coal Company deposit to the deep straight sided Know-all pocket. The sink-hole shape of these deposits might be due either to the deposition of the shale in sink-holes of pre-Coal Measure age, or to the dropping down of the shale into sink-holes of later origin. We believe the former supposition to be the true one, since the shale, although considerably slicken-sided, does not apear to be as greatly disturbed as would be expected if it had reached its present position in the latter way. Moreover sink-holes 150 feet deep do not occur among those of the present cycle. In some cases, at least, the shale was deposited in pre-Coal Measure caves and sinks. This is true in the case of the shale in the Gageville Mine.

These shale and coal pockets have been somewhat folded and much slickensided by the readjustment resulting from stresses. The sinking of the mass of peat as it changed to coal must have been an important factor in producing slickensides and minor faults.

The present position of the Coal Measure strata is determined by the pre-Coal Measure topography and by the post-Coal Measure erosion. The durability of the enclosing Cambro-Ordovician dolomite has protected the formation, preventing its complete removal.

Since its deposition, the sandstone has been cemented by silica and iron. Differential movements have jointed it intimately, and in places has produced slickensides. The coal and shale have been jointed, and in these open joints galena and blende have been deposited. Underground waters have also deposited in the shale "dice lead" and "strawberry jack." (See page 181.)

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*First and second annual reports of the Geol. Sur. of Mo., 1855, p. 90. G. C. Swallow, State Geologist.

**Ibid, p. 112. Report on Moniteau county.

***Preliminary report on coal, 1891. Geol. Sur., p. 38.

CHAPTER X.

MESOZOIC, CENOZOIC AND QUATERNARY.

Deposits of Mesozoic or Tertiary age have not been recognized in Miller county. It is not altogether improbable that Cretaceous sediments were at one time present in Miller county, but all traces of them have been removed.

PLEISTOCENE.

Glacial Age.—In the hilly and upland country there is no evidence of glaciation. The Kansan, the oldest Glacial epoch recognized in this country, is the one during which the ice reached its maximum southern limit in Missouri. James E. Todd* states that "Probably the ice sheet during the Kansan epoch may have extended as for south as Clinton, Carroll and Randolph counties."

Glacial boulders were found at eight localities in the bottom land of the Osage river and its tributaries, and three other erratics, preserved in private collections, were examined. In the N. E. ¼ of sec. 6, T. 41 N., R. 12 W., in a wagon road, is a granite boulder one foot long and six inches thick. Two hundred feet away from this are three other granite boulders, averaging two and a half feet long, two feet wide and one and a half feet thick. One-fourth of a mile west of these, another slightly larger boulder occurs in the alluvium. Mr. Joseph Hoecker, the owner of the land, states that other granite boulders occur in this vicinity, but at the time of our visit they were covered with soil. All of these boulders are in the bottom land and from 20 to 30 feet above the low water level of the Osage river.

In Judge J. C. Lurton's orchard in the S. W. ¼ of sec. 29, T. 41 N., R. 13 W., in the bottom land of the Osage river, and 30 feet above low water, is a boulder of granite measuring 3x3x2 feet. At the same elevation above the river, at King's Bluff, one-eighth of a mile west of this place, two other small granite boulders were observed.

In the E. ½ of the S. E. ¼ of sec. 1, T. 40 N., R. 14 W., are numerous small granite boulders strewn over the fields and along the edge of the bluff bordering the bottom land of Dog creek. (See Plate No.

*Formation of the Quaternary Deposits. Mo. Geol. Sur., Vol. X, 1896. Chas R. Keyes, State Geologist, p. 213.

II, Figure 2.) These are at least 60 feet above the low water level of the Osage river.

On William A. Barron's land in the S. E. ¼ of the S. W. ¼ of sec. 20, T. 40 N., R. 14 W., a large granite boulder four feet in diameter lies on the river bank. Mr. Barron stated that another rock exactly like this was formerly exposed, but had recently been covered by river silt. These boulders are 25 feet above low water level.

On John Weitz's farm, on a tributary of Shut-in branch in the middle of the S. W. ¼ of the N. W. ¼ of sec. 10, T. 40 N., R. 14 W., a considerable number of granite boulders have been found. Several cart loads have been removed, and new ones are unearthed in ploughing each year. Most of these are small, although one measured 2½x3¼x1½ feet. They are about 50 feet above low water level of the Osage river.

Just east of the ford on Saline creek, in the S. E. ¼ of sec. 25, T. 41 N., R. 14 W., a boulder of granite containing epidote was found in the Osage river bottom, about 25 feet above low water level.

In the S. W. ¼ of sec. 19, T. 41 N., R. 13 W., in a field just south of the Mary's Home-Tuscumbia road, a red granite boulder was discovered in ploughing a field in the Jim Henry creek bottoms. In the west edge of the N. E. ¼ of the S. W. ¼ of the same section, another granite boulder was found. These are well polished on one side, as if by glacial action. They are situated 75 feet above the low water mark of the Osage river.

Mr. John Buster owns a granite boulder which he says came from the N. E. ¼ of sec. 2, T. 40 N., R. 14 West. It was found at the edge of the bluff 40 feet above the river. Mr. Samuel Lawson possesses a small pebble of diorite which he found in the bed of Saline creek in the N. E. ¼ of sec. 26, T. 41 N., R. 14 W. Mr. H. M. Compton has a granite boulder, which he states came from the Saline creek bottom in the S. W. ¼ of the S. E. ¼ of sec. 23, T. 41 N., R. 14 W.

These boulders are subangular and are in some instances polished on one side. No glacial striae were noted.

That these granite boulders are not derived from dykes in the country rock is shown by their granite texture, the schistose character of some of them and the unmetamorphised condition of the dolomites surrounding the localities at which they occur. The lack of granite outcrops and the presence of the boulders only along the Osage river and its tributaries indicates that they are foreign.

Meek* writing in the fifties concerning a granite boulder found in

*Reports on the Geol. Sur. of the State of Missouri, 1855-71, Jefferson City, 1873, page 137.

the valley of the Big Gravois in Morgan, the adjoining county on the west, states "that it was most probably transported here by floating ice from some locality far north of this during the glacial period."

James E. Todd* believes that, previous to the Kansan epoch of the Glacial age, the Osage river may have flowed much farther northest than at present "by way of the valley of the Auxvasse or Big Muddy to the valley of Salt river and northeast passing somewhere near Qunicy." If such be the case, and the southern extension of the ice sheet were in Clinton, Carrol and Randolph counties, a damming back of the Osage river would be a certainty. If, on the other hand, the Osage river flowed as it now does and the assumed extension of the ice be correct, the damming back of the Osage river must have been due to the immense floods of water derived from the melting ice sheet.

The occurrence of several boulders at almost every locality noted, indicates that they were probably transported on icebergs. When the icebergs melted the boulders sank and became embedded in the river alluvium.

The approximate levels above the sea at which the observed boulders occur, is as follows:

LOCALITY.	ELEVATION.
N. W. ¼ of the N. E. ¼ of sec. 6, T. 41 N., R. 12 W., and vicinity	535-545
King's bluff	550
Ford of Saline creek	550
Judge Lurton's	555
Barron's	560
Dog creek	590
Weitz's	580
Section 19, township 41 north, range 13 west	605

The last elevation indicates that during or at the close of the first Glacial epoch the river at Tuscumbia was at least 75 feet higher than at present. This rise would affect the Osage river at least as far west as Benton county.

The presence of these boulders along the Osage river and its tributaries, and their absence from the surrounding hill country, indicates that the Osage river and its tributaries prior to the first Glacial epoch occupied practically their present channels.

RECENT.

ALLUVIAL DEPOSITS OF THE OSAGE AND MOREAU RIVERS AND THEIR TRIBUTARIES.

During the later part of the Glacial period the streams sunk their channels to a considerably greater depth than they are at the present

*Reports of the Missouri Geol. Sur., Vol. X, 1896, p. 213.

time. Since then they have been engaged in refilling these channels and again cutting them out.

The alluvial deposits in Miller county are confined to the Osage and Moreau rivers and the lower reaches of their tributaries. However, during high water, patches of alluvium are laid down even near the heads of some of the tributaries of these streams. The character of the alluvial deposits changes greatly from place to place. Close to the banks of the Osage river the clay content is high and the alluvium is a fine grained, yellowish, clayey loam, in which occur lenses of sand. Farther away from the stream, where deposits are made only in times of high water, the alluvium is a dark loam with a high percentage of vegetable matter. In the oxbows the organic content of the soil is much higher.

The beds of the Osage and the Moreau rivers are composed of flint pebbles, mainly angular but occasionally well rounded. In places these are cemented into a conglomerate. A striking example of this is seen on the west edge of sec. 21, T. 40 N., R. 12 W., where iron oxide seeps from the bank of the Osage river and cements the gravel, forming a conglomerate.

TRAVERTINE.

Travertine is very common along the bluffs of the Osage river. It is confined largely to the broken chert horizons through which the seepage of water is greatest. In the various caves stalactites, stalagmites and incrustations are common.

FOSSIL REMAINS.

Fossils in the Pleistocene or Recent rocks are rare. Near the middle of the N. W. ¼ of sec. 13, T. 39 N., R. 14 W., a Mr. Sidwell exhumed some bones, reported to be of immense size. They were found in a marshy area surrounding a spring. Although the bones were not seen, we judge from the description that they doubtless belonged to a mastodon.

(See section 26, Figure 44, which is a generalized section of all the formations in Miller county.)

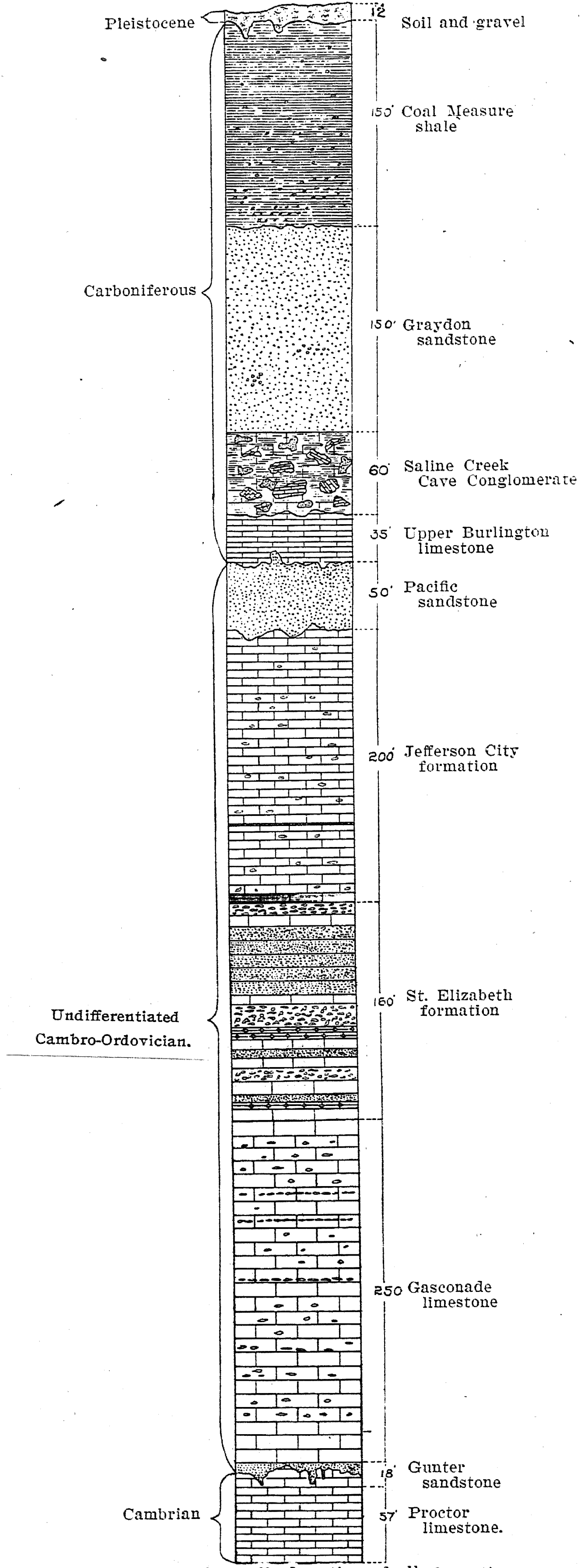


FIG. 44. Generalized section of all formations.

CHAPTER XI.

STRUCTURE.

FOLDING AND FLEXURING.

In very few places in Miller county are the strata sufficiently bent to warrant one in speaking of them as being folded. The gentle undulations, which are common in most parts of the county, may be more correctly spoken of as flexures. Both the folds and flexures are frequently complex, having superimposed upon them other folds and flexures of the second and third order.

The axes of the folds of the higher orders usually strike and dip in different directions and at different angles from those of the primary folds and flexures. This cross folding developes what are known as canoe shaped basins and domes.

All of the larger folds or flexures in Miller county are unsymmetrical, one limb being shorter and steeper than the other. A number of observations were made on the dip and strike of the limbs of the various shorter and steeper limbs with reference to one another. In some instances this limb was on the west and in others it was on the east side of fllexures and folds but no uniformity was found in the position of the a north and south fold, and similarly in regard to east and west folds.

The general dip of the strata over large areas is, as a rule, too slight to be recorded by a clinometer compass, on account of which the determination of the position and extent of most of the larger synclines and anticlines were necessarily made by determining the elevation of the contacts of the various formations. The majority of the dips measured were on limbs of the minor flexures.

Broadly speaking Miller county is a qua-quaversal dome with its crests near Sycamore Spring hollow and Ramsey postoffice in township 40 north, range 13 west. From its crest to the north line of the county the average dip per mile is 40 feet, to the east 23 feet, to the south 18 feet and to the west 8 feet. It has already been stated that superimposed upon the limbs of the dome are numerous secondary flexures, domes and basins.

On the east, south and west sides of the crest of the dome occur the only folds large enough to warrant special attention as such. On the west side of the crest strata of Gasconade limestone, dipping from 10° to 60°, S. 70° W., outcrop in the hollows from sec. 20, T. 40 N., R. 13 W., north-northwest to a point two miles north of the Osage river in township 41 north, ranges 13 and 14 west. Coon creek flows for most of its distance approximately parallel to the strike of these beds. Where the beds are unexposed in the ridges in the region of the steepest dips their course is easily followed by a row of chert boulders derived from the St. Elizabeth formation. West of the strike of the steeply dipping strata these fragments and boulders are very abundant, while to the east the boulders are all from the Gasconade limestone. The line between the two is quite sharp. On the east and south sides of the crest the steeply dipping beds cannot be traced for any considerable distance. The dip on the south is 15° S., while that on the east is 25°, N. 65° E.

Besides the above mentioned folds there are several prominent flexures in the county. In sec. 30, T. 40 N., R. 14 W., near Brockman's ford is a small qua-quaversal dome resembling in many ways the one previously described. In township 41 north, ranges 12 and 13 West, the Osage river flows nearly north along the axis of an unsymmetrical anticline. The west limb is one mile while the east limb is six miles long.

From Eldon north to the county line the strata dip 30 feet per mile. Along the western edge of the county in township 40 north, range 16 west, the strata dip at the rate of 140 feet per mile. The southeast corner of township 39 north, range 14 west, is the loci of a large synclinal basin. The high ridge in the southern part of township 39 north, range 13 west, marks the crest of a large east and west flexure, while the crest of a large north and south flexure at right angles to the above traverses sections 11, 14, 23 and 26 of this township. In the southeast corner of the county, on the east line, the beds dip west-southwest 125 feet per mile, instead of in the usual east-northeast direction.

Tavern creek from Bray's mill in sec. 9, T. 39 N., R. 12 W., to near Wilson's cave in the southeast corner of township 40 N., R. 13 W., flows at the foot of the short limb of an unsymmetrical flexures whose axis strikes N. 65° W., and dips slightly S. 65° E. The dip of the short limb is from 5 degrees to 25 degrees and the amplitude of the flexure is about 100 feet.

Steep local dips are common in the vicinity of the Coal Measure rocks. These dips are often as steep as 35° to 45° or even 75°. Twenty-five feet north of the cannel coal exposure in the S. W. ¼ of the N. W. ¼ of sec. 3, T. 41 N., R. 14 W., the Jefferson City formation dips 45 degrees north, 11 degrees east. At the Coal Measure shale outcrops in the N. W. ¼ of the N. E. ¼ of sec. 13, T. 41 N., R. 16 W., the Jefferson City formation dips toward the shale 35°, S. 85° E. These dips in all cases rapidly die out.

The gentle though complex folds and flexures of this region were not due to a single great orogenic movement, confined practically to one period, but are the results of quite superficial movements, of greater or less intensity beginning and continuing through the period of deposition of the oldest rocks up to the last great uplift, usually regarded as occurring in Tertiary times and which is attributed with having elevated this region.

Most of these were simply vertical movements practically independent of horizontal thrust and were due to the gradual rising and lowering of the earth's crust. In Miller county there are five well marked unconformities besides other local ones in the Gasconade limestone and St. Elizabeth and Jefferson City formations. All of these unconformities denote elevation or subsidence and each movement, however slight, produced some deformation of the strata. The place where rocks are once bent is a plane of weakness along which later deformation acts most readily. The last great uplift not only developed one major independent system of flexures, but it also emphasized more strongly the previously existing structures.

The steep local dips in the vicinity of the Coal Measure rocks are primarily due to the pre-Coal Measure solution, but have undoubtedly been intensified by post-Coal Measure folding.

The Upper Burlington limestone beds dip, as a rule, rather steeply and where typically exposed form synclinal basins. Figure 45 shows the plan and structure of an Upper Burlington limestone outlier located in the northwest corner of sec. 8, T. 41 N., R. 13 W. The synclinical form of the Upper Burlington limestone beds in this county is partially due to the initial dip of deposition. But, surrounded as they are by the more resistant Cambro-Ordovician dolomites, pressure has undoubtedly emphasized these synclinal basins.

FAULTING.

The faults south of the Osage river in Miller county are all tension or gravity faults. Raven's bluff in the northeast corner, sec. 8, T. 39 N., R. 12 W., one of the famous land marks along Tavern creek, is a big upturned block of faulted Gasconade limestone 130 feet high.* (See Plate XV.) This big block is at the west end of a narrow

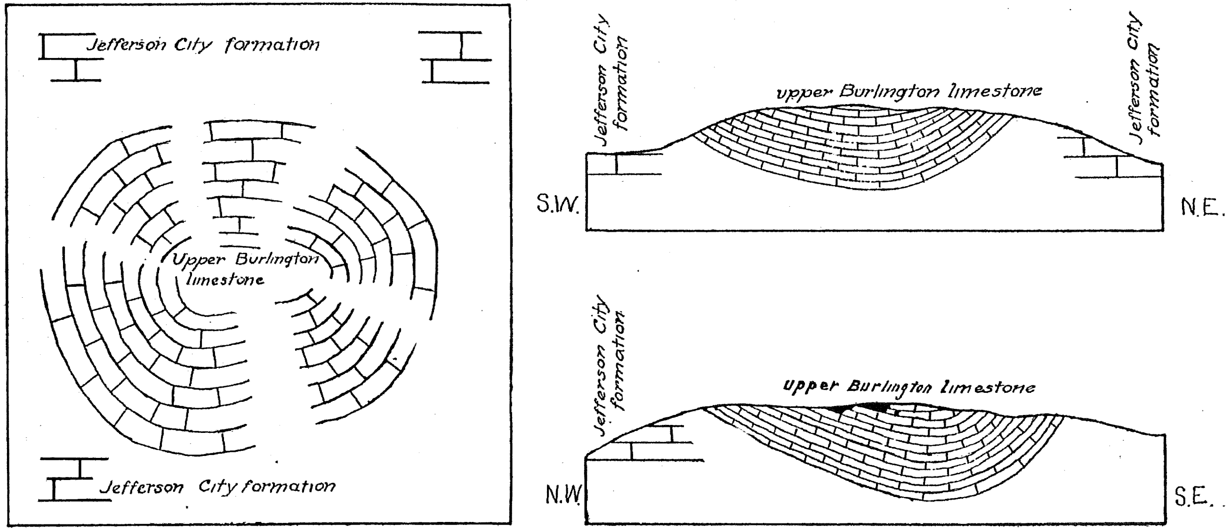
*The displacement at this place may be the result of undercutting or caving, as suggested elsewhere.—E. R. Buckley.

RAVENS BLUFF.

ridge, separating Tavern creek from two of its small tributaries. The bluff slopes rapidly from its summit to the valley to the west with about the same inclination as the dip of the beds. The ridge of horizontally bedded strata east of the titled block is 150 feet high and capped with 20 feet of loose boulders and soil of the St. Elizabeth formation. For a space of about 250 feet between the horizontal strata and the tilted block, the beds are concealed with a talus. The tilted block consists of beds of Gasconade limestone. The steepest dips, 55°, S. 35° W., occur close to the fault line. Away from it they decrease until at the base they are less than 25°. The total displacement could not be positively determined, but it is probably not less than 100 feet. This fault is along the strike—about N. 70° W.—of steeply dipping beds that have been traced for two miles.

An east and west fault with a downthrow to the south of 50 to 60 feet was observed along a branch of Barren forks in the N. W. ¼ of sec. 6, T. 38 N., R. 13 W. This fault strikes across the branch, and upon the upthrow side there are 60 feet of the St. Elizabeth formation capped with Jefferson City limestone. South of the fault, on the downthrow, shale and cotton rock beds which form the base of the Jefferson City formation are exposed in the bed of the creek. The exact line of faulting is obscured by talus and loose boulders. The last beds exposed, just north of the fault, dip slightly toward it. The extent of faulting could not be definitely determined, but it is persistent enough to entirely cut out the St. Elizabeth formation to the south. This fault can be made out along the wagon road from Brumley to Faith, where the ridge leaves Barren forks. At that place one passes suddenly from the cherty sandstone beds of the St. Elizabeth formation to the heavy pitted beds of the Jefferson City formation, which are about 60 feet above the base of that formation.

In the S. W. ¼ of sec. 5, T. 38 N., R. 13 W., along another branch of Barren forks the strata have been much disturbed both by folding and faulting. Two faults at right angles to each other were made out at this place. One strikes nearly N. and S., parallel with the valley, with its downthrow to the east, while the other strikes N. 80° E., with its downthrow to the south. Ten feet above the creek bed on the west side are beds and slabs of sandstone from the St. Elizabeth formation, which belong 60 feet below the top of that formation. From these beds up to the contact of the St. Elizabeth and Jefferson City formations, the slope is very gentle, and in the gutter along the roadside are many exposures of chert and sandstone belonging to the upper beds of the St. Elizabeth formation. Across the creek, east of the



Upper Burlington limestone outlier in the S. W. cor. of sec. 8, T. 41 N., R. 13 W.

FIG. 45.

sandstone is a steep slope of 70 feet high made up of beds of the Jefferson City formation. The strata along this steep slope are in some places horizontal, and in others they dip considerably in all directions. In the creek bed at this place the lowest beds of the Jefferson City limestone are exposed. One-fourth of a mile east-southeast, in a narrow ravine, the uppermost beds of the St. Elizabeth formation are exposed. These beds have a slight dip which carry them 10 feet above Barren forks.

The second fault which strikes north and south, was traced for about an eighth of a mile. It extends north, to the west end of the east and west fault. This fault has a displacement of 60 to 70 feet. North of the fault the strata of the St. Elizabeth formation dip rather steeply toward it.

These two die out within comparatively short distances, passing over into gentle folds.

A fault having a downthrow of 120 feet was observed in the S. W. ¼ of the N. W. ¼ of sec. 11, T. 38 N., R. 13 W. This fault is along a creek emptying into the Tavern. From the mouth of the creek to the line of displacement strata of the St. Elizabeth formation are continuously exposed. Above this the Jefferson City limestone outcrops at the level of the creek throughout its upper course. The exact plane of faulting is nowhere definitely shown, but along the approximate strike of the fault are blocks of both the St. Elizabeth and Jefferson City formations which dip in various directions. This fault, which has a general strike of north-northwest, south-southeast and a downthrow to the southwest, can be traced for a distance of about half a mile on either side of the creek.

A block fault occurs on the section line between secs. 13 and 14 in T. 38 N., R. 13 W., which has resulted from the dropping down of a block of Jefferson City limestone through the undermining of the St. Elizabeth formation by solution.

There are several localities in the southern part of the county where the relations of the strata give evidence of faulting. Between the east and west sides of a high ridge in the E. ½ of the S. E. ¼ of sec. 34, T. 39 N., R. 13 W., and the N. E. ¼ of sec. 3, T. 38 N., R. 13 W., there is a difference in the elevation of the Jefferson City limestone of almost 100 feet. It is presumed that this difference in elevation has resulted from faulting.

In secs. 29 and 32, T. 39 N., R. 13 W., the strata on the east side of Barren forks are nearly 160 feet higher than the corresponding beds on the west side. There are no dips which will account for this difference in elevation. It is probable that there is a fault parallel to the creek.

In the N. W. ¼ of sec. 36, T. 39 N., R. 14 W., where the Iberia-Brumley road crosses the Crocker-Tuscumbia road, the so-called cotton rock of the Jefferson City limestone is found at an elevation of 1050 feet. One-fourth of a mile west the same beds of cotton rock occur at an elevation of 970 feet. This was observed at various places for a distance of from one to two miles north and south of the road crossings. No sharp folding was observed and it is probable that a fault occurs at this place parallel with the ridge.

In the N. W. ¼ of sec. 13, T. 38 N., R. 14 W., within a distance of a fourth of a mile there is a difference of elevation of 90 feet between outcrops of the same beds of cotton rock. The difference in the elevation of the beds at the two places can only be accounted for by faulting.

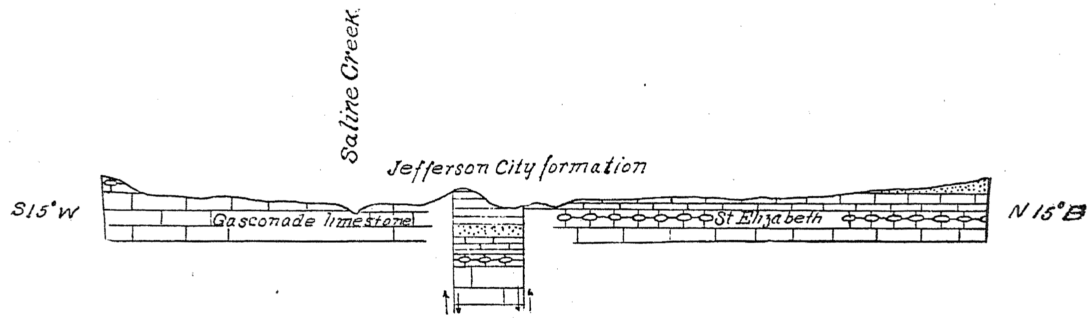
In the N. W. ¼ of sec. 4, T. 40 N., R. 15 W., on the west side of a cut on the Bagnell branch of the Missouri Pacific railroad, is a tension fault striking N. 65° W., and dipping 55°, N. 26° E. The beds on the north side dip slightly toward the fault.

In the north center of sec. 10, T. 40 N., R. 15 W., on the north cliff of the Osage river, is a tension fault in the Gasconade limestone. The apparent displacement is four feet, the southeast side being the downthrow. The fault strikes N. 55° E., and can be traced one-eighth of a mile.

Near the center of sec. 4, T. 41 N., R. 15 W., a fault striking northwest is poorly exposed. The downthrow side is to the northeast and the displacement is about 35 feet. It is a tension fault throwing the upper beds of the St. Elizabeth against the lower beds of the Jefferson City formation.

In the S. E. ¼ of sec. 1, T. 41 N., R. 15 W., there is an apparent fault in the creek bed. On the north side the lower beds of the Jefferson City formation are at creek level while on the south side of the valley they are 30 feet above it. This fault dies out within a quarter mile in either direction.

In the western portion of sec. 10, T. 41 N., R. 15 W., in the valley of a small tributary of Saline creek, is a fault which near the junction of the Eldon-Tuscumbia and Aurora Springs-Tuscumbia roads, has a displacement of at least 160 feet. The cross section (Fig. 46), shows the manner of occurrence. The main fault strikes east and west, lowering the Jefferson City formation on the north side of a small hill until it abuts against the upper portions of the Gasconade limestone. Extending from this fault in a northwesterly direction are two faults dropping a block of the Jefferson City down into the St. Elizabeth formation. The faults apparently die out in a quarter of a mile and are replaced by dips which grow continually less steep.



Fault in sec. 10, T. 41 N., R. 15 W. Scale 1″=133′.
FIG. 46.

Faults of several feet displacement are common in the railroad cuts in the east part of the county. These are all in the Jefferson City formation.

Minor faulting is common. It was observed in the Gunter sandstone near the Morgan county line, in the Graydon sandstone in the S. E. ¼ of sec. 23, T. 41 N., R. 13 W., and in numerous places in the Jefferson City formation. The minor faults, as a rule, have a displacement not exceeding several inches. In the Coal Measure shale minor faulting is not uncommon. Stresses in the shale pockets have been relieved by distributive faults apparently absolutely without system as regards direction. The resultant movement expressed itself in innumerable slickensided surfaces.

JOINTING.

Between 600 and 650 observations were made upon the strike of the joints. Two-thirds of these were made on joints in the Gasconade limestone, in which formation they are well developed. The strike of the joints in each township has been averaged separately for each formation.

Except in the "cotton rock" of the Jefferson City formation and the Graydon sandstone, the joints were mainly vertical or nearly so. Possibly one joint in a hundred in the other formations had a variation of from 5 degrees to 10 degrees from the vertical. In the following discussions, unless otherwise stated, the joints referred to are vertical.

The joints in the Proctor limestone are well developed and resemble in every way those in the more widely exposed Gasconade limestone.

The major set of joints strikes N. 70° E and N. 15° W. In the S. W. corner of sec. 23, T. 40 N., R. 13 W., joints striking N. 45° W. and N. 47½° E., were observed in beds pitching 15° N. 30° E.

The joints in the Gunter sandstone are well developed. Readings could not be obtained along the Osage river where the sandstone forms cliffs, but a number were taken in the vicinity of Sycamore spring hollow. The average directions of the two major sets were N. 57° E. and N. 25° W. One reading gave two sets striking N. 65° W. and N. 40° E.

The joints in the Gasconade limestone vary in different townships and in consequence have been separately tabulated. The following table shows the course of these in the various townships:

T. 41 N., R. 13 W. N. 20° W., N. 62½° E.
T. 41 N., R. 14 W. Major N. 18° W., N. 75½° E.
Minor N. 34° E., N. 60° W.
T. 41 N., R. 15 W. N. 13° W., N. 82° E.
T. 40 N., R. 16 W. N. 38° W., N. 48° E.*
T. 40 N., R. 15 W. (north of the river) N. 20° W., N. 83½° E.
T. 40 N., R. 15 W. (S. of the river) Major N. 18½ W., N. 76° E.
Minor N. 25° E., N. 65° W.
T. 40 N., R. 14 W. (north of the river) Major N. 18° W. (18 readings), 43½° W., (9 readings).
Minor N. 78½° E., (6 readings); N. 52° W., (2 readings).
T. 40 N., R. 14 W. (Secs. 13, 24, 36, 35, 34, 33, 32, 31.) Major N. 24° E. (12 readings); N. 75° W. (11 readings); Minor N. 15° W. (3 readings); N. 70° E. (5 readings).
T. 40 N., R. 14 W. (south of the river with the exception of the above sections.) Major N. 14° W. (15 readings); N. 75° E. (12 readings.)
Minor N. 47° E. (5 readings.)
T. 40 N., R. 13 W. Major N. 12° W., N. 70° E.
Minor N. 37° E., N. 61° W.
Minor N. 45° E.
T. 41 N., R. 12 W. Major N. 12½° W., N. 70° E. Minor N. 45° E.
T. 40 N., R. 12 W. Major N. 73° E., N. 19° W.
Minor N. 31° E., N. 52½° W.
T. 39 N., R. 14 W. N. 30° W., N. 75° E.
T. 39 N., R. 13 W. N. 18° W., N. 62° E.
T. 39 N., R. 12 W. N. 23° W., N. 62° E.
T. 38 N., R. 12 W. N. 19° W., N. 60° E.

These figures, based on more than 400 readings, show that there are two sets of major joints, one striking from N. 38° W. to N. 13° W., and the other from N. 83½° E. to N. 60° E. These joints strike approximately parallel to the axes of the main folds. Van Hise† explains these as tension joints due to the tensile forces set up by folding on the convex halves of anticlines and synclines in the zone of fracture.

*Too few readings were taken in this township to lay any dependence on the above figures.

†C. R. Van Hise Principles of pre-Cambrian Geology. 16th annual report, U. S. G. S., p. 669.

In the south and southeast part of township 40 north, range 14 west, the major joints strike east of north and south of east. The reason for this is not apparent, the only dip being a slight one to the southwest (about 10 feet per mile). There is here a minor set of joints striking parallel to the ordinary major joints. In several of the townships there is a minor set of joints striking approximately northeast and N. 60° W. In the northern part of township 40 north, range 14 west, the northeast set becomes more important than the N. 70° E. set. We are unable to determine whether or not this is on the axis of a local are from 2 to 20 feet apart—the more massive the dolomite beds the further apart are the joints.

The joints in the St. Elizabeth formation are, as a rule, much more poorly developed and less continuous than those in the Gasconade limestone. The heavy beds of the Bolin creek sandstone in the southeastern part of the county are an exception, there being two distinct sets of joints which strike N. 20° W. and N. 60° E.

On the north side of the river but few readings were obtained in this formation, but such as were taken correspond in a general way to those in the Gasconade limestone. The following is a list of the readings observed:

T. 41 N., R. 16 W.	N. 25° W., N. 70° E.
T. 41 N., R. 15 W.	N. 18° W., N. 77½° E.
T. 41 N., R. 14 W.	Two sets N. 50° E., N. 50° W.
	N. 20° E., N. 85° W.
T. 41 N., R. 12 W.	N. 2° E., N. 78° W.
T. 40 N., R. 12 W.	N. 33° W., N. 56° E.
T. 39 N., R. 13 W.	N. 10° W., N. 55° E.
T. 39 N., R. 12 W.	Major N. 19° W., N. 63° E.
	Minor N. 39° E., N. 51° W.
T. 38 N., R. 13 W.	N. 13° W., N. 68° E.
T. 38 N., R. 12 W.	N. 28½° W., N. 60° E.

The joints in the pitted dolomite beds of the Jefferson City formation are poorly developed and less persistent than those in the Gasconade limestone. On the south side of the Osage river the joints in the Jefferson City formation are variable in direction, being more or less curved. The following are average readings taken on the north side of the Osage river:

T. 41 N., R. 14 W.	N. 25° W.*
T. 41 N., R. 16 W.	N. 60° W., N. 43° E.
T. 42 N., R. 15 W.	N. 18° W., N. 85° E.
T. 42 N., R. 14 W.	Major N. 34° W., N. 73° E.
	Minor N. 60° W., N.
T. 41 N., R. 13 W.	N. 19° W., N. 67½° E.

*Only one outcrop and only one set of joints apparent.

The cotton rock of the Jefferson City formation seems to have no well defined system of joints, although perhaps there are more that strike northeast than in any other direction. The joints are not persistent in direction, and in places as many as six sets were observed. The joints very often cut the beds with knifelike sharpness. Many joints in the cotton rock cross the bedding planes at an angle of approximately 45 degrees, which is the only evidence among the joint planes of compressive stresses.

Curved or spherical joints are characteristic of the cotton rocks. These explain the shell-like fracture of many masses as well as the crescent or heart-shaped boulders which are of common occurrence.

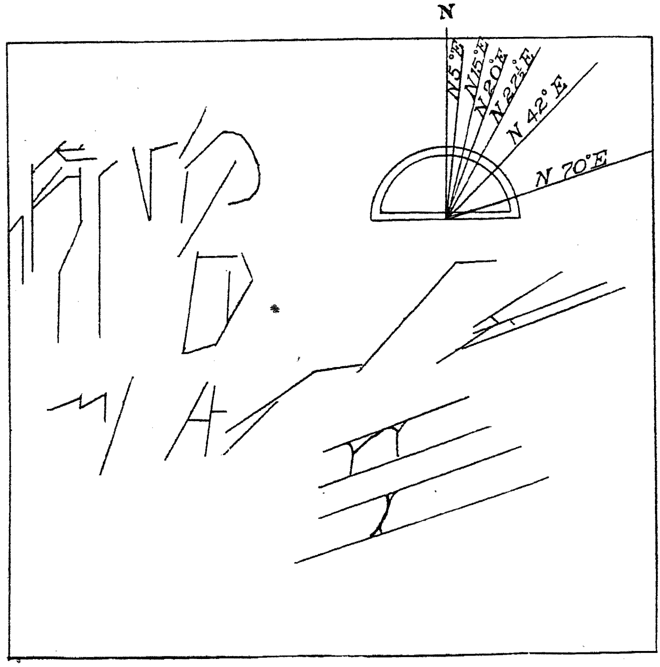
In general, it may be said that in the Cambro-Ordovician rocks there is a persistent set of joints striking approximately N. 20° W. and N. 75° E., and a minor set striking N. 45° E. and N. 60° W., the former set being the more persistent.

As far as our observations extend, the Proctor limestone possesses joints which do not occur in the overlying formations. The dike-like masses of sandstone fill what appear to be joints which strike N. 45° E. The Upper Burlington limestone in sec. 34, T. 42 N., R. 14 W., occupies what appear to be joint-like cavities in the Jefferson City formation, while deposits of Saline Creek cave-conglomerate and Coal Measure shale filling enlarged joints, are common. We may safely say that the major joints were formed after the deposition of the Jefferson City formation and prior to that of the Coal Measure rocks and probably prior to the deposition of the Upper Burlington limestone.

As mentioned above, the joints in the Upper Burlington limestone strike differently in each basin. The presence of Upper Burlington chert in the Coal Measure rocks may indicate the existence of joints in that formation prior to the Coal Measure subsidence, although the limestone prior to the Coal Measure deposition may have been changed to chert only along the bedding planes.

The joints in the Graydon sandstone are highly developed and it is due to weathering along these joints that the sandstone so often occurs in rectangular blocks.

In an exposure of Graydon sandstone in a tributary of Saline creek in the S. E. ¼ of sec. 2, T. 41 N., R. 15 W., numerous sets of discontinuous joints were observed. (See Fig. 47). In a space 7x8 feet the following vertical joints occur: N. 5° E., N. 20° E., N. 27° E., N. 42° E., N. 70° E. and E. and W. On comparing a considerable number of observations on joints in this formation no system is apparent. In exposures whose length is relatively great in comparison to their width,



Joints in Graydon sandstone. S. E. ¼ of sec. 2, T. 41 N., R. 15 W.
FIG. 47.

joints were noted in the N. W. ¼ of sec. 13, T. 40 N., R. 15 W., in the N. W. ¼ of sec. 3, T. 40 N., R. 15 W., and in the S. E. ¼ of sec. 2, T. 41 N., R. 15 W.

One quarter of a mile east of the southwest corner of sec. 3, T. 38 N., R. 14 W., is a Graydon sandstone mass elongated N. 70° W. to S. 70° E. It is ten feet wide at the west end, three feet wide at the east end and 125 feet long. Parallel to the long direction of the Graydon sandstone mass is a very well developed set of joints. At the east end this approaches almost to fissility.

Besides the joints, now existing as such, there are others filled with quartz, the relative age of which could not be determined. It appears, however, that in most cases the filled joints are in the shearing planes.

UNCONFORMITIES.

Well defined unconformities exist between the Proctor limestone and the Gunter sandstone; between the Saline Creek cave-conglomerate and the Gasconade, the St. Elizabeth, the Jefferson City and the Upper Burlington formations; between the Graydon sandstone and the Jefferson City, the St. Elizabeth, Gasconade and the Upper Burlington formations;

and between the Coal Measure shale and the Jefferson City, the St. Elizabeth and the Gasconade formations.* Local unconformities exist between the Graydon sandstone and the Coal Measure shale. In places there is a conglomerate at the base of the St. Elizabeth formation, and also within that formation itself. Local interruptions in sedimentation have been noted in the Gasconade limestone while in one place, evidence of a possible hiatus between the Gasconade limestone and the Gunter sandstone was observed.

The Proctor Limestone-Gunter Sandstone Unconformity.—The evidences of an unconformity between the Proctor limestone and the Gunter sandstone consists in the irregular surface upon which the Gunter sandstone was deposited and the presence of boulders of Proctor limestone in the Gunter sandstone.

In the center of the S. W. ¼ of sec. 15 T. 40 N., R. 16 W., the Gunter sandstone thickens, within a distance of 30 yards, from 7 to 18 feet. (See Fig. 3.) In the vicinity of Brockman's ford in sec. 30, T. 40 N., R. 14 W., the Gunter sandstone is from 2½ to 5 feet thick; in sec. 29, T. 41 N., R. 13 W., the thickness varies from 4 to 6 feet. At Ramsey's postoffice it is 12 feet thick, while in Sycamore Spring hollow, two miles away, it is only 6 feet thick. Although these variations in thickness might be accounted for by difference in original deposition, they are doubtless partially due to the unequal erosion to which the Proctor limestone was subjected prior to the deposition of the sandstone.

East of the center of the S. W. ¼ of sec. 15, T. 40 N., R. 16 W., the contact between the sandstone and the underlying limestone is very irregular, the former frequently filling depressions two feet deep and two feet wide. Sandstone "dykes" four feet long and one and a half inches wide fill the more or less regular crevices in the Proctor limestone. Cavities formed by the solution of portions of the limestone are also filled with sandstone. Boulders of Proctor limestone 2 to 12 inches in diameter are embedded in the sandstone. Plate III shows the contact between the two formations as seen on the Camden county side of the river at this place. It shows distinctly a depression of the river at this place.

At other places in Miller county the unconformity is poorly exhibited. At Brockman's ford the top of the Proctor limestone is slightly uneven, while at Ramsey's postoffice "veinlets" of sandstone penetrate

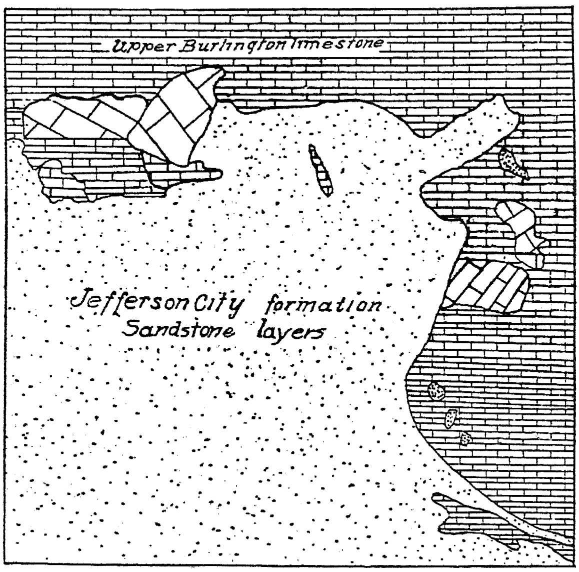
*If the sandstone called Graydon in this county is mainly Pacific, then one of the most striking unconformities is between this sandstone and the older formations. The description of the Graydon unconformity will in a large measure cover this.—E. R. Buckley.

the limestone. In sec. 29, T. 41 N., R. 13 W., the unconformity is not apparent.

The absence of fossils leaves us without a clue to determine the length of time represented by this break in sedimentation. The apparent unconformity is not great, although it may represent a very great length of time.

The Upper Burlington Limestone-St. Elizabeth and Jefferson City Formations Unconformity.—The evidences of an unconformity between the Upper Burlington limestone and the St. Elizabeth and Jefferson City formations are: (1) discordance in bedding, (2) a conglomerate at the base of the Upper Burlington limestone, (3) the fossil content and (4) the general field relations.

The Upper Burlington limestone, wherever typically exposed, dips at a considerable angle. The underlying St. Elizabeth and Jefferson City formations are usually horizontal. A conglomerate at the base of the Upper Burlington limestone was observed 100 feet northwest of the center of the N. E. ¼ of sec. 35, T. 42 N., R. 14 W., in a creek bed along which the Jefferson City formation outcrops. At this place the Upper Burlington limestone fills the open joints and other depressions in a gray, medium grained sandstone belonging to the Jefferson City formation. The south end of the exposure shows a conglomerate with Upper Burlington matrix, containing fairly well rounded pebbles of dolomite and sandstone from the Jefferson City and possibly from the St. Elizabeth formation. (See Fig. 48.)



Conglomerate at base of the Upper Burlington limestone. Scale 1″=2′8″.
FIG. 48.

The Upper Burlington limestone is extremely rich in fossils of Lower Carboniferous age. The few fossils of the St. Elizabeth and Jefferson City formations are all of Cambro-Ordovician age. The fossils thus indiçate a hiatus representing the Devonian and portions of the Ordovican and Lower Carboniferous ages.

The fact that the Upper Burlington limestone rests upon the St. Elizabeth and Jefferson City formations without regard to topographic position is evidence of the unconformity of the two formations.

The Saline Creek Cave-Conglomerate-Gasconade, St. Elizabeth, Jefferson City and Upper Burlington Formations Unconformity.—The Saline Creek cave-conglomerate fills caves, sinks and enlarged joints in the older formations. Pockets of the conglomerate have been found above the Gasconade, St. Elizabeth, Jefferson City and Upper Burlington formations. The Saline Creek cave-conglomerate contains boulders and pebbles derived from all of these formations. Figure 30 shows the relations between the Saline Creek cave-conglomerate and the Jefferson City formation as found in a cut on the Chicago, Rock Island and Pacific railroad in the southeast corner of the N. W. ¼ of sec. 26, T. 42 N., R. 15 W.

The Graydon Sandstone-Gasconade Limestone, St. Elizabeth and Jefferson City Formations Unconformity.‡—The evidence of unconformity between these formations is as clear as that between the Upper Burlington and the underlying formations. However, as the Graydon sandstone, as far as our observations have extended, is unfossiliferous, paleontologic evidence is wanting.

Figure 32 shows the Graydon sandstone as it occurs in the N. W. ¼ of sec. 13, T. 40 N., R. 15 W., almost abutting against the flat lying beds of Gasconade limestone. Steep dips in the Cambro-Ordovician strata are not as common in the vicinity of the Graydon sandstone as near the Coal Measure shale pockets. This is probably due to the fact that the sandstone fills valleys of erosion, while the latter usually fills sink-holes.

The general field relations existing between the Graydon sandstone and the underlying formations plainly indicate the unconformity. The Graydon sandstone rests upon the Gasconade, St. Elizabeth, Jefferson City and Upper Burlington formations. The outliers are found on the hill tops, along the intermediate slopes and in the bottoms of the valleys.

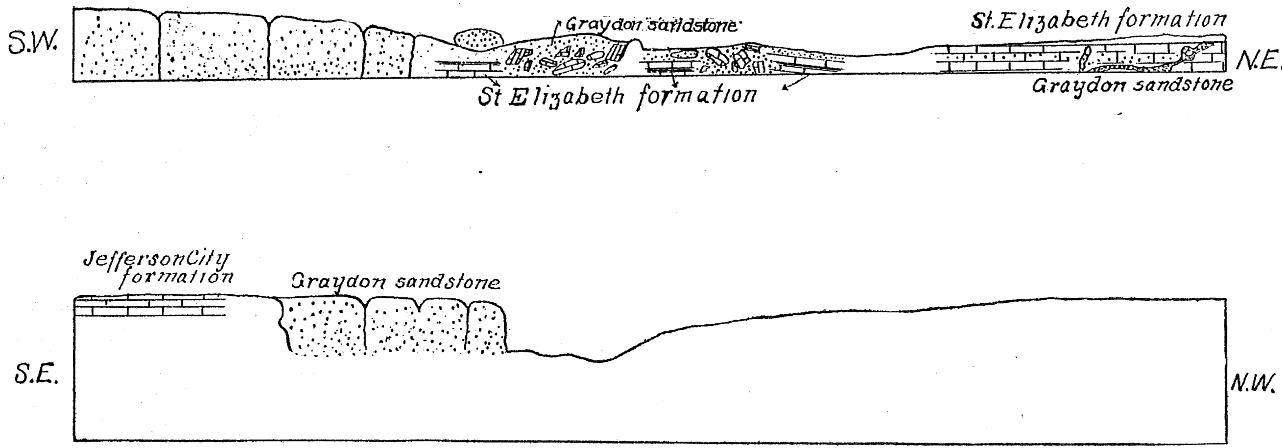
As previously mentioned, scattered throughout the Graydon sandstone are pockets of pebbles and single boulders derived from nearly all of the older formations.

‡Provided the Graydon sandstone, as considered in this report, is part Pacific, this will represent two unconformities of which the Pacific will be the most wide spread.—E. R. Buckley.

At four places—north center of the N. E. 1/4 of sec. 15, T. 42 N., R. 14 W., center of the N. 1/2 of sec. 29, T. 42 N., R. 15 W., S. W. 1/4 of the N. E. 1/4 of sec 12, T. 42 N., R. 15 W., and the S. E. 1/4 of sec. 9, T. 42 N., R. 15 W—basal conglomerates were observed. At the last locality the sandstone forms a cliff 25 feet high and 100 feet long on the southeast side of a branch of South Moreau creek. The Graydon sandstone exposure extends back into the county 125 feet where it is almost in contact with the heavy beds of the Jefferson City formation. (See Fig. 49.) Seventy-five feet down stream from the end of the bluff boulders of Jefferson City and St. Elizabeth dolomites, partially rounded, are embedded in the sandstone. The Graydon sandstone also fills crevices and cavities in the St. Elizabeth formation.

The Coal Measure Shale-Gasconade, St. Elizabeth, Jefferson City and Upper Burlington Unconformity.—This unconformity is shown by (1) discordance of bedding, (2) basal conglomerates, (3) fossils and (4) general field relations. Almost without exception, the shale beds dip at a considerable angle, while the surrounding Cambro-Ordovician and Lower Carboniferous strata are virtually horizontal. Although the shale pockets may be 150 feet deep, the surrounding strata are essentially horizontal. In some cases solution prior to the deposition of the shale has disturbed the immediately surrounding rock. Figure 39 represents the uneven contact between the shale and the Gasconade limestone in the Gageville mine. At the Son mine, a "cap" of Gasconade limestone is present, covering the Coal Measure shale, while in the W. 1/2 of lot 1, N. E. sec. 4, T. 39 N., R. 13 W., a Jefferson City formation ledge overhangs the shale two feet.

On a neighborhood road in the east center of sec. 14, T. 41 N., R. 16 W., the cracks and joints in dolomite beds of the Jefferson City formation are filled with Coal Measure shale. In the south center of the S. E. 1/4 of the N. W. 1/4 of sec. 1, T. 41 N., R. 16 W., in a branch of the South Moreau creek, patches of black shale fill grottoes and joints in the Jefferson City formation.



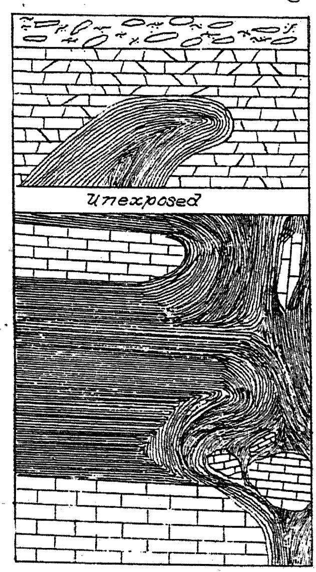
Contact of the Graydon sandstone, and St. Elizabeth and Jefferson City formations in the E. center of sec. 9, T. 42 N., R. 15 W. Scale 1′=165′.

FIG. 49.

Figure 50 was drawn from the south wall of a zinc prospect south of the center of sec. 8, T. 41 N., R. 15 W. The south and west sides of the shaft are formed of shale, while the north and east walls are composed of cotton rock of the Jefferson City formation. The cotton rock near the top of the shaft is somewhat crushed, and embedded in it is a mass of shale. Below the cotton rock, shale, containing boulders of dolomite, is common. In other parts of the shaft, the shale fills joints in the cotton rock.

The typical Coal Measure shale contains some boulders from the surrounding older formations. Those portions immediately in contact with the Cambro-Ordovician rocks seem especially conglomeritic.

The plant fossils which are common in the shale pockets indicate a time break between the deposition of the Cambro-Ordovician series and the Coal Measure shale, covering a portion of the Ordovician and all of the Devonian and Lower Carboniferous ages.



Contact of Jefferson City formation and Coal Measure shale in center of sec. 8, T. 41 N., R. 15 W. Scale 1″=3.5′.

Fig. 50.

Local Unconformities.—The local unconformities present in places at certain horizons in the Gasconade limestone have already been described (See page 42). The unconformity between the Coal Measure shale and the Graydon sandstone has also been mentioned.

SECTIONS ACROSS THE COUNTY.

Plate XV, figures 1-4 are sections across the county along the lines A-G, B-D, C-F and E-H, as indicated on the Geological map accompanying this report.

CHAPTER XII.

DOLOMITE AND CHERT AND THEIR ORIGIN.

DOLOMITE.

As stated elsewhere, there is no pure or even approximately pure limestone in the Cambro-Ordovican formations of Miller county. All are sufficiently high in magnesium carbonate to be classed as dolomite. Moreover the general field relations and the analyses of five typical specimens from about 600 feet of strata indicate that dolomitization was quite general and uniform throughout the entire thickness of these formations. As a recapitulation of what has already been stated in the descriptions of the various formations of this series, it may be said that the dolomites of the older, and therefore the lower, formations are less impure than those of the younger and higher formations. The cotton rock of the St. Elizabeth and Jefferson City formations, which is in many instances almost a calcareous shale, is the most argillaceous of the dolomites. The very fine grained dense dolomite of the St. Elizabeth formation, however, is very free from impurities.

The percentage of magnesium and calcium carbonate in the rocks varies with the amount of impurities. The fine grained, dense dolomite of the St. Elizabeth formation contains the highest percentage and the cotton rock the lowest.

$MgCO_3$ contained in typical samples.

No.		
1.	From Lower Gasconade limestone,	42.34%
2.	From Upper Gasconade limestone,	41.98%
3.	From cotton rock of St. Elizabeth formation,	38.98%
4.	From very fine grained, dense dolomit of St. Elizabeth formation,	44.74%
5.	From typical, heavy, pitted beds of Jefferson City formation,	40.22%

Theoretically pure dolomite contains 54.35 per cent. of $CaCO_3$ and 45.65 per cent. of $MgCO_3$. No. 4 lacks .91 per cent. of containing enough $MgCO_3$ to make it a theoretically pure dolomite, providing it is only composed of calcium and magnesium carbonate and contains no impurities. No. 3, a cotton rock, lacks 6.67 per cent., while Nos. 1, 2 and 5 are intermediate between the two. These analyses are valuable only in that they show quite uniform dolomitization throughout about 600 feet of the Cambro-Ordovician strata in this county. Number 5 was collected from a bed about 600 feet above No. 1, and between the two are beds of chert, sandstone, dolomite and shale.

It is generally held among geologists that dolomite may be formed in two ways,—either secondarily by the replacement of limestone, or directly by chemical precipitation. With the possible exception of the very dense, hard, compact dolomite of the St. Elizabeth formation, it is thought that the dolomites in this county were formed by secondary replacement of limestone.

*There are a number of cases on record where secondary replacement is very clearly the origin of the dolomite. In the north of England and elsewhere the Carboniferous limestone has been altered for a few feet on either side of joint planes into a dull yellow dolomite. Dana** has found elevated coral reefs heavily impregnated with magnesium. †Samuel Calvin and H. F. Bain have traced certain fossiliferous strata from the non-magnesian Trenton formation into the dolomitic Galena formation. In Miller county a few fossils were found which had been entirely altered to dolomite.

The generally very porous character of the dolomite beds is strong evidence that the dolomitization was secondary. It has been estimated that the change from limestone to dolomite implies a decrease in volume, or shrinkage, of about 13 per cent. This shrinkage would largely account for the innumerable small cavities contained in these dolomites.

The fact that dolomitization has occurred throughout all of the Cambro-Ordovician strata of this region, with indications that it was quite uniform, leads one to believe that it occurred practically simultaneous with the deposition of the limestone. Dolomitization was not found to be more pronounced along fault, bedding or joint planes than elsewhere; neither does it stop at shale beds, as usually happens when dolomitization is secondary. Furthermore, it appears that all the dolomitization occurred prior to Carboniferous time, as shown by the non-magnesian Burlington limestone which rests unconformably above the Ordovician rocks.

The cotton rock is a non-porous, soft, argillaceous dolomite, very different from the ordinary pitted, porous type. Although in a few places in the Jefferson City formation, the two apparently grade very gradually into each other, both vertically and horizontally, ordinarily, they are sharply separated from each other. The presence, in the same formation, of

*Text book of Geology, Geikie, 3rd. Ed. p. 321.

**Coral and Coral Islands, by Jas. D. Dana, Dodd, Mead & Co., N. Y. 3rd Ed., 1880, pp. 393-94.

†Iowa Geol. Sur., Geology of Dubuque county, by Samuel Calvin and H. F. Bain, pp. 492-93.

hackly and non-hackly dolomite, brings up the question as to whether or not the dolomitization of the beds occurred in the same way and at the same time. If they were deposited in a similar manner, why should one be porous and break with a hackly fracture, and the other non-porous and break with a conchoidal fracture? It is generally true that there are more shaly partings in the cotton rock than in the other beds, indicating some difference in sedimentation. However, until we have more knowledge of how these rocks were deposited and of the changes which have occurred since that time, the true conditions will remain hidden.

The very hard, dense, compact dolomite in the St. Elizabeth formation may have been precipitated directly from sea waters. We are lead to believe this because of its purity and non-porous texture.

CHERT.

The quantity, distribution, manner of occurrence, and character of the chert of the different formations have already been discussed in connection with the descriptions of the formations, but a brief recapitulation may not be out of place.

Quantity and Distribution:—In the Proctor limestone, Gunter sandstone and the Jefferson City formation, the cherts form but a small percentage of the rocks, while in the Gasconade limestone they comprise from 10 to 15 per cent., and in the St. Elizabeth formation from 15 to 30 per cent. In the few places that the Pacific sandstone was exposed, it was very cherty.

Manner of Occurrence.—Chert occurs either in beds; disseminated through the dolomite and sandstone; or in bunchy masses, either connected or isolated, but usually associated with fine-grained, dense dolomite in the St. Elizabeth formation.

Bedded Chert.—The most persistent chert beds occur in the St. Elizabeth formation. In this formation beds varying from a few inches up to eight feet in thickness can be traced over large areas. The heavy beds invariably present a crushed and brecciated appearance while the thin beds are but slightly fractured.

In the Gasconade limestone the chert beds seldom exceed two and a half feet in thickness and only three or four of these could be recognized over large areas. A great many of the beds are discontinuous, grading gradually into cherty dolomite and finally into dolomite. In the Proctor limestone there are occasional thin layers of chert, but these are not common. The beds of chert in the Jefferson City formation are ordinarily thin, and are mainly nodular, being limited to the shale or cotton rock. The nodules have various shapes and sizes and are usually connected by a thin sheet of banded chert of the same character.

The bedding planes separating the chert beds from the dolomite are always sharp and distinct, and seldom to any degree undulating except in the case of the nodular chert beds above described.

Irregularly Disseminated Chert.—A large part of the chert in the Gasconade limestone belongs to this class. (See page 36). It also occurs in the St. Elizabeth and Jefferson City formations, but not so abundantly. In the Gasconade limestone it varies from irregular fragments a fraction of an inch in diameter, to large, irregular seams several feet in length branching out in every possible direction. (See figures 5, 6, 7 and 8). The line of separation between the dolomite and these chert nodules is often very obscure, because the two usually grade into each other.

PETROGRAPHICAL CHARACTERS.

Thin sections of a few of the Cambro-Ordovician cherts were studied under the microscope. This study showed all of the cherts examined to be cryptocrystalline and of a chalcedonic nature. A majority of the sec--tions showed the chalcedony to be spherulitic. Where the spherulites are above the average size the chert is oölitic. In some oölitic chert specimens the nuclei of the oölites were grains of quartz around which silica had been deposited. In a section of an oölitic specimen from the Jefferson City formation, the necleus of one of the oölites was triclinic feldspar.

ORIGIN OF THE CHERT.

There has been considerable diversity of opinion regarding the origin of chert. Some geologists have held that it is of organic and others that it is of chemical origin. Sollas, describing the flints of Trimingham Chalk, believes them to be of organic origin.* Hinde found the chert beds of Axel Island, which are 260 meters thick, to be of organic origin.** Dr. C. R. Keyes states that the Lower Carboniferous cherts of Northeast Missouri are secondary, being siliceous concretions formed long after the original deposition of the beds.† Hovey believes that the cherts of the the Lower Silurian and Lower Carboniferous formations of northern and southwestern Missouri are chemical precipitates, either at the time of the deposition of the strata in which they occur or before their consolidation.†

Concerning the source of the silica forming the Trimingham chert, Sollas‡ states that it was derived from dissolved siliceous organisms.

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*Monograph, XXX, U. S. G. S., p. 18.
**Monograph, XIX, U. S. G. S., p. 252.
†Lead and Zinc Deposits of Missouri. Winslow, p. 733.
‡Loc. cited, p. 20.

Messrs. Murray and Renard* hold that pelagic organisms which secrete silica obtain it from the hydrated silicate of alumina or clay held in suspension, as well as from silica held in solution and, in case of siliceous sponges rooted for the most part in oozes and clay, from the silica in solution in sea water. Prof. Prestwich** states as his opinion in regard to the cretaceous flints of the chalk formation that silica in the colloidal or soluble state was present as a chemical precipitate in the mud of the chalk seas, and that, the colloidal silica having a strong affinity for other forms of silica, gelatinous substances (like the sarcode of sponges and other foreign bodies), aggregated about sponge spicules replacing the sarcode as they decayed, and about the tests of echinoderms and the shells of mollusks. The irregular masses thus produced continued to grow so long as there was any colloidal silica within the range of attraction.

It is now generally conceded that chemical deposits of cherts derive their silica from the circulating underground waters which carry silicic acid in solution.

A great majority, if not all, of the cherts in the Cambro-Ordovician formations in Miller county are of chemical origin and are secondary after dolomite. Some of the chert of the St. Elizabeth formation, from its manner of occurrence, is probably original, either through direct chemical precipitation or through organic agencies.

The evidence of the secondary origin of much of the chert is so plain that it cannot be doubted. Every gradation between the chert and dolomite has been observed. Nearly all of the fossils in the chert of the Cambro-Ordovician formations originally had calcareous casts which are now silicified and altered into chert. The beds of chert in the Gasconade limestone, for example, are not only between beds of dolomite, but their structure indicates that they are secondary after dolomite. In the same way some of the thinner basal beds of the St. Elizabeth formation in the southeast part of the county have exactly the same structure as the beds of somewhat cherty dolomite, directly associated with them. For some of the chert the evidence of secondary origin is not so clear.

The secondary cherts were formed through the action of circulating underground waters, through which the dolomite was replaced by silica. While the silica which replaced the dolomite was probably mainly derived from the quartz in the different formations, the original source of some of the silica was probably the chert which was deposited simultaneously with the dolomite.

Although the texture and structure of the rocks were to a great ex-

*Monograph XXX, U. S. G. S., p. 20.

**Lead and Zinc Deposits of Missouri. Winslow, p. 732.

tent influential in determining the position of much of the secondary chert, original siliceous masses in the rock undoubtedly have determined the position of many of the chert bodies as they occur today.

Mr. Bailey Willis has suggested that certain thin beds of dense, vitreous, oölitic chert in the upper portion of the St. Elizabeth formation are probably secondary after arenaceous dolomite.

There are two kinds of oölitic chert, that in which the oölites are of rounded grains of sand, and that in which they are of spherulitic chalcedony. The spherulitic, oölitic chert is found mainly south of the Osage river in the upper beds of the Gasconade limestone. The nucular, oölitic chert was formed when the sandy dolomite became silicified, the sand grains acting as centers about which the silica seggregated.

Probably all of the nodular chert is secondary after dolomite. Some of the nodules consist of alternating layers of siliceous dolomite and chert or alternate layers of variously colored chert, all of which points to its secondary origin.

Until evidence to the contrary is found, the heavy brecciated chert beds found so generally at the base of the St. Elizabeth formation, and the bunchy masses of cherts so common throughout the entire formation, will be considered, in part at least, original.

The heavy brecciated chert beds which are typically exposed at the mouth of Sugar creek in township 41 north, range 12 west, and in sec. 3, T. 41 N., R. 15 W., have a thickness of from 20 to 40 feet, and show absolutely no evidence of being secondary after dolomite. Dolomite is in no way associated with these beds either in isolated fragments in the beds or otherwise. There are no gradational phases, and no fossils of calcareous organisms were found. The great uniform thickness and persistence of these chert beds is additional evidence of their organic origin. They may represent the accumulation of vast numbers of siliceous remains of sea organisms but evidences of these remains have been entirely obliterated through subsequent solution, deposition and recrystallization.

Resumé.—From what is said above it will be easily inferred that a large part of the chert is thought to be secondary. The silicified casts of gasteropods and the gradations between chert and dolomtie clearly prove this in many cases. Although the heavy brecciated chert beds at the base of the St. Elizabeth formation may be secondary, the evidence at hand points most strongly to their being of organic origin, i. e., original.

CHAPTER XIII.

ECONOMIC CONSIDERATIONS.

BARITE.

Barite, or barium sulphate, ($BaSO_4$), in this county is commonly called "tiff" by the miners, while the mines or "diggings" are known as "tiff banks." This mineral occurs in all parts of the county either in crevices and cavities in the rock or as fragments in the residual clays. The latter deposits have been the source of nearly all the barite shipped from Miller county. In the "tiff banks," it is mainly concentrated next to the underlying country rock, although small pieces are scattered through the clay. Although the largest prospects occur in clay resting on the Gasconade limestone, it is evident from the rock fragments attached to the barite that at least a part of it has been derived from the once overlying St. Elizabeth formation. Barite was found in place in the Gasconade limestone and the St. Elizabeth, Jefferson City and the Coal Measure formations.

Galena, blende and calcite are the most commonly associated minerals, although pyrite, chalcopyrite, limonite, azurite and malachite are of frequent occurrence. While calcite at times occurs with the barite in the clay, it is more often represented by casts of the typical scalenohedral and rhombohedral forms. Pyrite and limonite frequently occur as long pencil-like stalactites embedded in barite. The barite is, in many instances, of two generations, an older, which is granular or crystalline, and a younger, which is well crytallized. Both generations are apparently younger than the associated minerals.

The Seigel Martin "tiff bank" located in the N. W. ¼ of the N. E. ¼ of sec. 12, T. 40 N., R. 16 W., on the top of a high bluff overlooking the Little Gravois creek, is a type of the "tiff banks" of Miller county. In this bank the barite occurs in reddish clay overlying the Gasconade limestone and is about 40 feet from the top of the formation. Nearly all the barite is seggregated in the two feet of clay immediately above the rock. It occurs in more or less rounded masses of the crystalline variety. The surfaces of the fragments are usually stained red with iron oxide, but the interior is white. Some bluish colored crystals with inclusions of small hematite and malachite crystals were observed. Brecciated, oölitic chert from the St. Elizabeth formation, in which the fragments are cemented with barite, occurs in the clay. Crystals and casts of crystals of calcite are common in the barite.

The barite in this county is usually mined at odd times by the farmers. The strip pit method is employed in mining and the cleaning is done by hand. The product is mainly sold to local merchants who ship it to St. Louis. Although one of the most abundant minerals in Miller county, it is being mined very little.

BUILDING STONE.

Excellent building stone for rough masonry abounds in Miller county. The wide distribution of good rock, coupled with the thinness of the soil, accounts for the numerous small quarries and the absence of any large ones. With a greater demand for substantial buildings and the introduction of better railroad and highway facilities, Miller county might become a considerable producer of dimension stone.

There are many horizons in the Gasconade limestone, in different parts of the county, from which stone of good quality for foundations, bridge abutments, and other rough masonry can be obtained. A careful selection of the quarry site would insure a coarse grained, even textured dolomite free from flint and of a pleasing white or drab color. Blocks eight to fifteen feet long and fifteen to twenty inches thick are obtainable. Two well developed sets of joints, one striking a little north of east and the other west of north, will greatly facilitate quarrying. That the stone is durable is indicated by the hard, rugged character of the outcrops.

William Whetnall operates a quarry in the Gasconade limestone in the N. E. ¼ of sec 5, T. 39 N., R. 14 W. The quarry has a ten-foot face and is 60 feet long. Two beds are quarried, the upper of which is 20 inches thick. With the exception of an occasional dark gray chert nodule, the stone in this bed is a compact, coarse grained dolomite. The lower bed is 30 inches thick and the stone is harder and more compact than in the upper. Six inches from the top there is a thin seam of black chert. The joints strike N., 85° W. N. and S., and are sufficiently far apart to permit the quarrying of blocks over 12 feet long. Both layers have a pleasing drab color and work well under the hammer. The stone is used chiefly for tombstones and fire places.

On the north side of the Osage river the St. Elizabeth formation contains very little stone suitable for constructional purposes, while on the south side sandstone of good quality can be obtained. It has been quite extensively quarried in the vicinity of St. Elizabeth. The new Catholic church at this place is being built of sandstone obtained from a quarry in the N. W. ¼ of sec. 32, T. 41 N., R. 12 W. A lower bed eight inches thick and an upper one three and a half feet thick are being quarried. The color varies from white to reddish brown. In places it is fine grained and in others coarse grained. Some of it is soft and friable, but most of it is hard and compact. The sandstone of the St. Elizabeth formation varies, within short distances, in iron content, in size of the grains and in compactness.

The Jefferson City formation furnishes two different stones which are used for building purposes, the "cotton rock" and the massive, pitted dolomite.

The "cotton rock" has been used extensively as a building stone throughout central Missouri. It is a compact, fine grained, argillaceous dolomite, having a white or cream color. It is soft and can be cut and dressed very easily. This rock occurs abundantly in the extreme northern and southern portions of Miller county where it is quarried on a small scale. When newly laid it has a pleasing appearance, but weathering has a tendency to open up the stratification planes with the result that layers scale off. Iron pyrites is a common impurity, and frequently through decomposition it produces brown streaks and patches.

The pitted dolomite beds occur in many parts of the county and constitute an excellent source of supply for rough dimension stone. The numerous cavities and occasional siliceous patches render it unfit for hammer dressed work. The rock is medium to coarse grained, and is strong and durable. It can be obtained in large blocks, and is well adapted for heavy foundation or footing purposes.

Small deposits of travertine or so-called Mexican onyx occur in many of the caves in the county, but no attempt has yet been made to market it. On the McDonald property in sec. 22, T. 40 N., R. 13 W., two shafts 15 feet apart reached a deposit of travertine filling a crevice 2½ feet wide in the upper beds of the Gasconade limestone. Some of this onyx is white and takes an excellent polish. Finely banded red, brown and yellow onyx also occurs. Near the McDonald deposit there is a cave in which the onyx occurs in the form of stalactites.

CEMENT.

Up to the present time no cement has been manufactured in Miller county. There is a bare possibility that certain strata in the Cambro-Ordovician formations might be used for the manufacture of natural hydraulic cement. However, the dolomites thus far examined contain too much magnesium to fit them for this purpose.

Although the Upper Burlington limestone and Coal Measure shale may in some places constitute excellent materials for the manufacture of Portland cement, they have not been found together in sufficient quantity to warrant the erection of a cement plant.

CLAY.

Both residual and transported clays occur in Miller county. The residual and stream clays will probably never be used for making anything but common brick. The Coal Measure shale, while equally good for brick, is also adapted for tile and some of the common grades of pottery. It may in places be suitable for vitrified and refractory wares.

The brick in the Iberia Academy building were made out of clay obtained in the western part of the village near the head of Lenox branch. This clay is residual from the dolomite of the Jefferson City formation.

In a gulch along the section line, one-fourth of a mile south of the northwest corner of sec. 14, T. 38 N., R. 13 W., is an exposure of white clay originating from the decomposition of calcareous shales near the base of the Jefferson City formation. In the creek just north of Brumley is a similar bed of clay resulting from the decomposition of the shales of the St. Elizabeth formation.

In sec. 20, T. 40 N., R. 14 W., on the bank of Lick creek, a bed of clay 100 feet long and 20 feet thick is exposed. This is in the river bottom, and therefore its areal extent could not be determined. This clay is plastic, has a brown color, and ought to make good brick. In other localities in the bottom land of the Osage river, transported clays suitable for brick probably occur, although they were not observed.

The clays and shales of the Coal Measure shale pockets are the highest grade clays in this county. They are variable in composition, the lime, sand and kaolin content changing rapidly from one depth to another in the same pocket.

At Mr. Henry Carrol's, in sec. 14, T. 38 N., R. 13 W., a grayish white shale having a considerable degree of plasticity occurs. At the Robinet Mines, 300 yards north of the center of sec. 32, T. 39 N., R. 14 W., a similar shale was observed. At Joseph Cotton's, in the south center of the N. W. ¼ of the N. E. ¼ of sec. 3, T. 41 N., R. 16 W., a greenish, fine grained, rather plastic shale occurs. Henry A. Wright sunk a shaft in the northeast corner of sec. 25, T. 42 N., R. 14 W., passing through white and gray shale banded with red and black. These shales have considerable plasticity and are fine grained. This pocket is less than 100 feet in diameter. In the S. W. ¼ of the N. E. ¼ of sec. 27, T. 41 N., R. 16 W., on the bank of a tributary of the Little Gravois, decomposed Coal Measure shale is exposed for 100 feet. It has a gray color and is very plastic. In the S. W. part of the S. E. ¼ of the N. W. ¼ of sec. 11, T. 41 N., R. 16 W., G. W. Shelton has a prospect from which a yellow, unctuous, plastic clay is obtained. Blue Coal Measure shale occurs in the north center of the N. E. ¼ of sec. 15, T. 42 N., R. 14 W. It is unctuous and reasonably plastic.

Small lenses of plastic gray shale occur interbedded with the coal at McClure's coal bank. At the Republic coal mine, a two and a half foot bed of shale lies nine and a half feet above the coal. This shale when fresh is yellow to black in color. Limb like masses of pyrite and limonite 1 to 2 inches long and ½ inch in diameter are disseminated through it. In the N. W. ¼ of sec 7, T. 41 N., R. 13 W. occur two small gulches on the sides of which fine grained, plastic, gray colored clay is exposed. The clay was too poorly exposed to determine whether it is Coal Measure shale, somewhat decomposed, or residual clay from the Jefferson City formation.

COAL.

From the earliest times, geologists have recognized and reported the true nature of the coal deposits of Miller county. Henry King,* who passed up the Osage river in the fall of 1839, writes in regard to these coal deposits: "It is necessarily very limited in its extent and should not deceive those interested into any false hopes or great expense in its exploration. I deem this caution the more necessary as I have already seen persons ignorant of the subject imposed upon by its spacious appearances." Swallow,** Meek,*** Potter† and Winslow,‡ all speak in similar terms concerning this coal.

For local needs the coal is valuable, but the supply is totally inadequate to warrant the erection of extensive coal mining plants.

The geology and location of the chief pockets in Miller county have been described in connection with the Coal Measure shale.

The Republic coal mine, formerly known as the Barnard coal bank, was first worked in the eighties, the product being largely consumed in the immediate locality, although some coal was shipped to Jefferson City. In the fall of 1901, the Republic Coal company of Chicago constructed a spur from the Missouri Pacific tracks to the mine and installed an expensive conveyor. In the spring of 1902, the mine was abandoned.

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*Report of a Geological reconnoissance of that part of the State of Missouri adjacent to the Osage river, made to Wm. H. Morrell, chief engineer of the state, by order of the Board of Internal Improvement, by Henry King, M. D. Geologist, president of the Western Academy of Natural Science, etc., etc.

**First and second annual reports of the Geol. Sur. of Mo., G. C. Swallow, State Geologist, Jefferson City, 1855, p. 134.

***Ibid (Moniteau county), p. 112, also reports of the Geol. Sur. of the State of Missouri, 1855-71, p. 133.

†Geol. Sur. of Mo. Iron Ores and Coal Fields, 1872, p. 281.

‡Preliminary report on coal, Mo. Geol. Sur., 1891, p. 171.

McClure's coal bank was opened fifteen or sixteen years ago, and has supplied about 150 tons of coal to the blacksmiths of the neighborhood and to stores at Eldon and Aurora Springs. Mr. McClure's prospect, which is located in the southwest corner of the S. E. ¼ of sec. 12, T. 41 N., R. 16 W., was opened up some thirty years ago. The one in the east center of the N. W. ¼ of the N. W. ¼ of sec. 13, T. 41 N., R. 16 W., was worked before the Civil War, the product being used by the neighboring blacksmiths. Other localities in which coal has been found are as follows:

In a prospect hole on Blyth's fork, one half mile southwest of Olean.

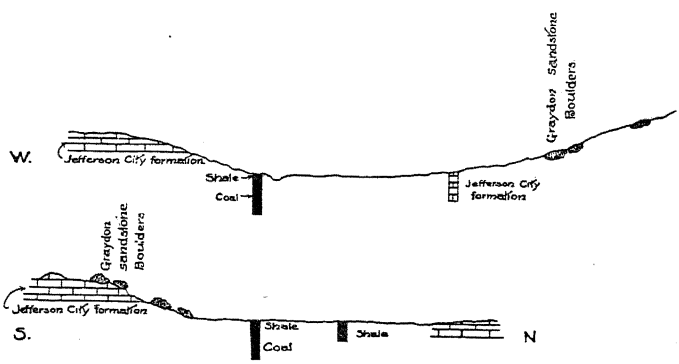
In the bed of a small branch of Saline creek in the S. W. ¼ of the N. E. ¼ of sec. 35, T.42 N. of R. 14 W., on James Miller's land. The opening which was made here is now filled. On the dump is a badly decomposed bituminous substance reported to be bituminous coal.

In the N. E. ¼ of the S. E. ¼ of sec. 2, and three-eights of a mile north of the southeast corner of sec. 2, T. 41 N., R. 14 W., are old prospects from which coal is reported. At present the rock on the dump is too badly decomposed to determine its exact character.

In the southwest corner of the S. E. ¼ of the N. E. ¼ of sec. 18, T. 41 N., R. 15 W., on Mr. Bunch's land, a prospect is reported to have penetrated 13½ feet of coal and not to have reached bottom.

Mr. G. W. Shelton reports 6 to 8 feet of bituminous coal and an unknown thickness of cannel coal in a prospect near the center of sec. 11, T. 41 N., R. 16 W.

In the N. E. ¼ of the S. W. ¼ of sec. 11, T. 41 N., R. 16 W., in a prospect on a branch of Indian creek, the Simmons heirs have 6 feet of coal at the bottom of a shaft. Fig. 51 shows two cross sections of this prospect.



Cross sections of Simmons heirs coal prospect. Scale 1″=200′.
FIG. 51.

Coal, badly decomposed, lies on the dump of a prospect in the N. W. ¼ of the N. E. ¼ of sec. 17, T. 41 N., R. 15 W.

Thirty-five feet of coal is reported in a prospect in the south center of sec. 31, T. 42 N., R. 15 W., on H. N. Knowall's land in the South Moreau valley. Some coal has been mined at this place and sold in Eldon. The prospect is now abandoned.

Impure coal and bituminous shale were observed on a dump located west of the center of the S. E. ¼ of sec. 31, T. 42 N., R. 15 W.

In the north center of the S. W. ¼ of sec. 3, T. 41 N., R. 16 W., badly decomposed coal occurs in Coal Measure shale. The quantity of coal is not great.

Coal occurs on the dumps of several small prospects in the south center of sec. 11, T. 38 N., R. 14 W.; also in the W. ½ of lot 1 N. E., sec. 3, T. 39 N., R. 13 W.

Coal is reported in the following wells:

T. W. Cotton, N. W. ¼ of sec. 11, T. 41 N., R. 16 W.; Mrs. Martha Babcock, west center of S. W. ¼ of the S. E. ¼ of sec. 16, T. 41 N., R. 15 W.; Mrs. Boan, east center of S. W. ¼ of sec. 17, T. 41 N., R. 15 W.; C. H. Coykendall, near center of sec. 17,

T. 41 N., R. 15 W.; James L. Jobe, one-eighth mile west of the center of sec. 11, T. 41 N., R. 16 W.

In Iberia, T. B. Garner reports a thin seam of coal at 23 feet, and a 6½ foot seam at 53 feet. In Ramsey's well, at the same place, a six foot vein of coal is reported.

The above list includes nearly all the places at which coal was observed or where there is good reason to believe that it exists, and there is no evidence to warrant the belief that any of the deposits are very extensive. The exposures of Cambro-Ordovician dolomite are usually so near the coal that the diameter of the Coal Measure areas cannot in any case exceed a few hundred feet and, in most cases, less than a hundred. The chances are that the intercalated shales of the Jefferson City formation may have been in some instances mistaken for Coal Measure shale in some of the wells enumerated.

The coal is relatively light in weight and is much jointed, in consequence of which there is considerable waste in mining. The best grade of coal from the pockets is said to be an excellent steam coal.

The localities at which cannel coal has been found are enumerated on pages 103-105. The deposits are as limited in area as are those of bituminous coal.

The area in the west central portion of the north half of Miller county which is mapped as undetermined Jefferson City Coal Measure strata doubtless contains some coal pockets hidden beneath the chert covered hills. However, these pockets cannot be expected to be of greater areal extent than those already discovered.

There appears to be no evidence to support the theory that the prairie land to the north of the hill country is underlain with a continuous bed of coal. There is no evidence of coal except such as may occur in occasional pockets.

GAS AND PETROLEUM.

The conditions for the origin, storage and preservation, of these fuels do not exist in this county, and the presumption is altogether against their occurrence.

GOLD AND SILVER.

The visitor to Miller county everywhere hears rumors of gold and silver discoveries. The belief in the existence of these metals in Miller county can be traced to four sources: (1) to the finding of iron pyrite which bears a slight resemblance to some gold ores; (2) to the tradition of rich silver mines once worked by the Indians and Spaniards; (3) to the reports issued by unreliable assayers; and (4) to the so-called Colorado "miner" and the "divining rod expert." Iron pyrite is not gold and of itself has no value except when it occurs in large quantities; the tradition of silver mines is indefinite and unreliable; the value of assays depends upon the reliability of the assayer; and "divining rod experts" should be avoided as unreliable. Gold and silver ores very rarely occur in any rocks except such as have been modified by igneous intrusions. There is very little, if any, probability that these ores occur in Miller county.

IRON.

Nason,* in his report on the Iron ores of Missouri—included Miller county in the so-called Osage district. All of the iron ore in this county with the exception of a few scattering boulders of limonite, occurs south of the Osage river. Although found in many localities, the largest deposits are in townships 39 and 40 north, ranges 12 and 13 west.

HISTORY OF IRON MINING IN MILLER COUNTY.

Very little could be learned of the history of iron mining in Miller county. Iron deposits were known to exist in this and neighboring counties at a very early date. The earliest mention of the deposits in Miller county was made in Meek's† report. At the time Meek made his survey of Miller county, Mr. Charles Sample, of St. Louis, had dug a number of shallow pits in limonite deposits in secs. 15, 22 and 23, T. 40 N., R. 13 W. Besides the deposits in these localities Meek observed others of considerable size elsewhere in the county.

About ten years after the close of the Civil War, and shortly after the publication of Meek's report on the Geology of Miller county, and that of Adolph Schmidt** on the Iron Ores of Missouri, there was a boom in iron mining in Miller county, as a result of which a number of new banks were developed. The mining was carried on by large outside corporations, who prospected the southern part of the county very thoroughly. Innumerable shallow pits were dug, but in not more than a dozen localities were the deposits considered important enough to work. Statistics as to the output of the various banks could not be obtained. It is known, however, that some of the ore was carried by wagon to the railroad at Hancock and Dixon, and some was hauled to Capps and shipped by boat down the Osage river. At several of the "banks" the ore was never moved from the dump piles. Considerable of the ore hauled to Capps was never shipped and may be seen today in piles near the steamboat landing.

Mining was carried on more or less spasmodically for a period of five years, when it was entirely abandoned. Since that time scarcely any

*Nason, Frank L. Report on Iron Ore of Missouri, p. 174.
†Geol. Sur. of Mo., 1855-71, p. 112-34.
**Geol. Sur. Mo., 1879.

attempt has been made to develop these properties, although several new ore bodies have been located. Poor transportation facilities, combined with the discovery of enormous deposits of iron ore in the Lake Superior region, are the most potent reasons for the cessation of iron mining in the county.

CHARACTER OF THE ORE.

Hematite and limonite are the two important iron ores of this county. The hematite occurs as soft red, hard red and blue specular ore. The latter is very finely crystalline and frequently contains small cavities nearly filled with tiny crystals of quartz. The limonite occurs mainly as the peculiar "pipestem" ore which occurs as boulders strewn over some of the ridges and as massive and reniform deposits in the rock. No large bodies of the pipestem ore were observed in place, although Meek* observed it in situ in the Sample mine in sec. 23, T. 40 N., R. 13 W. This ore consists of long slender tubes, resembling very closely stalactites or stalagmites. These tubes are frequently united in a signle mass having a roughly cylindrical shape, and are from one to fifteen inches in diameter. Sometimes they are so united as to form a nearly solid mass but more often each pipestem preserves its individual shape. Pyrite, marcasite and the copper carbonates, malachite and azurite are often associated with the limonite.

METHOD OF OCCURRENCE.

The iron ores occur as loose boulders, lying on the slopes or tops of ridges; as residual masses, in clay, a few feet below the surface of the ground; as pocket like deposits in the rocks: and occasionally as thin beds between horizontal strata of dolomite.

DISTRIBUTION OF THE ORES.

The limonite is closely associated with chert and dolomite, while the hematite, with few exceptions, occurs with either Ordovician or Carboniferous sandstone. A greater part of the limonite, both in "situ" and as boulders, occurs in the region along the Osage river, which is very largely underlain by Gasconade limestone. The amount of hematite in this region is small compared with the limonite. While there are no known deposits of iron ore in the Jefferson City formation, in this county, there are numerous boulders of limonite and specular hematite scattered over the ground which it underlies. In the southeast part of the county, where the Bolin creek sandstone member has its greatest development and where nearly all of the larger deposits of hematite are located, very little limonite has been found.

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*Mo. Geol. Sur., 1855-71, p. 130.

DESCRIPTION OF IRON BANKS.

The McDonald Bank No. 1.—This bank includes a number of small pits in a large sink hole in the upper part of the Gasconade limestone, in the southeast corner of S. W. ¼, sec. 15, T. 40 N., R. 13 W. The ore is mainly limonite, although some hematite was observed. The limonite occurs either as a cement binding the brecciated chert beds, or as small beds or lenses. Very little ore was observed except what was exposed on the dump pile. This consisted of limonite, some pyrite and occasional boulders of pipe stem ore.

McDonald Bank No. 2.—This bank is located in the S. W. ¼ of sec. 23, T. 40 N., R. 13 W., at the contact of the Gunter sandstone and the Gasconade limestone. The pit is 60x45x8 feet. The limonite occurs as a horizontal ledge having a maximum observed thickness of 5 feet. In places it is apparently much thicker. The limonite is porous and the cavities contain soft yellow rust and thin streaks of marcasite. The surface of the limonite often shows the crystal forms of marcasite, of which it is probably an alteration product.

Lambert Iron Bank.—This bank is located on Brushy Fork, in the W. ½ of lot 1 N. W., sec. 5, T. 37 N., R. 13 W. The ore is massive mamillary or soft hematite and underlies about an acre of ground. It occurs near the bottom of the St. Elizabeth formation and is associated with steeply dipping beds which are suggestive of faulting. Crystals of quartz and calcite are scattered abundantly through the ore.

Bond Iron Banks.—These banks consist of two pits located in carboniferous sandstone on the N. E. ¼ of sec. 15, T. 39 N., R. 13 W. The ore is a soft red, greasy hematite, some of which is suitable for mineral paint. The hematite in some cases has a radiating structure, and all of it is so impregnated with calcite that it effervesces freely. In the center of some of the pieces of soft red hematite were found small pieces of hard blue specular ore. Minute cavities in the ore are commonly lined with tiny crystals of quartz or hematite.

These iron banks in Carboniferous sandstone are surrounded with beds of sandstone, chert and dolomite, belonging to the St. Elizabeth formation. Except south of the banks, where there is a dip of 30°, N. 25° E., the beds of the St. Elizabeth formation are horizontal.

Bolin Creek Bank.—This iron bank is located in the S. W. ¼ of sec. 15, T. 39 N., R. 12 W. The ore consists of residual boulders of hard siliceous hematite embedded in the greasy, red clay of a sink hole in the Bolin creek sandstone. The clay is sometimes used by neighboring farmers as a substitute for paint. The sandstone in which the deposit occurs is deeply stained by limonite.

Miscellaneous.—Besides the above mentioned banks there are two others, located respectively in the S. E. ¼ of the N. E. ¼ sec. 14, T. 38 N., R. 12 W., and in the N. E. ¼ sec. 26, T. 39 N., R. 12 W. At both places the ore is hematite, and occurs in the Bolin creek sandstone. There are numerous other places in the county where undeveloped deposits of iron ore occur, the locations of which are shown on the economic map accompanying this report.

ORIGIN OF THE IRON ORES.

There are two factors of primary importance in the genesis of the iron ores of this region. These are (1) the structure of the strata in which they occur, and (2) the influence of the wall rock. All of the deposits are in areas of folding, brecciation or sinks due to the solution of the underlying rocks. These structures combined with the porous nature of the various formations would afford a very free underground water circulation along definite channels. The limonite occurs only in the limestone and chert, while the hematite is confined to the sandstone either of Carboniferous or Silurian age.

The original source of the iron was probably in the various formations, in which the iron was disseminated in small amounts in the form of the carbonate or the sulphide, though probably the former. As the genesis of the limonite and hematite is different they will be treated separately.

Limonite.—The limonite deposits are all secondary after pyrite or marcasite which were largely replacement products of dolomite and chert. Some, however, as shown by their stalactitic and stalagmitic forms, were deposited in caves or caverns. The iron disseminated in the formations was taken into solution by percolating waters, probably as the carbonate or sulphate. These waters converged into definite and favorable channels and, meeting with reducing agents such as H_2S or carbonaceous material the iron was precipitated as the sulphide. Often the dolomite and chert were dissolved simultaneously with the precipitation of the iron sulphide. Later as oxidizing waters from the surface became dominant the sulphides were changed by oxidation into limonite.

Hematite.—The sandstone in which the hematite occurs differed from the dolomite and chert, in that it contained but little carbonaceous or reducing matter and afforded a nearly direct water course for descending oxidizing waters. The iron of the present deposits was probably derived by the leaching out of the iron contained in the sandstone near the place where they now occur. In two or three of the iron banks the sandstone on either side of the deposit had been thoroughly leached of its iron content and was nearly pure white, while further away it resumed its normal reddish brown color. Descending waters, charged with organic acids, taking the iron in solution, probably as the carbonate, were converged into the sinks and sharp troughs of synclinal folds, and there the addition of oxidizing waters precipitated the iron according to the following reaction.

$$2FeCO_3+O_2=Fe_2O_3+2CO_2.$$

LIME.

Up to the present time, lime burning in this county has been carried on in a very primitive manner. In the rural districts each farmer makes his own lime by heaping and burning together wood and limestone boulders which have been covered with earth and sod. Sometimes a hole is dug in the hillside and in this the lime is burned.

The dolomite of the Cambro-Ordovician formation and the non-magnesian limestone of the Upper Burlington are both suitable for the manufacture of quick lime.

The pitted, massive dolomite beds of the Jefferson City formation and the massive beds of the Gasconade limestone are fairly well adapted to the manufacture of lime. At Jefferson City, Cole county, the heavy pitted dolomite of the Jefferson City limestone is used extensively for the manufacture of lime. It is said, however, that, outside of Jefferson City, this lime, probably on account of its color, is unable to compete with the lime produced from the Upper Burlington limestone. Lime made from dolomite is dark colored and slow to set, but it is claimed to be especially strong after hardening.

The areal extent of the Upper Burlington limestone in Miller county is indicated on the general geological map. Its thickness is variable and owing to the poor exposures the quantity can only be determined by drilling.

Mr. J. E. Sullen has operated a kiln in the center of sec. 26, T. 42 N., R. 14 W., intermittently, for eight years. He states that during this time he has sold $525 worth of lime, of which nearly one-half was produced in 1900. The entire output was sold to farmers and towns people in the immediate vicinity. Abandoned or temporary kilns are found on nearly all the exposures of Upper Burlington limestone. A modern lime kiln, situated on the Chicago and Rock Island railroad, should be able to supply the local demand for lime for at least 100 miles of railroad.

The Upper Burlington limestone produces a very pure, white lime. It is quick setting and slacks rapidly. This is the same kind of stone used for manufacturing the well known Ash Grove lime. Experience at Ash Grove has shown that as a fuel for burning lime, black oak is superior to coal or any other kind of wood.* Black oak abounds in the forests in the vicinity of the Upper Burlington limestone outcrops. The occurrence of good limestone combined with cheap and superior fuel makes this an excellent county for the manufacture of quick lime. However, owing to the limited extent of some of the Upper Burlington limestone areas, the ground should be prospected by drilling before a plant is located.

LEAD AND ZINC.

Miller county is within the so-called Central Missouri lead district. This district, as a whole, has been much less exploited than either the Southwestern or Southeastern, and the product is consequently small.

The greater share of the lead output of Miller county has been mined along the Saline and the North Little Saline creeks, in secs. 2, 5, 8, 10, 11, 13, 14, 23 and 24, T. 41 N., R. 14 W. This area, known as the "Saline diggings," extends four miles east and west, and five miles north and south. Other "diggings" are scattered throughout the county.

HISTORY OF LEAD MINING IN MILLER COUNTY.

Mr. H. M. Breckenridge, Jr.,† was among the first, if not the first writer to mention the occurrence of lead in the region tributary to the Osage river. He says that as early as 1811, hunters reported an abundance of lead in the country adjacent to the Osage river. Soon after this, Schoolcraft** stated that lead had been found in the Osage coun-

*E. M. Shepard, Geol. Sur. of Mo., Vol. XII, p. 209.

†Views of Louisiana, together with a Journal of a Journey Up the Missouri River in 1811, p. 146.

**Schoolcraft, H. R., "A view of the lead mines of Mo.," p. 60-61.

try. Henry King, M. D.,* in his report of 1839 states that lead is found everywhere along the Osage river, and that the Little Tavern, the Saline and the Little Gravois, are among the creeks on which good lead indications exist.

In the fifties, it is said, that the pioneers gathered galena from the creek beds and smelted it in hollow logs to obtain lead with which to make bullets.

Up to the time of Meek's† visit to Miller county in 1855, only a few insignificant prospect holes had been sunk and little or no "mineral" had been produced. He notes the occurrence of galena both in the rock and in the clay at a number of places.§

Capp's diggings are said to have flourished before the war, and enough galena was mined to warrant the errection of a smelter. Temple E. Bell, in 1853, employed two slave miners on the present Loveall tract, but during the war times, active mining was discontinued. Wonderful bonanzas reported to have been discovered were at this time lost, never to be re-found.

Shallow mining began on a large scale in 1868 or 1869. Perhaps the first mining was at the Clay Diggings in the N. W. ¼ of sec. 15, T. 42 N., R. 14 W. The discovery of the Fox Diggings soon followed, and then that of the Curty and Indian Grove Diggings. About this time the Loveall Diggings were re-opened and worked on a large scale. In 1871 or 1872 followed the discovery of the most important producers, known as the Walker, Grass Roots and the Gageville Diggings. All of the galena produced came from the clay and in consequence the cost of mining the ore was very little. The deepest shafts, sunk to bed rock, represented but a half week's work, and the most improved hoist was a portable windlass.

In 1878 the price of lead fell from $5.15 to $3.40 per hundred weight, and lead mining in Miller county became unprofitable. Also about this time Miller county became a center for the production of railroad ties, and the farmer who had formerly employed his winter months profitably in mining, found more lucrative employment in cutting ties. The low price of lead and the abundance of tie timber partially account for the lapse in lead mining in Miller county.

*Report of a Geol. Reconnoissance of that part of the State of Mo. adjacent to the Osage river, made to Wm. H. Morrell, Chief Eng. of the State, by order of the Board of Internal Improvement, by Henry King, M. D., Geologist, Pres. of the Western Acad. of Nat. Sciences, etc.

†Geol. Sur. of Missouri 1855-74, pp. 112-134.

§Ibid 131-132.

SMELTING.

The first lead smelter, of which we have any record, was operated at Capp's before the Civil War. In 1870, a lead furnace was erected on Saline creek one-fourth of a mile north of the northwest corner of sec. 26, T. 41 N., R. 14 W. Soon after, a second furnace was erected on the site of Mr. Greene Blackburn's house in the S. E. ¼ of S. W. ¼ of sec. 23, T. 41 N., R. 14 W. In the fall of 1874, a furnace was built at the Gageville mines on the ridge northwest of the main shaft. In 1881-2, a second smelter was built at Gageville, in the valley south of the main shaft. The ruins of this furnace are still standing. All the others have disappeared.

THE PRODUCTION OF LEAD AND ZINC.

Mr. Winslow* gives the following table of production for Miller county:

Period.	Lead.				Zinc.			
	Ores.		Metal.		Ores.		Metal.	
	Tons.	Values.	Tons.	Values.	Tons.	Values.	Tons.	Values.
Before 1870	100	$6,000	70	$11,900	....	....	....	....
1870-1879	2,000	100,000	1,410	166,380	....	....	....	....
1880-1893	100	4,300	70	5,740	....	....	....	....
Totals	2,200	$110,300	1,550	$184,020	....	....	....	....

Our estimates for the first and the last period are almost identical with Mr. Winslow's. For the production between "1870-1879," our estimate of the output is from 150-250 tons less than Mr. Winslow's. From 1894-1902, the output approximated 160 tons, of which the McBride and Lawson diggings produced 75 tons, the Gageville mines, 27½ tons, and the Loveall diggings, 12½ tons.

During the same period, 3,000 pounds of zinc blende were sold, 2,000 being from the Sight Me prospect.

*Mo. Geol. Sur., Vol. VII, page 526.

The revised table would then read as follows:

Period.	Lead.				Zinc.			
	Ores.		Metal.		Ores.		Metal.	
	Tons.	Values.	Tons.	Values.	Lbs.	Values.	Lbs.	Values.
Before 1870...........	1,000	$6,000	70	$11,900	.. ..	....	....	. ...
1870-1879........	1,850	92,500	1,295	143,900	.. ..	....	....	....
1880-1893...............	100	4,300	70	5,740	....	....	....	....
1894-1902...............	160	6, 880	112	8,467	***3,000	*$49 50	1,800	$82 80
Totals............	2,210	$109,680	1,547	170,007	3,000	$49 50	1,800	**$82 80

*Price taken from ore schedule of the Missouri and Kansas Zinc Miners' Association, adopted Jan. 22, 1900, for 60 per cent. ore, free from iron.

**Value spelter N. Y. C. Average for Dec., 1899, $0.046 per pound.

***Average N. Y. C. price of lead for 1898, 3.78 cents per pounds.

CHARACTER OF THE LEAD ORES.

Galena is the only lead ore which has been mined in Miller county. In some of the mines an impure, nodular cerussite, known as "mineral clinker," has been found. About 400 pounds has been shipped from the Walker diggings.

The galena produced in this county is of a very high grade. Mr. Regis Chauvenet made an analysis of a sample from the Walker diggings for Dr. Schmidt's report† and found only the following percentages of impurities:

Insoluble siliceous matter..	0.15
Iron	0.24
Bisulphide of iron	.51
Zinc	Trace
Silver	None
Copper	None
Antimony	None

Indeterminable quantities of cobalt and nickel are included with the iron. The galena contained about 86 per cent. of lead.

The "soft" lead produced from this ore is in constant demand for metallurgical purposes. Zinc and silver are entirely absent and the iron content is low.

CHARACTER OF THE ZINC ORES.

Up to the present time only three thousand pounds of zinc ore have been marketed from Miller county. All of this was blende.

†Report of the Geol. Sur. of the State of Mo., including Field Work of 1873-74, G. C. Broadhead, State Geologist, Jefferson City, 1874, p. 507.

ASSOCIATED MINERALS.

The associated minerals include barite, calcite, crystallized dolomite, pyrite, marcasite and chalcopyrite.

Barite is by far the most abundant of the associated minerals, while calcite stands next in importance. There is a greater preponderance of barite over calcite in the residual clay than in the rock. At the McBride and Lawson diggings calcite is comparatively common in the rocks, while almost lacking in the clay. At the Fox diggings, it was noted that calcite was more abundant and the pieces of greater size as the rock was approached. This is not true of the barite. This condition is due to the fact that calcite is more readily soluble than barite.

Crystallized dolomite was observed associated with the ore at the Stevens' prospect, but it is not common. Pyrite and marcasite are rarely found with the galena. They occur most abundantly in the Coal Measure shale. Chalcopyrite, and its decomposition products, limonite, azurite and malachite, were noted at several of the diggings, notably the Waite prospect, the Meyer prospect and the Walker diggings.

MODE OF OCCURRENCE.

The ore deposits of Miller county can be divided into (1) disseminated ores, (2) sheets, (3) chimneys, (4) circles and (5) residual ores. The first is characteristic of the Coal Measure shale pockets, the second of the coal and Cambro-Ordovician strata, the next two of the Cambro-Ordovician formations, and the last of the clay overlying the Cambro-Ordovician formations.

Disseminated Ores.—Shale, when deformed through pressure, has a tendency to bend instead of break, and consequently joints or other parting planes sufficiently open for an abundant circulation of water are not formed. Water penetrates the mass much more uniformly than it does the jointed Cambro-Ordovician formations. As a result "pebbles" of zinc blende or galena form wherever the mineralized waters encounter a strong precipitant. These "pebbles" are distributed throughout the mass and are entirely independent of one another.

While disconnected crystals of galena occur along the crevices in the dolomite of the Cambro-Ordovician formations, no true disseminated ores were found.

Sheets.—Sheets are ore bodies whose length and breadth, when lying horizontally, and whose length and depth when standing vertically, are relatively great as compared with their thickness. The ore may completely fill the opening between the walls, and where the country rock is undecomposed the sheet is said to be "tight." The country rock adjacent to the sheet may be badly decomposed, and the galena, broken into pieces, may be imbedded in residual clay.

The horizontal sheets, which are usually located along bedding planes, are of little commercial importance in this county. The galena and zinc blende in the coal occur mainly in horizontal, although sometimes in vertical, sheets.

The vertical sheets, commonly called crevices, are usually in joints which have been enlarged by solution. The formation of joints and their direction and persistence in the various formations have been discussed in another part of this report. (See pages 131-135.) As to the number and direction of the ore bearing crevices in Miller county, the following data may be of interest:

PROSPECTS IN THE JEFFERSON CITY FORMATION.

1 N. -S.-; 2 N.25°W.; 4 from E. -N.82°E.; 1 N.55°E.

PROSPECTS IN THE ST. ELIZABETH FORMATION.

3 from N.70°-80°E.; 1 N.45°E; 1 N.-S.; 1 N.20°W.

PRODUCTIVE (OVER 1,000 LBS.) PROSPECTS IN THE GASCONADE LIMESTONE.

2 N.-S.;- 1 N.5°W.; 2 N.10°W.; 1 N.12°W.; 1 N.25°W.; 2 N.35°W.; 2 N.50°W.; 1 N.57°W.; 1 N.65°W.; 1 N.75°W.; 1 N.78°W.; 1 N. 85°W.; 1 N.89°W.; 2 E. -W.; 3 N.85°E.; 1 N.83°E.; 1 N.80°E.; 4 N.75°E.; 1 N.74°E.; 1 N.72°E.; 4 N.70°E.; 2 N.65°E.; 2 N.60°E.; 4 N. 55°E.; 1 N.45°E.; 1 N.33°E.; 1 N.20°E.; 1 N.12°E.; 1N.8°E.

NON-PRODUCING PROSPECTS IN THE GASCONADE LIMESTONE.

1 N.-S.; 1 N.20°W.; 1 N.25°W.; 1 N.30°W.; 1 N.35°W.; 1 N.80°W.; 1 N.85°W.; 1 E.-W.; 1 N.50°E.; 2 N.45°E.; 1 N.20°E.; 1 N.15°E.; 1 N.10°E.

The observations in the Jefferson City and the St. Elizabeth formations are too limited to generalize upon, although the approximately east and west crevices in both formations are more numerous than those in all other directions. Three of those striking east and west in the Jefferson City formation were obtained from Meek's report.

The data on crevices in the Gasconade limestone are at least abundant enough to make some provisional generalizations. The readings have been divided into two classes, first, those from which 1,000 pounds or more of ore have been produced (Fig. 52), and second, those from which less than 1,000 pounds have been mined. (Fig. 53.) The diagrams are decidedly unlike. Twenty-one of the eighty-two rich crevices strike from E. and W. to N. 60° E. In the same position on the "poor

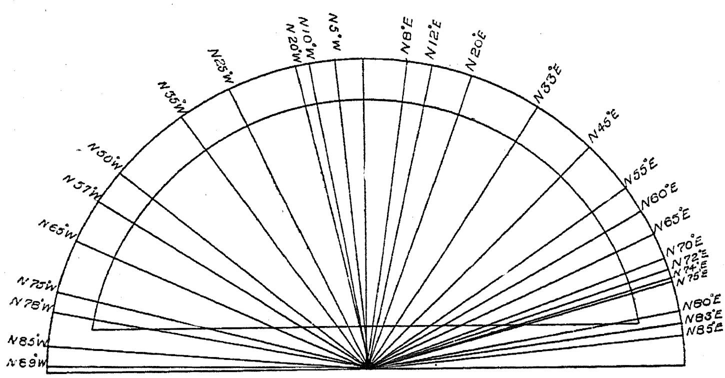

Diagram showing direction and number of crevices in Gasconade limestone which have produced over 1,000 pounds of galena.

FIG. 52.

crevice" diagram, there are no crevices. On both diagrams there are several crevices coursing a little N. of W., but the proportion of those on the "poor crevice" diagram is much greater. One-fifth of the "poor crevices" are within 5 degrees of N. 45° E., while of the rich crevices only one lies between N. 40° E. and N. 50° E. About one-sixth of each set strike from N. 12° W., N. 12° E. It would be well in prospecting for lead in the Gasconade limestone, to pay special attention to those crevices striking between N. 60° E. and E. and W. The richest crevices thus far worked in the Gageville, the Walker and the Grass Root diggings, strike in these directions. The crevices striking or coursing a little west of north are the richer and here again the diagram shows that the rich crevices coursing a little west of north are more numerous than those coursing east of north. Whether or not future developments will bear out these conclusions, time alone can determine.

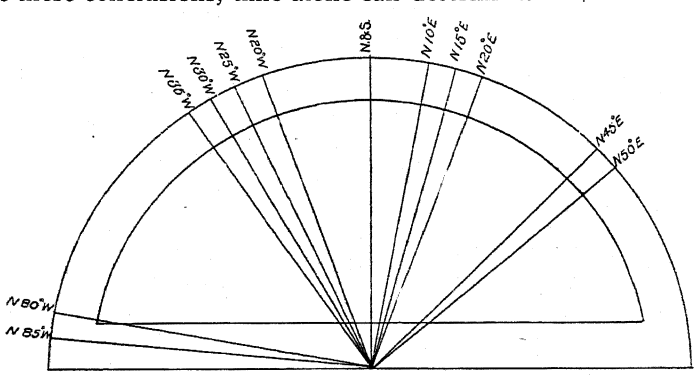

Diagram showing direction and number of non-productive crevices.

FIG. 53.

Chimneys.—Chimneys are more or less conical openings in the rock, which are commonly the upward extention of sheets. They are usually formed at the junction of N. and S. and E. and W. joints and are ordinarily filled with clay. It is of interest to note that the largest masses of galena, which have been found in Miller county, have occurred in chimneys. This finds ready explanation in the fact that such were the natural places for solutions of diverse nature to mingle, causing active local precipitation.

Circles.—Dr. Schmidt considers circles, which are deposits having the shape of truncated cones and in which the galena occurs in seams and fragments in semi-disintegrated dolomite boulders, to have originated "by a gradual disintegration by a vertical water course or spring in the underlying limestone."* There are two circles in Miller county, the Walker mines circle and the Loveall circle. Owing to the fact that neither of these were in a condition to be examined, leaves us without data upon which to draw conclusions as to origin.

Residual Deposits.—In the residual deposits galena is distributed in the clay, especially in that immediately overlying the rock. The galena is more or less rounded, is usually associated with barite or calcite, and streaks are often found which are especially rich. Development shows that these rich streaks correspond to ore bearing crevices in the rocks. The galena in these residual deposits originally occurred in seams in the rock. The disintegration and decomposition of the rock has removed the more soluble constituents leaving the mineral embedded in clay. Crevices, which have been enlarged by solution are frequently found filled with a red, plastic clay. Along the walls and in the lower part of these seams the galena is usually concentrated.

RELATION OF ORE DEPOSITS TO STRUCTURE.

Except in the case of the jointing there appears to be very little relation between the structure and the position of the ore deposits. Ore has been mined both on gentle anticlines and synclines, as well as from horizontal strata.

Brecciation occurs in places, but usually it is unaccompanied by faulting. Apparently the breccias have been formed by solution through which fragments were detached from the sides of the crevice and re-cemented by calcite or barite. No faults of consequence occur associated with the lead mines. In the shale pockets, movement has caused the shale to be slickensided, but the faulting, of which they are evidence, could not be measured.

*Report of the Geol. Sur. of the State of Mo., G. C. Broadhead, State Geologist, Jefferson City, 1874, p. 522.

At Gageville, there is a distinct enrichment of ore in the dolomite above an impervious layer of Coal Measure shale at the 55 foot level. The miners consider the upper surface of both Coal Measure shale and the intercalated shales of the Cambro-Ordovician formations extremely favorable positions for ore. They speak of both shales as "mineral band."

THE GEOLOGICAL DISTRIBUTION OF PROSPECTS.

The Proctor Limestone and Gunter Sandstone.—These formations underlie only a few square miles, most of which area is covered by alluvium. No ore has been reported from either formation.

The Gasconade Limestone.—The Gasconade limestone is very porous and consequently contains many openings in which minerals may be deposited. As the beds of Gasconade limestone are homogeneous and massive, the fractures produced are well defined and continuous.

Out of two hundred and eleven localities, at which galena or zinc blende have been found in this county, one hundred and ten, or over one-half are in the Gasconade limestone. Of these, eighteen are within 25 feet of the contact with the St. Elizabeth formation; in thirty-two cases, the ore continues to a depth of 50 feet below the top of the formation; in thirty-one instances, the ore has been found at a depth of 80 feet, and in fourteen, at a depth of 120 feet. At only three localities was ore found in the lower half (120 feet) of the formation. In eleven instances the occurrence of lead was merely reported and its stratigraphical position was not definitely determined.

In many of these cases the galena occurred in clay which had resulted from the decomposition of dolomite beds above those upon which the clay rests. This fact emphasizes the importance of the upper beds as the ore bearing horizon of this formation, and the almost entire uselessness of prospecting for ores in Miller county below the upper half of this formation at least. In some instances it is very probable that the ore in the clay was derived from the overlying Jefferson City and St. Elizabeth formations. At the Walker and Loveall diggings, galena was found in brecciated, oölitic chert which must have been derived from the once overlying St. Elizabeth strata. At the Gageville mines a very small amount of ore has been found above the lowest bed of the St. Elizabeth formation. The miners call galena in that position "lost mineral."

The richness of the ore in the upper beds of the Gasconade limestone is probably due to the porosity of the lower beds of the overlying St. Elizabeth formation and to the fact that the upper beds of the Gasconade limestone are usually situated well above the level of ground water, the topographical position most favorable to deposits originating largely through downward percolating waters.

The St. Elizabeth formation.—The lithological character of this formation makes it unfavorable to the production of ore deposits of commercial importance.

Thirty occurrences of lead ore, about 14 per cent. of the total number, are located in the St. Elizabeth formation. No zinc blende was observed in the formation. There seems to be no definite or persistent horizon at which the galena occurs.

Five per cent. of the marketed galena of Miller county has come from this formation, and of this amount the McMillan diggings have furnished practically 95 per cent.

The Jefferson City Formation.—Lithologically, this formation, with its alternation of impervious shales and cotton rocks and its relatively pervious sandstones and porous dolomites, is rather favorable to ore deposition. This same alternation, however, would tend to the development of several small ore horizons rather than one large one. The mines at Fortuna, Moniteau county, are in the Jefferson City formation, where the rock is lithologically more uniform.

Prospects are more abundant in this formation than in the St. Elizabeth, thirty-nine being located. Up to the present time, however, the Jefferson City formation has produced less than the St. Elizabeth, its output being but 3 per cent. of the total. The product comes from four or five different diggings showing it to be more widely distributed.

The Coal Measure Shale.—The deposits in the Coal Measure shale are altogether different from those occurring in the Cambro-Ordovician rocks. The ore occurs in four forms: as "pebble" or "strawberry" ore, disseminated throughout the mass of the shale; as a thin layer coating the surface of boulders; filling cavities in boulders; and as thin sheets in the shale, either as lenses or as discontinuous sheets normal to bedding.

The ore is very fine and in the case of the "pebble jack" is beautifully crystallized.

A striking difference between these deposits and those of the Cambro-Ordovician rocks is the preponderance of zinc blende, which in the latter formation is seldom encountered. The shale pockets are too abundant and widespread to be explained by a mere local segregation of zinc salts in the mineralizing solutions. Their wide distribution is shown by the location of the Little Nugget mine, which is in the northeast portion of the county, the Whitaker shaft which is in the south central part of the county, and the McClure shaft which is in the northwest corner. At the Gageville mines no blende is reported from the Gasconade limestone, while in the Coal Measure shale, penetrated by the main shaft, and in a shale pocket in the gulch near the smelter, zinc blende occurs. At the Loveall diggings no blende is reported from the circle in the Gasconade limestone, but in the shale pocket, less than one-fourth of a mile north, blende alone was found. A strong affinity must exist between the soluble zinc salts and the organic precipitant present in the shale pockets.

Calcite and barite occur in the cavities of the boulders included in the Coal Measure shale, although rarely associated with ore. At the Little Nugget mine galena and barite were found coating sandstone boulders.

There are thirty-seven prospects in the Coal Measure shale, of which number fifteen are in coal. Zinc blende is either found alone or associated with lead. Of the twenty-two prospects in the Coal Measure shale, zinc blende occurs in fifteen; galena and zinc blende in five; galena in one and cerussite in one.

PROSPECTS IN THE ST. ELIZABETH FORMATION.

The Crump Diggings.—The Crump lead diggings, located in the S. W. ¼ of the S. E. ¼ of sec. 2, T. 42 N., R. 15 W., are said to have been at one time very productive. The galena occurred loose in the clay, occasionally attached to a fragment of oölitic chert. At the middle of the north line of sec. 11, T. 42 N., R. 15 W., Mr. Tate, of Enon, Missouri, sunk a shaft 100 feet deep. The upper 10 feet of this shaft is in the Jefferson City limestone and the remainder in the St. Elizabeth formation. The shaft at present is abandoned. The rock on the dump has no appearance of being brecciated. Narrow seams in the dolomite showed small particles of galena. In a small clay pocket in the dolomite, a few scattered crystals of blende were noted.

The McMillan Diggings.—The McMillan diggings, more commonly known as the "Hazel Root Diggings," are located in secs. 33 and 34, T. 42 N., R. 14 W. They are situated on a gently sloping hill 60 feet above the base of the St. Elizabeth formation. Calcite and barite are both associated with the galena, being most abundant at the northern end of the diggings. The galena occurred mainly in clay contained in crevices striking N. 70° to 75° E. Schmidt,* who visited the McMillan diggings when they were being worked, from 1870-73, states that dolomite was reached at a depth of from 10-25 feet. The dolomite was much altered and softened and "in places contains thin seams of galena." He places the output at 200,000 pounds.

Tipton's Prospect.—In the east center of the S. E. ¼ of the N. E. ¼ of sec. 14, T. 41 N., R. 16 W., on Little Gravois creek, N. A. Tipton has sunk a ten-foot shaft in the upper twenty feet of the St. Elizabeth formation. At this place the dolomite and flint are somewhat brecciated. Galena occurs as isolated cubes both in calcite and dolomite. In some cases the galena is older than the calcite.

Bunker's Prospect.—In the southwest corner of the N. W. ¼ of the S. W. ¼ of sec. 19, T. 41 N., R. 15 W., blende occurs imbedded in the crevices of a porous, calcite filled dolomite, in a creek bed. Blende also occurs in the calcite and is reported from the clay in that vicinity. Some of the blende has been altered to smithsonite. The main crevices strike N. 80° E. and N. 20° W., the former being the better defined.

C. H. Coykendall's Prospect.—On the Coykendall property in the N. E. ¼ of the S. W. ¼ of sec. 17, T. 41 N., R. 15 W., a ten-foot shaft has been sunk to a depth of 45 feet. The shaft is traversed from north to south by a vertical clay opening 5 feet wide

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*Ibid, page 567.

and 20 feet deep, filled with red clay. Numerous boulders derived from the country rock are imbedded in the clay and partially rounded by solution. Other seams branch off from this main one and each is filled with clay and boulders. The galena occurs either loose in the clay or filling cracks in brecciated chert and dolomite. About 2,000 pounds have been mined.

PROSPECTS IN THE JEFFERSON CITY LIMESTONE.

The Hoff Diggings.—These diggings, known also as the Wine Sap Diggings, are located in the northeast corner of sec. 6. T. 41 N., R. 13 W., and are situated on the gentle slopes of a north and south ridge.

Mr. Adolf Schmidt,* who visited these mines when they were being operated, says that they were discovered in 1872. He says in the report referred to, that two crevices running N. E. and S. W. (by compass they strike (N. 55° E.,) connected by a run at right angles were being worked. In these crevices and the numerous connected chimneys, the galena was found associated with calcite in the clay. Cerussite, known as "Mineral Clinker," also occurred in the clay with the galena. Dr. Schmidt says that from 1872 to 1874 the diggings were worked intermittently by two men producing in all 21,000 pounds of galena. Up to the present date, the production has probably been about 35,000 pounds. No mining has been done for several years.

The Olean Diggings.—In the N. ½ of section 18, and the S. ½ of sec. 7, T. 42 N., R. 14 W., about two miles a little south of east of Olean, from 50,000 to 60,000 pounds of galena was dug from the clay during the latter half of the 70's. This production of galena has induced several companies to sink shafts into the rock at this place. Up to the present time these explorations have not been successful.

The Franklin Diggings, located in the S. W. ¼ of the N. W. ¼ of sec. 18, T. 42 N., R. 14 W., were worked mainly from 1875-78. Galena has been found in the clay which fills east and west crevices at this place. Cerussite is frequently found with the galena in the clay. None of these mines were over 20 feet deep. Mr. B. P. Franklin, the owner, says that 17,000 to 18,000 pounds of galena has been produced. A shaft was recently sunk in the north center of the north forty in which these diggings occur, and some lead was found in the cavities of the heavy dolomite beds. The shaft followed a crevice striking N. 82° E.

John M. Starling's Diggings, located in the S. E. ¼ of the N. E. ¼ sec. 18, T. 42 N., R. 14 W., have produced about 12,000 pounds of galena. One shaft, at present filled with water, is 90 feet deep. Galena is found mainly associated with barite, although cerussite and limonite after pyrite are common.

Long's Diggings, located in the N. W. ¼ of the N. E. ¼ of sec. 18, T. 42 N., R. 14 W., are mainly in clay. Galena and cerussite, associated with barite, occur in the clay.

The W. P. Gilleland Diggings are located in the N. E. ¼ of the N. W. ¼ of sec. 18 and the S. W. ¼ of S. W. ¼ of sec. 7, T. 42 N., R. 14 W. Galena, cerussite and calcite occur associated together in the clay at this place. In a prospect hole in sec. 7, shale containing gypsum crystals is reported to have been passed through. Mr. Gilleland estimated the output at from 25,000 to 30,000 pounds.

The Van Meter Diggings.—These diggings are located in the N. E. ¼ of the N. W. ¼ of sec. 18, T. 41 N., R. 15 W., and are situated in a small branch of the Little Gravois creek. A great many holes were dug at this place, the deepest of which is said to have been 52 feet. The galena was mostly found in the clay, although some is reported to have been taken from the rock. Calcite is the only mineral associated with the galena at this place. The output of these diggings has been estimated at approximately 50,000 pounds.

The Meyers Prospect.—This prospect is located in the S. W. ¼ of sec. 31, T. 41 N., R. 14 W., and is situated on the gentle slope of a high ridge. Galena, barite, calcite, chalcopyrite, limonite, malachite and azurite have been found in the decomposed dolomite along joint planes which strike N. 25° W. Crustification† is at times present. The order

*Ibid, p. 511.

†Posepny "Genesis of Ore Deposits." N. Y. 1902, p. 12.

from the dolomite wall rock being, (1) chalcopyrite largely altered to limonite, malachite and azurite; (2) barite or calcite, and (3) galena. The prospect holes which are from 4 to 20 feet deep have produced about 20 pounds of lead.

PROSPECTS IN THE GASCONADE LIMESTONE.

The Gageville Mines.—The Gageville mines, which are also known as the Hackney diggings, have been operated more extensively than any of the other mines in this county. They are owned by the Gageville Mining Co., of which G. C. Ramsey of Jefferson City is president and Joseph N. Deihl is manager. These mines are located in the W. ½ of the N. E. ¼ of sec. 14, T. 41 N., R. 14 W. They are situated upon a north and south ridge which has been covered with shallow clay diggings. The richest prospects are reported to have been at the south end of the ridge.

In March, 1872, W. A. Hackney and John Buster opened a shaft in a sink hole 125 feet west, and 10 feet below the present main shaft. This sink hole proved to be a chimney 18 feet deep and 7 feet in diameter, which was filled with red clay carrying a high percentage of galena. At the bottom of the chimney there is a crevice striking N. 74° E., which was followed 8 feet, where it ran into a pocket of Coal Measure shale. The upper surface of the shale was followed 75 feet and the rock immediately above is said to have been very rich. Sixty thousand pounds of galena are reported to have been taken from this prospect.

From the time of this strike up to the present, more or less mining has been done on different parts of the ridge. During the winter of 1901-02 there were three drillers and from twelve to eighteen miners on the hill.

The main shaft of the Gageville mines, which is 132 feet deep, is, with the exception of 11 feet of Coal Measure shale, in the Gasconade limestone. The dolomite beds are undisturbed, although slightly wavy. Galena occurs in the dolomite throughout the entire depth of the shaft. Pockets of red clay are reported at the bottom of the shaft, although they are less abundant than at the 70 to 80 foot levels. The ore is reported to have been richest immediately above and below the shale. The rich horizon above the shale was from 5 to 20 feet thick. From 150,000 to 200,000 pounds of galena was mined from clay openings in the rock.

A drift 60 feet long, extending N. 25° E., was made to connect the main shaft with the air shaft. This drift follows approximately the contact of the Coal Measure shale and the Gasconade limestone. The dolomite in places is closely jointed and in others partly brecciated. Where cemented, the cracks are usually filled with barite.

The following section from the top down was obtained in the air shaft:

Section 26.

0-2 feet yellow soil containing many flint fragments.
2-7½ feet very compact red clay with many flint fragments.
7½-13½ feet a heavy brecciated chert bed characteristic of the base of the St. Elizabeth formation, called "Moory"* flint. It is still practically horizontal.
13½-56 feet heavily bedded dolomite, in some places badly decomposed, forming a dolomitic sand. Some galena occurs at the bottom of the shaft.

James Buster and David Alberson are working a shaft 80 feet north of the main shaft. At this place the following succession was noted:

Section 27.

0-2 feet yellowish soil and flint fragments.
2-10 feet compact red clay with many flint fragments.
10-18 feet "Moory" flint.
18-19 feet clay opening between the "Moory" flint and the underlying heavily bedded dolomite.
19-80 feet badly decomposed dolomite. Two drifts have been run at this level following joints which strike N. and S. and N. 70° E.

Although practically horizontal the rock is badly jointed and very much decomposed. Solution breccias recemented with barite are common. The galena occurs in cubes 3-4

*Winslow so spells the name. Mo. Geol. Sur., Vol. VI, p. 335.

inches in diameter, either in the clay or rock, or without barite. The cubes are usually somewhat corroded. The galena occurs in a rudely defined pipe-like body, the longer diameter of which coincides with the jointing plane. At the intersection of the N. and S. and N. 70° E. joints occur cone-shaped openings filled with very red clay. These openings are known to the miners as chimneys. From September 7, 1901, to January 18, 1902, this shaft was worked intermittently by two men who, together mined 36,920 pounds of galena.

Pinkston and Harbison have a prospect 150 yards north of this, which is situated upon an east and west run. One hundred yards west of the main shaft Johnston Bros. and Rush have a prospect in the badly decomposed dolomite. The galena occurs both in the clay and in an east and west joint.

John Buster is working a prospect 125 feet N., 60° E. of the main shaft. At this place the galena occurs through the dolomite being especially abundant above a thin layer of shale.

The heaviest deposits of ore have occurred in the upper 50 to 80 feet of the Gasconade limestone. The greater part of the ore which has been sold was obtained from the clay diggings.

Nodular cerussite, which in one instance enclosed a badly decomposed piece of galena, occurs in the clay with the galena. The galena varies in size from minute particles up to bunches weighing as much as 15,000 pounds.

Zinc blende was found in the Coal Measure shale but not in the dolomite. Barite is more commonly associated with the galena than calcite. The miners say that in this locality the white, finely granular barite is a more favorable indication of paying galena than the common white, crystalline variety.

The Gageville Mining Co. has drilled about 3,000 feet during the last year. The rate of drilling in the open ground on the hill was from 20 to 40 feet a day, while in the hard ground in the valley only from 10 to 15 feet could be made.

The output of the Gageville mines to May, 1874, according to Dr. Schmidt's* report, was 300,000 pounds. About 55,000 pounds were produced from May 1901 to March 1902. The total output will reach approximately 700,000 to 800,000 pounds.

Grass Root Diggings.—The Grass Root diggings are located in the N. W. ¼ of the S. W. ¼ of sec. 33, T. 41 N., R. 14 W. Galena was discovered at this place by Reuben Vaughn in the spring of 1872, and for two years forty men mined at this place. Since 1874 the area has only been worked intermittently.

The diggings are situated on a high, steep hill near Saline creek. The prospect holes are located on all sides of the hill, although it is reported that those on the northeast have been the richest. The main crevice crosses the crest of the hill and strikes N. 75° E. It has a width of 12 feet at the surface but narrows down to a thin seam at a depth of 20 feet. From this seam 200,000 pounds of ore was mined.

Other crevices striking N. 20° E., S. 25° E. and N. 50° W. occur at this place. Most of the galena mined at this place was obtained from red clay seams, from chimneys or from the loose clay covering the surface of the ground.

Dr. Schmidt† states that on the upper part of the northeastern slope "A shaft was sunk to a depth of 80 feet and passed through 25 feet of clay so rich in galena that 100,000 pounds were raised. The shaft then struck solid limestone with occasional seams and specks of galena and penetrated 55 feet into it, until it struck a chert layer. As the galena was very scarce and the work not paying, the exploration was stopped for the present."

The galena obtained from the Grass Root diggings was coarse "cog" mineral. Associated with the galena were some nodular masses of cerussite, barite and calcite, some of which have a rich amber color. The total production of galena has been in the neighborhood of 500,000 pounds.

The Walker Diggings.—These diggings, which are also known as the Conlogue mines, are located in the S. W. ¼ of sec. 5, T. 41 N., R. 14 W. Mr. F. V. Conlogue of Eldon,

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*Report of the Mo. Geol. Sur., 1874. G. C. Broadhead, State Geologist, Jefferson City, p. 569.

†Ibid, p. 569.

Missouri, is the principal owner. The diggings are situated on the sides of the ridge bordering a branch of Saline creek. Although the upper part of the shafts are in the St. Elizabeth formation, the ore all occurs in the Gasconade limestone or the clay contained in it. This famous "circle" is a cone-shaped depression, 5 feet deep and 8 feet in diameter at the top.

Both Dr. Schmidt* and Mr. Winslow** visited these mines, the former in 1874 and the latter in the early 90's. Dr. Schmidt describes the "circle" as follows: "These shafts followed a crevice in the altered rocks and were very productive. The uppermost shafts, sunk on the summit of the spur, struck finally a very large circular deposit which is being worked at present."

Section 28.

The shafts pass through about:
3 feet of soil.
6 feet of fractured chert layers, with chert sand.
10 feet clay, with chert fragments.
15 feet hard, bluish crystalline. magnesian limestone; porous, owing to numerous denticulated cavities throughout the whole mass.

"This rock exists here in fissured layers. Below it a very large circular opening was struck, 30 to 40 feet wide above and getting rapidly wider with the depth and filled with loose, soft and wet red clay (tallow clay), in its upper part. while the lower part was filled with broken down masses of limestone more or less altered and softened, mostly angular, with broken veins and seams of barite and galena through and between them. Large cavities between the broken masses are filled with red clay. The whole mixture contained in its main portion 5 to 10 per cent. of galena, mostly slabs and chunks. The excavation has now reached a depth of 85 feet, at which depth the deposit has a diameter of nearly 80 feet. The walls are in some places very marked and cut off the galena; in other places, however, thick seams of galena run into the moderately hard wall rock. Some of these have been followed to a distance of over 30 feet. Seams of galena also extend to a greater depth, but the rock appears to get harder and more solid."

Mr. Winslow states, "The galena as seen in the undisturbed pillars is firmly imbedded in calcite or barite lining cavities. Sheets of barite were seen attached to the wall of the chamber, and galena is said to have been found in similar sheets both attached to the surfaces and penetrating crevices in the wall and floor."

At present a tunnel extends along an east and west crevice from a branch of the bottom of the "circle." Some galena is exposed along this tunnel. In places the country rock forms a solution breccia. The ore-bearing zone is vertical and about six inches wide.

The main crevices in the Walker diggings have a strike of from N. 85° E. to E. and W. A second less important series has a strike of N. 35° W.

The barite at this mine is unusually abundant. Excellent transparent crystals and pseudomorphs of barite after calcite are common. Some are marked with dedrites of manganese oxide. Amber and amethystine-tinted calcite is abundant. Chalcopyrite and its alteration products are common. Although most of the ore was galena, about 400 pounds of cerussite has been obtained.

The order of crustification of the country rock is as follows: (1) Chalcopyrite, largely altered to malachite; (2) Crystalline barite; (3) Chalcopyrite; (4) Crystallized barite.

In the S. E. ¼ of the S. W. ¼ of sec. 5, T. 41 N., R. 14 W., thin seams of galena striking S. 89° E. and N. 50° W., occur in the dolomite.

Dr. Schmidt† places the output at the time of his visit at about 1,000,000 pounds. The men who mined here at that time were interviewed during the present season and without exception their estimate of the output was from 350,000 to 800,000 pounds.

The Fox Diggings.—The Fox Diggings are located in the N. W. ¼ of sec. 31, T. 41 N., R. 14 W. These diggings, which are said to have been opened in 1871, are situated on the sides of a ridge capped by the St. Elizabeth formation.

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*Ibid, p. 567.

**Mo. Geol. Sur., Vol. VII. C. R. Keyes State Geologist, Jefferson City, 1894. p. 707.

†Ibid, p. 568.

The greater part of the galena mined was found in the clay within 10 feet of the surface and in crevices and chimneys. Mr. Edward Spaulding, to whom we are indebted for this information, stated that apparently the galena pinched out upon reaching the rock.

The trend or the strike of the crevices in these diggings varies greatly. The following is the strike of some of the ore-producing crevices: N. 8° E., N. 55° E., N. 70° E., N. 85° E., N. 75° W., N. 57° W.

The galena occurred in unusually large bunches, one of which weighed 7,000 pounds. Calcite and cerussite both occur with the galena.

The Tate company of Enon sunk a shaft at this place in the summer of 1901. It was filled with water at the time that part of the county was being surveyed and therefore could not be examined. The dump pile showed some shale which resembled lithologically the Coal Measure shale of this region. Mr. Spaulding stated that this shale was found about 30 feet below the surface. In some places it pinches out and in others it is 3 feet thick. Above this shale the ore is reported to be good. The output of these diggings has been in the neighborhood of 175,000 pounds.

McBride and Lawson Diggings.—Messrs. McBride and Lawson own several groups of diggings in the N. W. ¼ of sec. 24, T. 41 N. R. 14 W.

In the northwest corner of this section there are a number of prospect holes situated 10 to 15 feet below the St. Elizabeth-Gasconade contact. Galena was discovered here by Mr. Alberson ten years ago. The ore occurred in clay near the top of the ground and in openings in the rock. It was associated with calcite, barite and iron pyrite. One opening, striking N. 5° E. contained a flat deposit of galena one yard wide and from one-fourth of an inch to six inches thick.

In the west central part of the northwest quarter of the same section, occurred a rich run of ore 40 feet below the Gasconade-St. Elizabeth contact with a general north direction, (the majority of the readings being N. 5° W.) Mr. Alberson reports that the ore was mostly in clay, the pay dirt being from four to ten feet wide and from two to three feet deep. The width of the deposit seemed to have no effect upon the quantity of ore. The ore which at times went under bridges of solid rock was followed 150 feet into the dolomite. In the rock the clay opening was in places 6x7 feet, while at others it was almost completely closed by dolomite boulders known to the miners as "key rocks." In one place where a "key rock" was removed from the opening, a cave seven feet high and fifteen feet long and five feet wide was encountered. Hanging from the cap rock of this cave were stalactites of block galena, some weighing 500 pounds. The floor of the cave was filled with four feet of clay and lead, the latter of which had fallen from the roof. No galena was found attached to the rock on the bottom of the cave. In the narrower portions the ore occurred in horizontal and vertical sheets, usually the former.

Galena is said to have been present in the rock as far as the tunnel extended. One piece of galena was found which weighed 997 pounds. Large pieces of calcite were commonly present in the rock, although very little occurred in the clay. Much of the calcite has a beautiful amber tint. These diggings were apparently abandoned because the blasting which is required in the hard ground was too expensive.

In the center of the northwest quarter of the same section and across the ridge from the diggings above described, Mr. Alberson prospected along an opening striking N. 65° W. After following this opening 75 yards a cross seam striking N. 12° W. was encountered. Both of these openings produced galena, which occurred mainly in the clay. These deposits occur 40 feet below the contact of the Gasconade and St. Elizabeth formations. Barite, cerussite and calcite are associated with the galena.

In the north middle of the S. E. ¼ of the N. W. ¼ are several prospects known as the Whip-poor-will Diggings. The openings at this place have a strike of N. 80° E. to S. 80° W. The galena occurs associated with barite of two generations.

The combined output of these diggings is estimated by Mr. McBride at 250,000 pounds of galena. Of this amount 150,000 pounds have been produced during the last seven or eight years.

The Curty Diggings.—The Curty diggings are located in the N. E. ¼ of the N. W. ¼ of sec. 11, T. 41 N., R. 14 W. They are situated on the sides and bottom of a rather steep gulch and are from 10 to 70 feet below the top of the Gasconade limestone.

The lead occurs in clay openings in the rock and in badly decomposed dolomite. Most of the openings strike N. 85° E., although one was observed which had a strike of N. 10° W. Small areas of brecciated flint were observed at this place. The ore is mainly galena, although cerussite is of common occurrence. A gray variety of cerussite, having the appearance of badly corroded galena, is commonly known by the miners as "burnt" lead. Calcite is commonly associated with both the galena and cerussite.

These diggings were discovered in 1871 or early in the spring of 1872, since which time they have produced approximately 200,000 pounds of galena.

Loveall Diggings.—These diggings are, with perhaps one exception, the oldest in Miller county. Meek* apparently mentions them when he says "In the S. W. ¼ of sec. 2, T. 41 N., R. 14 W., in the bed of a small branch of Saline creek, about 150 feet below the summit of the country. I saw, in some gray layers of Second Magnesian limestone, occasional crystals of lead ore; and Mr. Belche informed me he has picked up loose, in the bed of this creek, near here, several hundred pounds of ore. It does not appear to exist here in a fissure, but is disseminated in the form of isolated crystals through the rock."

As early as 1858, Mr. Temple E. Bell had two negro slaves working the tract and he is said to have gotten out a few thousand pounds. Two years ago considerable work was done on these diggings, but since then they have been worked intermittently.

The diggings are situated in the center of the S. ½ of sec. 2, T. 41 N., R. 14 W., along the gently sloping sides and bottom of a small tributary of Saline creek. They are in the Gasconade limestone within 40 feet of the St. Elizabeth-Gasconade contact.

The galena occurred scattered through the clay on the top of the rock and in a "chimney" or "circle" in the stream bed. This was the site of the recent work mentioned above. The "circle" at the surface is 100 feet from east to west and 65 feet from north to south. It gradually contracts towards the bottom, and at a depth of 60 feet its dimensions are less than half those of the surface. The "circle," which was originally filled with clay and rounded boulders of dolomite and chert is now filled with water. The best ore is said to have come from within 3 to 4 feet of the circular walls. The galena from this part of the circle varied in size from a pea to that of one's fist. In the center of the circle the galena was more sparsely disseminated, although in larger masses. The ore is all galena and the gangue consists of two generations of barite. Some galena associated with oölitic chert has been clearly derived from the St. Elizabeth formation. In the neighboring clay diggings some cerussite has been found. North of the "circle" is a deposit of Côal Measure shale in which are boulders containing blende. No blende is reported from the "circle."

The output of galena from these diggings has been approximately 45,000 pounds, of which 25,000 pounds was obtained two years ago.

The Indian Grave Diggings.—These diggings are located in the N. W. ¼ of sec. 14, T. 41 N., R. 14 W., on a gap in a north and south ridge, 20 feet below the top of the Gasconade limestone. The diggings were named from two huge piles of dolomite boulders 20 feet in diameter and 5 feet high, clearly marking Indian graves. The galena was found in the black soil and white dolomitic sand, filling crevices striking N. 70° E. The prospect holes were not over 15 feet deep and the galena crystals occur associated with barite.

These diggings were abandoned when the Gageville mines were discovered, and have been worked very little since. The output is placed at 10,000 pounds.

The Melton Diggings.—These diggings are located in the northeast corner of sec. 23, T. 41 N., R. 14 W., on a gentle hill slope from 0 to 60 feet below the base of the St. Elizabeth formation. The galena was found in clay openings and chimneys. The more important crevices strike N. 75° E., N. 12° E. and N. 33° E. Exceptionally pure calcite and two generations of barite are found with the galena.

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*Geol. Sur. of Mo., 1855-74, p. 132.

Mr. Winslow* gives the output as 50,000 pounds.

The Swallow Diggings.—These diggings are located in the S. W. ¼ of sec. 14, T. 41 N., R. 14 W., and have produced about 20,000 pounds of ore. The ore occurs in clay crevices, striking N. 83° E., and about 60 feet below the top of the Gasconade limestone.

The galena is associated with barite of two generations.

In the center of the east half of the same quarter, are some diggings 40 feet below the top of the Gasconade limestone. The galena occurs in clay.

The Blackburn Diggings.—These diggings are located in the N. E. ¼ of sec. 10, T. 41 N., R. 14 W., on G. L. Wimmial's farm. There are two distinct mining tracts. One is on a gentle slope of the valley of the north Little Saline and about 100 feet below the top of the Gasconade limestone. Here the ore occurs imbedded in clay openings in the intercalated flint of the Gasconade limestone.

The second tract, from which most of the galena has been obtained, is from 0 to 40 feet below the top of the Gasconade limestone. The ore occurs in the rock and in clay openings, and is associated with amber or lemon-colored calcite, in pieces as large as one's head. One crevice strikes N. 45° E. The total product of these diggings is in the neighborhood of 150,000 pounds.

Compton Diggings.—The Compton diggings are located near the center of the S. E. ¼ of sec. 8, T. 41 N., R. 14 W., in the upper 100 feet of the Gasconade limestone and are situated on the slope of the valley of the Walker Mines branch of Saline creek. Both calcite and barite occur associated with the galena. The crevices, which strike N. 60° E., are filled with clay in which the galena occurs. The mines have been worked intermittently from the early seventies until 1901. In 1900, some 4,000 pounds were produced. Mr. H. M. Compton, the owner gives the total product as 33,000 pounds.

In the western part of the N. E. ¼ of the same section, in the upper 80 feet of the Gasconade limestone, occur other old diggings. One set of crevices strikes N. 55° E., and another N. 12° W. The ore is in red clay and is associated with barite. The product is said to have been 5,000 pounds of lead and 33 tons of barite. During 1901, a shaft was sunk 72 feet through decomposed dolomite containing clay pockets. Galena was encountered in seams in the dolomite. Barite was abundant in the intercalated chert beds, some of which are brecciated. Calcite is present but not associated with the galena. From the 44 foot level to the bottom of the shaft some blende was encountered. Above the 44 foot level a few crystal casts, apparently of blende, were found in the barite. Iron pyrite, chalcopyrite and its decomposition products, limonite and malachite, also occur.

From a mass of dolomite 4x8x10 feet in the south center of the same section, Mr. Compton has cleaned 700 pounds of ore. The dolomite was exceedingly open and the lead, associated with calcite, occurred disseminated throughout the mass. Malachite stains were noted.

PROSPECTS OUTSIDE OF THE SALINE CREEK DISTRICT.

Johnston Bros.' Prospect.—In the S. W. ¼ of the S. E. ¼ of sec. 24, T. 41 N., R. 13 W., Johnston Brothers recently mined 920 pounds of lead from the clay in a N. 72° E. crevice. This prospect is situated on a "ball" about 30 feet below the top of the Gasconade limestone. The dolomite is, in places, very much decomposed. The galena occurs with barite and limonite, the latter an alteration product of pyrite. Thin seams of galena penetrate the limestone on either side of the opening.

Hutchison's Prospect.—This prospect is located on William Hutchison's land in the S. W. ¼ of the N. W. ¼ of sec. 3, T. 40 N., R. 16 W., in the upper 40 feet of the Gasconade limestone. A St. Louis company, several years ago, sunk two shafts on this place, one 20 and the other 45 feet deep, and connected them with a drift. The dolomite is very open, much jointed and badly decomposed. Breccias, cemented with calcite, were observed. The ore occurs in the soft dolomite. Running nearly at right angles from the main crevice are many seams containing some galena.

In a gulch 100 feet north of these shafts, galena has been found in the clay and brecciated chert about 70 feet below the top of the Gasconade limestone.

Galena was first found at this place about ten years ago and the production has been about 3,200 pounds.

*Mo. Geol. Sur., Vol. VII, Jefferson City, 1899, p. 709.

The Waite Prospect.—In lot 3, N. W. sec. 3, T. 39 N., R. 13 W., on the slope of Barren forks, is a prospect hole 10 feet deep, on a N. 75° E. crevice. The shaft is on the crest of a gentle anticline and in the upper 30 feet of the Gasconade limestone. The dolomite is rather siliceous and contains thin, blue, shaly parting planes. Along the bedding planes occur layers of barite and calcite, one to three inches in thickness. These minerals also occur in the numerous cavities in the limestone. Blende occurs sparsely disseminated through the dolomite and associated with the barite. Some of the blende has been altered to brownish, mammillary smithsonite. Chalcopyrite and its decomposition products, limonite, malachite and azurite, occur with the barite. While in some instances the chalcopyrite is surrounded by barite, as a rule, it is next to the country rock and the barite incrusts it. Small particles of galena occur in the barite.

At the foot of the slope, fifteen feet below the shaft, there is a two and a half foot bed of black and bluish chert. The cavities in this chert are mainly filled with barite, although some galena is reported to have been found.

On the Little Tavern in lot 6, N. W. sec. 2, T. 39 N., R. 12 W., in the upper 20 feet of the Gasconade limestone, is a clay seam striking N. 80° W., in which galena was found. Galena is also reported at the bottom of the crevice and in the wall rock.

Two hundred yards south of the last prospect, in the northwest corner of the W. ½ of lot 5, N. E., is another prospect on land owned by Mr. Whitaker. This prospect is on a N. 35° W. crevice, 10 feet long and 2 feet wide, in the upper 40 feet of the Gasconade limestone. The sides of this pocket-like opening are coated with blende. Iron pyrites and barite are abundant. The order of crustification is (1) country rock, (2) limonite (after marcasite or iron pyrite), (3) blende, (4) barite. Mr. Whitaker reports that a vein of blende and barite which has never been worked dips under the creek at this place.

The Rothwell Mine.—This mine is located in the W. ½ of lot 5 N. E., sec. 2, T. 39 N., R. 12 W. It is situated 20 feet above the bed of Little Tavern creek and in the upper 40 feet of the Gasconade limestone. The ore is blende, some of which has been altered to smithsonite. It is associated with a little marcasite and pyrite and considerable barite. At the time the mine was visited, the shaft could not be entered, so that it is necessary to incorporate the following from Winslow's* report: "The adjoining sketches illustrate the conditions of occurrence. The vertical gash vein, illustrated in A, is traceable in a sinuous line across the bottom of the pit and up its two sides, a horizontal distance of about 4 feet. It pinches out at the top. In a flat opening on the western side, a little above the vertical deposit, a mass of galena and barite about a foot in diameter was found. Some galena occurred mixed with the blende in several openings, and also some copper pyrites and smithsonite. The surface of the magnesian limestone at the contact with the ore is generally stained a red color."

Stark's Prospect.—Stark's prospect is located in the S. W. ¼ of the S. E. ¼ of sec. 17, T. 40 N., R. 13 W. A small seam of galena along a bedding plane of the Gasconade limestone, dipping 60°, S. 70° W., has been mined. This seam varies from a mere knife edge to a sheet 5 inches thick. Calcite, which is apparently older than the galena, occurs with it. In other places in this vicinity, galena has been found both in the clay and in the dolomite. Mr. Stark reports that 300 pounds of galena have been mined from this prospect.

The Stevens Mine.—In the southeast corner of sec. 23, T. 40 N., R. 14 W., in the upper 100 feet of the Gasconade limestone, the Central Missouri Mining and Mineral Company sunk a shaft 87 feet deep, on land owned by Joshua Stevens. The shaft is situated in the bottom of a small ravine and is at present filled with water.

At a depth of 22 feet, blue flint carrying blende and chalcopyrite was penetrated. At 43 feet, a 2-foot bed of cherty dolomite, in which a little galena and blende is imbedded, was passed through. From 43 to 87 feet the rock is reported to be barren. In places, breccias, probably solution breccias, occur, in which the fragments have been cemented together with barite.

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*Mo. Ge Sur., Vol. VII, p. 709.

The ore, which is mainly blende, occurs both alone and with barite. Chalcopyrite is frequently present and is clearly older than the barite. In places stellate aggregates of pink and gray crystals of dolomite line the cavities. The order of crustification is (1) country rock, (2) crystallized dolomite, (3) chalcopyrite, (4) barite.

In the bed of Cattail creek, just east of the mine, is a white dolomite, containing disseminated black chert, thin seams of barite, chalcopyrite, blende and galena. This is the ore horizon of the 22-foot level in the mine. This dolomite contains great chert concretions two to four feet in diameter and one to two feet in height. The outer layer is a blue or black barren chert, while within there is a confused mass of dolomite, blue or black chert, barite, blende and galena. The mass has apparently been formed by the removal in solution of the more soluble portions of the chert and dolomite and the subsequent infiltration of barite, galena, blende and pyrite. Nearly all of the pockets at the surface have been worked out. This mine has produced about 300 pounds of mineral, while about 400 pounds of galena and blende together have been obtained from the flint concretions.

Capp's Diggings.—These diggings are located in the N. W. ¼ of the S. W. ¼ of sec. 7, T. 40 N., R. 13 W. They are situated in the upper portion of the Gasconade limestone. They were worked before the Civil War and, at that time, a small lead smelter was operated in connection with them. They were reopened in the 70's and have been worked intermittently ever since. The property has changed hands several times and is now being worked by the Kansas City Mining Company. Practically all the ore so far produced has been derived from the clay on top of the rock and in crevices. Some work has been done in the solid rock with indifferent success. Calcite and some barite are associated with the galena.

Schmidt* places the total product at from 30,000 to 40,000 pounds.

The Pope Diggings.—These diggings are located in the N. ½ of sec. 6, T. 40 N., R. 12 W., in the upper eighty feet of the Gasconade limestone. Galena is reported to have been found in the soil on the hillside and in places thin seams of galena occur in the rock. A crevice three feet wide and striking N. 70° E., occurs at this place. It contains a vein of lead varying in thickness from a mere knife edge to 3 or 4 inches. On the north side of the hill a crevice was worked which had a strike of N. 65° E., and a dip of 5° N., 25° W.

The diggings are situated on both the north and south sides of the hill. The badly decomposed dolomite in which the lead occurs contains a few thin partings of greenish blue shale.

In 1900 a shaft was sunk 25 feet deep, which passed through a bed of black chert at a depth of 15 feet. It is reported that, at the surface, in the vicinity of this shaft, galena was especially abundant, while deeper down the mineral almost entirely disappeared.

On the south side of the hill barite is abundant in the clay, while on the north side both calcite and barite are abundant. The rocks in the vicinity of the shaft contain many very thin seams of galena.

Near the middle of the N. ½ of sec. 6, T. 40 N., R. 12 W., below the above mentioned black flint layer, galena occurs in thin sheets alnog the bedding planes of the dolomite. Clay pockets carrying large sized pieces of galena, calcite and barite occur at this place.

In the bed of a small ravine in the N. E. ¼ of sec. 6, T. 40 N., R. 12 W., lead occurs in knife edge seams which strike N. and S.

It was impossible to approximate the former output of these old diggings. In 1900 about 15,000 pounds of galena were produced.

GALENA AND BLENDE IN COAL.

Swallow** and Meek** mention the occurrence of galena and blende in the coal pockets of Central Missouri. Winslow† in his discus-

*Rep. of the Geol. Sur. of Mo., 1873-74, Jefferson City, 1874. G. C. Broadhead, State Geologist, p. 570.

**First and second annual reports of the Geol. Sur. of Mo. G. C. Swallow, State Geologist, Jefferson City, 1855, pp. 91, 192, and Meek's Rep. same Vol., p. 113.

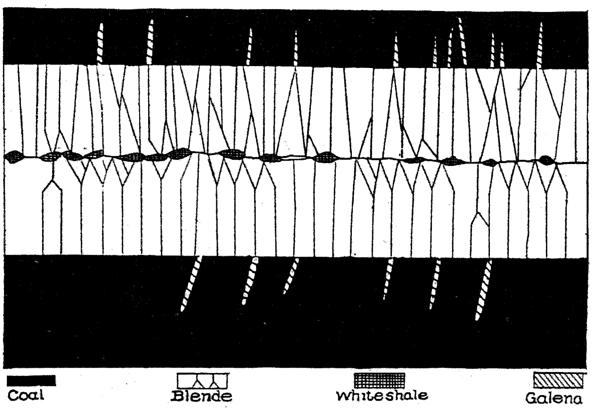
†Mo. Geol. Sur., Vol. VII, Jefferson City, p. 486.

sion of the origin of the Missouri lead and zinc ores incidentally speaks of finding both of these ores in coal.

At the Republic Coal Mine lenses of blende occur parallel to the bedding. Mr. Rower Simmons reports that in the bituminous coal in the northwest corner of the N. E. ¼ of the S. W. ¼ of sec. 11, T. 41 N., R. 16 W., twelve seams of blende from a half inch to three inches thick occur parallel to the bedding planes, and from one to one and a half feet apart.

In the southwest corner of the S. E. ¼ of the N. E. ¼ of sec. 18, T. 41 N., R. 15 W., Mr. Bunk reports that nodules of blende occur in the upper portion of a 13-foot bed of bituminous coal. At the bottom of the bed the blende occurs in sheets along joint planes perpendicular to the bedding. These sheets, three in number, were from one to one and a half inches thick.

At McClure's "coal bank" lenses of blende, three to four feet in diameter and one-half to one and one-half inches thick, are common These lenses are parallel to the bedding of the coal. They are sometimes accompanied by or incased in gypsum. Innumerable thin veinlets of blende extend from the main blende seams on all sides. Some of these occur at right angles to the main bed, while others are inclined at an angle. These minor veins, although at times but one sixty-fourth of an inch apart, are usually one-eighth of an inch apart. They appear to occur along two systems of joints approximately at right angles to one another. (See Fig. 54.) Galena is frequently associated with the coal in a similar manner.



Blende, galena and coal from McClure's prospect.

FIG. 54.

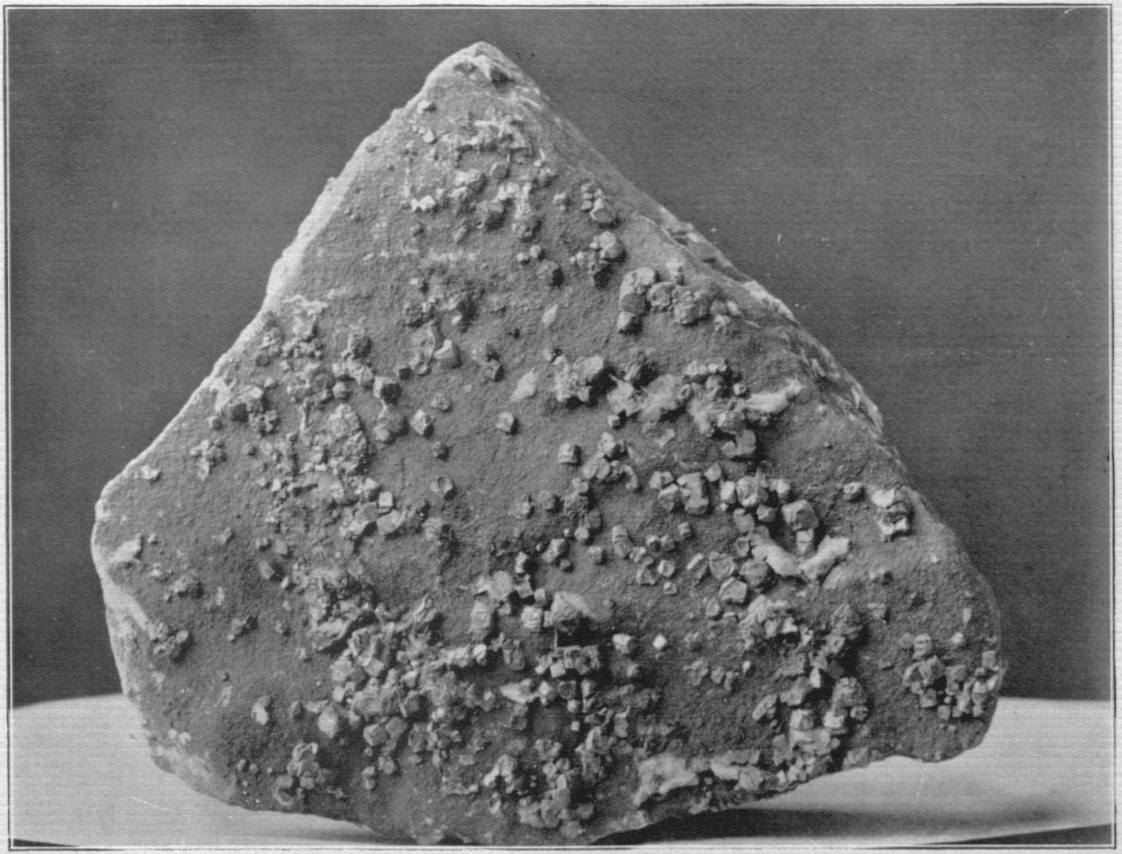
The blende which occurs in the coal pockets has a dark amber to black color. Peacock blende is common. That from McClure's coal bank is said to run 66½ per cent. zinc.

The blende appears to have been deposited after the coal was formed. Some at least, was deposited after the joints were formed. At the Stover "coal bank," in Morgan county, blende occurs along both bedding planes and vertical joints. In some places vugs one foot long and one-half an inch wide were observed in which blende crystals were beautifully developed on the walls. At the McClure coal bank a piece of blende was found, upon the exterior of which is a perfect imprint of a fern. Apparently, in this case, the blende had not filled a pre-existing cavity, but had metasomatically replaced the coal. That all movement had not ceased prior to the deposition of at least some of the galena and blende is shown by the fact that both of these minerals are found having beautifully slickensided surfaces. The occurrence of gypsum with the blende may indicate that the zinc was carried in solution as the sulphate. However, it must be borne in mind that gypsum in the presence of limestone is an ordinary decomposition product of iron pyrites, which is common in the coal. The small veinlets of blende and galena extend both above and below the main lenses. In the interior of the blende white clay sometimes occurs in small amounts. This white bleached clay contrasts strongly with the black shales characteristic of the coal pockets. Their carbonaceous content may very well have acted as a precipitant for the mineral carried in solution.

The prospectors in Miller county often express the view that the presence of blende in coal is against all the theories of geology. On the contrary, however, provided the coal is sufficiently jointed to permit a free circulation of water, and provided the circulating waters contain metallic salts in solution, its presence in coal is to be expected. The extremely common occurrence of iron pyrites in coal is a case analogus to that of blende, the one being the sulphide of iron and the other the sulphide of zinc. The occurrence of blende in the coal deposits of Miller county is due to the free circulation of mineral charged waters from the surrounding Cambro-Ordovician rocks through the open seams in the coal which furnishes favorable conditions for precipitation.

PROSPECTS IN THE COAL MEASURE SHALE.

The Little Nugget Mine.—The Little Nugget Mine is located in the N. W. ¼ of sec. 15, T. 41 N., R. 13 W. Galena and blende occur in two distinct ways, first disseminated through the shale, and second filling cracks and crevices in the imbedded boulders. The first method of occurrence is the more common. The dissem-



SANDSTONE INCRUSTED WITH CRYSTALS OF GALENA FROM LITTLE NUGGET MINE.

inated crystals vary from one-half to one-sixteenth of an inch in diameter. Galena predominates. The galena crystals are a combination of the cube and octahedron. On some of the cube faces vicinal octahedral faces form a slightly raised truncated pyramid. Blende is crystallized in fine trisoctahedrons. The blende is a high grade "rosin jack." Crystals are especially abundant in some parts of the clay, while in others they are entirely wanting. The perfection of both the galena and blende crystals is due to the slight resistance which the soft shale offers to the crystallizing forces. Since the shale is quite insoluble it is thought that the sulphides, in forming, forced the plastic shale aside to make room for the growing crystal.

A crystal of blende exactly similar to those occurring in the shale was found imbedded in a piece of Upper Burlington limestone. The removal of the blende crystals left perfect casts of the crystals in the limestones. These crystals probably assumed their present position after the Upper Burlington limestone was deposited in the Coal Measure pocket. Not only are they mineralogically like the blende in the shale, but their position in the limestone was such that if they were of earlier origin they would either have been knocked off or somewhat altered by erosion and weathering. One of two explanations seem most possible,—either the force of crystal growth was sufficient to crush the limestone into a rude approximation of the crystal form after which the limestone was cemented around it, or the limestone was removed by solution as the crystals grew.

The "dice mineral" and "strawberry jack" are disseminated throughout the shale pocket. Mr. John Holtzhauser, the superintendent, states that ore was most abundant at the 40-50-foot level, the best being at 45 feet.

Galena and blende are also found in the cavities of chert, dolomite and limestone boulders. The ore in the concretionary cherts is often in concentric rings, occupying cavities formed by the removal of soluble layers. Barite and calcite also occur in cavities cementing the brecciated sandstone and limestone. Some iron pyrites occur in the crevices.

Galena also occurs on the surface and in the open crevices of sandstone and limestone boulders, especially in the case of the former. (See plate XVII.) In such cases it is usually associated with crystallized and crystalline barite, the latter of which is the older. At least a part of the galena is older than the barite.

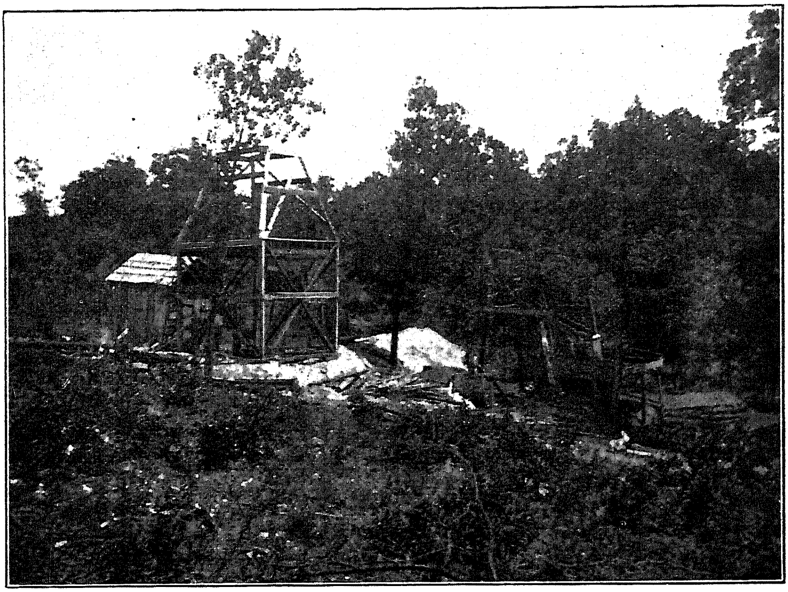
As before mentioned, the country rock in the vicinity of the mine is considerably disturbed. Breccias occur, the cementing material being both calcite and dolomite.

All the ore in the main shafts, although above water level, is absolutely fresh. A small prospect seven feet deep showed some lead cubes slightly corroded. The freshness of the ore is due to the slow circulation of the water, resulting from the impervious character of the shale and the deoxidizing effect of the carbonaceous matter in the shale. Surface water circulating slowly would soon lose its oxidizing power in this highly carbonaceous shale.

The mine is on R. L. Morgan's land and is leased by the Little Nugget Mining Company of Jefferson City. This company has one well-timbered shaft 135 feet deep; a second shaft 48 feet deep, in the disturbed rock at the edge of the deposit; and a third, which is at present being sunk. About 7,000 pounds of galena have been washed from the shale and sold.

The McClure Prospect.—(See Fig. 55). The method of occurrence of the ore in this prospect is similar to that at the Little Nugget mine. Blende is the predominant ore and it occurs in crystal aggregates from three-quarters of an inch to two inches in diameter. It is usually a high grade rosin jack. In places galena is associated with the blende.

Galena and blende occur in the crevices of the various boulders, being especially common in the concentric cavities of the concretionary cherts. The ore is all fresh, showing little evidence of weathering. The small bits of carbonaceous material, previously referred to as scattered throughout the shale, have formed the nuclei around which the "strawberry jack" has been precipitated. (See fig. 56). In those pieces in which traces of the carbonaceous material still exist the crystals of the aggregate radiate from the carbonaceous material in much the same manner as the separate seeds of a fir cone radiate from the stem. There is every gradation, from crystal aggregates in which the carbonaceous matter predominates to those in which it is entirely absent. Often a crystal aggregate which shows no carbonaceous material on the exterior encloses a bit of vegetable matter in its interior. About one piece in four still contains carbonaceous matter but the



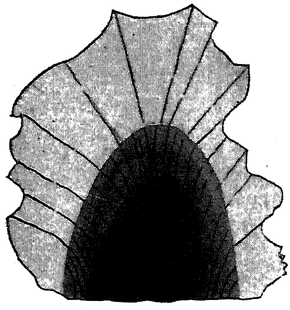
McClure Mines.
FIG. 55.

mineralogical character of all is so uniform that a common origin is probable. This is a striking example of the influence of organic matter in the precipitation of zinc sulphide.

The fossil nuts before mentioned (page 106), have exteriors of iron pyrites and interiors of sphalerite. In one case the blende in its growth appears to have broken the earlier formed shell of iron pyrites.

Iron pyrites is not especially abundant. In some cases, where the galena and blende occur in seams, it is present as a thin film between the rock and the ore. It also occurs at the bottom of the Saline Creek cave-conglomerate, increasing in quantity with depth.

The dryness of the mine, until it reached the bottom of the shale, has been mentioned before. Drill holes in the limestone, on the east side, show some water, while those in the shale are dry. Mr. McClure reports that in the drill-hole sunk in the coal mine, water was encountered at 60 feet, lost at 110 feet and regained at 130 feet. This water filled the drill-hole to within 30 feet of the surface and is very peculiar, as the shaft, which was absolutely dry until the last drill-holes were put down, is but 40 feet northwest of the coal prospect. Possibly the drill may have penetrated the edge of the deposit. In a well in the Jefferson City limestone, 500 feet northeast of the mine, water stands within 25 feet of the surface. Taking into account the difference of elevation, the water level at the well is 125 feet above that at the mine.



Cross section of blende crystal showing the ore of carbonaceous material.
FIG. 56.

Mr. McClure reports that the cuttings from 20 feet of the lower 30 feet of the trial drill-hole would average 20 per cent. in blende. The shaft is 136 feet deep and is all timbered. A horse power hoist has been used in sinking, although at the time of our last visit, a steam hoist and pump were being installed. As yet no ore has been sold.

The Sight Me Prospect.—For location, geology and water conditions see page 107.

This prospect, which is located on the Foote land, was worked during the winter of 1901-02 by the "Sight Me Mining Company," of Kansas City. The ore is mainly blende. Galena and blende occur principally in cavities in boulders. The galena is mainly confined to the chert boulders, although a few pieces were found in sandstone. The blende occurs in "cotton rock," dolomite, chert and sandstone. Some crystals were noticed in the shale. In one place a small sheet of blende was observed occupying a joint perpendicular to the bedding in the shale. On account of the sparsity of joints in the shale, such occurrences are uncommon.

Mr. McLaughlin* states that this mine, under the former management, produced in 1898, 1,000 pounds of blendes.

The Son Prospect.—The location and geology of this prospect have already been described on page 108.

The ore is mainly blende, which occurs in concretionary chert and as a cement in certain apparently brecciated cherts. This prospect was worked by the Central Missouri Mining and Developing Company of Kansas City, during the winter of 1901-02. The development consisted of drilling three holes, from which rich cuttings are reported, sinking a 33-foot shaft and running two short drifts.

No water was struck in the last drill-hole down to a depth of 100 feet. At this point a strong stream was encountered which flowed out at the top. The shaft was flooded when the drift cut into this drill-hole.

Joseph Cotton's Prospect.—(See page 103). This prospect contains blende, both as "pebble" jack in the shale and as sheets parallel to the bedding planes in the cannel coal. Galena also occurs to a less extent in the shale and cavities in the flint boulders. A piece of grayish, calcareous chert with attached blende crystals was found, in which the blende crystals had made a perfect impression. There seem two possible explanations for this phenomena—either the chert is younger than the blende and so formed around the blende, or the crystallizing force of the blende was strong enough either to impress its crystal form into the chert or to control the solution of the chert sufficiently to form a cast of the blende crystals in it. The chert seems to grade into a siliceous dolomite, the whole resembling closely the chert and dolomite noted in various places in the lower portion of the Jefferson City formation, for example, sec. 11, T. 42 N., R. 15 W. One is inclined to regard the latter explanation as the more probable.

E. A. Watt's Prospect.—This prospect is located in the west center of the S. E. ¼ of the N. W. ¼ of sec. 1, T. 41 N., R. 16 W., along a small tributary of the South Moreau. The shaft was sunk on the contact of the Jefferson City formation and the Coal Measure shale. Both galena and blende in the form of pebble ore were found in the shale while the pits in the decomposed dolomite forming the foot wall carried considerable blende.

In the N. E. ¼ of the N. E. ¼ of sec. 7, T. 42 N., R. 15 W., in a stream bed, L. G. Berkley has sunk several ten-foot holes in a small deposit of Coal Measure shale apparently occupying a crevice in the Jefferson City limestone.

The dolomite surrounding the shale is very much decomposed and is full of very fine grained blende. At the surface the blende is replaced by smithsonite (zinc carbonate), or is represented by crystal casts.

GENERAL CONSIDERATIONS.

The Coal Measure shale is slickensided, but the surfaces fit one another so perfectly that little space is left for the circulation of water. It is along the joints that the maximum deposition of ore has taken place in the Cambro-Ordovician rocks. Not only does the

*Manuscript notes on the lead and zinc of Central Missouri, gathered during Mr. Leo Gallaher's administration.

shale lack the larger openings so necessary to a comparatively rapid and free water circulation, but it lacks the small cavities by virtue of which the dolomites are so porous. The Coal Measure shales are particularly impervious and on this account water circulation cannot have been on a large scale. The large amount of organic matter present in the shale rather than the abundant circulation of water seems largely to have determined the deposition of the minerals.

The Cambro-Ordovician rocks in the vicinity of the shale pockets are very soft and badly decayed. This rock is an ideal place for the deposition of minerals and the few shafts sunk in the dolomite near the contact look more promising than do those situated in the shale. Not only is the rock porous in the vicinity of the shale, affording a free water circulation, but the shale acts as a dam, ponding back the waters and allowing them to become thoroughly mixed.

It is a well known fact that ore deposits in contact with shales are often especially rich. In the Wisconsin lead and zinc field rich "flats" of ore lay above the "oil" rock, a very carbonaceous shale at the top of the Trenton limestone. An especially rich blende deposit occurs in a brecciated and decomposed white chert beneath Coal Measure shale at the Massasoit mine at Joplin.* At the Moss Back mine at Galena, Kansas,** a similar rich zone lies beneath the shale. Winslow in speaking of the Alba Company's mine one half mile south of Alba, Missouri, states: ***"A consideration of all these facts plainly shows that we have here another instance of a coal pocket, around the margin of which the ores occur in a breccia of residuary materials derived from the Lower Carboniferous rocks."

In prospecting for lead and zinc outside of the shale pockets two things should be borne in mind. First, one cannot expect the immunity from water so peculiar to the prospects in the shale. Adequate preparations should be made to take care of the water, although more will not necessarily be encountered near the Coal Measure shale than in the Cambro-Ordovician strata away from it. Second, it will doubtless be ascertained that the size of the ore bodies is roughly in direct ratio to that of the Coal Measure shale areas. Therefore, it is important that one should determine the size of the shale deposit prior to expending any money on development.

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*Preliminary report on the lead and zinc deposits of the Ozark Region. H. F. Bain 22nd annual report U. S. Geol. Sur., Washington, D. C., 1902, p. 180.

**Ibid., p. 184.

***Missouri Geological Survey, Vol. VII, p. 577.

THE DEPOSITION OF THE ORES IN THE CAMBRO-ORDOVICIAN FORMATIONS.

The comparatively small amount and the shallowness of the mining which has been done in Miller county renders a comprehensive discussion of the ore deposits an impossibility. However, certain conclusions were reached which may be of interest.

The lead deposits of Miller county, situated in the Cambro-Ordovician formations, belong to the third and most important class of Van Hise's genetic classification of ore deposits, namely: "Ores which receive a first concentration by ascending waters, and a second concentration by descending waters."* In Miller county it is thought that the work of descending waters has been far more important than that of ascending waters.

As before mentioned, the Cambro-Ordovician series was laid down in shallow water, which condition is very favorable to the precipitation of the minute metallic contents held in solution by sea water. Doubtless, in many cases, organic matter may have generated by its decomposition hydrogen sulphide which is a powerful precipitant.

Robertson's analyses of Cambro-Ordovician dolomites in the central districts show the presence of minute quantities of lead and zinc. Among the rocks analyzed was one from a prospect shaft near the Rothwell mines. The rock contained no visible ore. The analysis, which was run in duplicate, is given below:**

Lead—Per cent.	Zinc—Per cent.	Copper—Per cent.	Manganese—Per cent.
.00156	.00080	.00040	.00049
.00143	.00024	.00064	

It is altogether probable that water was active in the concentration of this minute metallic content into crevices during the period when Miller county was land, prior to the deposition of the Upper Burlington limestone, and again after that period and prior to the deposition of the Coal Measure rocks. However, at present it is impossible to differentiate such concentration from that of later origin.

That the ore now worked was at least partially concentrated after the Coal Measure deposition, is proven by the fact that there is above the Coal Measure shale in the Gageville mine a considerable secondary

*Some principles controlling deposition of ores. "Van Hise, p. 428 in Genesis of Ore Deposits," A. I. M. E., 1901.

**Mo. Geol. Sur., Vol. VII, p. 480.

enrichment. Moreover if the present crevices had been opened by solution at that time the Saline Creek cave-conglomerate or the Coal Measure shale would most certainly have filled them. Ore is also found in the Coal Measure shale, and it is probable that the deposition of this ore was contemporaneous with the chief enrichment of the Cambro-Ordovician strata.

Van Hise*, in his discussion of the origin of the central Missouri ore deposits, names the Devono-Carboniferous shales as the upper impervious bed bounding the water circulation of the first concentration. In Miller county the Devonian shales may never have existed, but if they did, they were eroded away prior to the deposition of the Upper Burlington limestone. In Miller county the Coal Measure shales are probably partially replaced by sandstones. Moreover, before the close of the Coal Measure period they were completely eroded from some portions of the county. The Coal Measure shale may not have been sufficiently continuous at the close of the Coal Measure period to control the water circulation. It may be that the sandstone strata formed outlets for the escape of the ascending water. No relation has as yet been noted between the Graydon sandstone and the mining prospects. Leaving the Devono-Carboniferous shales out of consideration, the intercalated shales and fine grained argillaceous dolomites ("cotton rocks") of the St. Elizabeth and Jefferson City formations are perhaps sufficiently impervious to confine the water circulation.

The chief water bearing horizon was doubtless then, as now, the Gunter sandstone, although the cavernous dolomite of the Gasconade formation and the sandstone of the St. Elizabeth formation doubtless carried much water. We are unable to reconstruct the topography of Miller county at the time of the elevation of the Coal Measure rocks. It is thought that the more broken country was in the vicinity of the present Osage river, but this stream does not appear to have cut down to sufficient depth to sever the northern portion of the county from the artesian circulation of the Ozark Plateau. Waters found their way into the rocks to the south and in their descent along the north dipping strata dissolved, from the rock traversed, minute quantities of the included metals. These matallic salts were carried in solution down the slope by the water and were deposited wherever the waters found a passage to the surface. Perhaps the present "diggings" are situated along especially open joints or at places from which the overlying impervious beds were first removed. That this first concentration was not very important

*Preliminary report on the lead and zinc deposits of the Ozark Region. H. F. Bain, C. R. Van Hise and Geo. I. Adams, 22nd annual U. S. G. S., p. 55.

is indicated by the fact that in the Gageville mines no great enrichment lies immediately below the Coal Measure rocks. How the water passed through this, we are unable to state. The shale probably pinches out in places, since some prospect holes have not penetrated it. In this first concentration by ascending waters the intermingling of solutions was probably the most important cause of precipitation.

With the partial removal of the imperfectly impervious beds above the ores of first concentration, surface waters began a second concentration, which in Miller county seems to have very largely determined the present position of the ore bodies. This water being charged with carbonic acid and other solvents, derived from the air and the vegetation, was potent in enlarging, by solution, the crevices, leaving in the crevices, clay, which is the insoluble residue of the dolomite. At the same time the galena contained in the crevice and the surrounding rocks was detached and remained in the clay. As erosion wore away the upper beds, this clay and lead descended with the rock. While much of the clay was washed away, the greater specific gravity of the galena caused its descent to approximate the vertical. In consequence the galena in the clay, even on the surface of the rocks, closely preserves the direction of the crevice from which it was derived. Thus the ore which originally occupied a vertical seam, perhaps through several hundred feet of rock, has been mechanically concentrated in ten or twenty feet of clay at the surface.

While one portion of this second concentration was mechanical another was chemical, as Van Hise and Weed have recently shown. The lead in the clay is all more or less rounded and corroded. This is due to the fact that surface waters have the power of dissolving galena with exceeding slowness. The lead salt was carried downward in solution and on meeting a precipitant was thrown down as the sulphide. A very good example of secondary enrichment is the rich zone lying above the Coal Measure shale in the Gageville mine. Here the precipitant was probably hydrogen sulphide, which was carried by water oozing from the carbonaceous shale. Shale is in the miners parlance "mineral band" and the miners state that galena is always found above the "mineral band." While in some cases, the carbonaceous matter in the shale was doubtless the dominant precipitant, in others, where the shale is less carbonaceous, the check offered to circulating waters by the shale and the consequent commingling of solutions from different sources may have been more important. We are unable to state, that chemical reaction between the iron and the zinc sulphides and the soluble lead salts has been important in precipitating the galena of this district. Mining development has not been extensive enough to prove the presence of sphalerite and iron pyrites at lower depths.

We believe that the position of the ore was largely determined by descending waters. Not only does the greater enrichment above the shale bed indicate this, but the galena found suspended from the roofs of caves points in this direction.

Above ground water level some secondary ores were formed. In the Saline diggings considerable amounts of impure cerussites ("mineral clinker") are present, while outside small amounts of cerussite and smithsonite occur. The formation of these carbonates is probably due to reaction between calcium carbonate (limestone) and the soluble metallic salts.

ROADS AND ROAD MATERIALS.

The upland area in the northern part of the county is sufficiently level, so that the roads are usually located on land lines. The grades are comparatively gentle, except in the vicinity of the larger streams. Clay, thickly studded with chert fragments, constituting what is known as "hard pan," usually underlies the soil at a depth of from 6 inches to 2 feet. This forms an excellent sub-soil for a road foundation. The soil which lies above the "hard pan" makes excellent roads in summer and fall, but in winter and spring these roads are almost impassable. Once or twice a year the roads are "worked" by scraping the dirt from the sides up into the middle of the road. Seldom, however, are any permanent improvements made.

The roads on the upland area are the most traveled of any in Miller county. The farming population is most dense on the prairies, but much of the produce raised by the people of the hilly country and bottom lands is transported to the market, a part of the way, at least, on the upland roads. In consequence, these upland roads should be the first, in Miller county, to be improved. The various streams afford an abundance of gravel, well adapted for the improvement of the clay roads.

Gravel containing pebbles over 2½ inches in diameter should be screened before being used. Gravel which contains clay, iron oxide or calcium carbonate in sufficient quantity to serve as a binder is usually preferable to the clean gravel. However, the presence of a binder in Miller county is less important than in some districts. Prior to surfacing a road with gravel, the large stones and stumps should be removed and the road graded and rolled.

The roads in the brakes and bottom land country follow topographic rather than land lines. They are located either on the ridges or in the valleys. With the exception of where the roads pass from the ridges to the valleys, the grades are, as a rule, very gentle. The residual gravel of all the Cambro-Ordovician formations is an excellent material for surfacing the roads.

This gravel drains rapidly, is free from dust in the summer and at all times forms a smooth hard surface. It possesses sufficient iron oxide to bind naturally. The ridge roads carry the principal traffic in the hilly country.

Rock exposures are numerous along all the roads and stone for macadam could be obtained very cheaply. A portable stone crusher could be used to advantage. The heavy pitted dolomite beds of the Jefferson City formation and the massive dolomite beds of the Gasconade limestone are doubtless best suited for this purpose. Both of these rocks have a uniform texture and are semi-crystalline. They would crush with comparative ease and would bind well. The cotton rock has been used locally to a small extent as a road material, and although it binds very readily it is soft and wears rapidly.

SAND.

There are two sandstones, the Graydon and the Bolin Creek member of the St. Elizabeth formation, which are frequently incoherent enough to be cheaply crushed into sand. The Graydon sandstone is most abundant on the north side, while the Bolin Creek sandstone occurs altogether on the south side of the Osage river. The Graydon sandstone is more frequently soft and friable than the Bolin Creek, and therefore constitutes the more valuable source of sand supply.

While in places both sandstones are almost without iron, the quantity of such sand is insufficient to constitute a source of supply for glass making. The sand possesses neither the fineness of grain nor the admixture of clay essential to a good moulding sand.

Both sands have been used locally for a number of years in mortar, and as far as known have given good satisfaction. If the grains were more angular they would impart greater strength to the mortar.

Sand for mortar is obtained from a 35 foot ledge of the Bolin Creek sandstone along Bolin Creek. Graydon sandstone has been quarried for sand on the south side of the Osage river at three localities: on the Fitzgerald farm in the center of sec. 10, T. 40 N., R. 15 W.; in the S. W. ¼ of sec. 19, T. 40 N., R. 13 W., near the range line; and in the north center of sec. 33, T. 39 N., R. 14 W. On the north side of the Osage river Graydon sandstone has been crushed for sand at the following localities: N. E. ¼ of sec. 25, T. 42 N., R. 14 W.; S. E. ¼ of sec. 2, T. 41 N., R. 15 W.; northeast corner of sec 16, T. 42 N., R. 15 W.; north center of sec. 19, T. 42 N., R. 15 W.; and S. W. ¼ of sec. 20, T. 42 N., R. 14 W.

In the construction of the Chicago and Rock Island Railroad, considerable crushed Graydon sandstone was used in the concrete. In the construction of the bridge across the Osage river, crushed dolomite from the Gasconade limestone was substituted.

The beds of the streams throughout Miller county contain almost inexhaustible quantities of excellent gravel, while in the Osage river bottom there is an abundant supply of sand. This latter, however, is not as clean as that derived from the sandstones.

SILICA.

Both of the terms "chalk" and "kaolin," as used in this county, refer to a white powdery silica which has been formed by the disintegration of chert with the removal of a large portion of the associated impurities. Decomposed chert in this form is known commercially as "silica." It is a soft, white incoherent substance which is unctuous to the touch and very absorbent.

The gradual alteration of chert into silica both horizontally and vertically can be observed in all the silica banks. In places the silica is found in the form of the concretionary chert nodules. The interior of some of these nodules is still unaltered chert, while in other instances the alteration has only taken place where parting planes occur between concentric layers of the nodules.

The Gasconade limestone is the only formation in which "silica" occurs in commercial quantities. In this formation the chert from which it is chiefly derived is secondary. Small quantities of silica occur wherever the chert of the Gasconade limestone has been weathered for a long time. The more important occurrences of silica are enumerated below.

A bank belonging to Mr. West Hackney is located in the N. W. ¼ of sec. 36, T. 41 N., R. 14 W. This is an open cut 250 feet long, 40 feet wide and 15 feet deep. The following is a section of the cut from top to bottom:

Section 29.

No.	Elev.	
1	14½-17½	3 feet of soil.
2	12-14½	2½ feet of silica and chert in beds varying in thickness.
3	11²/₃-12	4 inches of decomposed dolomite, stained dark brown by limonite.
4	8²/₃-11²/₃	3 feet of dolomite, chert and silica. These continually replace one another laterally.
5	5²/₃-8²/₃	3 feet of talus.
6	3¹/₆-5²/₃	2½ feet of dolomite with disseminated silica and chert.
7	2²/₃-3¹/₆	6 inches of silica and chert in thin beds.
8	2¹/₆-2²/₃	6 inches of silica, partially decomposed.
9	1²/₃-2¹/₆	6 inches of dolomite.
10	1½-1²/₃	2 inches of silica and decomposed dolomite.
11	0-1½	1½ feet of silica.

The silica near the bottom of the bank is better in quality than that at the top. This bank has produced a large quantity of silica.

In the northeast corner of the N. E. ¼ of the S. E. ¼ of sec. 14, T. 40 N., R. 14 W., considerable silica has been mined. At this place two layers, two and a half feet thick respectively, have been quarried. A white seam of chert which runs through the second layer in places completely replaces the silica and in others is itself almost entirely replaced by silica.

One-eighth of a mile southeast of the last locality the same beds, somewhat thinner, are quarried. This bank is owned by Mr. Alvin Reine.

Mr. Joseph B. Johnson has a silica bank in the southwest corner of sec. 19, T. 41 N., R. 13 W., from which eight to ten tons of silica have been shipped.

Silica also occrus along Dog creek in sec. 12, T. 40 N., R. 14 W.; on Coon creek in the S. E. ¼ of sec. 1, T. 40 N., R. 14 W.; on a cliff overhanging the Osage river on the line between secs. 27 and 34, T. 41 N., R. 13 W.; and in the N. W. ¼ of the S. W. ¼ of sec. 6, T. 40 N., R. 12 W. A three foot bed was observed in a ravine in sec. 23, T. 40 N., R. 15 W.

Silica is usually shipped to St. Louis by boat, although sometimes by rail. The usual price is said to be $2.00 per ton at the bank.

SOILS.

The soils of Miller county are of two kinds, residual and transported. The transported soils occur mainly in the bottom lands as a result of stream deposition. The residual soils are found almost exclusively on the tops of the hills, ridges and tablelands and are a product of the decomposition of the rocks which immediately underlie them. The latter class includes all soils which have not been trasported for any considerable distance.

Residual Soils.—Proctor limestone and Gunter sandstone.

The areas underlain by the Proctor limestone and the Gunter sandstone are either largely covered by transported soils or lacking in soil of any kind.

The Gasconade Limestone.—The areas underlain by Gasconade limestone, with the exception of the bottom lands where the soils are transported, are very little cultivated. This is due largely to the ruggedness of the topography and not to the unproductiveness of the soil. The tops of the ridges are so narrow and the hill sides so steep that the decomposition products are washed away almost as soon as they are formed. It is unusual to find arable tracts of over two or three acres. There is much more rock exposed in the areas underlain by Gasconade limestone than in any other areas in Miller county. The residual soil of the Gasconade limestone is dark brown or black, compact and clayey and fairly productive. The subsoil is a red or yellow clay, filled with flint fragments. The dumps of prospect holes, twenty years old, composed of this sub-soil do not support vegetation of any kind.

The St. Elizabeth Formation.—The soils resulting from the decomposition of the St. Elizabeth formation are as variable as are the rocks of that formation. The extremes are an exceedingly loose sand and a very dense, compact clay. The sand and clay soils are not very fertile, but the intermediate phases are often fairly productive. The sandy soils occur more especially on the south side of the Osage river and the clayey soils on the north side. The flat topped ridges are easily cultivated. The depth of the soil of the St. Elizabeth formation varies greatly. In places it is only a few inches deep, while in others, as in the vicinity of Iberia, it is ten feet or more.

Jefferson City Formation.—The soil resulting from the decomposition of the Jefferson City formation is the most fertile residual soil of Miller county. It is a black, loamy soil having a very desirable texture and porosity. Its thickness varies from nothing on the "balls" to 14 feet on the prairie land. The sub-soil is often a hard-pan of red clay containing many flint fragments.

Carboniferous Formations.—The rocks of these formations underlie such small areas that they scarcely deserve mention as soil producers. Wherever the Upper Burlington limestone occurs the soil contains numerous chert boulders which must be removed before the land can be easily tilled. Otherwise, the soil is very productive. In the neighborhood of the Graydon sandstone, the soil is usually very sandy. The yellowish or reddish color of much of the soil overlying the Jefferson City formation in the northern part of the county, is due to the presence of sand from the Graydon sandstone and chert from the Upper Burlington limestone, which once covered a greater part of the county. The disintegration of small areas of Coal Measure shale contributes fertile soil to limited areas.

Transported Soils.—The transported soils occur in the bottom lands of the Osage and Moreau river systems. The Osage river and its tributaries drain land which is underlain with all the formations from the Proctor limestone to the Coal Measure shales and all contribute a share to the soils of the bottom lands. The Moreau river receives detritus mainly from the St. Elizabeth, Jefferson City and Carboniferous formations. The difference in the source of the detritus of the two streams, makes the soils somewhat different both in composition and texture. The soil of the Osage bottom land is deeper than that of the Moreau and is ordinarily more finely comminuted.

Soils and Industries.—Until recently the chief crops raised in this county were corn and wheat. Within the past few years, however, apple orchards have been planted with a remarkable degree of success. The high iron content of the soils of the ridge land renders them especially favorable to apple culture. With the completion of the Chicago and Rock Island Railroad, a large territory should be opened up to this pursuit. The climate seems too vigorous for the successful cultivation of the peach.

There is much land underlain by the Gasconade limestone and the St. Elizabeth formation, which is almost valueless for agricultural purposes. If the underbrush and black oak were cut out and the white oak saplings allowed to mature, much of this land would produce timber which is especially valuable for ties. With the removal of the underbrush, the grass would rapidly regain its original growth and the grazing value of the land would be greatly increased.

In the future cattle raising will undoubtedly be a more important industry than it is at the present time. Sheep raising and the introduction of the Angora goat are among the very probable developments of the future.

WATER SUPPLY.

Few counties surpass Miller in the abundance and purity of their water supply. The water is obtained from four sources, (1) springs, (2) streams, (3) wells and (4) artificial ponds.

Of the rain which falls upon the earth, a portion evaporates, another portion runs off of the surface and the remainder percolates downward into the rocks.

SPRINGS.

The springs in the hill country have determined the location of many of the farm houses. A map showing the location of the houses would serve almost equally as well as a map of the location of the springs. The water, when not contaminated by nearness to barns and outbuildings, is of excellent quality, usually hard and cold. The springs are usually situated along the outcrops of the water bearing horizons mentioned on page 195.

In the S. W. ¼ of sec. 19, T. 40 N., R. 14 W., an unusually fine spring issues from the Gunter sandstone which is 3½ feet thick at that place. A rapidly flowing stream 2 feet wide and 6 inches deep is formed by it. The spring has eaten back into the Proctor limestone and the

Gunter sandstone, forming a cave 10 feet wide at the base and 5 feet high.

In sec. 29, T. 41 N., R. 13 W., a large spring issues at the contact of the Gunter sandstone and Gasconade limestone. Sixty feet up the bluff, a smaller spring issues from the Gasconade limestone, but disappears in a crevice 30 feet lower down.

Half way between St. Elizabeth and Iberia, by the road side, is a large spring flowing from the upper part of the Gasconade limestone. Near the Camden county line in the southwest corner of the S. E. ¼ of sec. 17, T. 38 N., R. 14 W., is a creek 10 feet wide which heads in a spring flowing from the upper part of the Gasconade limestone.

There are fewer springs along the Moreau and its tributaries than on the Osage river. This is due to the fact that the valleys of the former have not cut through any important water-bearing horizon. The best spring observed along the Moreau or its tributaries was in the southeast corner of sec. 1, T. 41 N., R. 16 W.

Several farmers have piped spring water into their houses. The Brumley hotel usues for domestic purposes a spring issuing from the contact of the St. Elizabeth and Jefferson City formations.

The Composition of Spring Water.—All spring water contains a greater or less per cent. of mineral matter in solution. A mineral water may be defined as a natural water, which, from its peculiar chemical composition, is of value in the treatment of disease.

Sulphur water flows from the upper 40 feet of Gasconade limestone on Mr. Hale's land, on the county line, in sec. 12, T. 38 N., R. 12 W.

In the southwest corner of the S. E. ¼ of sec. 23, T. 41 N., R. 14 W., a sulphur spring issues from the east bank of Saline creek. The stream is about one inch in diameter, but is said to flow constantly. The water has a slight sulphur taste. Pebbles in the spring are blackened and smell strongly of sulphur, while those in the creek near by have been colored red. Gas in considerable quantities bubbles from this spring. The water is said to be beneficial in the treatment of diseases of the eye.

The Aurora springs, situated in the S. E. ¼ of the S. E. ¼ of sec. 9, T. 41 N., R. 15 W., flow from the upper 35 feet of the Gasconade limestone. At one time these springs were considered among the most valuable of Missouri's medicinal waters. The following analysis appears in Bulletin 32 of the United States Geological Survey, page 168:

Grains per gallon	20.878
Iron carbonate	5.130
Calcium sulphate	2.427
Sodium chloride	4.009
Magnesium chloride	6.949
Lithia	1.430
Ferrous oxide	.933

WELLS.

The townspeople and farmers residing on the ridges usually depend, for their domestic needs, either on (1) rock penetrating wells, (2) cisterns and dug wells, or (3) flowing wells.

Water Bearing Horizons.—The rain water which percolates downward into the earth is largely contained in horizons of porous rock. It is from these horizons that the wells derive their water and it is from these that the springs flow.

Here, as elsewhere, sandstone is the most important water-bearing rock. The Gunter sandstone is perhaps the most important water-bearing formation in this county. The shattered chert beds of the Gasconade limestone are zones of considerable water flowage, as shown by the masses of travertine deposited upon their outcrops.

There are three horizons in the St. Elizabeth formation along which water circulates abundantly. The most persistent of these is the broken chert bed at the base of the formation. On the south side of the Osage river the Bolin Creek member is an important water bearer. The cellular conglomerate sandstone at the top of the formation is also an almost constant aquifer.

The intercalated sandstone beds in the Jefferson City formation are also water-bearing horizons.

Rock-Penetrating Wells.—Water can usually be obtained in the Gasconade limestone at from 30 to 50 feet from the surface. At Tuscumbia the wells at the base of the bluff encounter an abundant supply of water at from 20 to 30 feet, but those on the hill, which is surrounded on three sides by steep slopes, do not strike water at less than 100 feet.

Wells in the St. Elizabeth formation usually have an abundance of water, though in some localities the use of cisterns is necessary. The wells in the vicinity of the Aurora Springs depot are from 105 to 120 feet deep. In drilling these wells, it is reported that from 70 to 80 feet of dolomite and 8 to 10 feet of flint were passed through before entering the water-bearing sandstone. The water rises from 20 to 30 feet above this sandstone and is said to be practically inexhaustible.

Where the Jefferson City formation is thin the wells usually penetrate the upper beds of the St. Elizabeth formation and from these water is obtained in abundance. The wells at Mary's Home are from 30 to 100 feet deep, although sufficient water is usually obtained at a depth of from 30 to 50 feet. The water is apparently derived from the upper beds of the St. Elizabeth formation.

Cisterns and Dug Wells.—Where comparatively deep wells are required to reach a water-bearing horizon, cisterns are in common use.

Cement-lined cisterns furnish water to the people living on the ridge at Tuscumbia. Cisterns are common on all the more elevated ridges in the areas underlain with the St. Elizabeth and Jefferson City formations. Shallow wells dug in the alluvium furnish water to many of the families in the bottom land areas. The water, as a rule, is soft.

Flowing Wells.—Several flowing wells are situated in the valley of Blyth's fork in the vicinity of Olean. One on Mr. J. C. Johnston's place is said to have passed through 10 feet of alluvium and 57½ feet of interstratified flint and sandstone. Before rock was struck, an abundance of water is reported. This well flows 7½ gallons per minute. Mr. Johnston has a second flowing well in his yard, and there are others at the canning factory, the flour mill, the livery stable and Johnston Brothers' store. The last two do not flow at present, the former because of imperfect piping and the latter because of wells which have been since sunk at a lower level. Alternating beds of impervious shale and porous sandstone and chert combined with the dip of the beds give rise to conditions favorable for flowing wells at this place. There is very little hope of obtaining artesian wells where the land is more than 25 feet above the level of the creek at Olean.

One of the drill holes at the Son prospect in sec. 19, T. 41 N., R. 15 W., is a flowing well. This is situated near the top of the Gasconade limestone. The hole is 140 feet deep, no water having been struck up to 100 feet. The well is 12 feet above the bottom of the Little Gravois creek at that place. In the bottom of Bailey's Branch, two and a half miles northwest of Iberia, George Graves obtained a flowing well at 60 feet in the Gasconade limestone.

The Purity of Well Water.—Through man's negligence and ignorance well water frequently becomes contaminated. The shallow wells sunk in the bottom land areas are especially dangerous since the alluvium not only carries a high percentage of organic matter, but, being porous allows impurities to readily enter the well. Comparatively deep wells situated near stables are a constant source of danger. All wells should be cased with iron pipe to a point below some bed of clay, shale, or other impervious strata.

ARTIFICIAL PONDS.

In Miller county the farmers living on the ridges construct small, artificial reservoirs in the impervious clay subsoil. During the winter and spring, these depressions are filled with rain water from surface drainage. These reservoirs provide sufficient water for the stock except during the most severe droughts.

WATER POWER.

The larger springs of this county have a sufficient flow to furnish power to mills of small capacity.

G. L. Wright runs a small carding mill, using for power the "Big Spring" situated on the section line in the N. E. ¼ of sec. 34, T. 41 N., R. 14 W. At this place the water issues from a number of holes in the "hard pan" in the bottom of Little Saline creek. A circular embankment 25 feet in diameter and 5 feet high has been built above the bottom of the creek to confine the water. From this reservoir the water passes into a race and onto an over-shot wheel. The amount of water fluctuates somewhat, although entirely independent of local rains. The drought of the summer of 1901 somewhat reduced its flow.

Springs situated somewhat less than one-fourth of a mile up a gulch tributary to Tavern creek, furnish power for Bray's flour mill in sec. 9, T. 39 N., R. 12 W.

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