THE GEOLOGY *of the* POTOSI *and* EDGEHILL QUADRANGLES

By C. L. DAKE

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BOARD OF MANAGERS

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Missouri Bureau of Geology and Mines,
Rolla, Mo., July 30, 1930.

To the President, Governor Henry S. Caulfield, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen: It is my pleasure to transmit herewith a report covering the stratigraphy and mineral resources of the Potosi-Edgehill Quadrangles.

This report and the companion volume by Josiah Bridge on the Eminence-Cardareva Quadrangles, present the results of several years work covering the most difficult problems of the Ozark region. They are valuable contributions to our knowledge of the geology of the southern half of the State.

Respectfully submitted,
H. A. BUEHLER,
Director and State Geologist.

INTRODUCTION.

SCOPE OF THIS INVESTIGATION.

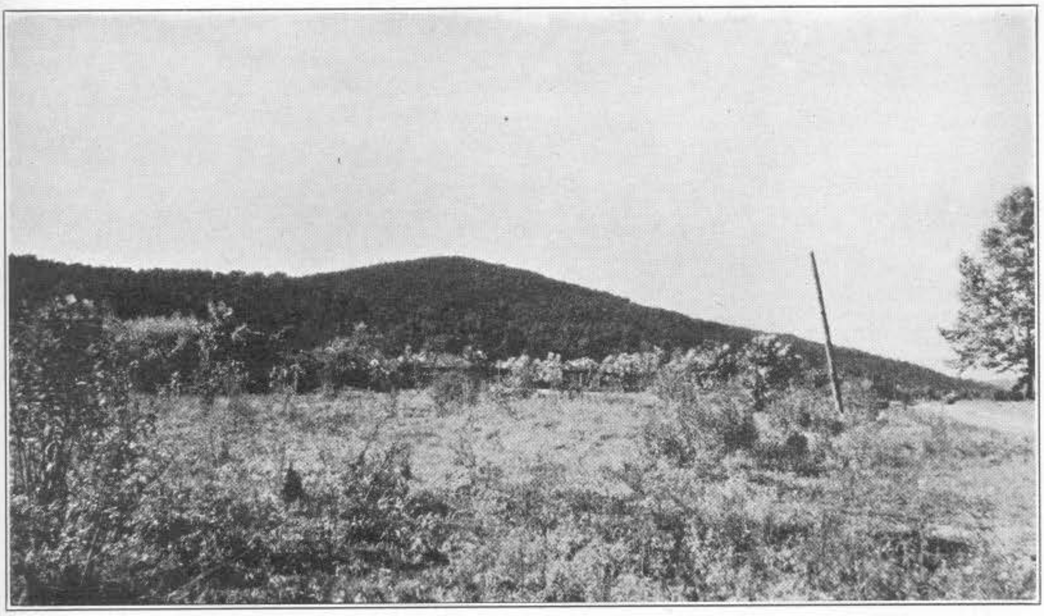
This report had its origin in the demand for a stratigraphic study of the chief barite producing region of the United States. Since the area is a critical one in its bearing on the geologic history of the Cambro-Ordovician of the Ozark uplift, much time was spent in working out the details of the stratigraphic succession and correlation. Though the Edge Hill quadrangle does not lie in the important barite producing area, it holds such a commanding position in the stratigraphic history of Southeast Missouri, that it was deemed advisable to include it in the report.

ACKNOWLEDGMENTS.

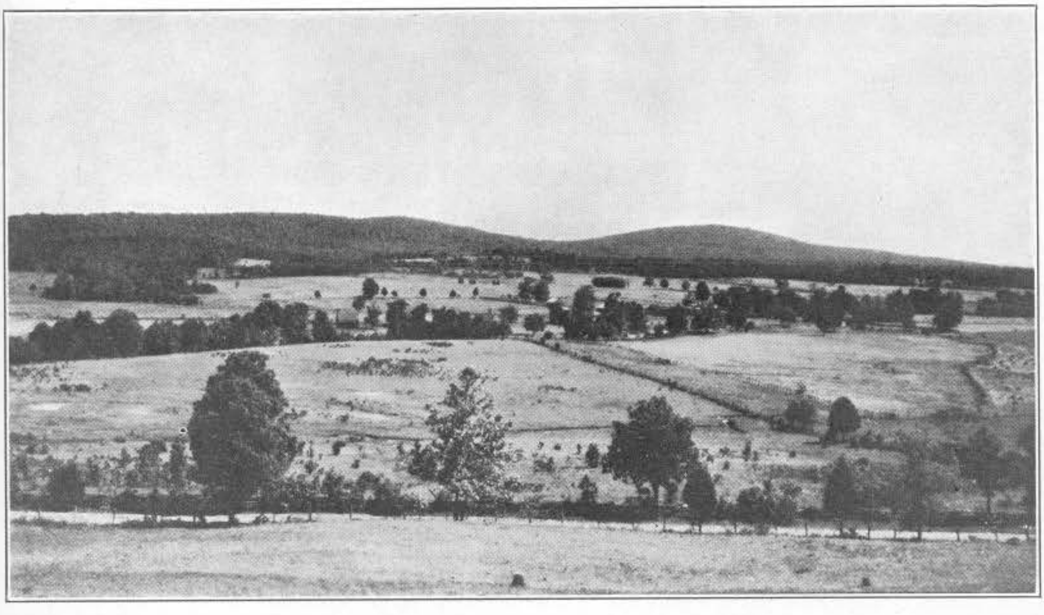
In the field work the writer was assisted during the summer of 1922 by Prof. W. D. Shipton of Washington University, and Mr. J. E. Jewell; during the summer of 1923 by Mr. Geo. G. Harris; and during the summer of 1924 by Mr. C. L. Martin. At the same time Prof. Josiah Bridge was working on a similar problem on equivalent beds in the Eminence quadrangle, about sixty miles to the southwest. During each summer important conferences were had with him in both areas, and he and the writer made a trip to Hahatonka and to Proctor Creek in Camden and Morgan counties, late in the fall of 1922, to study the possible relations of the Eminence to the Proctor.

During the summer of 1923, Mr. C. O. Reinoehl of this bureau, upon the writer's request, prepared narrow strips of topographic map connecting the Potosi and Rolla quadrangles, also the Potosi and Eminence quadrangles, with a view to making careful sections tying the two latter areas to the already mapped Rolla quadrangle, in an attempt to settle the stratigraphic position of the so-called "Upper Eminence."

Time did not permit, during the summer of 1923, the completion of the geology along these profiles, and this work, together with about five square miles in the northwest corner of the Potosi sheet, had to be left to the following summer. In 1924 this work was completed, and extensive reconnaissance carried on in the



A. High Top Mt., seen from the south. A conspicuous porphyry peak.



B. Belleview Valley, west of Belleview, looking north, porphyry ridges in the distance.

area southeast of the St. Francois Mountains, in Madison, Iron, Wayne and Reynolds counties.

During this summer, Mr. Reinoehl prepared a topographic base of a considerable area in Camden and Laclede counties, including Decaturville and Hahatonka, to facilitate geologic mapping in those regions, and during the summer of 1925, the writer studied this area, with the hope of establishing the relation of the Proctor and Eminence formations.

The Edge Hill topographic sheet appeared in 1926, and during that summer, Prof. Bridge and the writer made extensive reconnaissance across this sheet and into adjacent areas to the south and east, as well as into the Decaturville-Hahatonka region, collecting fossils, and studying the relations of the various formations but doing very little detailed mapping. During this season, Mr. Ronald Mabrey assisted the writer for about two weeks. In 1927 with the aid of Prof. G. A. Muilenburg, the mapping of the Edge Hill sheet was continued; and was completed during the summer of 1928, with the aid of Mr. S. A. Lynch, and Mr. T. D. Murphy.

Dr. E. O. Ulrich, of the United States Geological Survey, made special trips to Missouri, during the summers of 1923, 1924, 1926, and 1928, for conferences with Prof. Bridge and the writer, in an effort to settle disputed questions of correlation in these quadrangles, and has been very kind in identifying fossil collections and rendering other assistance.

The writer is greatly indebted to Mr. T. F. Blount of Potosi, and Mr. B. G. Halbert, of Palmer, for much information, and many courtesies.

Prof. G. A. Muilenburg assisted in the field studies on the igneous rocks, and he examined all of the thin sections, and wrote all of the petrographic descriptions, which are presented as prepared by him.

All of the paleontologic identifications for the report have been made, or at least have been checked, by Prof. Josiah Bridge, except where otherwise specifically acknowledged.

PREVIOUS WORK.

There are comparatively few publications that deal with the geology of the area embraced in this study.

In 1855, Dr. Litton presented a report which was included in the First and Second Annual Reports of the Geological Survey of Missouri, by G. C. Swallow, State Geologist. On pages 40-63 of that report, Dr. Litton describes in some detail the distribution and importance of the various lead diggings in Washington County, with brief statements as to the mode of occurrence of the ore, but there is no reference to the stratigraphy or structure of the region.

Broadhead, in the report on Iron Ores and Coal Fields (p. 415) refers, in 1872 to marble on Tom Sauk Creek; and again, in the Report of the Geological Survey of the State of Missouri, including Field Work of 1873-1874, there is another brief reference (p. 56) to the marble.

Winslow, Missouri Geological Survey, vol. VI, 1894 (pages 267-302), describes the history of early lead mining in Missouri, with frequent references to Washington County; and in vol. VII (pages 678-683), describes several of the more important diggings, with much detail about the occurrence of the ore, but with no specific discussion of the stratigraphy or structure of the area embraced in the Potosi and Edge Hill quadrangles. In vol. VI (pages 355 to 356), occurs a very brief reference to drusy limestone and beds of sandstone between Potosi and Palmer, but no statement is made as to their place in the stratigraphic column.

Haworth, Missouri Geological Survey, vol. VIII, 1895, makes reference (p. 87), to the topographic expression of the porphyry in the Black River region (Edge Hill sheet) and shows two photographs (Pl. III and Pl. VI) of Johnson's Shut-in, on the East Fork. At other places in his paper on the Crystalline Rocks of Missouri (vol. VIII), he refers more or less incidentally to igneous rocks at localities within these two quadrangles (see pages 136, 178-180, 218).

Marbut, Missouri Geological Survey, vol. X, 1896, makes very brief mention of physiographic features near Potosi (pp. 37-38).

Wheeler, Missouri Geological Survey, vol. XI, 1896, describes the clays near Shepard, in Iron County (p. 178).

Buckley, in his report on the Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Missouri Bureau of Geology and Mines, 2nd ser., vol. IX, pt. 1, 1908, describes diamond drilling near Palmer, and presents a detailed log of one of the holes with his correlation of the formations (p. 55-57).

Crane, in his report on The Iron Ores of Missouri, Missouri Bureau of Geology and Mines, 2nd ser., vol. X, 1912, mentions iron ore production south of Potosi (pp. 343-346), with brief descriptions of some of the pits, and lists (p. 264) reported occurrences of iron ore bowlders in that part of Iron County lying within the area embraced in this report.

Tarr, in his paper on the Barite Deposits of Missouri, University of Missouri Studies, vol. III, no. 1, has discussed briefly the stratigraphy, structure, and economic geology of that portion of the Potosi quadrangle in which active barite production occurs.

Weigle, in Technical Publication No. 201 of the American Institute of Mining and Metallurgical Engineers, 1929, the Barite Industry of Missouri, has also discussed briefly the stratigraphy of the area about Potosi, and the occurrence and origin of the barite.

METHOD OF DESCRIBING LOCALITIES.

In general, where it is necessary or desirable to refer to exact localities, they are described in terms of the ordinary land survey, by section, township, and range. In certain portions of the region, however, the older Spanish land grants prevail, and the country is not sectionized. In these areas, all locations are given as though the normal land survey lines were projected across the unsectionized tracts. That is, even though no sections appear, the description is given as in a certain section, township, and range. The described locality can be found very easily, by projecting the lines of adjacent surveyed sections across the old grants.

CHAPTER I.

GEOGRAPHY AND PHYSIOGRAPHY.

Location.

The Potosi quadrangle is located wholly in Washington County in eastern Missouri, and embraces about 235 square miles of territory between parallels 37° 45′ and 38° 00′ north latitude, and between meridians 90° 45′ and 91° 00′ west longitude. It lies well toward the east flank of the Ozark plateau, and constitutes the northwest border of what is commonly termed the St. Francois Mountains. The Edge Hill quadrangle, of the same size and scale, borders the Potosi on the south, and includes portions of Washington, Iron and Reynolds counties, the southeast corner of the sheet embracing a typical section of the main St. Francois Range.

History and Settlement.

The early history of the area now comprised in Washington County is essentially a history of the development of lead mining in the State. Accurate information, involving exact dates, is difficult to secure, but it would seem that the first discovery of lead in Missouri was on the Meramec, in the year 1700, and the first serious effort at mining occurred at the same locality about 1719. The Mine La Motte deposits, in Madison County, are believed to have been discovered about 1720. Old Mine and Mine Renault, the latter named after Philip Francis Renault, the French explorer, are said to have been opened between 1724 and 1726, and therefore rank as among the very oldest mines in the state, if not in the entire Mississippi valley. A portion of the original grant at Old Mine is included in the area of the Potosi quadrangle. For several years, mining was pushed vigorously, but with subsequent failure of the company backing the enterprise, Renault returned to France in 1742, and the industry languished.

In 1763, La Breton (also known as Burton) discovered lead, on the present site of Potosi. The village that sprang up was known as Mine au Breton, the name being changed to Potosi, about the year 1823.

Moses Austin, an experienced lead miner from Virginia, arrived at Mine au Breton about 1797, and in consideration of a large grant of land, erected a furnace the following year. Before his time, all of the mining had been shallow clay diggings. He sunk the first regular shaft 80 feet into the solid rock. He built a shot tower in 1799, and supplied the arsenals at New Orleans and Havana. From this date on, lead mining increased rapidly in importance. The well-known Palmer mines were opened in 1814, and by 1831, employed about 200 people. For a number of years, Palmer was a thriving town, but is now almost deserted.

With the development of the enormous disseminated lead deposits of Flat River and Bonneterre, which were not extensively worked until after 1880, lead mining in Washington County decreased rapidly, though there has been sporadic development down to the present time.

The presence of barite, associated with the lead of Washington County, was recognized as early as the beginning of the last century, but there does not appear to be any record of active mining of that mineral until after the close of the Civil War. At the present time, the area surrounding Potosi is the most important barite producing district in the United States.

Population and Industries.

Potosi, the county seat of Washington County, and the largest town within the area of the two quadrangles, has a population of 1284. It is the terminus of a short branch of the St. Louis, Iron Mountain and Southern Railroad, extending west from Mineral Point. This branch, of which about one mile lies within the quadrangle, is the only railroad in the entire area of the two sheets. Potosi is at the junction of Highways 8 and 21. Caledonia, about 12 miles south of Potosi, on Highways 21 and 32, is a village of 143 persons, the center of a prosperous agricultural community. Belgrade, about four miles west of Caledonia, is about the same size, and is also located in a good farming region. Though not on a highway, it is reached by a fairly good county road.

Palmer, which is credited with having had a population of over 1000 persons, during the height of its prosperity, is now nearly deserted, but still maintains a store and blacksmith shop. There are stores at Shirley and Sunlight. A portion of the village of Old Mines is included in the northeast corner of the Potosi sheet, where Highway 21 leaves the north border of the quadrangle. Mineral Point and Cadet lie a few miles east of the north end of the Potosi sheet, on the main line of the St. Louis, Iron Mountain and Southern Railroad.

On the Edge Hill quadrangle, the largest villages are Black, Edge Hill, and Redmondville, with a population of about 50 persons each. Other villages shown on the map consist of two or three houses each, with a country store and postoffice. Belleview, with a population of over 100, lies just off the east border of the map, near the junction of Highways 32 and 21, and Graniteville is on Highway 21, a few miles farther southeast. Not far off the south edge of the map, on Highway 21, are Lesterville, and Centerville, the latter the County Seat of Reynolds County. East End, about three or four miles west of the sheet, on Highway 32, is the terminus of a logging railroad that connects with the Salem Branch of the St. Louis and San Francisco railroad near Steelville.

On the Potosi quadrangle, the rural population averages about 11 or 12 persons per square mile, and on the Edge Hill quadrangle, about 8 or 9 persons. In the heart of the Tom Sauk Country, there is one block of 18 sections, in which there are only 8 houses. This is the wildest section embraced in the area of the two sheets, and is the most sparsely populated.

In the Potosi quadrangle, the chief industry is barite mining. Throughout the entire area, the best of the timber has been cut off, but small sawmills still operate, and a good many ties, both hewed and sawed, are being taken out.

Except for the gently rolling region, about Caledonia, Belgrade and Belleview, the only farm lands of any consequence are along the narrow valleys. The chief crops are corn and hay, mostly fed locally. The main farm products marketed are hogs and cattle.

The area is apparently well suited to fruit, though but little is raised, the chief drawback being the lack of marketing facilities. With the coming in of good highways, this handicap to fruit raising should rapidly disappear.

Transportation.

The only railroad to touch either quadrangle is a short spur of the St. Louis, Iron Mountain and Southern, terminating at Potosi, and connecting with the main line at Mineral Point.

From the northeast corner of the area Cadet, on the main line of the Iron Mountain, is reached over ordinary country roads. From Caledonia, the same line may be reached at Bismark over Highway 32, or at Ironton over Highway 21. From the northwest portion of the Edge Hill quadrangle, Highway 32 leads west a few miles to East End, the terminus of a logging railroad connecting with the St. Louis and San Francisco near Steelville. The service is not regular however.

Highway 21 enters the Potosi quadrangle at Old Mines in the northeast corner, extends south through Potosi to Caledonia, and cuts across the northeast corner of the Edge Hill sheet. It is completed and gravelled throughout the entire distance. Highway 8 extends west from Potosi through Shirley and Berryman to Steelville. There is a fair county road from Caledonia to Belgrade, but the southwest portion of the Potosi quadrangle has very poor roads, and is difficult of access, though it is proposed to open it up in the near future with a unit of the Farm to Market system.

Highway 32 extends west from 21, across the north end of the Edge Hill sheet to Bixby and Salem. The roads through the southern portion of the Edge Hill sheet are inferior. They are rough, and at times of high water, cannot be travelled, for lack of bridges. Highway 21 from Lesterville to Centerville, is in excellent condition, and approximately parallels the south border of the map, at a distance of about one to four miles from the sheet edge.

Climate.

The area embraced in these two quadrangles has a mean annual temperature of about 55°. The winter average is about 30°, the summer average about 80°. The extreme ranges are from about 25° below zero, to about 110° above, but these extremes are rarely reached. In general the summers may be characterized as hot, the winters as mild.

The average rainfall is between 40 and 45 inches, but is quite variable, some seasons being much wetter and others much drier than this average. Ordinarily the spring and early summer are marked by heavy rainfall, and the late summer and early autumn are frequently quite dry.

Relief.

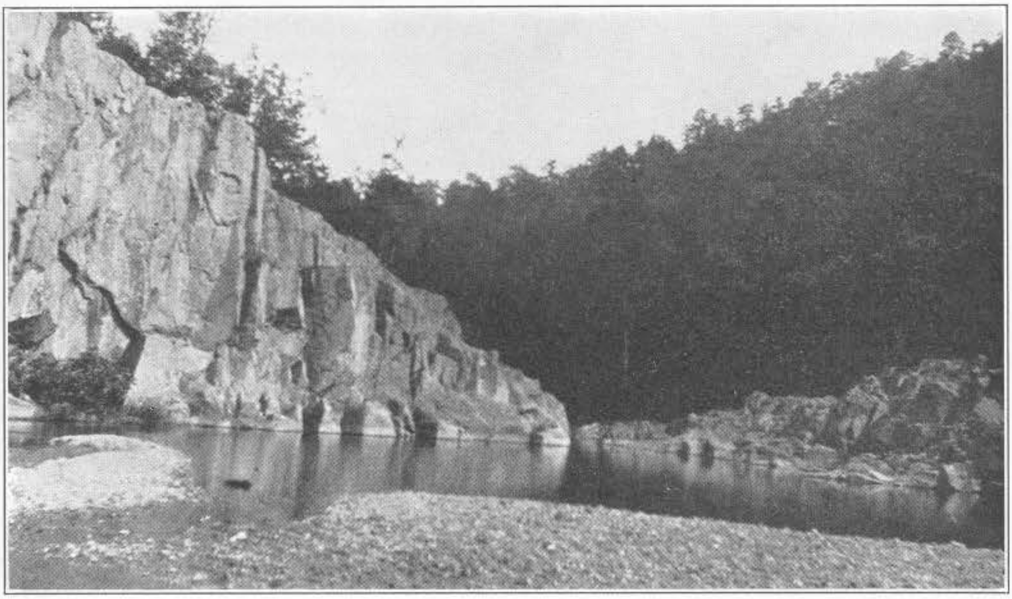
The lowest point on the Potosi sheet is at the north border, on Fourche a Renault Creek, which is at an elevation of about 730 feet. The highest is Little Pilot, a porphyry knob, in the northwest corner, just above 1400 feet, and the next highest is in sec. 4, T. 35 N., R. 1 E., about two miles southwest of Sunlight, where a knob capped with Eminence chert float resting on Potosi dolomite, rises to just above 1320 feet. The average local relief on the sheet is between 200 and 300 feet.

The lowest points on the Edge Hill sheet are those where the East Fork and the Middle Fork of Black River leave the south border, each being at about 730 feet. The highest is Wildcat Mountain, rising to a little over 1760 feet, and the second highest is Little Tom Sauk[1], just over 1720 feet, both porphyry. There are in the quadrangle a number of other porphyry knobs rising above 1500 feet, as well as two or three sedimentary peaks of that height, the highest area of sedimentary rocks being in T. 34 N., R. 2 E. The average local relief on the Edge Hill quadrangle is between 300 and 500 feet, the area being much more rugged than that of the Potosi quadrangle.

The general upland level approximates 1100 feet, at the north end of the Potosi sheet, gradually rising to above 1300 feet in the central portion of the Edge Hill and then declining slightly southward. This upland seems to consist of remnants of an old peneplain, since it appears to be quite independent of structure, distinctly bevelling across several formations from Potosi to Roubidoux in age, and clearly truncating faults of large displacement.

Little Pilot Knob, secs. 25 and 36, T. 38 N., R. 1 W., and the knob on the north line of sec. 2, T. 37 N., R. 1 W., both rising well above this upper plain, are resistant porphyry monadnocks, on the Potosi sheet, and on the Edge Hill quadrangle, are many such porphyry peaks, which overtop the upper plain (Pl. I, A and B). It should be pointed out that, contrary to widespread popular belief, these peaks are not volcanic cones. Their

[1]Variously spelled Taum Sauk, Tom Saulk, Tom Suck, and Tom Sauk, the latter form accepted by the United States Geological Survey. This mountain is in Reynolds County. It should also be noted that there is a Taum Sauk Mountain in Iron County, shown on the old Iron Mountain sheet, where its height is given as 1800 feet.



A. Johnson's shut-in, on the East Fork of Black River, SW. ¼ sec. 16, T. 33 N., R. 2 E., carved in porphyry.

B. Detail of pot-holes in Johnson's shut-in shown above.

conical shape (Pl. I, A) is doubtless responsible for this mistaken idea. They are actually carved by normal erosion, from rocks of volcanic origin it is true, but in an area where all trace has long since been obliterated, of the former peaks from which the volcanic material was emitted. The present form of the peaks was largely acquired in pre-Cambrian time, since when they have been completely buried one or more times by later sediments, and then resurrected by still later erosion, in essentially their pre-Cambrian form.

The region, as a whole, is dissected to early maturity, the upland areas being narrow sharp divides, while the stream valleys for the most part are also narrow, with mere ribbons of flood plain, which constitute the only tillable land over most of both quadrangles.

A notable exception to this is the area in the southeast corner of the Potosi and the northeast corner of the Edge Hill sheets, around Belgrade, Caledonia and Belleview. From this area the softer Davis shale and non-cherty Bonneterre dolomite have been much more completely eroded, giving the gently rolling aspect of later maturity. Actually, however, the present streams are slightly intrenched below this plain, representing slight rejuvenation, since it matured, so that it should, perhaps, be better spoken of as youthful, with respect to the streams that are now dissecting it. This area is a prosperous agricultural community (Pls. I, B; V, B; and XIX, B).

Above the plain developed on the Bonneterre and Davis, are a number of sharp knobs of porphyry, the tops of which rise to about 1100 to 1200 feet, and which therefore correspond closely to the general upland level of the main peneplain. They now bear the position of monadnocks rising above the local Bonneterre plain by reason of their superior hardness.

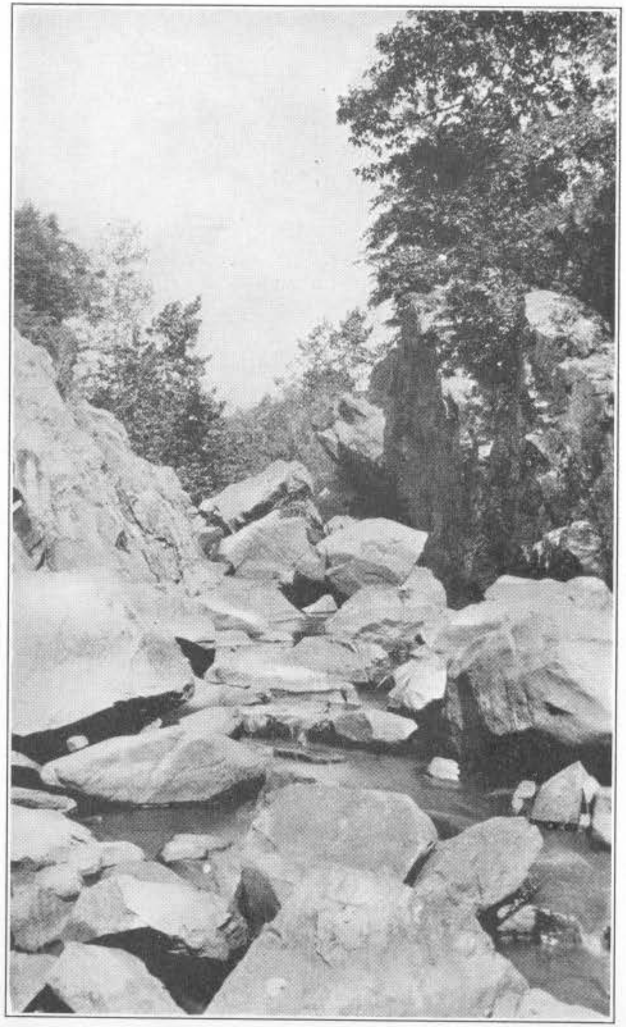
While the lower plain about Caledonia and Belleview (Pls. I, B and V, B), is undoubtedly related to the erosion of less resistent beds, it does not seem proper to speak of it as a stripped structural plain, since at the extreme eastern edge of the quadrangles it lies in part on Lamotte, while at Belgrade, nearly the full thickness of the Bonneterre is present, and near Sunlight, the plain rests partly on Davis. In other words, it distinctly bevels across westwardly dipping beds. It, therefore, probably represents a lower and younger partial peneplain, above which the porphyry knobs rise as monadnocks to the level of the higher, older, and more perfect peneplain.

This more rolling area is delimited on the north by an obsequent fault-line scarp (Pl. V, A), facing south, the softer Davis and Bonneterre of the upthrown (south) side being more worn down than the cherty Potosi, Eminence, and Gasconade of the downthrown (north) block. On the west the lowland is bordered by an east-facing escarpment resulting chiefly from west-dipping beds of harder cherty dolomite, overlying the softer Davis shale. Locally faulting plays a part also in this escarpment. To the south of the plain is a north-facing escarpment (Pl. V, B), made by the same cherty beds dipping slightly south into a synclinal area between two main porphyry ranges.

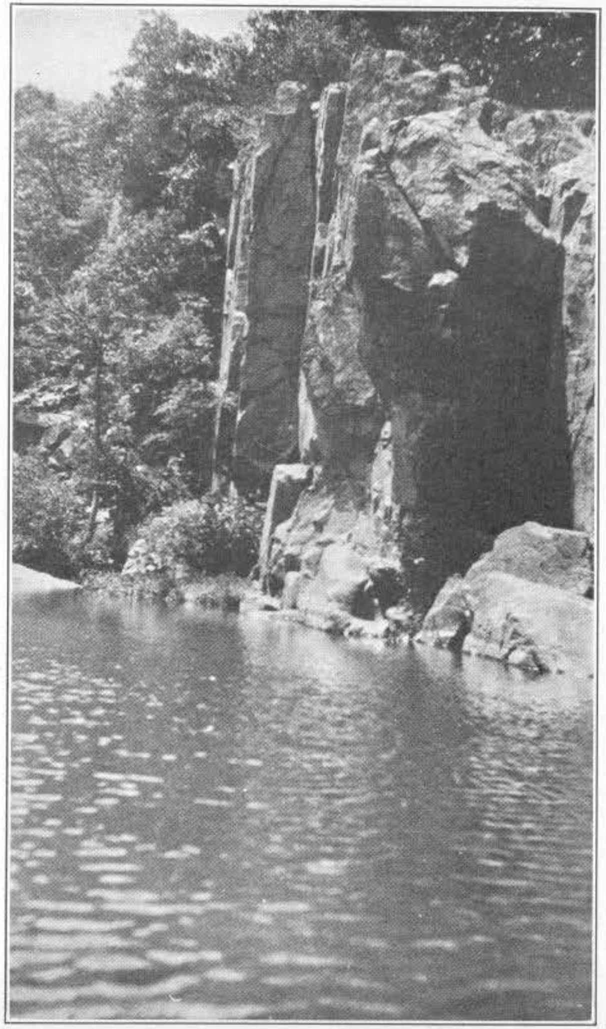
Since the rocks throughout the quadrangle are nearly horizontal, the drainge is rather typically dendritic in pattern, and only to a very minor extent modified by local structure. The superior hardness of the porphyry knobs, and the inferior resistance of the Davis and Bonneterre are such local factors already discussed.

Another case of local structural control of topography is illustrated by the Roubidoux-capped upland in the north third of T. 36 N., R. 1 E., and the south half of T. 37 N., R. 1 E. In this section the resistant Roubidoux sandstones dip from 50 to 100 feet to the mile northwest, and the upland is flanked by an escarpment facing southeast across the north part of T. 36 N., the face of which is sharply dissected by south and southeast-flowing streams. On the other hand Lost Creek and Little Lost Creek approximate northwest dip-slope gradients in their head waters, and have an appearance of much greater maturity, because held up on the surface of the more resistant sandstone beds, which must have been stripped only very recently of the overlying dolomites of the Jefferson City.

Still another example of local structural control is to be seen in the ridge followed by the secondary road across the SW. ¼ sec. 34, and the SE. ¼ sec. 33, T. 36 N., R. 1 E., and into the NW. ¼ sec. 4, T. 35 N., R. 1 E. This ridge, with its steep southeast face, and northwest backslope, is very definitely a result of northwestwardly dipping beds. As a matter of fact, it is a portion of the conspicuous, though very ragged, east-facing escarpment produced by the weak Davis "shale" and the more resistant Derby-Doerun, which have been stripped back from the Bonneterre plain about Caledonia, Belleview, and Belgrade, as a result of down-dip recession, on a low and rather irregular westward regional dip.



A. Shut-in on Mill Creek, along Highway 21, between Glover and Lesterville, one of the gateways to the Tom Sauk Country.



B. Joint control of erosion in Johnson's Shut-in.

Drainage.

The Potosi quadrangle lies wholly in the drainage basin of Meramec River, most of the waters being gathered into Big River and its tributaries on the east, while less than one-fourth of the area, lying on the west border, drains westward through tributaries of the Courtois (locally pronounced Codaway).

Big River itself crosses the southeast corner of the quadrangle, its most important tributaries being Clear Creek and Brock Creek in the south part of the area, and Mine au Breton (locally Burton Creek) and Fourche a Renault (locally pronounced Fourshano) to the north.

The chief tributaries of the Courtois, which does not itself touch the quadrangle, are Cub, Trace, Little Hazel, Little Lost, and Lost Creeks, listed in order from south to north.

Most of the area of the Edge Hill sheet drains southward through the East and West Forks of Black River. The main tributaries of West Fork are Brushy Creek, Little Brushy Creek and Strother Creek on the west side, and Clayton and Ottery Creeks on the east. The main west-side tributary of the East Fork is Imboden Creek, with its chief branch Shut-in Creek; its main east-side tributary is Tom Sauk Creek with its main branch, Little Tom Sauk. The north central part of the sheet is drained directly by the head waters of Big River, which has its source near the village of Enough. The northwest corner drains into Cub Creek, a branch of Courtois Creek, and the northeast corner into Cedar Creek, a branch of Big River.

A very prominent divide running in a general east-west course through the north third of the Edge Hill map, constitutes the watershed between the drainage basin of Meramec River on the north, and Black River on the south. This divide is followed for several miles by State Highway No. 32, the chief route between Ironton and Salem. The highway has been largely relocated since the first edition of the Edge Hill topographic sheet was issued, but has been corrected on the map accompanying this report.

Most of the streams of both quadrangles occupy narrow valleys with fairly steep gradients. The East Fork of Black River, for example, on the Edge Hill sheet, drops from 1021 feet at the Sawyer School, to 728 feet at the south edge of the sheet, a fall of 293 feet in a distance of about 11 miles, or a gradient of over 25 feet per mile. Since most of the area is wooded, with little cultivated land, the streams are very clear, except in time of flood. Over most of the area, the only tillable land is the narrow fringe of flood plain along the streams. This land is largely subjected to overflow.

Many of the streams have been superimposed through the overlying sediments onto the old porphyry knobs. The much greater resistance of the porphyry to erosion has resulted in typical "narrows" at these points. Such narrows or water-gaps are known locally as "shut-ins" (Pls. II, III, and IV). The locations of these features are given in detail in the section on "Scenic attractions."

Springs are moderately abundant in that part of the area immediately underlain by the Potosi and Eminence dolomites, and least common on the outcrops of the Davis shale and Roubidoux sandstone. No really large springs, such as those for which the Ozark region is famous, occur in either quadrangle. In the Potosi quadrangle, Shirley Spring, on Highway No. 8, just west of Shirley, in the W. ½ SE. ¼ sec. 21, T. 37 N., R. 1 E., and Trout Lodge Spring, in the S. ½ SW. ¼ sec. 4, T. 37 N., R. 1 E., are among the best. Both issue from the Gasconade formation. The Palmer Spring, in the village of Palmer, in the SW. ¼ NW. ¼ sec. 13, T. 36 N., R. 1 W., issues from the Potosi formation, as does also the one in the center of the SW. ¼ sec. 25, T. 36 N., R. 1 W. Another good spring issues from about the Potosi-Derby-Doerun contact, near the center of the NW. ¼ sec. 6, T. 35 N., R. 1 E. Still another good spring flows from the Potosi, in the E. ½ NE. ¼ SE. ¼ sec. 36, T. 37 N., R. 2 E. The group of springs at Old Mines, just off the northeast corner of the quadrangle, on Highway No. 21 also issues from the same formation. No one of these springs probably averages as much as two second-feet.

On the Edge Hill quadrangle, one of the best known springs is probably the one commonly said to be the source of Big River. It is located in the W. ½ NW. ¼ NW. ¼ sec. 28, T. 35 N., R. 1 E., and like most of the other springs of the area, issues from the Potosi dolomite. Other good springs issuing from the same formation are listed below:

LOCATION OF SPRINGS ISSUING FROM THE POTOSI.

West ½	sec. 6, T. 33 N., R. 1 E.
Center NE. ¼	sec. 17, T. 33 N., R. 1 E.
SE. ¼ SE. ¼	sec. 20, T. 33 N., R. 1 E.
W. ½ NW. ¼	sec. 29, T. 33 N., R. 1 E.
N. ½ NE. ¼	sec. 30, T. 33 N., R. 1 E.
Center north line	sec. 33, T. 33 N., R. 1 E.
SW. ¼ SW. ¼	sec. 34, T. 33 N., R. 1 E.
Cent. NW. ¼	sec. 12, T. 34 N., R. 1 W.

A few springs of importance issue from the very top of the Derby-Doerun, just below the Potosi formation, which is undoubtedly chiefly responsible for their occurrence. These are listed below:

SPRINGS ISSUING FROM THE DERBY-DOERUN.

NE. ¼ NE. ¼	sec. 29, T. 33 N., R. 1 E.
S. ½ NE. ¼	sec. 29, T. 33 N., R. 1 E.
W. ½ NW. ¼	sec. 20, T. 34 N., R. 1 E.

Probably the largest of the above springs will not average as much as two second-feet. Doubtless other springs as large have been overlooked and many smaller ones have not been reported at all.

Importance of the Topographic Base in Geologic Mapping.

Errors on the topographic base are reflected as errors in delineating the geology on the geologic map accompanying this report.

In a number of instances in the rougher wooded portions of the map the head of one valley is connected with the mouth of another. In this case it is impossible to show the formations in their proper relations and such adjustment has been made as would best express the actual conditions.

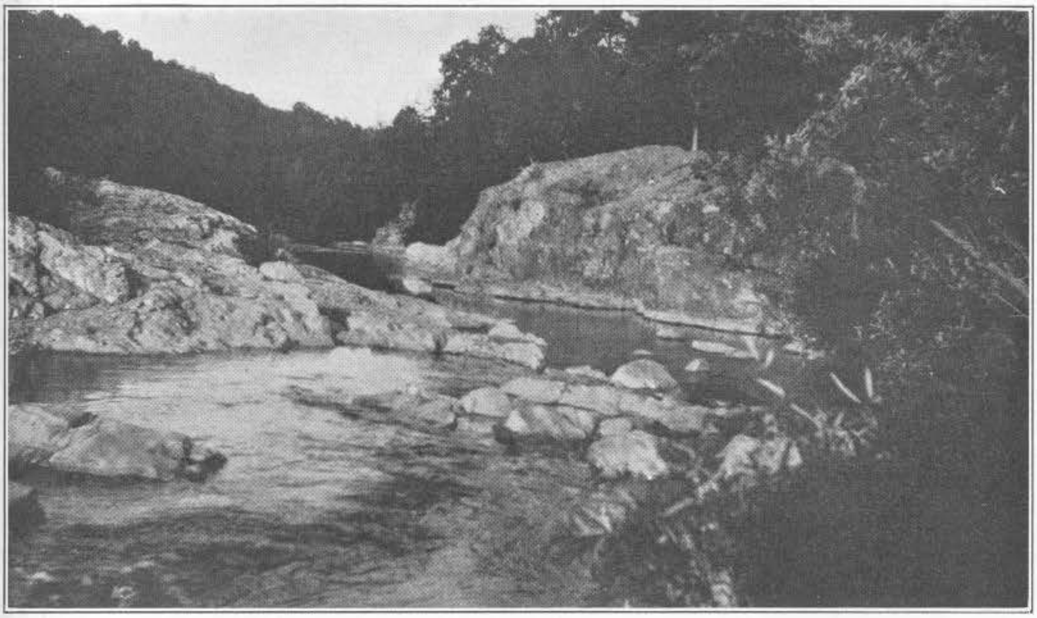
In this region most of the large prophyry knobs have many sedimentary spurs. In a majority of cases these spurs, where they join the porphyry knobs, are marked either by flats or, more strikingly, by saddles. In many cases these flats or saddles have been omitted, some of the latter being from 40 to 80 feet in depth. Where this mistake has occurred the formations are shown as covering steep slopes, when in reality they occur in an entirely different position.

A particularly good example of a saddle at the junction of a sedimentary spur with a main porphyry knob occurs on the west side of Goggins Mountain, in the E. ½ SE. ¼ sec. 14, T. 33 N.,

R. 1 E., where the topography is correctly delineated. Misplaced patches of Gasconade and Potosi are shown on steep slopes in sections 25 and 26, T. 33 N., R. 2 E., that really occur on extensive flats, or form the tips of prominent knobs, separated from the porphyry by conspicuous saddles.

Scenic Attractions of the Area.

The area covered by this report is one of great scenic beauty, particularly that portion of it embraced in the Edge Hill quadrangle. From the crest of the escarpment west of Belgrade and Belleview, or from many points along Highways 32 and 21, in the northeast corner of the Edge Hill quadrangle and the southeast corner of the Potosi sheet, magnificent views may be had of the distance escarpments and porphyry peaks (Pls. I, B; V, B; and XIX, B). The southeast third of the Edge Hill sheet, known throughout southeast Missouri as the "Tom Sauk country," is extremely wild and rugged (Pl. I, A), having a maximum relief of slightly over 1000 feet from the lowest point on Black River to the highest peak, Wildcat Mountain. The area is almost entirely wooded, and very picturesque. Not the least striking features are the "shut-ins" already described (see drainage), some of which, in their wildness and beauty, rank close to the mountain scenery of the west. They vary greatly, however, in their picturesqueness. The most beautiful one in the area, known locally as Johnson's Shut-in (Pls. II and III, B), is located in the SW. ¼ sec. 16, T. 33 N., R. 2 E., on the East Fork of Black River. The bed of the river is over solid porphyry, which has been carved into numerous deep pot holes (Pl. II, B) and enlarged joint planes, filled with water so clear that the bottom is easily visible at a depth of 10 to 15 feet. Other very striking "shut-ins" occur on Big River in the NW. ¼ sec. 23, T. 35 N., R. 1 E. and on Shut-in Creek along the line between secs. 29 and 30, T. 34 N., R. 2 E. These three may be reached directly by automobile, though at present the trails through the gorges are very rough and poorly kept. The most easily accessible one occurs along Highway 21, where it crosses Cedar Creek (Pl. IV, A), in the SW. ¼ sec. 18, T. 35 N., R. 3 E. The most beautiful part of this gorge occurs about 200-300 yards east of the highway, down the creek, within easy walking distance. Another striking "shut-in" occurs on Ottery Creek just east of Edge Hill, in the E. ½ sec. 3, T. 33 N., R. 1 E. Still others of minor interest occur on Saline Creek, in the S. ½ sec. 18, T. 35 N.,



A. Shut-in on Cedar Creek, near Cedar Lodge, about one mile south of Caledonia, carved in porphyry.

B. Waterfall over porphyry, in shut-in on unnamed creek, SE. ¼ SE. ¼ sec. 26, T. 35 N., R. 1 E.

R. 3 E.; on a small unnamed creek in the NE. ¼ sec. 13, T. 35 N., R. 1 E.; at Mountainville Store, on Big River, in the SE. ¼ sec. 22, T. 35 N., R. 1 E.; just above the Hanson School, on James Creek, in the NW. ¼ sec. 17, T. 35 N., R. 2 E.; along Highway 21, in the NE. ¼ sec. 13, T. 35 N., R. 2 E.; on the East Fork of Black River, in the SE. ¼ sec. 35, T. 34 N., Г. 2 E.; along the main road, northwest of Caledonia, at the southwest corner of sec. 35, T. 36 N., R. 2 E.; on the secondary road in the NE. ¼ sec. 3, T. 35 N., R. 2 E.; in the E. ½ NE. ¼ sec. 10, T. 33 N., R. 1 E.; in the SE. ¼ SW. ¼ sec. 19, T. 35 N., R. 2 E.; in the SE. ¼ SE. ¼ sec. 26, T. 35 N., R. 1 E. (Pl. IV, B); and in the NE. ¼ SW. ¼ sec. 24, T. 35 N., R. 1 W.

The remarkable clearness of the water, which is to be attributed largely to the scarcity of cultivated lands and to the highly cherty character of the residuum, adds great charm to the streams of the Edge Hill area.

The sparse population, the ruggedness of the area, the clearness of the streams, and the very primitive conditions that still prevail (Pls. I, A; II, and III), make the Tom Sauk country most attractive to the lover of out-door life, and this promises to be one of the most popular playgrounds of the Ozark region.

Fishing is excellent in the streams of this and adjacent areas, and game is probably more plentiful than anywhere else in the State.

The area is easily reached by Highway 21, which passes through the east side of the Potosi and the northeast corner of the Edge Hill sheets, and is in excellent condition, affording good connections to St. Louis. Highway 8, from Potosi west across the north half of the Potosi quadrangle is usually in good condition, and is a very attractive drive (Pl. XXIII, A). Highway 32 is good from No. 21 west across the north half of the Edge Hill quadrangle. At the present time, the south half of the latter quadrangle can be reached only by rough but picturesque trails, but the trip into the Tom Sauk country is possible to the hardy motorist and is worth the effort. The best route is to leave Highway 21 at Graniteville, and go via Munger. Directions can be secured at Graniteville, by inquiring the way to Munger and Johnson's Shut-in on the East Fork of Black River.

The trip can also be made by leaving Highway 21 at Lesterville. From Potosi to Lesterville, the entire trip is very picturesque (see plates I, B; III, A; V, B; XIX, B; and XXIII, B).

CHAPTER II.

STRATIGRAPHY.

STRATIGRAPHIC SUMMARY.

In the accompany table are listed the formations found in the Potosi and Edge Hill quadrangles. This table expresses the writer's view as to the age of these units.

ALGONKIAN SYSTEM.

The pre-Cambrian rocks of Southeast Missouri consist of rhyolite porphyry, rhyolitic tuff and agglomerate, granite porphyry, granite, and basic dikes. All of these types are found in the area covered by this report.

Rhyolite Porphyry.

Distribution.—Rhyolite porphyry is by far the most abundant type of igneous rock occurring in the area under discussion. It outcrops over a total of about two square miles, on the Potosi quadrangle. The chief area lies in the southeast corner, in the vicinity of Caledonia, Belgrade, and Sunlight. This group of exposures embraces at least fifteen distinct porphyry knobs, ranging in size from a few square feet to nearly a square mile, and is a foothill phase of a large porphyry range, not far beyond the south border of the map, of which Johnson Mountain is the most conspicuous peak, occupying the north central part of the Edge Hill quadrangle.

Several of the smaller knobs are quite inconspicuous. One, lying in the center of the W. ½ sec. 36, T. 36 N., R. 2 E., is known only from abundant porphyry float in the yard of a house on the west side of the Caledonia-Potosi road, coupled with a report of a dug well bottomed on porphyry, and with the fact of steep quaquaversal dips in the adjacent sediments. Another, lying in the center of the N. ½ sec. 35, T. 36 N., R. 2 E., was first suspected from the steep dips in the adjacent sediments, and verified by the extremely feldspathic character of the sandstone,

A. Escarpment caused by Palmer fault, north of Belgrade. The plain in the foreground is carved on Bonneterre on the upthrown side. The hills in the background are the downthrown side on Eminence and younger beds.

B. The escarpment west of Belleview, from the junction of Highways 21 and 32, looking southwest.

TABLE OF FORMATIONS.

Era	Period	Epoch		Formation and thickness	Character
Cenozoic	Quaternary	Recent		?	Residual soil and alluvium
PALEOZOIC	Pennsylvanian,	Des Moines		Cherokee (?), 0-30	Residual massive sandstone, with white and purple clay, chiefly in old sinks.
					Important unconformity
	Mississippian,	Osage		Burlington-Keokuk (?)	A single residual fossil in chert probably indicates former presence of Mississippian beds over the area.
					Important unconformity
	ORDOVICIAN	Canadian, Beekmantown	Canadian of Ulrich	?	Higher Beekmantown formations were probably present at one time, but have been removed by erosion.
				Roubidoux, 0-100	Chiefly sandstone, with much chert, and thin dolomite lenses.
					Unconformity
			Ozarkian of Ulrich	Gasconade, 140±	Crystalline gray cherty dolomite, Cryptozoons abundant.
				Van Buren, 80±	Some "cotton rock" at base, well bedded, much dense white chert.
					Important unconformity
	CAMBRIAN	Saratogan or St. Croixian		Eminence, 0-200	Gray dolomite, more crystalline than Gasconade. Much rusty-weathering chert. Poorly bedded. Craggy outcrop.
				Potosi, 0-400*	Dark gray to chocolate brown crystalline dolomite, with abundant quartz-chalcedony druses. Foetid odor rather characteristic. Poorly bedded. Pinnacle outcrops.
					Important unconformity
			Upper Cambrian of Ulrich	Derby-Doerun, 0-110 (Elvins of Ulrich)	Light gray to buff, finely crystalline to earthy dolomite, non-cherty, step-like outcrops.
				Davis, 0-180 (Elvins of Ulrich)	Gray to green shale, thin-bedded limestone, massive limestone and limestone conglomerate. Non-cherty.
				Bonneterre, 0-300	Massive gray to buff crystalline dolomite, dome-shaped to craggy outcrops. Non-cherty.
				Lamotte, 0-223*	White to buff or reddish-brown cross-bedded sandstone. Numerous shale layers. Non-cherty.
					Important unconformity
PROTEROZOIC	ALGONKIAN (?)				Rhyolite porphyry, granite porphyry, granite, and basic dikes.

*Well records, made available since the map was issued, give greater thickness for the Lamotte and Potosi, than are shown in the section on the margin of the map.

and by a single porphyry boulder about two feet in diameter, lying in thick woods, far from any road.

The second group of these knobs on the Potosi quadrangle occurs at the northwest corner. The most prominent is Little Pilot, in secs. 25 and 36, T. 38 N., R. 1 W. Another occurs about a mile southwest, and still another in secs. 23 and 14, T. 38 N., R. 1 W., in the southwest corner of the De Soto quadrangle. That this porphyry range extends eastward from Little Pilot, at least two miles, to the east line of sec. 29, T. 38 N., R. 1 E., but buried by the sedimentaries, seems to be well attested by the fact that along a line across the central portion of sections 30 and 29, T. 38 N., R. 1 E., the sedimentary contacts are unusually high, and dip rapidly away from this line both to the north and the south, as they usually do from the buried porphyry ranges of southeast Missouri.

Aside from these two main groups, no other porphyry knobs were noted, within the area of the Potosi quadrangle. At two points, however, small fragments of the porphyry were found in the float. One was in the W. ½ NW. ¼ sec. 22, T. 36 N., R. 1 E., and the other in the S. ½ SE. ¼ sec. 22, T. 37 N., R. 2 E. While both occurrences are close to roads, they are only secondary trails and little used. Nevertheless it is quite possible that in both cases the fragments were carried there and dropped by someone driving along the road. Both occurrences lie just at or below the basal Gasconade conglomerate, and since this is a widespread and fairly prominent conglomerate horizon, they may be pebbles weathered from it. It is barely possible that they mark the sites of buried and still unexposed porphyry peaks, although the sedimentary contacts of the vicinity do not seem to be unusually high, as would probably be the case if there were buried prophyry knobs near by.

On the Edge Hill sheet, the porphyry has a very much more extensive development than on the Potosi quadrangle, the total area of outcrop slightly exceeding 40 square miles. One prominent range culminates in Johnson Mountain, 1700 feet in height, the peak of which lies in the west half of sec. 24, T. 35 N., R. 1 E. The range extends eastward through Pruitt Mountain, and Logan Mountain, and intersects the northeast corner of the map in several unnamed knobs of subordinate height. West of Johnson Mountain, the range passes beneath the sedimentaries, and is known to continue, chiefly because of the occurrence of a single inconspicuous porphyry knob in the E. ½ sec. 24, T. 25 N., R. 1 W.

The greatest development of the porphyry in this quadrangle lies in the southeast third of the sheet, which constitutes a prominent southwest prong of the main St. Francois range. Among the more notable peaks in the area are Bell Mt., Goggins Mt., Lindsay Mt., High Top Mt., Little Tom Sauk Mt., Wildcat Mt., and several unnamed peaks, which rise to heights of 1500 feet, or more. Many smaller knobs are known, in the area bordering this important group.

Two occurrences of porphyry not shown on the state map are known west of the Edge Hill sheet. One is at Goodwater, and has been visited. The other lies somewhere on the headwaters of Strother Creek, and is reported on the strength of abundant porphyry pebbles in the gravels of that stream, at the west border of the quadrangle. The latter occurrence is substantiated by steep dips toward the northeast, in the Davis, in the valley in the SW. ¼ sec. 25, T. 34 N., R. 1 W., just off the sheet edge, where the top of the Davis rises abnormally high, though no porphyry float was found in this particular valley.

Lithologic character.—The rhyolite porphyry is, for the most part, very fresh and unweathered. In fact, it is much more deeply decayed, at least locally, beneath the Cambrian capping, than on the present exposed surfaces. This may be partly pre-Cambrian weathering effects, but is probably in part also a result of active circulation of areated waters along the porous basal conglomerate. At places, particularly along the main road about a mile east of Caledonia, porphyry pebbles in the Lamotte, against a large porphyry knob, are so deeply weathered as to crumble in the fingers. It seems impossible that the pebbles could have been so soft as this, when worked over by the Cambrian sea, without going completely to pieces, and hence it is believed that part, at least, of the decay is later than the deposition of the conglomerate bed. It is probable, however, that the boulders were already much weathered, on the pre-Cambrian land surface.

The rhyolite porphyry consists dominantly of a dense, essentially non-crystalline ground mass, varying in color from red to black, in which there is a sparing development of phenocrysts of glassy quartz and pink orthoclase, the latter mineral commonly being the more abundant. The quartz crystals are rarely much over a millimeter in diameter, and in some varieties, are scarcely visible. The orthoclase crystals are commonly 2 to 5 millimeters across, and are usually much more conspicuous than the quartz.

Several thin sections were cut of various phases of the rhyolite porphyries, and detailed descriptions, prepared by G. A. Muilenburg, are given herewith:

RHYOLITE PORPHYRY FROM GOGGINS MOUNTAIN.

Megascopic.—In the hand specimen, this phase of the rhyolite is dark reddish-brown in color, with occasional areas that have a slightly bluish or purplish cast. It consists chiefly of a fine-grained groundmass in which are embedded small crystals of orthoclase and quartz. These are distributed rather uniformly and rarely are over 1/16 of an inch in their greatest dimensions. Distributed rather sparsely throughout the rock, apparently along flow lines, are small, flat, lens-like segregations of colorless quartz and purple fluorite. Occasionally hematite may be recognized in irregular grains, varying in size from minute specks, barely visible with a hand-lens, to grains readily seen with the naked eye.

That phase of the rock with the purplish or bluish cast shows considerably more flowage than does the more uniformly red phase and contains fewer phenocrysts.

Microscopic.—Under the microscope the following original minerals may be seen, arranged approximately in the order of their abundance: Orthoclase, quartz, plagioclase, hematite, apatite, fluorite. Among the secondary minerals resulting from alteration are sericite, kaolin, limonite and calcite.

Subhedral phenocrysts of orthoclase, sometimes exhibiting perthitic intergrowths with albite, are the most conspicuous constituents as seen under the microscope. They show a tendency towards parallel arrangement, due to flowage, and this is also well shown by the quartz, which occurs in large numbers of small grains. Albite occurs sparingly in somewhat rounded and resorbed crystals. Both orthoclase and albite show but little alteration to sericite and kaolin. Both feldspars show considerable fracturing and the quartz exhibits marked undulatory extinction. Apatite occurs sparingly in rod-like crystals, and fluorite was noted even more sparingly, in miarolitic segregations, with quartz along flow lines. Hematite is seen in irregular grains, usually surrounded by limonitic material, and as finely divided particles in the matrix.

Less than 15 per cent of the rock consists of recognizable crystalline minerals. The remainder is an aggregate of felsitic material, too fine-grained to identify positively, but probably consisting largely of feldspar, quartz, and glass.

RHYOLITE PORPHYRY FROM LITTLE TOM SAUK MOUNTAIN.

Megascopic.—The rhyolite porphyry on Little Tom Sauk Mountain is in most respects similar to the phase described from Goggins Mountain. The most conspicuous difference notable in hand specimens is a greater abundance of phenocrysts of quartz and feldspar, and a more pronounced kaolinization.

Microscopic.—Under the microscope the same mineral components were noted as in the preceding case, except that no fluorite was seen. In thin section, kaolinization of the feldspars stands out pre-eminently. They are in most cases so highly altered that further identification is impossible. Quartz occurs abundantly in large anhedra, showing strong magmatic corrosion. The groundmass is more coarsely grained and the percentage of recognizable material is greater, constituting approximately 25 percent of the whole.

RHYOLITE PORPHYRY, JOHNSON SHUT-IN.

In the hand specimen much of the rhyolite from this locality is almost identical with the Goggins Mountain phase. It is slightly more porphyritic, the phenocrysts are a little larger, and quartz is somewhat more in evidence. Under the microscope these same characteristics are easily seen. The phenocrysts range from euhedral, in the case of quartz to subhedral in the case of feldspar. Both minerals show much corrosion. The feldspar includes orthoclase, microcline, and albite, with an appreciable amount of perthite. Kaolinization and sericitization are not particularly prominent, either in phenocrysts or groundmass. Small irregular grains of epidote occur sparsely distributed throughout the slide, and secondary hematite is present in sinuous "streaks," giving the rock the prominent red color. A radiating, fibrous structure is quite pronounced in some slides but in most cases it appears broken and crushed, as if the magma had been spherulitic originally, but had suffered crushing during extrusion. Similar crushing is apparent in many of the phenocrysts.

With this phase of the rholite is associated a brecciated phase in which fragments of a decidedly porphyritic material, differing from the preceding in the absence of the broken spherulites, are embedded in a much finer grained, almost non-porphyritic matrix. This non-porphyritic matrix is very similar to the Goggins Mountain phase. Judging from the relationship of the fragments and the matrix, the latter, during the process of extrusion, picked up fragments of the former. These fragments subsequently became sub-angular by corrosion and solution, and stand out rather prominently in hand specimens. Their prominence is further accentuated by the fact that they are somewhat brownish in color while the matrix is red.

Still another phase of the rhyolite is seen in the Johnson Shut-in. It may be referred to as "spherulitic," similar to the type already described, except that the spherulites are much more abundant. In hand specimens it is fine-grained and dark red. The spherulites range from about ⅛ of an inch to nearly ⅜ of an inch in diameter, with the majority measuring about ¼ of an inch. A few small phenocrysts of quartz and feldspar may be seen, but on the whole the rock would be classified megascopically as non-porphyritic.

In thin section most of the spherulites are seen to consist of radiating aggregates of orthoclase and quartz, but some consist of concentric layers of cryptocrystalline and glassy matrix. The larger ones usually show the best crystalline structure while the smaller ones are mostly cryptocrystalline. Interspersed between the spherulites are small aggregations of mixed quartz and feldspar; and in the matrix, away from the spherulites, phenocrysts of orthoclase, albite, perthite, and resorbed quartz may be seen. Finely divided hematite forms the coloring matter in both spherulites and matrix.

Another and still different variety was noted both here and elsewhere, and contains an abundance of miarolitic cavities filled with white quartz and feldspar which, in sharp contrast with the dark red background, gives the rock a mottled appearance. Under the microscope, the feldspar of these cavities is seen to be chiefly well-crystallized orthoclase, with an occasional crystal of albite. The groundmass is felsitic and contains a few phenocrysts of orthoclase.

The spherulitic phase of the rhyolite described above is particularly well exposed in Johnson's Shut-in, on the East Fork of Black River, in the SW. ¼ sec. 16, T. 33 N., R. 2 E., and also in the SW. ¼ sec. 22, T. 35 N., R. 2 E. It consists of a dense bluish-black groundmass in which phenocrysts are very rare and minute, splotched with irregular, more or less roundish, masses of pink orthoclase and clear quartz.

For the most part the rhyolite porphyry is massive, though primary flow structure, evidenced by parallel banding, in some cases much contorted, is not uncommon. Jointing is very prevalent, though apparently essentially without system (Pls. II, and III, B), and causes the rock to break into rather sharply angular blocks. Resistance to weathering, coupled with the effect of joints, results in a talus much more angular than that derived from the granite porphyries. Nothing comparable to secondary flow cleavage has been observed at any point.

There seems to be but little question that most of these rhyolites are extrusive. At Pilot Knob they are associated with abundant tuff and coarser agglomerate, and along Highway 21, on the south slope of Tiptop, beds interpreted as ash are interlayered with typical rhyolite (Pl. VI). Ash beds seem to alternate with rhyolitic flows, at Johnson's Shut-in, on the East Fork of Black River, in the SW. ¼ sec. 16, T. 33 N., R. 2 E., and at the same locality are beds interpreted as flow breccias (Pl. VII). The great abundance of primary flow structures, as well as the peculiar spherulitic phases described above, are also in line with the interpretation of the rhyolite porphyries as dominantly extrusive. The large proportion of non-crystalline groundmass and the sparing development and small size of the phenocrysts are also favorable to this view.

Topographic expression.—In areas where the porphyry occurs as relatively isolated peaks, projecting through the overlying sedimentaries, more or less striking individual mountains result, several of which are very commanding in appearance (Pl. I). Perhaps the most striking is Johnson Mountain, in secs. 23 and 24, T. 35 N., R. 1 E., Edge Hill quadrangle. Little Pilot Knob, secs. 25 and 36, T. 38 N., R. 1 W., on the Potosi sheet is another such isolated peak.

On the other hand in the area dominated by porphyry, with the sedimentaries occupying only narrow basins between the old pre-Cambrian peaks, the individual mountains are less conspicuous, although the country is extremely rugged, the local relief in the vicinity of Tom Sauk and Wildcat Mountains, in the southeast portion of the Edge Hill quadrangle reaching 1000 feet, with very narrow valleys and steep, rocky slopes.

At many points, the streams have been superimposed from the cover of Paleozoics onto a very rugged buried pre-Cambrian topography. As a result, many of the valleys show sudden constrictions known locally as "shut-ins," that are extremely gorge-like and picturesque (see Pls. II, III, and IV).

It is evident that the old pre-Cambrian relief must have been much greater than the maximum now shown, since most of the present valleys are floored with a considerable thickness (several hundred feet, as shown by drilling at Saco, Madison Co., and Annapolis, Iron Co.), of Cambrian rocks, the thickness of which must be added to the present relief, to get any adequate idea of how rugged the region was, when it was invaded by the Cambrian sea.

Stratigraphic relations.—These porphyry knobs are clearly old buried hills, against which the Paleozoic rocks lap with distinct unconformity. Within these quadrangles, the rocks actually seen in contact with the porphyry are the Lamotte sandstone, the Bonneterre dolomite, and the Davis shale.

The contact with the Lamotte is best exposed along the Caledonia-Bismarck road, about a mile east of Caledonia, at the extreme east edge of the Potosi sheet. Here is a well-developed basal conglomerate, in which are badly weathered pebbles and boulders of porphyry ranging up to a foot or more in diameter, in a matrix which looks as though it might be a partly reworked pre-Cambrian soil. Many of the pebbles are so soft that they can be picked to pieces with the fingers.

A good contact with the Bonneterre is shown in the N. ½ SE. ¼ sec. 35, T. 36 N., R. 2 E. Here the Bonneterre, which is distinctly sandy, but grades laterally into purer dolomite, contains pebbles of porphyry, but little weathered, and in addition pebbles of quartzitic sandstone and dense finely-crystalline dolomite, of which mention will again be made in a later paragraph. Other good cases of porphyry pebbles at the contact of the Bonneterre and the porphyry knobs are to be seen on the Belgrade-Salem road, in the SE. ¼ NE. ¼ sec. 22, T. 35 N., R. 1 E.; in the NE. ¼ sec. 11, T. 35 N., R. 1 E.; and in the SW. ¼ SW. ¼ sec. 22, T. 35 N., R. 2 E., in the little valley north of the secondary road. Many fine exposures of the same contact are to be seen along the valley of Tom Sauk Creek. A particularly fine example of this contact occurs on Highway 21, on the south slope of Tip Top, south of Ironton (Pl. VI, B).

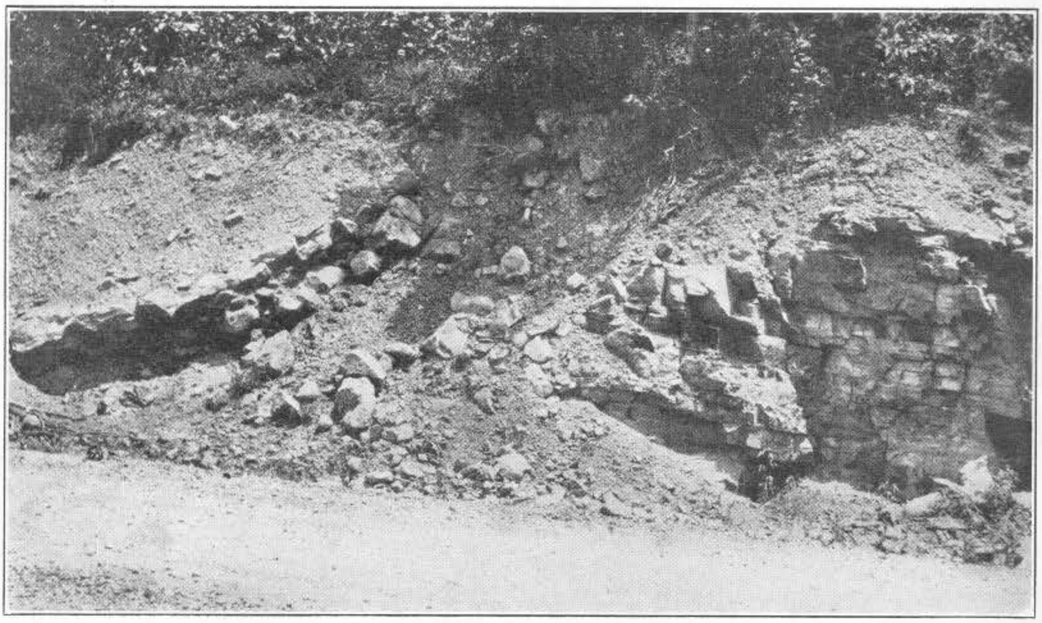
The Davis is best seen in contact with the porphyry just northwest of an old house near the center of the south line of sec. 10, T. 35 N., R. 1 E., where the shale beds enclose numerous pebbles of the porphyry. A single porphyry pebble about 1½ inch in diameter was also found embedded in the Davis, near Black in Reynolds County (NE. ¼ NE. ¼ sec. 29, T. 33 N., R. 1 E.).

No formations younger than the Davis were actually found in contact with the porphyry. At many places the distribution of heavy residual Potosi chert is such as to indicate that the Potosi overlapped the porphyry, though no actual contacts have been seen on the quadrangles. On the northeast slopes of Pruitt and Logan Mountains in secs. 15 and 16, T. 35 N., R. 2 E., residual Potosi rests against the porphyry, and many other examples occur on the Edge Hill sheet. It is probable that the Eminence rests against the porphyry at Little Pilot Knob, though no actual contact was observed. Some of the higher porphyry knobs were still uncovered as late as Gasconade time it appears, since Gasconade float laps against the porphyry on the west slope of Little Pilot Knob (Sec. 25, T. 38 N., R. 1 W.), on the southeast slope of Bell Mountain (N. ½ sec. 1, T. 33 N., R. 1 E.), on most of the higher sedimentary spurs of Little Tom Sauk Mountain, and at many other points. The writer has seen both the Potosi and Eminence formations in actual contact with the porphyry in the Eminence quadrangle, and at a single locality on the Cardareva sheet, porphyry pebbles occur in Gasconade dolomite in place.

Assuming that but little porphyry has been eroded from the top of these knobs since the Paleozoic was stripped away from them, it is improbable that beds younger than Gasconade, or possibly very locally the Roubidoux, came into contact with them in this area. At many points, the *base* of the Gasconade laps against the porphyry peaks at elevations as high as 1200 feet, and in places as high as 1400 feet. If the Gasconade had anything like its normal thickness in this area, its upper surface, especially with the dips observed away from the knobs, should pass well above all but the very highest porphyry peaks. With average thicknesses of the Bonneterre, Davis, Derby-Doerun, Potosi, and Eminence, most of the peaks in this area would have been completely overtopped before Potosi deposition closed, and practically all of them, before the end of the Gasconade. Of course, it must be realized that the formations all thin appreciably, in the vicinity of the knobs, but making due allowance for the known amount of thinning it still seems probable that the porphyry of this quadrangle was almost completely buried before Roubidoux time.

Structure.—At almost every point where the sediments lap against the porphyry, the knob is surrounded by steep quaquaversal dips, ranging from 3 or 4 to 25 or 30 degrees (Pls. VI, B, and XIX, A). These are doubtless in large part the results of initial dips, which may be assumed to have been somewhat accentuated by unequal settling of the adjacent sedimentary beds as a result of solution and compacting in them that was

A. Thin-bedded rhyolitic ash, south slope of Tiptop, Highway 21, south of Ironton.



B. Contact of the above ash and the basal Bonneterre. Note coarse conglomerate and initial dip.

of course impossible in the underlying porphyry knobs (see Structure, Initial dips). Significantly, the dips are much higher where the beds adjacent to the porphyry are limestones, than they are in the Lamotte sandstone.

Age and correlation.—Nothing very definite can be asserted as to the age of these porphyries, except that they are pre-Upper Cambrian, the Lamotte and Bonneterre being now referred to the Upper rather than to the Middle Cambrian. Since, however, no comparable igneous rocks of Lower or Middle Cambrian age are known in the nearest adjacent regions where Lower or Middle Cambrian occur, the prophyries can be referred with considerable confidence to the pre-Cambrian. Whether they belong to the Archean or to the Algonkian is a much more difficult question, but the notable absence of deformation effects, particularly of any schistosity that might point to extreme conditions of dynamic metamorphism, would seem to indicate later rather than earlier pre-Cambrian; and the writer is inclined to the view that these rocks are Algonkian rather than Archean. Admittedly, however, no definite conclusions can be drawn.

Van Hise[1] tentatively refers these rocks to the Algonkian, without assigning any very definite reason; and Haworth[2] is quoted as saying: "It is quite remarkable that this comparatively large Archean area should differ so widely from the ordinary Archean rocks of America. Instead of being composed principally of great masses of schists and gneisses, not a single instance of either of these has been found, but in their stead are granites, porphyries, and porphyrites."

Keyes[2] elaborates on this view, calling attention, by way of contrast, to schists in a deep well in Kansas City, and concludes that the igneous rocks of southeast Missouri are probably Algonkian.

Rhyolitic Tuff and Agglomerate.

On the slopes of the porphyry knob in secs. 23 and 14, T. 38 N., R. 1 W., just off the northwest corner of the Potosi quadrangle, thin-bedded slabs of tuff are abundant in the float, but were not found in place.

Fine-grained material, interpreted as ash beds, is interlayered with typical rhyolite, in Johnson's Shut-in on East Fork

[1]Correlation papers: Archean and Algonkian; Bull. U. S. Geol. Survey, no. 86, 1892, p. 504.

[2]Bull. Geol. Soc. America, Vol. 7, 1896, p. 375.

of Black River, in the SW. ¼ sec. 16, T. 33 N., R. 2 E. The petrographic description, by Muilenburg, follows:

RHYOLITE TUFF, JOHNSON'S SHUT-IN.

Megascopic.—In hand specimens the rock varies from light pink through bright red to a dark, purplish-brown. Most of the specimens show thin laminations, strongly suggestive of bedding, and in several places, in the field, cross-bedding was noted. The material is so fine-grained that only a few constituents can be recognized, even with the aid of a handlens. Locally, along the laminations, a yellowish-green coloration is seen, suggestive of epidote.

Microscopic.—From a study of several thin sections, quartz, orthoclase, a plagioclase (probably albite), sericite, epidote, hematite and apatite were recognized. Orthoclase and quartz are most abundant and occur in angular fragments of rather uniform size. These are mingled in an aggregate of non-crystalline material, more or less colored with hematite. Laminations are in most instances not so distinct as in hand specimens, but where epidotization has taken place, it follows along certain well-defined lines, indicating the stratification. Interbedded with the stratified material are several beds that appear to be flow breccias. Rock fragments, as well as individual broken crystals are embedded in a glassy matrix showing distinct flowage. In all cases a considerable amount of alteration to sericite is visible. This type of alteration was followed by silicification and that in turn by the introduction of hematite into some of the beds.

At the same locality (SW ¼ sec. 16, T. 33 N., R. 2 E.), are beds which have been interpreted as flow breccias (Pl. VII). These consist of masses of rhyolite porphyry embedded in a still denser porphyry, in which there is pronounced flow structure, that seems to bend about the included blocks.

Agglomerates occur in Madison County, in the N. ½ sec. 15, T. 31 N., R. 6 E., and both tuffs and agglomerates are well developed on Pilot Knob, in Iron County, and at numerous other points in the St. Francois Mountains. On the south slope of Tiptop, along Highway 21, south of Ironton, in Iron County, thin bedded material (Pl. VI) interpreted as ash, is interlayered with rhyolitic porphyry.

Beds interpreted as agglomerates, though they may possibly be conglomerates of pre-Cambrian age, also occur at Redmondville, in the SE. ¼ NE. ¼ sec. 30, T. 34 N., R. 1 E. Here they contain many radiating masses of a green mineral which has been identified in thin section as epidote. They are definitely unconformable beneath the Bonneterre.

Granite Porphyry.

Distribution.—Granite porphyries are less widespread than the rhyolites, and are not found in the area of the Potosi quadrangle. Their most extensive development is near the southwest end of the Tom Sauk Range, in the SE. ¼ sec. 16, the E. ½ sec.

21, and the NW. ¼ sec. 22, T. 33 N., R. 2 E. This is the occurrence to which Haworth[1] refers, at the falls on the East Fork of Black River. Actually, however, the falls (in Johnson Shut-in) are on porphyry, the granite which outcrops up the hill to the east, shedding considerable granite porphyry debris into the gorge. Granite porphyries also make up the south end of High Top Mountain, in sec. 4, T. 33 N., R. 2 E. To the west, a small body of the same rock was also observed where the north end of Goggins Mountain crosses the west line of sec. 6, T. 33 N., R. 2. E. The total area of outcrop is probably not over three square miles, on the Edge Hill sheet.

Lithologic character.—On the average, the granite porphyry is much more deeply weathered than the rhyolitic variety. Jointing does not seem to be as closely spaced, so that it weathers into much larger blocks, and these blocks succumb much more rapidly to the attack of the atmosphere, so that the talus usually consists of much larger and more rounded bowlders than that of the rhyolite, in this respect resembling the famous Elephant Rocks of Graniteville.

The granite porphyry is a rock of pinkish color, with a finely-crystalline groundmass instead of the dense glassy back-ground of the rhyolite porphyry. There is a sparing development of quartz, orthoclase and biotite phenocrysts, these being larger, on the average, than in the rhyolite. Quartz crystals up to 3 millimeters, and orthoclase phenocrysts up to 7 or 8 millimeters are not uncommon.

Several thin sections of the granite porphyry have been ground, and petrographic descriptions, by Muilenburg, follow:

GRANITE PORPHYRY.

Megascopic.—In the hand specimens, this rock is dull pink in color, mottled with lighter-colored areas, giving to the whole a grayish-pink cast. Texturally the main mass is rather uniformly even granular and somewhat fine-grained, with varying amounts of orthoclase phenocrysts, ranging in size from ¼ to ¾ of an inch. Close examination reveals also quartz, biotite, hornblende, magnetite and epidote, and a small amount of granular ground-mass.

Microscopic.—In thin section under the microscope, the following primary minerals were recognized: Orthoclase, quartz, albite, hornblende, biotite, magnetite, apatite, titanite, zircon, rutile. In addition as a result of alteration, several specimens showed varying amounts of kaolin, sericite, chlorite, epidote, leucoxene and a carbonate, probably calcite.

Approximately 95 percent of the rock consists of recognizable minerals while the remainder is a granular feldspathic aggregate. Occasional large phenocrysts of orthoclase stand out rather prominently in a finer-grained even granular matrix consisting of the other minerals named. The most prominent feature shown in all

[1]Crystalline Rocks of Missouri; Missouri Geol. Survey, vol. VIII, 1894, p. 178.

sections examined is the micrographic texture. This is the result of micro-intergrowths of quartz and orthoclase, somewhat after the manner of graphic granite in pegmatite dikes. The granite porphyry differs from the granite described on page 40, not only in texture, which could well be accounted for as a result of marginal phases that cooled more rapidly, but also in mineral composition. Plagioclase is present very sparingly in the porphyry and abundantly in the granite and certain accessory constituents, abundant in the porphyry are lacking in the granite. Further, there is also a marked difference in the extent and intensity of the alteration of the feldspars. These differences indicate quite clearly that the two are separate and distinct types.

Neither primary flow structure, nor secondary flow cleavage have been noted in the granite porphyries. The lack of flow structure in the granitic as contrasted with its abundance in the rhyolitic porphyries; the completely crystalline groundmass, as contrasted with the dense aphanitic groundmass of the rhyolite; the coarser phenocrysts of the granite porphyry; together with the observed field relations (p. 40), suggest that the granite porphyry is intrusive into the rhyolite.

Topographic expression.—The granite porphyry is so limited in extent and so closely associated with the rhyolite, that it has no individual topographic character. Though somewhat less resistant to the weather than the rhyolite, this fact is exhibited only in a much more rounded talus, and a somewhat deeper soil, but not in any appreciably less notable relief. In fact, it makes High Top Mountain (Pl. I, A), one of the highest peaks in the area. In this respect it is quite in contrast with the granite of the larger areas about Ironton, where that rock not uncommonly makes the lowlands between mountains of the more resistant rhyolite.

Stratigraphic relations.—The granite porphyry appears to be intrusive into the rhyolites. While no stringers of the former were actually seen cutting the latter, the contact between the main masses of the two rocks nowhere being well exposed, there seems to be a tendency for the granite porphyry to become finer-grained, near the contact with the rhyolite, as though representing a chilled marginal phase. Again, whereas the structure of the rhyolites, probably representing alternating flows superimposed on one another, seems to dip at rather low angles, usually under 30 degrees, the contact between the granite porphyry and the rhyolite seems to be much steeper, as though the former actually cut across the latter. While, therefore, the nature of the contact does not permit of a positive interpretation, still there seems to be a suggestion that the granite porphyry is younger than the rhyolite, and intrusive into it.

The granite porphyry is clearly older than the Bonneterre, which laps against it with definitely unconformable relations, the base of the dolomite carrying arkosic detritus derived from the weathering of the older igneous rock. This relationship may be best seen in the NE. ¼ sec. 22, and the NE. ¼ sec. 16, T. 33 N., R. 2 E. In the latter locality beds of Davis age also overlap onto the granite porphyry, and in both sections a thick mantle of Gasconade float overlaps the igneous rock, though no Gasconade was seen in place, against the granite porphyry.

Structure.—The same steep dips in the bordering sediments that characterize the rhyolite knobs, are also to be seen adjacent to the granite porphyry.

Age and correlation.—The only fact that can be stated positively regarding the age of the granite porphyry is that it is pre-Bonneterre. As already pointed out, however, it is probably younger than the rhyolite. The absence of deformation sufficient to develop schistosity suggests, as in the case of the rhyolites, that the rock is probably late, rather than early pre-Cambrian. Its possible relation to the true granites is discussed on p. 41.

Granite.

Distribution.—No granite was noted in the Potosi quadrangle, and only one small outcrop in the Edge Hill area. This is a low, inconspicuous patch at the east end of Logan Mt., a prominent porphyry knob. The granite is in the SE. ¼ SW. ¼ sec. 14, T. 35 N., R. 2 E., and consists of two or three isolated ledges, covering a small portion of an open field. Haworth[1] shows a patch of granite about a mile due south of Caledonia, but very careful search of the locality shows only a coarse phase of the rhyolitic porphyry, and neither granite nor granite porphyry could be found.

Lithologic character.—It is a reddish granite, moderately coarse, and somewhat uneven in texture. Quartz and orthoclase are the conspicuous minerals, the latter crystals reaching, in a few cases, as much as 8 or 10 millimeters in length. Biotite is present, but inconspicuous. The granite is massive, with no evidence of any schistose or gneissic structure. A thin section was cut, and a petrographic description, by Muilenburg, follows:

[1]The crystalline rocks of Missouri; Mo. Geol. Survey, vol. VIII, 1895, Pl. V, opp. p. 80.

GRANITE.

Megascopic.—The rock is predominantly pink in color but specked with small, dark greenish-black areas. Among the minerals recognizable with the unaided eye, orthoclase, plagioclase and quartz stand out most prominently, while biotite and magnetite are subordinate. Texturally it falls in the granitoid group since it is entirely crystalline and coarse grained, with a rather uniformly even-granular structure.

Microscopic.—In thin section under the microscope the following minerals were recognized: Quartz, orthoclase, albite, biotite, apatite, zircon, magnetite, epidote, sericite, kaolin, and hematite.

The specimens examined showed a great deal of alteration. Many of the feldspars could not be determined with accuracy on account of the excessive kaolinization and sericitization. However, albite appears to be nearly as abundant as orthoclase. Zircon is abundant for an accessory mineral and the crystals are unusually large. Biotite is quite inconspicuous. The thin section shows a thoroughly crystalline rock, consisting of subhedral to anhedral crystals, closely interlocking and even-granular.

Stratigraphic relations.—The granite occurs at the northeast end of Logan Mt., a large porphyry knob. The two types of rock are not here in contact, so that their relations are obscure. The older view has been repeatedly expressed[1] that the granite and porphyry grade into one another. In this locality, there are between the typical granite, and the typical porphyry, ledges of rock, the texture of which seems to be intermediate between the two, and it may be that such cases constitute the evidence that led to the above view. On the other hand, it is quite possible that the granite intrudes the porphyry and that the phase that looks like gradational material is the chilled margin of the granite intrusive. This particular locality yields no satisfactory evidence in support of either view.

Age and correlation.—At this locality, there is nothing whatever, to indicate the age of the granite. Since, however, granites at many other places in southeast Missouri are known to be pre-Lamotte, it is practically certain that this rock is of the same age. The absence of schistose or gneissic structure is suggestive, as in the case of other igneous rocks, of late rather than early, pre-Cambrian age.

Its relation to the granites of Graniteville is not known, though, like them, it is notable for its high soda content, and abundance of plagioclase, largely albite.[2] The outcrop is about 8 miles, in a straight line, northwest of Graniteville. The rock is somewhat finer-grained, and perhaps a little less even in texture than the Graniteville rock, being intermediate in appearance between that phase and the granite porphyry already de-

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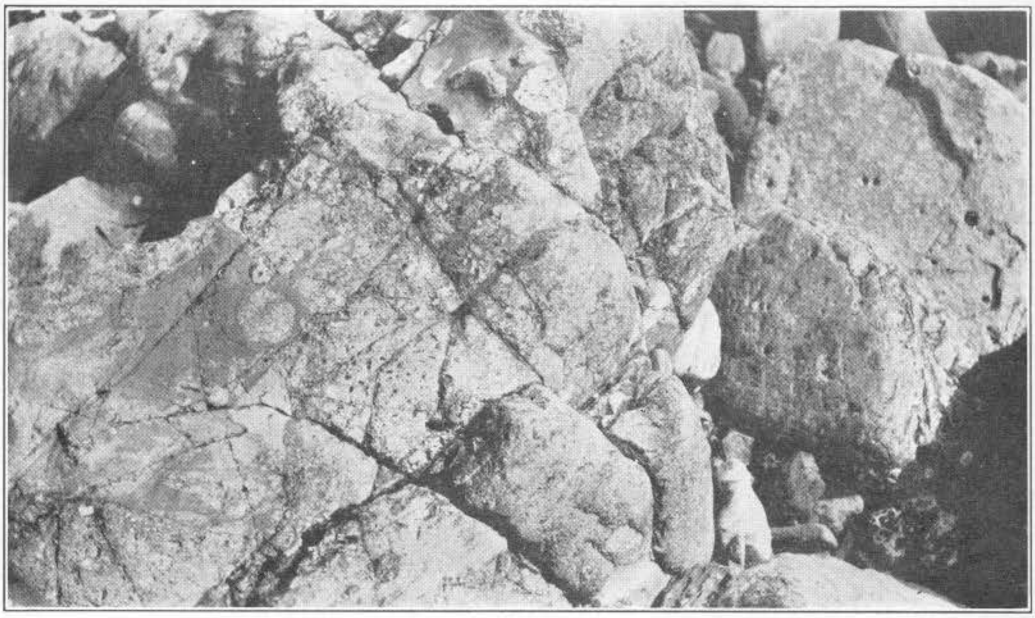
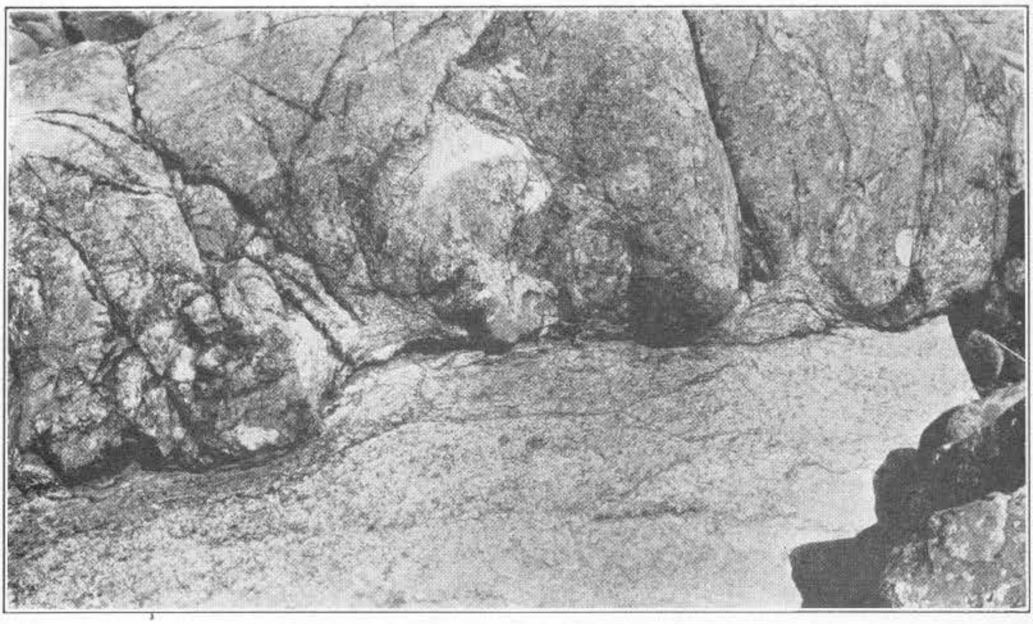
[1]Haworth, Erasmus, op. cit., pp. 209-219.

[2]Haworth, Erasmus, op. cit., pp. 139 and 152.



A. Flow breccia, Johnson's Shut-in, East Fork Black River, SW. ¼ sec. 16, T. 33 N., R. 2 E.



B. Contact flow breccia and rhyolite, Johnson's Shut-in.

scribed. There does not appear to be any evidence that would oppose the view that this is an offshoot of the main mass of granite of the St. Francois Mountains.

Its relation to the granite porphyry is likewise unknown. It is considerably more sodic than that rock, and if it is a portion of the same intrusive, there must have been considerable differentiation.

Nor is anything definite known of its relation to the rhyolites. Certain conditions, already cited, suggest, but do not, constitute satisfactory evidence, that the granite porphyry cuts the rhyolite. Unless the granite is a phase of the same intrusion however, this fact would have no bearing on the possible relation of the granite and rhyolite; and the higher sodic character of the granite seems to suggest that the rocks are not part of the same intrusive.

On Knob Lick Mountain, granite dikes of somewhat different character have recently been found to cut the rhyolite,[1] but it is by no means certain whether they are related to this intrusive or are an entirely different generation of granite.

Basic Dikes.

Distribution.—No dikes have been noted cutting the porphyry within the Potosi quadrangle, though a fragment of fine-grained dark basic rock in the float, on the south slope of the saddle near the center of sec. 3, T. 35 N., R. 2 E., suggests the proximity of one.

On the Edge Hill sheet, a very large basic dike occurs in secs. 21, 22, 26 and 27, T. 34 N., R. 2 E., and either a dike or a sill in sec. 10, T. 33 N., R. 2 E. The latter body is dipping at a very flat angle, perhaps between 5 and 10 degrees, and may well be a sill, between successive rhyolitic flows, instead of a dike. Little evidence of bedded structure could be observed in the rhyolite, but a somewhat persistent benching on the hillside at least suggests that the flows approximate the horizontal, and lends plausibility to the view that the basic mass is a sill. The body ends so abruptly as to suggest that it is faulted off, rather than that it pinches out.

The basic rock in secs. 21, 22, 26 and 27, T. 34 N., R. 2 E., seems to be much more nearly vertical and is probably a very large dike. Nowhere could a complete section across it be ob-

[1]Muilenburg, G. A., personal communication.

served, but the distinctive character of the soil and float, which in sec. 26, T. 34 N., R. 2 E. covers a belt approximately ¼-mile wide, suggests that it is an unusually thick dike. It has been traced nearly two miles.

A small body of practically identical basic rock in the NE. ¼ NE. ¼ sec. 21, T. 34 N., R. 2 E. is entirely isolated by sediments, and its relation to the larger dike obscured. It is distinctly not along the trend of the larger body, and if it is a part of the large dike, has probably been isolated from it by faulting, prior to the deposition of the sediments.

Along the center of the line between sections 9 and 16, T. 34 N., R. 2 E., occur float boulders of a peculiar dark rock that looks like a fine-grained phase of the basic dike material, with inclusions of rhyolite. On the strength of this float a small dike was mapped, though only rhyolite was seen outcropping.

At the west base of Pruitt Mt., in the SW. ¼ SE. ¼ sec. 17, and the NW. ¼ NE. ¼ sec. 20, T. 35 N., R. 2 E., is an oblong area of coarsely granular basic rock, apparently intrusive into the rhyolite, though no actual contacts could be observed. This rock appears to have a coarsely diabasic texture, but is so deeply weathered that little could be made out regarding its character.

Haworth[1] reports a basic dike carrying garnet cutting the rhyolite at the falls on the East Fork of Black River, in sec. 16, T. 33 N., R. 2 E. Undoubtedly many smaller dikes have been overlooked, in the mapping.

The total area of outcrop of the basic rock is considerably less than a square mile.

Lithologic character.—This basic material is a dark-colored rock with typical diabasic texture, and consists of visible crystals of plagioclase and augite. Near the center of the body, the rock is coarse, some of the augite crystals reaching a size of 8 to 10 millimeters. Near the border, float bowlders of much denser, almost aphanitic, rock were found, presumably derived from the chilled margins of the intrusive, though actual outcrops of the contact were not observed. Thin sections were ground, both of the coarser and finer phases, and petrographic descriptions, by Muilenburg, follow:

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[1]Op. cit., pp. 126, 127, 136.

BASIC DIKES, IMBODEN CREEK.

Gabbro.

Megascopic.—In the hand specimens this rock has a dark gray color, is rather coarse-grained and shows considerable alteration to a greenish serpentinous product. Augite, plagioclase, biotite and magnetite can be identified quite readily. Some of the feldspar is light colored and shows but little cleavage and some is dark gray, with good cleavage and an abundance of prominent albite twinning.

Microscopic.—In thin section the following minerals were identified. Plagioclase (a calcic variety near labradorite and a sodic variety near oligoclase), augite, enstatite, biotite, olivine, magnetite (both primary and secondary), apatite, kaolin, sericite, chlorite, serpentine and a carbonate, probably calcite. Texturally, the rock is inequigranular, coarse-grained, granitoid, with abundant interlocking, lath-shaped crystals of plagioclase. The feldspar is fairly fresh but the ferromagnesian minerals are extremely altered to magnetite, chlorite and serpentine. Most of the olivine is entirely replaced by secondary products, among which magnetite is most abundant, and can be identified only from the structure and crystal outlines. The pyroxene designated as augite is probably partly diallage, but the extreme alteration makes further identification impossible. The rock is provisionally classed as an olivine gabbro

Another phase of this gabbro occurs in a dike (or sill?) on Little Tom Sauk Mountain. Here it is finer-grained and contains less feldspar and correspondingly more enstatite and has somewhat of an ophitic texture, so that it approaches diabase. The ferromagnesian constituents are all highly altered to chlorite and serpentine, and olivine seems to be absent.

A marginal phase of this same rock shows a fine crystalline groundmass consisting of plagioclase, pyroxene, magnetite, and secondary alteration products, in which are embedded lath-shaped plagioclase crystals. This phase may be termed a basalt porphyry.

Topographic expression.—The area covered by basic rocks is so limited that they can hardly be said to have any topographic identity. They are more easily attacked by weather than the rhyolites, and yield a talus of well-rounded bowlders. As a result of this lack of resistance, they are more deeply soil-covered than the other igneous rocks, and outcrops are rare. For the most part, they have been traced by their characteristic soil and bowlders.

Age and correlation.—The basic material clearly intrudes the rhyolite porphyry, and is, therefore, younger than that rock. Beyond that, it is quite impossible to date the sill, since it is not in contact with any other rock. The large dike, however, was clearly truncated by erosion, before Potosi time, since large areas of heavy Potosi residuum rest upon it. It is therefore post-rhyolite and pre-Potosi. Thus far it has not been possible to assign it more definite age limits, inasmuch as the contact with the Davis and Bonneterre are wholly concealed. However, in the NE. ¼ sec. 21, T. 34 N., R. 2 E., pebbles of basic rock are included, along with rhyolite bowlders, in a mass of arkosic conglomerate, which apparently dips beneath Bonneterre. The area between the outcrop of the conglomerate and that of the undoubted Bonneterre dolomite is, however, covered, and the relations cannot be stated with absolute certainty. The conglomerate is essentially similar to that known elsewhere in the basal Bonneterre, and there seems to be good reason to believe that the dikes are pre-Bonneterre in age. Since basic dikes in Ste. Genevieve County are reported[1] to cut the Bonneterre, thus raises an interesting question, as to whether they belong to the same period of intrusion.

In the Ste. Genevieve County report just cited, the basic dikes are tentatively assigned to the Comanchean. One bit of information, so far as the writer knows unpublished, suggests, however, that they may be older. Several years ago Dr. Weller showed the writer the basal contact of the Ste. Genevieve formation not far from McBride. In the basal conglomerate there were not only rounded pebbles of silicified Devonian corals, but at least one pebble of basic igneous rock, showing conclusively not only that there were pre-Ste. Genevieve basic rocks somewhere in the area, but that erosion had exposed them in the pre-Ste. Genevieve interval. The patches of conglomerate mapped in Ste. Genevieve County as Tertiary,[2] which carry both water-worn Devonian corals and basic igneous rock, are far more thoroughly lithified than any Tertiary deposits known elsewhere in the Mississippi Valley, and are undoubtedly much older than the age assigned them. The basic dikes are of course older than these conglomerates, which might well be basal Ste. Genevieve overlap.

CAMBRIAN SYSTEM.

Lamotte Sandstone.

Name.—The name is derived from old Mine La Motte, and was proposed by Winslow[3], for the series of basal sandstones overlying the crystallines and below the limestone beds in which the lead ores are found. It has been used ever since, in essentially the way it was first defined, except that it is now written as one word, instead of as two.

Distribution.—The outcrops of this formation in the Potosi quadrangle are limited to 2 or 3 square miles, chiefly in an

[1]Weller, Stuart, and St. Clair, Stuart, The geology of Ste. Genevieve County; Mo. Bureau of Geol. and Mines, 2nd ser., vol. XXII, 1928, p. 250.

[2]Op. cit., p. 248.

[3]Winslow, Arthur, Lead and zinc deposits; Mo. Geol. Survey, vol. VI, 1894, p. 347.

irregular branching patch on the extreme east edge of the map, south of the main Palmer fault zone, and extending generally northeast from Caledonia. Two or three small inliers also occur which result from erosion of the dome-like areas, already mentioned, bordering the porphyry knobs. Less than a square mile of the formation is also exposed in the northeast corner of the Edge Hill quadrangle, in one large and three small patches, bordering porphyry knobs.

Recent churn drilling by the St. Louis Smelting and Refining Co.,[1] near Black and near Shepard, shows the presence of typical Lamotte beneath the Bonneterre, in these areas (see also pp. 55-56).

On the headwaters of Tom Sauk Creek, in the E. ½ secs. 12 and 13, T. 33 N., R. 2 E., and across sections 7 and 18, T. 33 N., R. 3 E., occurs sandstone, most of which is conglomeratic and arkosic, which is either Lamotte, or perhaps more probably actually a lateral gradation of basal Bonneterre, toward the porphyry, near the head of an old pre-Cambrian valley, where clastic material was abundant, while true Bonneterre was being deposited elsewhere. Similar material occurs just north of the shut-in on Ottery Creek, in sec. 3, T. 33 N., R. 1 E., and also in the SE. ¼ sec. 30 and the NE. ¼ sec. 31, T. 34 N., R. 3 E. Since it is a lithologic equivalent of beds elsewhere called Lamotte, and since it would undoubtedly be referred to as Lamotte by drillers, in analogy with sandstone at or near the base of the Bonneterre elsewhere in Southeast Missouri, it has been differentiated on the map from the Bonneterre color, though the writer is inclined to believe that it is actually the time equivalent of basal Bonneterre more remote from the old mountain nucleus. Similar sandstone, found only as float, is fairly common, at many points where Bonneterre laps against the porphyry, and at several points it occurs stratigraphically high in the Bonneterre, where there is definite evidence that it is a shore phase of the Bonneterre, and not Lamotte. Such, for instance, is the arkosic sandstone float found on the north slope of Logan Mountain, in the SW. ¼ sec. 14, T. 35 N., R. 2 E., and at places along the southeast face of the same mountain in secs. 22 and 28, T. 35 N., R. 2 E.

Sandstone essentially similar has been observed in the head of the valley near the center of the N. ½ sec. 31, T. 33 N., R. 3 E.

[1]Campbell, E. T., Personal communication.

Thickness.—Since the Lamotte was deposited on a very uneven erosion surface of the porphyry, its thickness varies greatly and rapidly from place to place. The maximum thickness actually exposed at any one point in the area is about 100 feet, near the point where Goose Creek leaves the east border of the Potosi quadrangle, but it is probable that in old valleys of the pre-Cambrian erosion surface, much greater thicknesses are present.

In the recent drilling at Black[1] 223 feet of Lamotte was encountered in hole No. 5, 125 feet in hole No. 3, 87 feet in hole No. 1, and 63 feet in hole No. 9, all of which bottomed in the sand, indicating that the full thickness of the formation had not been drilled. On the other hand, hole No. 4 penetrated 95 feet of sand between the Bonneterre and the porphyry, hole No. 2 encountered 40 feet of clean sand and 30 feet of arkose above the igneous floor, and hole No. 8 went through 25 feet of sand and 15 feet of arkose, above the solid porphyry basement. These figures indicate clearly enough the extreme variability in thickness of this basal clastic deposit of the Cambrian.

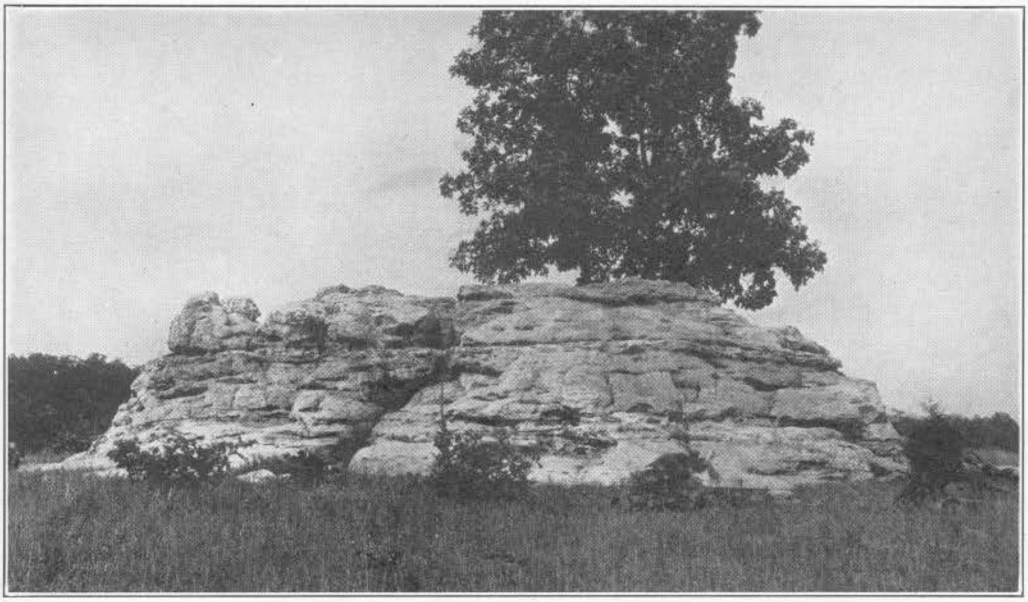
Lithologic character.—The Lamotte consists essentially of a quartz sandstone, varying in color from light gray to reddish-brown, red, and shades of yellow-brown, depending on the amount or iron, and its degree of hydration.

The base of the formation is best exposed at the sheet-edge, a mile east of Caledonia on the Bismark road, where it consists of a heavy conglomerate of badly weathered porphyry boulders up to a foot or more in diameter, in a matrix that carries a great deal of clay, and looks like a partly reworked residual pre-Cambrian soil.

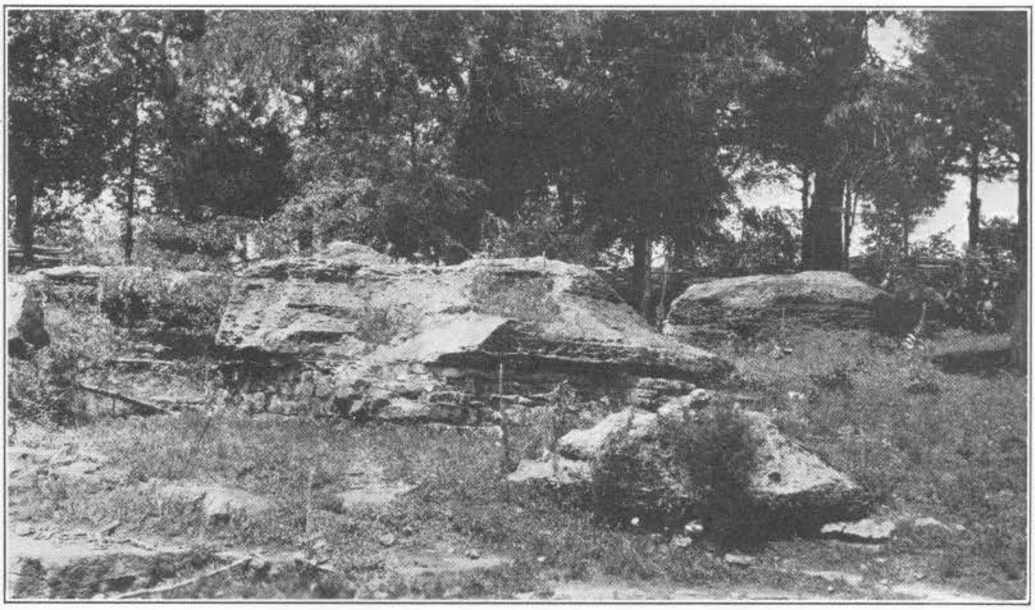
Clay layers a few inches thick are common throughout the formation, and at the bend in the private lane in the south central part of the north half of sec. 35, T. 36 N., R. 2 E., the transition beds from the Lamotte to the Bonneterre comprise several feet of thin-bedded slightly calcareous shale, that was at first mistaken for Davis, and resembles that formation so closely as to be recognized for Lamotte transition only by its stratigraphic position below undoubted Bonneterre.

Ordinarily the transition from the Lamotte to the Bonneterre is through alternating beds of sandstone, very sandy dolomite, and nearly pure dolomite, and occupies a vertical range of from 10 to 20 feet. This phase is best seen about 1½ miles north

[1]For location of holes, see p. 56.



A. Pinnacle of Lamotte sandstone, Irondale road, SE. ¼ sec. 25, T. 36 N., R. 2 E.



B. Lamotte-Bonneterre transition beds, on Highway 21, about 2 miles north of Caledonia.

of Caledonia, on the Potosi road, in the center of the W. ½ sec. 36, T. 36 N., R. 2 E.

Conglomerate was noted in the transition beds at only one point, in Goose Creek, in the village of Caledonia, and is no more conspicuous, and probably no more significant than conglomerate layers within the formation at many points. Some of the pebbles resemble chert, but on close examination are seen to be a very dense phase of the pre-Cambrian porphyry. Other small pebbles are highly kaolinized feldspar crystals.

In general, the Lamotte sandstone is well-bedded, in places even thin-bedded and shelly. Cross-bedding is fairly conspicuous, and varies from minute types related to the formation of ripples, up to beds several feet thick, inclined at angles of 10 to 15 degrees. More rarely it is massive, and weathers into pinnacles (Pl. VIII, A).

Under the writer's supervision, Mr. E. H. Griswold made screen tests, and computed the effective size and uniformity coefficients of several samples of Lamotte sandstone, and also of other sandstones collected during the course of the field work on this area. These results are tabulated below, and should be com-

MECHANICAL ANALYSES OF SANDSTONES.

Screens.		Lamotte, N. ½ sec. 7, T. 35 N., R. 3 E.	Lamotte, W. ½ sec. 36, T. 36 N., R. 2 E.	Lamotte, S E. Cor. sec. 25, T. 36 N., R. 2 E.	Lamotte, Iron Mt., Mo.	Gunter, Hahatonka, Mo.	Gunter, 1 mi. W. of Van Buren.	Roubidoux, ½ mi. N. of Buick, Mo.
Through.	On.							
....	6	00.00	00.00	00.00	00.00	00.00	00.00	00.00
6	8	00.00	00.00	00.00	00.10	00.00	00.00	00.00
8	10	00.00	00.00	00.00	00.25	00.00	00.00	00.00
10	14	00.35	00.00	00.25	00.72	00.05	00.00	00.25
14	20	00.54	1.95	00.32	00.80	00.10	00.15	00.54
20	28	10.32	34.20	3.65	2.38	00.15	4.65	3.75
28	35	45.45	43.70	23.67	5.80	1.57	19.97	16.95
35	48	33.60	15.75	34.25	43.85	16.22	32.55	33.50
48	65	5.74	3.24	29.00	36.15	31.28	25.63	29.85
65	100	00.75	00.86	5.84	4.98	38.30	13.85	12.80
100	150	00.68	00.25	1.48	1.82	11.35	2.35	2.17
150	200	00.13	00.00	00.00	00.30	00.73	00.00	00.00
200	Pan	1.82	00.00	1.16	2.07	00.07	00.01	00.00
Loss by dusting.....		00.62	00.05	00.38	00.78	00.18	00.84	00.19
Total..........		100.00	100.00	100.00	100.00	100.00	100.00	100.00
Effective size.......		.295	.355	.212	.208	.143	.184	.187
Uniformity coefficient		1.58	1.55	1.77	1.48	1.61	1.93	1.82

pared with the results obtained on a large number of Roubidoux and St. Peter samples previously studied.[1]

Of the three Lamotte samples studied above, the percentages retained on the 20-mesh screen are 0.32, 0.54 and 1.95. This is slightly coarser than the Roubidoux,[2] in which only one sample out of 12 studied has any grains that will not pass the 20-mesh; also coarser than the St. Peter, only 4 out of 23 of which has any grains too large to pass the 20-mesh. The three Lamotte samples show 3.65, 10.32, and 34.20 percent retained on the 28-mesh, whereas the Roubidoux, out of 12 samples, shows 3 with less than one percent, and only 4 with over 5 percent. Also of 23 samples of the St. Peter, 13 show less than one percent on the 28-mesh, and only 3 over 3 percent. The effective size of the three Lamotte samples is .212, .295, and .355 mm., respectively. Of 12 Roubidoux samples, only three exceed .195 mm., and of 17 St. Peter samples, only three exceed .195 mm. Thus the Lamotte is seen to be distinctly coarser than the typical Roubidoux or St. Peter sandstones.

The uniformity coefficient of the three Lamotte samples is 1.55, 1.58, and 1.77, respectively. The twelve samples of Roubidoux vary from 1.54 to 2.35, with an average of 1.83, and 26 samples of St. Peter vary between 1.43 and 2.31, with an average of 1.84.[3] The Lamotte, exclusive of conglomerates and basal arkosic beds, is therefore seen to be as uniform in texture as the St. Peter or Roubidoux, though slightly coarser.

Three thin sections of the Lamotte sandstone were prepared for microscopic study, and brief descriptions follow:

1. Sample from the N. ½ sec. 7, T. 35 N., R. 3 E. This is from basal beds, very close to the porphyry. The sandstone carries considerable ferruginous clay, and is moderately friable. Minerals other than quartz are very rare. The grains are moderately rounded, but the surfaces are minutely roughened, as though by etching subsequent to deposition. A very few grains show secondary quartz enlargement. Many show incipient fracturing, probably developed prior to deposition.

2. Sample from the center of the W. ½ sec. 36, T. 36 N., R. 2 E. This sample is from near the top of the formation, and much more remote from the porphyry than the preceding one. It is a cleaner sandstone, and is more firmly cemented. With a hand lens, the sand appears to be sharply angular, but in thin section, this appearance is seen to be wholly the result of secondary quartz enlargement. Rounding of the original grains was exceptionally perfect, but practically every grain has undergone secondary growth, and now many of them show well-

[1]Dake, C. L., The sand and gravel resources of Missouri; Mo. Bur. Geol. and Mines, 2nd ser., vol. 15, 1918; also

Dake, C. L., The problem of the St. Peter sandstone; Mo. Univ., School of Mines Bull., vol. 6, no. 1, 1921.

[2]Dake, C. L., Problem of the St. Peter Sandstone, pp. 157-158.

[3]Dake, C. L., loc. cit.

developed crystal faces. Fracturing is less marked than in the preceding sample. There is very little feldspar, and minerals other than quartz are comparatively rare.

3. Sample from the southeast corner of sec. 25, T. 36 N., R. 2 E. This sample is also from near the top of the formation, and even more remote from known porphyry exposures. It is the whitest of the three, and is less firmly cemented than the preceding one, being much like the first sample, in that respect. As in number two, the grains were formerly remarkably well-rounded, but have undergone extreme secondary enlargement, so that with the hand lens, they appear sharply angular. The grain size is slightly more variable than in the others.

For purposes of comparison, thin sections of St. Peter sandstone were prepared, from the quarry at Klondike and from the quarry at Pacific. There is no question but what the original degree of rounding in samples two and three of the Lamotte, described above, is considerably more perfect than in either of the slides of St. Peter sandstone examined. The apparent angularity is wholly the result of secondary growth.

The scarcity of grains other than quartz, and the perfection of rounding are strong arguments in favor of derivation from distant rather than local sources.

The Lamotte is distinguished from the Roubidoux by its stratigraphic position, and by the notable absence of chert, which is an extremely abundant constituent of the higher sandstone. Their residual soils, both rather sandy, and both characteristically reddish, are easily distinguished by the presence or absence of chert.

Topographic expression.—The area of exposure is so small that the formation shows little definite relations to the topography.

Its outcrop, while mostly confined to the valley of Goose Creek, also occupies rolling uplands to the north and south. The soil, though sandy, still shows the beneficial influence of the formerly overlying Bonneterre.

Stratigraphic relations.—As already pointed out the formation rests unconformably on a rather rugged pre-Cambrian erosion surface. (See also Structure, Initial Dip.) Basal conglomerate, with well-rounded boulders of porphyry up to a foot or more in diameter is well exposed on the Caledonia-Bismark road, about a mile east of Caledonia, near the sheet edge. The matrix consists of a somewhat sandy clay that suggests reworked pre-Cambrian soil. Many of the pebbles are very deeply weathered, as contrasted with the very fresh condition of the recent pebbles of porphyry on the same outcrop.

The contact with the Bonneterre, though slightly undulatory, is no more so than can be easily accounted for by normal inequalities of continuous deposition, accentuated by local deformation. No sign of an actual erosion break has been noted within the area mapped, nor has the writer seen any evidence for a break elsewhere in southeast Missouri between these two units. The data cited by St. Clair,[1] depending almost wholly on drillers correlations of the dolomites of the Upper Lamotte, and the variable interval between these lenses, and the base of the Bonneterre, seem to be very weak. The identification of various lenses of dolomite in the Upper Lamotte is uncertain, and in view of the beautiful gradation between the Lamotte and Bonneterre, wherever the contact is open to observation, there does not seem to be the slightest evidence of unconformable relations. Gradation phases are well shown along the Potosi road, about 1½ miles north of Caledonia, in about the center of the W. ½ sec. 36, T. 36 N., R. 2 E., where sandstone and sandy dolomite grade upward into nearly pure dolomite.

Locally a fine conglomerate, or better a coarse grit, occurs at the top of the Lamotte, in the bed of Goose Creek, in the village of Caledonia. The pebbles, none of which exceed ¼-inch in diameter, consist of highly kaolinized feldspar crystals, and a very dense phase of the local pre-Cambrian porphyry that much resembles chert, and is easily mistaken, upon first glance, for that material. About ¾-mile east of this occurrence of conglomerate, there is a very prominent porphyry knob which persisted until well into or through Bonneterre time as shown by the fact that the Bonneterre actually laps against its base. The conglomerate is therefore as easily accounted for as many that occur some distance from these knobs, in Ste. Genevieve County, within the Lamotte itself; or as those that occur well up in the Bonneterre, some distance from the porphyry, near the center of sec. 17, T. 35 N., R. 2 E. Such conglomerates are derived from the old pre-Cambrian sources, and are related to the unconformity between the pre-Cambrian and the Cambrian, and in no way indicate an erosion interval between the Lamotte and Bonneterre.

Paleontology.—St. Clair[2] reports *Obolus lamborni* and a few imperfect trilobite remains, but does not specify the horizon within the formation. Ulrich[3] also mentions *Obolus lamborni*,

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[1]Weller, Stuart, and St. Clair, Stuart, The geology of Ste. Genevieve Co., Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, p. 37.

[2]Op. cit., p. 39.

[3]Ulrich, E. O., Revision of the Paleozoic Systems; Bull. Geol. Soc. America, vol. 22, 1911, p. 623.

but fails to note the portion of the formation from which the fossils were collected. To date the author has found no other references to Lamotte fossils except the meager fauna from the Bonneterre transition. An inquiry addressed to Dr. C. E. Resser of the United States National Museum brought a reply to the effect that the Museum had no knowledge of any other collections from the Lamotte.

Age and correlation.—Although no fossils have been found in the Lamotte, in this area, its position next above the pre-Cambrian porphyry and next below the Bonneterre dolomite, as well as the fact that it can be traced with nearly perfect continuity from the type area of the Lamotte, serve to establish its identity with that formation. The Lamotte, formerly considered Middle Cambrian in age, is now generally assigned to the Upper Cambrian,[1] of which it is probably the lowest representative in Missouri.

In his "Revision," Ulrich correlated it with the central part of the Honaker limestone of Virginia, with the base of the Conasauga shale of Tennessee, with the central Conasauga of Alabama, with the Rogersville of Tennessee, with the Hinckley formation of Wisconsin, and with the basal Reagan of Oklahoma. His latest unpublished correlation table indicates its equivalence with the Hickory sandstone of Texas, the Reagan of Oklahoma, and the Mt. Simon sandstone of Wisconsin, and suggests doubt as to whether its horizon is represented in the southern Appalachians.

Bonneterre Dolomite.

Name.—The Bonneterre dolomite is named from the town of Bonneterre, where the beds are especially well exposed. It is a portion of the St. Joseph limestone of Winslow,[2] in which he apparently included everything from the top of the Lamotte to the base of the Potosi, as that formation is now defined. The St. Joseph is the equivalent of the Fredericktown limestone of Keyes,[3] which seemingly also included everything between the Lamotte and Potosi (Lesueur).

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[1]Op. cit., p. 623, and Pl. 27.

[2]Winslow, Arthur, Lead and zinc deposits; Mo. Geol. Survey, vol. VI, 1894, p. 331 and p. 347.

[3]Keyes, Charles Rollin, A report on Mine La Motte sheet; Mo. Geol. Survey, vol. IX, sheet report no. 4, 1896, pp. 48-52.

Nason,[1] in 1901, uses, apparently for the first time, the term Bonneterre, as a partial equivalent for the St. Joseph. Nason clearly includes a considerable part of the Davis, and all the Derby-Doerun in the Potosi, so that his term Bonneterre comes much closer to the present usage, than did the older term St. Joseph. He places the top of the Bonneterre just below an "edgewise" conglomerate, though from his description, it is by no means clear whether this is the lowest conglomerate bed in the formation. Bain and Ulrich[2] also draw their contact at an edgewise conglomerate, but particularly specify a bed 8 feet below the "marble-bowlder" horizon. It is therefore certain that they place in the Bonneterre about 100 feet of very typical Davis, including many "edgewise" beds fully as significant as the one they stress to mark the contact. Buckley[3] appears to have been the first to draw a logical contact, and to properly delimit the Bonneterre, and it is in the sense used by him, that the formation is now described.

Distribution.—The Bonneterre outcrops rather extensively over the southeast quarter of the Potosi sheet, occupying an area of nearly 20 square miles, delimited on the north by the Palmer fault zone, on the east by the Lamotte sandstone, and on the west by the Davis.

On the Edge Hill sheet, it makes the floor of the Belleview valley, the outcrop in this valley alone occupying some twelve square miles of the northeast corner of the map and extending far to the eastward, beyond the limits of the map, across the eastern portion of the plain. In addition, it is exposed as narrow strips, in many of the deeper valleys over the eastern and southern portions of the Edge Hill quadrangle, especially adjacent to the porphyry knobs. The total area of outcrop on the quadrangle is about 30 square miles.

Thickness.—Most of the region over which the Bonneterre outcrops is gently rolling, and nowhere is there more than 100 feet of the formation exposed in the sides of any single valley.

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[1]Nason, F. L., On the presence of a limestone conglomerate in the Lead Region of St. Francois Co., Missouri; Amer. Jour. Sci., 4th ser., vol. 11, 1901, p. 396.

Nason, F. L., The geological relations and the age of the St. Joseph and Potosi limestones of St. Francois County, Missouri; Amer. Jour. Sci., 4th ser., vol. 12, 1901, pp. 358-361.

[2]Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, No. 267, 1905, pp. 21-26.

[3]Buckley, E. R., Geology of the disseminated lead deposits of St. Francois and Washington Counties, Mo. Bur. Geol. and Mines, vol. IX, 2nd ser., 1908, pp. 26-44.

On account of the large number of porphyry knobs, about which the local dips are very erratic, it is quite impossible to arrive at any satisfactory estimate of the amount of regional dip, so that the width of its outcrop area affords no clue to its thickness. Beyond saying, therefore, that it is certainly over 100 feet, and that it might well be several hundred, no definite statement can be made, from surface observations alone. According to Buckley's interpretation[1] of the core from a deep hole at Palmer, the Bonneterre at that place has a thickness of 278 feet. This probably does not include the transition zone of alternating sandstone and dolomite at the Lamotte contact.

During the summer of 1926, the St. Joe Lead Company drilled a number of holes in the region around Belgrade. Their engineer in charge, Mr. Larson, kindly placed at the disposal of the Survey the depths to (1) the base of the "shale" (Davis), and (2) the top of the "sand" (Lamotte) in these holes, taken directly from their logs. These are given below:

TABLE OF HOLES PENETRATING THE BONNETERRE NEAR BELGRADE.

No. of hole.	Location.	Depth to base of shale.	Depth to top of sand.	Thickness of Bonneterre.
19	S. ½ SW. ¼ sec. 21, T. 36 N., R. 2 E.	Started on Bonneterre.	393 ft.	393 +
20	SW. ¼ SE. ¼ sec. 21, T. 36 N., R. 2 E.	Started on Bonneterre	293 ft.	293 +
21	NE. ¼ sec. 28, T. 36 N., R. 2 E.	Started on Bonneterre.	184 ft.	184 +
18	NW. ¼ sec. 28, T. 36 N., R. 2 E.	Started on Bonneterre.	190 ft.	190 +
24	NW. ¼ sec. 28, T. 36 N., R. 2 E.	Started on Bonneterre.	231 ft.	231 +
11	SE. ¼ sec. 36, T. 36 N., R. 1 E.	23 ft.	279 ft.	256
10	Cent. sec. 25, T. 36 N., R. 1 E.	191 ft.	508 ft.	317
3	NW. ¼ sec. 36, T. 36 N., R. 1 E.	171 ft.	425 ft.	254

[1]Buckley, E. R., op. cit., pp. 55-57.

BELGRADE—Continued.

No. of hole.	Location.	Depth to base of shale.	Depth to top of sand.	Thickness of Bonneterre.
8	SE. ¼ sec. 36, T. 36 N., R. 1 E.	114 ft.	430 ft.	316
4	SE. ¼ sec. 35, T. 36 N., R. 1 E.	71 ft.	301 ft.	230
7	SE. ¼ sec. 35, T. 36 N., R. 1 E.	201 ft.	475 ft.	274
9	NW. ¼ sec. 2, T. 35 N., R. 1 E.	94 ft.	356 ft.	262
13	NE. ¼ sec. 3, T. 35 N., R. 1 E.	87	348 ft.	261
16	SE. ¼ sec. 4, T. 35 N., R. 1 E.	175 ft.	413 ft.	238
15	SW. ¼ sec. 2, T. 35 N., R. 1 E.	135 ft.	393 ft.	258
17	SE. ¼ sec. 3, T. 35 N., R. 1 E.	218 ft.	472 ft.	254
22	NW. ¼ sec. 21, T. 36 N., R. 2 E.	790 ft.	1157 ft.	367

The least thickness, where the overlying Davis is present, is 230 feet, the greatest thickness reported is 393 feet. Using only those holes where the Davis is present, the average is about 265 feet. The figure of 393 feet for the hole in the S. ½ SW. ¼ sec. 19, T. 35 N., R. 2 E., is rather surprising. The Company's log, however, compiled from cores, checks the original mapping in showing the hole spudded in on Bonneterre. This is in a highly faulted area, and the explanation may be beds repeated or tilted to give this excessive apparent thickness. The figure of 367 feet in hole 22 is also unusually high, and since it is also in the vicinity of a major fault the figure is probably excessive. This seems the more likely, since the Davis is reported as 215 feet thick in the same hole, which is much above the average for this general locality.

Mr. E. T. Campbell of the St. Louis Smelting and Refining Company placed at the Survey's disposal the logs for six diamond drill holes near Shepherd, in Iron Co. The correlations are by

Mr. McQueen of this Bureau, and by the writer. All of the holes started on either Davis or Derby-Doerun. A summary of the correlations follows:

RECORD OF DIAMOND DRILL HOLES NEAR SHEPHERD.

No. of hole.	Location.	Depth to Bonneterre.	Thickness of Bonneterre.
1	N. ½ NE. ¼ SW. ¼ sec. 11, T. 34 N., R. 1 E.	192	271
2	SW. ¼ SE. ¼ sec. 11, T. 34 N., R. 1 E.....	115	219
3	N. ½ SE. ¼ NE. ¼ sec. 11, T. 34 N., R. 1 E.	180	260
4	NW. ¼ NW. ¼ sec. 14, T. 34 N., R. 1 E....	212	2 6
5	NE. ¼ SW. ¼ SW. ¼ sec. 14, T. 34 N., R. 1 E.	52	148
6	Near cent. sec. 12, T. 34 N., R. 1 E........	158	273

The exceptional thinness in hole number 5 is explained by the fact that here the Bonneterre laps against an old porphyry knob, on which the hole was bottomed at 224 feet. In hole number 2, solid porphyry was encountered at 385 feet. The Bonneterre is therefore thin in this hole, again, by suppression of its basal beds, against a hill on a pre-Lamotte surface. In three of the four remaining holes, typical Lamotte-Bonneterre transition was encountered, in which the drilling stopped. Hole number six passed out of Bonneterre into prophyry, with sandy beds at the base. Eliminating holes two and five, in which the Bonneterre is unduly thin because of hills on the pre-Lamotte surface, which persisted into Bonneterre time, the average for the other four is 265 feet, and the maximum variation 17 feet, and even this may be partly inaccurate location of contacts, rather than actual variation in thickness. This average is practically identical with that for the area about Belgrade and Sunlight.

Recent churn drilling by the St. Louis Smelting and Refining Co.[1] near Black also has given considerable data on the thickness of the Bonneterre. The information is tabulated below:

RECORD OF CHURN DRILL HOLES NEAR BLACK.

No. of hole.	Location.	Depth to Bonneterre.	Thickness of Bonneterre.
1	NE. ¼ NW. ¼ sec. 26, T. 33 N., R. 1 E....	180	240
2	NW. ¼ SW. ½ sec. 26, T. 33 N., R. 1 E....	275	315
3	NE. ¼ SE. ¼ sec. 22, T. 33 N., R. 1 E.....	161	250
4	SW. ¼ SE. ¼ NW. ¼ sec. 22, T. 33 N., R. 1 E.	240	300
5	SW. ¼ NW. ¼ NE. ¼ sec. 22, T. 33 N., R. 1 E................................	10	265
6	SW. ¼ NE. ¼ SE. ¼ sec. 15, T. 33 N., R. 1 E.	60	275
7	SE. ¼ SW. ¼ NW. ¼ sec. 14, T. 33 N., R. 1 E.	45	310
8	NW. ¼ SW. ¼ sec. 10, T. 33 N., R. 1 E....	35	285
9	SW. ¼ SE. ¼ NE. ¼ sec. 16, T. 33 N., R. 1 E.	55	280
10	NE. ¼ NE. ¼ NW. ¼ sec. 16, T. 33 N., R. 1 E................................	45	270
11	NE. ¼ SE. ¼ SW. ¼ sec. 8, T. 33 N., R. 1 E.	445	195

In this group of holes, the figures range about the same as for those already given. The exceptional thinness in hole No. 11 may be accounted for, again, by suppression of the basal beds against a porphyry knob, since the hole bottomed in arkosic material. Eliminating this hole, the average is about 280 feet, or very close to that already given. The fact that the holes are located close to a fault, where the beds may be tilted, may possibly be the reason the average here is somewhat more than in the other areas.

In the city well at Potosi, McQueen[2] assigns 355 feet of beds to the Bonneterre, a rather exceptional thickness, although perhaps not surprising when it is kept in mind that in general, the formations thicken toward the basins away from the porphyry uplands.

[1]Cuttings furnished by E. T. Campbell.
Correlations are by T. D. Murphy, of this Bureau, from a study of the cuttings.
[2]See log, p. 226.

In deep drilling at Saco, in Madison County, two holes, closely adjacent, show respectively 465 and 470 feet of very characteristic gray Bonneterre, lying between typical brown Potosi above, and reddish, slightly dolomitic limestones, below. The cuttings are on file in the Survey offices, and have been very carefully studied by McQueen[1] in establishing these contacts. In these holes, the Davis and Derby-Doerun are absent, the Potosi resting directly on the Bonneterre. How much greater the thickness may have been, before the pre-Potosi erosion, cannot be told.

Lithologic character.—The basal beds of the Bonneterre are usually sandy, and a very fine example of alternating calcareous sandstone and sandy dolomite may be seen along the Caledonia and Potosi road (Pl. VIII, B), in the SW. ¼ sec. 1, T. 35 N., R. 2 E., and the NW. ¼ sec. 36, T. 36 N., R. 2 E. In places, these beds, where freshly broken, are clearly a dolomite, with closely spaced sand grains, but appear much more sandy on the weathered and leached surface, in fact would ordinarily be called sandstone.

At one point near the center of the N. ½ sec. 35, T. 36 N., R. 2 E., there is considerable gray to greenish-gray shale at the Bonneterre-Lamotte contact, that might with equal propriety be mapped with either formation. The actual contact between the two is usually soil-covered, and not visible.

Much of the lower portion of the formation consists of a completely crystalline but rather fine-grained buff-colored dolomite, sparingly mottled with gray. This portion of the formation is rather smooth-weathering. It is well exhibited in the SE. corner sec. 26, T. 36 N., R. 2 E., and again in the NW. ¼ NW. ¼ sec. 27, T. 36 N.. R. 2 E.

The upper portion is, on the average, much more massive (Pl. IX, A), more coarsely crystalline, is a lighter gray in color, contains numerous vugs lined with dolomite or calcite crystals, is more cavernous, or pitted on exposed surfaces, and weathers with a very deceptive "sandy" appearance. The "sandy" surfaces, if examined closely, however, are seen to consist of individual dolomite crystals with curved faces ranging up to 1 or 2 millimeters in diameter, so loosely aggregated that they may be crumbled in the fingers, into dolomitic "sand." This phase remarkably resembles the Eminence, both in its craggy, cavernous weathering, and in its sandy-appearing surfaces; but lacks the

[1]Personal communication.

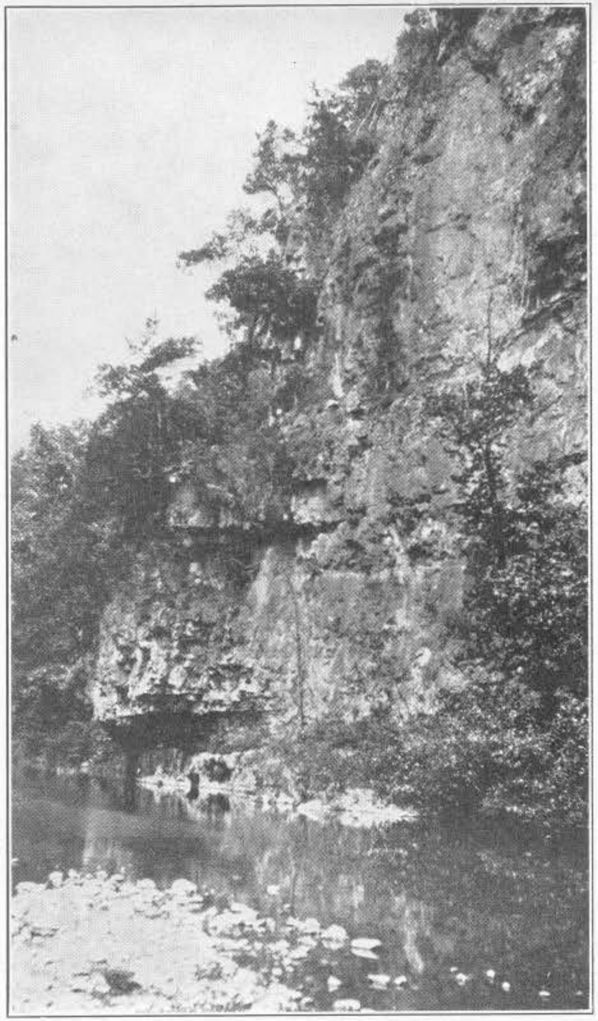
chert so abundant in the younger dolomite. This coarsely crystalline phase of the upper Bonneterre is extensively developed throughout the St. Francois Mountain area, south of Fredericktown in Madison County; around Coldwater and Brunot in Wayne County; and in the vicinity of Des Arc, Annapolis, Chloride, the Arcadia Valley, and the Belleview Valley in Iron County.

Occasional thin seams and splotches of greenish material are probably glauconite (chlorite of older writers), but the glauconite seems to be much more sparingly developed than in the Lead Belt proper. This apparent scarcity of glauconite may, however, in part be accounted for by the fact that exposures are usually poor, and that there are practically no artificial cuts or excavations, which show fresh surfaces. The apparent scarcity of shale in the formation may, perhaps, be ascribed to the same cause, the thin shale seams being inconspicuous, or completely covered, on the natural exposures.

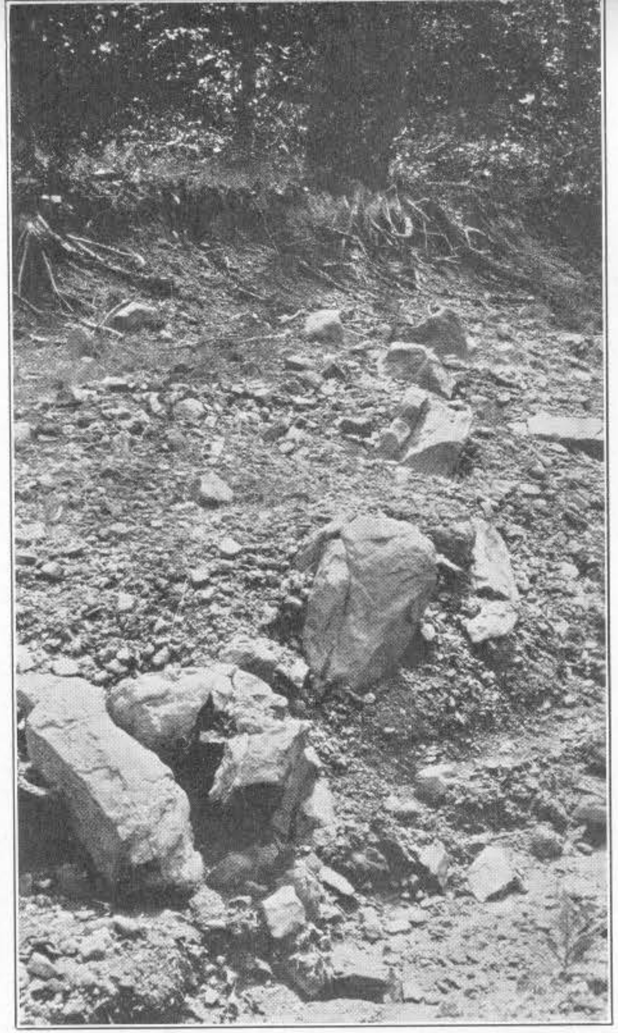
The deep hole at Palmer[1] seems to bear out the conclusion that glauconite (chlorite ?) is less abundant than in the Lead Belt, but shows the presence of more shale than a study of the weathered outcrop would lead one to expect.

At several localities slightly argillaceous beds occur in the base of the Bonneterre, that seem to be entirely indistinguishable from the Davis, except for their stratigraphic position. Where Shut-in Creek crosses the north line of sec. 6, T. 33 N., R. 2 E., there are mottled brownish thinly-bedded somewhat shaly limestones that were first mapped as Davis on a preliminary reconnaissance trip through the area. Later more detailed studies show that the beds in question pass beneath 100 feet of coarse granular dolomite identical with that mapped throughout the area as Bonneterre. The entire sequence is non-fossiliferous. It seemed far more likely that a few feet of shaly beds resembling Davis could occur in the impure basal Bonneterre near the porphyry, than that 100 feet of coarse granular beds like the Bonneterre could occur in the Davis. On the strength of this reasoning, the beds in question were assigned to the Bonneterre. Very similar beds occur in secs. 30 and 31. T. 34 N., R. 3 E., which would undoubtedly be mapped as Davis, except for the fact that they pass below coarsely granular beds believed to be Bonneterre, which in turn pass below undoubted Davis with typical "edgewise." The assignment of these beds to the Bonneterre has been

[1]Buckley, E. R., loc. cit.



A. Massive outcrops of the Bonneterre on the East Fork of Black River, SE. ¼ SW. ¼ sec. 28, T. 33 N., R. 2 E.



B. Roubidoux boulders, slumped far below their normal position, in an old solution sink, on Highway 8, cent. sec. 22, T. 37 N., R. 1 E.

strikingly confirmed by finding remarkably similar material in cuttings in the holes at Black, beneath 200 feet of typical coarsely crystalline Bonneterre, which itself underlies characteristic fossiliferous Davis.

The Bonneterre, in common with all the formations below the base of the Potosi, is essentially non-cherty. Much of the chert and druse noted in the soil is residual from Potosi and younger horizons. McQueen's study of the insoluble residues secured by digesting the cuttings of the formation in acid, shows that there is disseminated silica, some of which is in the form of sand grains, but an appreciable part of which occurs as minute particles of chert. Why the silica of the higher formations should segregate as chert, and not that in the Bonneterre, is as yet unexplained.

There are numerous porphyry knobs in the area, against which Bonneterre laps, though actual contacts are rarely seen. The basal conglomerates are evidently for the most part thin, and occupy the area covered by the heavy talus from the porphyry knobs. Such conglomerate may be seen near the center of the SE. ¼ of sec. 35, T. 36 N., R. 2 E.; and very fine exposures occur in the E. ½ NE. ¼ sec. 22, T. 35 N., R. 1 E.; in the SW. ¼ SW. ¼ sec. 22, T. 35 N., R. 2 E.; and the center of the NE. ¼ sec. 11, T. 35 N., R. 1 E.

Near the center of sec. 17, T. 35 N., R. 2 E., the Bonneterre is highly conglomeratic at least ¼-mile from the nearest porphyry knob now exposed. This is the most striking exhibit of the conglomerate noted at any distance from the porphyry.

The soil of the Bonneterre, where the formation outcrops widely, is characteristically a very deep red, but may usually be distinguished from the highly red soils of the Potosi and Eminence, by the relative scarcity of druse or chert.

In the table, on page 70, are given analyses of two phases of the Bonneterre, one a sample from the transition beds at the base of the formation, the other a typical coarse granular bed, characteristic of the formation throughout the St. Francois Mountains. The latter sample was secured some 40 or 50 feet above the base. Both approach very closely the proportions of lime and magnesia of theoretical dolomite.

An interesting feature is the fact that both samples contain silica (2.5%) in much larger quantities than do the Potosi and Eminence, though the Bonneterre is not a chert former, and the Potosi and Eminence leave heavy chert residuum on the weathered surface. This is probably in part because so much of the silica of the Bonneterre is in the form of sand, or combined in clay, glauconite, and other silicates, instead of the disseminated chert. Some of the latter, however, does occur, so this is not the entire explanation. A peculiar marble-like phase of the Bonneterre is of so much interest that it is described in a separate section.

Topographic expression.—Most of the area immediately underlain by the Bonneterre is a gently rolling plain, the local relief of which scarcely exceeds 100 feet, but which is surmounted by several very aburpt porphyry knobs, against which the formation laps. Cliff exposures are rare, except along Big River, where they seldom exceed 30-40 feet in height, and on Black River, where they reach as much as 75 feet (Pl. IX, A). Elsewhere, the outcrops, though fairly numerous, are usually low and flat, and confined to road ditches, or the bottoms of shallow valleys. The soils are moderately fertile, and almost free from chert, except that derived from the higher formations. The Bonneterre plain constitutes the richest farm land in the two quadrangles, and the area about Belgrade, Caledonia and Belleview is a prosperous agricultural district (Pls. I, B; V; and XIX, B), somewhat resembling in character and appearance the well-known Arcadia Valley near Ironton, where the geological relations are almost identical.

Cedar "glades" constitute a conspicuous feature of the Bonneterre outcrops in Belleview valley. They are also common on the outcrops of the Derby-Doerun.

Where the Bonneterre occupies the bottoms of narrow valleys, in the southeastern portion of the Edge Hill quadrangle, it has no individual topographic expression.

Stratigraphic relations.—The relations of the Bonneterre to the Lamotte have already been described under the older formation. Nowhere in the area did the writer find a good exposure of the contact between the Bonneterre and the overlying Davis, though the general impression is that of gradation from massive dolomite through more thin-bedded members, into shale. Nothing whatever was noted that pointed to unconformable relations, although it would be impossible, from what was seen, to state positively that the unconformity reported by Bain and Ulrich[1] does not occur in this area.

[1]Bain, H. Foster, and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, no. 267, 1905, p. 23.

Paleontology.—The only fossils found in the Bonneterre formation, within the area of these quadrangles come from a drill core from hole No. 23, located in the NE. ¼ SE. ¼ sec. 21, T. 36 N., R. 2 E., and were supplied by Mr. C. L. Larson, of the St. Joe Lead Co. They are from a depth of 1070 feet, or 17 feet above the "white sand" (Lamotte). They have been identified by Prof. Bridge as *Dicellomus politus* (Hall).

Branson[1] figures *Obolus lamborni* (Meek) as a Cambrian index fossil from Missouri, but does not mention the formation of which it is characteristic.

Walcott, in his Cambrian Brachiopoda[2] lists the known brachiopods from the formations, as follows:

Micrometra sp.—Basal Bonneterre at Flat River.
Micrometra (*Paterina*) cf. *stissingensis*—Basal Bonneterre at Flat River.
Obolus lamborni—Basal Bonneterre at Mine Lamotte and Flat River.
Obolus sinoe—Basal Bonneterre at Mine Lamotte.
Lingulella acutangula—Basal Bonneterre at Mine Lamotte.
Lingulella cf. ora—Basal Bonneterre at Flat River.
Lingulella desiderata—Shales at Bonneterre.
Dicellomus nanus—Basal Bonneterre at Flat River and Mine Lamotte.
Dicellomus politus—Basal Bonneterre at Flat River.

Bain and Ulrich[3] also refer to trilobites, and to orthid shells, resembling Billingsella, but no descriptions are available.

A considerable fauna has been reported from Ste. Genevieve County,[4] from the lower 100 feet of the formation. The list is given below:

FAUNA OF THE BONNETERRE FORMATION IN STE. GENEVIEVE CO.

Lingulella leos Walcott.
Obolus, 2 undet. sp.
Micromitra alabamensis Walcott.
Micromitra sculptilis (Meek).
Acrotreta.
Linnarssonella girtyi Walcott.
Hyolithes sp.
Plates of some chiton.
Agnostidae of at least five species.
Four species all closely allied to Appalachian and Cordilleran forms assigned to *Anomocarella* by Walcott.
Maryvillia sp.
Hystricurus, 3 species.
Menomonia cf. *calymenoides* (Hall).
Kingstonia, 2 n. sp.

[1]Branson, E. B., Geology of Missouri; Univ. of Mo. Bull., vol. 19, no. 15, 1918, pp. 96-97.
[2]Mon. U. S. Geol. Survey, vol. 51, pt. 1, p. 137.
[3]Op. cit., p. 22.
[4]Weller, Stuart, and St. Clair, Stuart, Geology of Ste. Genevieve Co., Missouri; Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, p. 45.

Millardia.

Norwoodia aff. *gracilis* Walcott.
"*Saratogia*" aff. *wisconsinensis* (Hall).
"*Crepecephalus*" *texanus* Shumard.
Crepecephalus comus Walcott.
Crepecephalus thoosa Walcott.
Crepecephalus, 5 or 6 unnamed species.

Age and correlation.—The position of what is herein called Bonneterre, next above the basal Lamotte sand, and next below the typical Davis with its characteristic edgewise conglomerate, together with the almost perfect continuity into the type area, leave no doubt whatever that it is the equivalent of the original Bonneterre.

For many years, this formation, like the Lamotte, was assigned to the Middle Cambrian, and Bain and Ulrich[1] so classify it. Ulrich[2] later places it in the Upper Cambrian. Walcott[3] also first assigned the formation to the Middle Cambrian, but attention is called in a footnote, to a later assignment to Upper Cambrian.

In his "Revision," Ulrich[4] correlated the Bonneterre with the top of the Honaker limestone of Virginia, with the middle Conasauga shale of Tennessee and Alabama, with the Maryville limestone of Tennessee, with the Dresbach sandstones and shales of Wisconsin, and with the Honey Creek member of the upper Reagan sandstone of Oklahoma. In his latest unpublished correlation table, he indicates his belief that the horizon of the Bonneterre is represented by the upper Maryville and upper Conasauga of the southern Appalachians, by the lower part of the Cap Mountain of central Texas, by beds he calls Cap Mountain in Oklahoma, next beneath the Honey Creek, and by the upper part of the Eau Claire of Wisconsin.

St. Clair[5] indicates that it is probably equivalent to the Katemcy of Texas, and some part of the Deadwood of the northern Rockies.

Marble Phase of Bonneterre.

During the summer of 1923 a very interesting, and puzzling situation was discovered in southern Washington County, about two miles north of Caledonia, in the N. ½ SE. ¼ sec. 35, T. 36

[1]Op. cit., p. 22.

[2]Revision of the Paleozoic Systems, pl. 27 and p. 623.

[3]Walcott, C. D., Cambrian Brachiopoda; Mon. U. S. Geol. Survey, vol. 51, pt. 1, 1912, p. 137.

[4]Loc. cit.

[5]Weller, Stuart, and St. Clair, Stuart, op. cit., p. 45.

N., R. 2 E. The outcropping sedimentary beds are basal Bonneterre, lapping against a very small porphyry knob, exposed in a creek bed. The sediments dip slightly away from the porphyry, and are distinctly arkosic nearest the igneous rock, but grade laterally into nearly pure dolomite.

The actual contact between the porphyry and the sediment is concealed, but twenty feet above the creek bed, is exposed a conglomerate with abundant porphyry pebbles in an arkosic matrix that seems to grade laterally into typical basal Bonneterre dolomite. Outcrops are not perfectly continuous, and there is a possibility, seemingly remote however, that this is a younger conglomerate plastered down over the Bonneterre. It is thought that the conglomerate is actually part of the Bonneterre formation. The included porphyry pebbles grade from tiny fragments up to masses several inches in diameter. Among them are also pebbles of quartzitic sandstone and dense finely-crystalline marble.

The marble pebbles range up to two inches in diameter, and are moderately rounded. Microscopic examination shows them to consist almost exclusively of very fine crystals of carbonate, with here and there patches of slightly larger grain.

With them are also associated pebbles of quartzitic sandstone up to 2 or 3 inches in diameter. Microscopic examination shows this sandstone to consist of remarkably rounded and polished grains of quartz, a few of which have been enlarged to nearly twice their original size by secondary silica, in optical continuity with the original particles. Almost all the grains show some enlargement.

When studied without the nicols, with the light cut down by a diaphragm, the old surfaces of the rounded grains within the enlarged mass are seen to be minutely pitted, giving a frosted appearance of the type so commonly associated in the mind with St. Peter sand grains. This remarkable rounding and frosting show on almost every grain, even to the very smallest. Considerable carbonate is present as a cement, between the grains.

Certain patches of the sand grains are well cemented with silica, and suggest pebbles derived from a still older sandstone or quartzite, and now included within the pebbles described above.

In the matrix of the conglomerate, which consists chiefly of carbonate, are many grains of quartz which show enlargement, similar to that of the grains in the quartzitic pebbles. These grains in the matrix show rather clear evidence of having been fragmented since enlargement, and were presumably derived from the same formation that yielded the pebbles.

Careful search in the immediate vicinity has thus far revealed no outcrop of either the marble or the quartzitic sandstone, from which these pebbles could have been derived.

The marble pebbles are wholly unlike the ordinary Bonneterre in the quadrangle, and it is positive that they are pebbles in a conglomerate, and not brecciated particles of the Bonneterre itself. Nor are there any beds in the Lamotte, from which they could have been derived, even admitting the remote possibility of a post-Lamotte, pre-Bonneterre erosion sufficient to have yielded them.

The quartzitic sandstone pebbles are a much harder and more vitreous type of sandstone than any thus far seen in the Lamotte.

Since the above discoveries, Mr. E. Taylor Campbell, geologist for the St. Louis Smelting and Refining Company, brought in a sample of marble almost identical in megascopic and microscopic character, with the pebbles described above. It came from the west base of Goggins Mountain, Reynolds County, near the center of the north line of sec. 14, T. 33 N., R. 1 E., about 18 miles southwest of the locality where the writer first found the marble pebbles just described.

It was not until the summer of 1927 that the writer had an opportunity to push this interesting problem further. During mapping of the Edge Hill quadrangle, very similar dense marble was discovered at the east border of a porphyry knob on the south side of Padfield Branch, in the SW. ¼ NW. ¼ sec. 11, T. 33 N., R. 1 E. This immediately revived interest in the problem, and a systematic search was begun, in the hopes of discovering more areas of this rock.

Distribution.—In addition to the initial discovery locality, in the N. ½ SE. ¼ sec. 35, T. 36 N., R. 2 E., on the Potosi quadrangle, where only pebbles of the marble were noted in the Bonneterre, but no outcrops of the material were found, a number of localities have been discovered in the Edge Hill quadrangle. These are listed below. An inconspicuous outcrop, the one reported by Mr. Campbell, occurs near the head of a small north-side branch of Goggins Hollow, near the center of the north line of sec. 14, T. 33 N., R. 1 E. A much larger outcrop laps against the east flank of a small porphyry knob, on the south side of

Padfield Branch, in the SW. ¼ NW. ¼ sec. 11, T. 33 N., R. 1 E. A small and inconspicuous outcrop occurs in a small ravine, northeast of the Pinkley School, on the southeast side of Tom Sauk Creek, in the NE. ¼ NE. ¼ sec. 27, T. 33 N., R. 2 E. A somewhat more conspicuous occurrence was noted in the SE. ¼ NE. ¼ sec. 24, T. 33 N., R. 2 E., just above the mouth of a small gully on the east side of the main valley running south through the east half of the section.

Other occurrences are in the NE. ¼ SE. ¼ sec. 34, T. 34 N., R. 1 E.; in the E. ½ sec. 3, T. 33 N., R. 1 E.; in the N. ½ sec. 6, T. 33 N., R. 2 E.; where Imboden Fork crosses the west line of sec. 4, T. 33 N., R. 2 E.; in the W. ½ SW. ¼ sec. 27, T. 34 N., R. 2. E.; near the center of the N. line sec. 1, T. 33 N., R. 1 E.; in the SW. ¼ SE. ¼ sec. 33, T. 34 N., R. 2 E.; and near the center of the NE. ¼ sec. 34, T. 34 N., R. 2 E.

The most conspicuous outcrops, however, thus far noted occur in the E. ½ sec. 25, T. 33 N., R. 2 E.; the SE. ¼ sec. 19, T. 33 N., R. 3 E.; and along the main valley and its south-side tributaries, across sec. 30, T. 33 N., R. 3. E.

Attention must be called, at this point, to the fact that of these occurrences, several are not shown in the correct color on the map. The ones on which the green print used for this marble has been omitted are located as follows:

Near center N. line	sec. 1, T. 33 N., R. 1 E.
SW. ¼ NW. ¼	sec. 11, T. 33 N., R. 1 E.
Near center N. line	sec. 14, T. 33 N., R. 1 E.
W. ½ SW. ¼	sec. 27, T. 33 N., R. 2 E.
SW. ¼ SE. ¼	sec. 33, T. 34 N., R. 2 E.
Center NE. ¼	sec. 34, T. 34 N., R. 2 E.

Attention should also be called to the fact that the small patch shown in green in the NW. ¼ NW. ¼ sec. 26, T. 34 N., R. 1 E. is porphyry, not marble, and should be shown in red.

A study of the areas described above recalled to the writer certain dense red and mottled limestones seen several years ago in Madison and Iron Counties, and another visit to these localities resulted in the discovery of several other outcrops of identical marble.

In Madison County, an excellent exposure occurs in an old quarry in the SE. ¼ sec. 23, T. 33 N., R. 6 E. There are also good exposures at several points in sec. 32, and at least one along the main road in the NW. ¼ sec. 31, T. 33 N., R. 6 E. Similar beds outcrop near French Mills, in the SW. ¼ sec. 15, and the NE. ¼ sec. 21, T. 32 N., R. 5 E. Other outcrops in Madison

County were visited, near the center of the S. ½ sec. 17, near the center of the N. ½ sec. 20, and near the center of the N. ½ sec. 19, T. 32 N., R. 5 E. Just over the line in Iron County, there are very fine outcrops in the S. ½ sec. 24, T. 32 N., R. 4 E.

A study of the older Missouri reports shows that this marble has been widely observed, though little or nothing was worked out relative to its age and stratigraphic position. A partial list of the localities observed by former workers is herewith appended, with references.

Swallow[1] refers, without any discussion, to marble in secs. 34 and 35, T. 34 N., R. 3 E.

Broadhead[2] lists, with the briefest of descriptions, and without discussion of age or relations, the following occurrences of marble in the St. Francois Mountain region. On and near Stouts Creek, sec. 5, T. 33 N., R. 3 E., and sec. 31, T. 34 N., R. 3 E.; at Farnhams quarry, sec. 19, T. 33 N., R. 4 E.; SW. corner sec. 5, T. 32 N., R. 4 E.; sec. 6, T. 32 N., R. 4 E.; SW. ¼ NE. ¼ sec. 33, T. 33 N., R. 4 E.; in Reynolds County, on Tom Sauk Creek; in Madison County, near the mouth and near the head of Cedar Creek; and on Leatherwood Creek, near its mouth on St. Francois River. In a slightly later report, Broadhead[3] also lists several occurrences of the marble, but makes no statement as to its age or stratigraphic relations, except to say it rests above the porphyry. He mentions the following localities. East side of Twelvemile Creek, sec. 8, T. 31 N., R. 6 E.; west side of St. Francois River, sec. 11, T. 31 N., R. 5 E.; west side of SW. ¼ sec. 10, T. 32 N., R. 6 E.; sec. 9, T. 31 N., R. 5 E.; sec. 13, T. 32 N., R. 5 E.; sec. 34, T. 32 N., R. 5 E.; at the shut-in on Morris Creek (Marsh Creek ?), sec. 35 (T. 32 N., R. 5 E. ?); and on the land of the Cooper heirs on Cedar Creek (probably one of the localities later described by Keyes).

Winslow[4] considers the marbles to be a portion of the Paleozoic series, but says nothing more concerning their age or stratigraphic relations. He describes them from the Kramel lands in sec. 2, T. 22 (32?) N., R. 2 E., and from sec. 19, T. 22 (32?) N., F 4 E. Ladd, in the Winslow report cited above,

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[1]Swallow, G. C., First and Second Annual Reports of the Geological Survey of Missouri, 1855, p. 166.

[2]Broadhead, G. C., Iron ores and coal fields; Geol. Surv. of Mo., 1872, Appendix B., p. 415.

[3]Broadhead, G. C., Report of the Geological Survey of the State of Missouri for 1873-1874, pp. 355-356.

[4]Winslow, Arthur; A report on the Iron Mountain sheet; Geol. Surv. of Mo., vol. IX, 1894, pp. 30 and 73-74.

described the marbles, but adds nothing to the knowledge of their relations. He mentions additional localities as follows: Boundary of secs. 19 and 13, T. 33 N., R. 4 E.; Childers Quarry, SW. ¼ sec. 35, T. 34 N., R. 3 E.; and the Dennis Reagan place, about a mile up the creek (Stouts Creek ?) from the Childers quarry (probably in the NW. ¼ sec. 3, T. 33 N., R. 3 E.).

Keyes[1] considers these marbles to be a part of the Fredericktown (Bonneterre) formation, and lists the following localities: SE. ¼ sec. 25, T. 33 N., R. 5 E.; south central part of sec. 29, T. 33 N., R. 6. E.; S. ½ NW. ¼ sec. 28, T. 33 N., R. 6 E., and just north of the main east-west road along the headwaters of Slater Branch. (The latter locality is in the SE. ¼ sec. 23, T. 33 N., R. 6 E.)

E. T. Campbell, of the St. Louis Smelting and Refining Co., furnished logs of their recent diamond drilling near Shepherd in Iron Co. In their hole number two, located in the W. ½ SW. ¼ SE. ¼ sec. 11, T. 34 N., R. 1 E., he describes 46½ feet of beds which are interpreted as an occurrence of the marble. The beds occupy the interval between 324.6 feet, and 371 feet, lying below typical Bonneterre and resting on porphyry. His notations are as follows:

324.6—350, white and pink lime with cavities, mottled with greenish-gray shale.
350—352, reddish lime with red shale partings.
352—369, pink lime mottled with gray shale.
369—371, gray crystalline limestone.

There can be little question that this is a phase of the marble already described. The total area of outcrop of the marble, on the quadrangle is not much over a square mile.

Lithologic character.—The beds in question present a wide range of lithologic variations. On the whole, they resemble most closely certain phases of the Davis, particularly the "Marble bowlder" horizon, and might very readily be mistaken for that formation, except for their position beneath undoubted Bonneterre.

The most characteristic phase is a light gray, very dense, almost lithographic, nearly pure limestone, which breaks with a decidedly conchoidal fracture. This phase is exceptionally well developed at the south end of the porphyry knob on the south side of Padfield Branch, in the W. ½ NW. ¼ sec. 11, T. 33 N., R. 1 E., where several feet of the rock is seen dipping south away

[1]Keyes, C. R., A report on Mine La Motte sheet; Mo. Geol. Survey, vol. IX, 1896, pp. 50 and 105-108.

from the porphyry, and under the adjacent Bonneterre. Almost absolutely identical beds occur in Iron Co., near the center of the SW. ¼ sec. 24, T. 32 N., R. 4 E., where they also dip south off a porphyry knob and under adjacent typical Bonneterre. The same dense light gray phase is well developed in Madison County, at an old quarry in the SE. ¼ sec. 23, T. 33 N., R. 6 E. Here again the marble beds are dipping south off a porphyry knob, and seem to pass below typical Bonneterre.

At the first locality cited (W. ½ NW. ¼ sec. 11, T. 33 N., R. 1 E.) certain of the dense gray beds are very irregularly seamed with thin discontinuous wavy green clay films, and mottled with seams and patches of brown coarsely crystalline calcite. In other localities similar mottled beds occur, and in certain places, the clay seams and coarser calcite patches make up a considerable proportion of the rock, with the dense gray marble unevenly distributed throughout the mass, giving a strikingly nodular appearance, which locally is developed to such an extent as to closely resemble a conglomerate, for which it might easily be mistaken. Not uncommonly the basal part of a given bed is dense gray marble, grading up into the nodular phase, which closely resembles conglomerate only on the top surface of weathered beds, where the dense gray nodules stand out in strong relief. This pseudo-conglomeratic phase is extensively developed on the head of Little Tom Sauk Creek, particularly in the SE. ¼ NE. ¼ sec. 24, and the E. ½ SE. ¼ sec. 25, T. 33 N., R. 2 E. Similar nodular beds occur in Iron County, near the center of the SW. ¼ sec. 24, T. 32 N., R. 4 E., and in Madison Co., in the SE. ¼ sec. 23, T. 33 N., R. 6 E. There seems to be more than one horizon of the nodular material.

Interbedded with the dense gray and nodular phases of the formation are fine-textured, dense, pink to red marbles. These are especially well developed along the valley in the SW. ¼ sec. 19, and the NW. ¼ NW. ¼ sec. 30, T. 33 N., R. 3 E., and in the SE. ¼ SE. ¼ sec. 24, T. 33 N., R. 2 E. These red limestones vary from massive beds two or three feet thick to thin-bedded shaly members. A very similar red marble outcrops in Madison County, along the road in the center of the NW. ¼ sec. 31, T. 33 N., R. 6 E.

Locally, there seem to be gradations from the dense gray to the dense red marble, some of the beds showing beautiful mottlings of red, pink, and gray. The beds described above are all limestones, rather than dolomites, since they effervesce very strongly in dilute hydrochloric acid. In this respect, also, they resemble the marble bed of the Davis.

At a single locality, a dense-textured, peculiar reddish-brown dolomite, which does not effervesce with cold acid, outcrops in the SE. ¼ NE. ¼ sec. 25, T. 33 N., R. 2 E., just above a bed of the nodular marble. It is remarkably like certain reddish-brown beds of the Davis (p. 81), and constitutes another of the striking similarities between this group of rocks and the higher horizon.

At a few localities, interbedded with the marble, are coarse granular beds very similar to the typical granular Bonneterre above. This material occurs in the SW. ¼ SW. ¼ sec. 19, T. 33 N., R. 3 E., and entirely similar interbedding of granular dolomite with the marble occurs in the E. ½ sec. 3, T. 33 N., R. 1 E. Like the ordinary Bonneterre, these granular beds seem to be a dolomite, and effervesce only very faintly with cold dilute hydrochloric acid. The greatest development of the coarser dolomitic beds, beneath marble, was seen in the S. ½ sec. 20, T. 32 N., R. 5 E., in Madison County. Here the coarser dolomitic beds clearly underline the nodular marble, and in turn are underlain by non-dolomitic limestone, much like the nodular variety above.

Analysis of the typical dense-textured marble, from the S. ½ sec. 4, T. 32 N., R. 4 E., on Marble Creek, in Iron County, is given on the following page. This sample is practically identical with the occurrences on the Edge Hill sheet. The low content of magnesia is particularly noteworthy.

LIMESTONE AND DOLOMITE ANALYSES—POTOSI-EDGE HILL AREA.

Analysis Number.	1331	1333	1335	1334	1336	1337	1338	1339	1340	1332	1341
Horizon.	Bonneterre marble	Lamotte-Bonneterre gradation	Bonneterre 40 ft. above base	Davis, red-brown beds middle of formation	Derby dolomite	Potosi, about 150 ft. below top	Potosi, close to top of formation	Eminence, 40 ft. above base	Eminence, near top of formation	Basal Van Buren	Gasconade about 15 ft. below Roubidoux contact
Silica, SiO_2	0.31	2.48	2.60	4.45	7.50	1.35	0.40	0.22	0.28	5.55	1.00
Ferric Oxide, Fe_2O_3	0.17	2.01	1.96	4.95	0.42	0.24	0.25	0.16	0.24	0.28	0.29
Manganese Oxide, MnO	......	0.52	0.43	0.12	......	......	......	......	......	......	......
Alumina, Al_2O_3	0.95	0.50	2.33	2.33	3.63	0.24	0.28	0.32	0.48	2.37	0.91
Alkalies, $(NaK)_2O$	0.14	0.17	0.49	0.41	0.98	0.12	0.10	0.90	0.33	0.38	0.35
[1]Loss on Ignition	43.19	44.74	44.54	42.65	41.02	46.45	47.25	47.39	46.91	43.84	45.95
Lime, CaO	53.73	29.17	28.04	27.54	26.42	29.30	29.42	29.92	29.73	27.80	32.04
Magnesia, MgO	2.20	19.98	19.30	17.54	19.63	21.74	22.02	22.00	22.14	20.50	19.67
Total	100.68	99.57	99.69	99.99	99.60	99.44	99.72	100.91	100.11	100.72	100.21
[2]Calcium Carbonate, $CaCO_3$	95.90	52.07	50.06	49.17	47.17	52.29	52.51	53.40	53.07	49.62	57.18
[2]Magnesium Carbonate, $MgCO_3$	4.60	41.78	40.37	36.69	41.06	45.46	46.05	46.01	46.30	42.87	41.13
Insoluble	0.73	3.19	5.20	6.42	10.59	1.48	0.59	0.33	0.28	7.53	1.57
Location.	Iron Co., S. ½ sec. 4, T. 32 N., R. 4E	Washington Co., SW. ¼ SW. ¼ sec. 25, T. 36N. R. 2E.	Washington Co., SE. Cor. sec. 13, T. 35N. R. 2E.	Iron County, center of west line, sec. 2, T. 34N. R. 2E.	Washington Co., NE. ¼, SW. ¼ sec. 8, T. 35N. R. 2E.	Washington Co., SW. ¼; sec. 13, T. 38N. R. 1E.	Washington Co., NW. ¼, sec. 3, T. 37N. R. 1E.	Washington Co., Cent SW. ¼; sec. 33, T. 38N. R 1E.	Washington Co., SW. ¼, SW. ¼ sec. 35, T. 38N. R. 1E.	Washington Co., S. ½, NE. ¼; sec. 23, T. 37N. R. 1E.	Washington Co., Cent, SW. ¼; sec. 21, T. 37N. R. 1E.

[1]Loss on ignition includes CO_2 organic matter and other volatiles at 900°c.
[2]Calculated from CaO and MgO.
Analyses by Mundt, of this Bureau.

Topographic expression.—The marble beds nowhere outcrop extensively enough to show any characteristic individual topographic features.

Stratigraphic relations.—Wherever the base of the marble is exposed, the beds rest with evident unconformity on the rhyolite porphyry. This relationship is best exhibited on the head of Little Tom Sauk Creek, near the center of the line between secs. 30 and 31, T. 33 N., R. 3 E., where a thin sandstone, with a basal conglomerate of rhyolite pebbles, intervenes between the porphyry and the marble. At the mouth of Cedar Creek, in Madison County, in sec. 25, T. 33 N., R. 5 E., very heavy conglomerate beds, including coarse rhyolite bowlders, underlie the marble.

The relations with the overlying Bonneterre are less obvious. The evidence is obscure and appears, even, to be somewhat contradictory. That the marble in most instances, underlies the main bulk of the Bonneterre formation admits of no dispute.

Between the typical marble below and the typical Bonneterre above, there intervenes at several points, distinct conglomerate, in which many of the pebbles are marble, clearly of the type common in the subjacent beds. The pebbles are distinctly rounded and worn, and both white and red varieties of the marble are represented. In all cases noted, the matrix is distinctly sandy, with rounded or subrounded quartz grains, and subrounded to subangular particles of rhyolite porphyry. At only one point was this conglomerate actually seen in place. This was along the valley side just west of, and perhaps 20-40 feet below the 1150-foot saddle in the E. ½ SE. ¼ sec. 25, T. 33 N., R. 2 E., where the conglomerate occurs two or three feet above a typical nodular bed of the light gray marble, and not over 20 feet below very massive, coarsely crystalline Bonneterre. Wholly similar conglomerate occurs abundantly as float near the center of the SW. ¼ sec. 30, T. 33 N., R. 3 E., 20-40 feet below the Bonneterre, resting on slopes of the marble, though the slabs could not be traced to the parent ledge.

In the S. ½ NE. ¼ sec. 24, T. 33 N., R. 2 E., practically identical conglomerate was found in the float, in the horizontal interval between steeply dipping beds of marble and similarly dipping beds of Bonneterre a few yards away, beneath which the marble obviously passed.

Entirely similar conglomerate float, with the same sort of pebbles, and practically identical matrix, was found above dense light gray and nodular marble in Madison County, near the center of the S. ½ sec. 32, T. 33 N., R. 6 E. At this point, the overlying Bonneterre seems to have been stripped completely away.

In the first occurrence noted, in Washington County, in the N. ½ SE. ¼ sec. 35, T. 36 N., R. 2 E., the pebbles of white marble occur in a very sandy matrix that grades laterally into typical Bonneterre, in place, and in the conglomerate are also pebbles of quartzite.

In several other sections a hasty search failed to show this conglomerate at the contact. It has been found, however, in Washington Co., in Reynolds Co., in Iron Co., and in Madison Co., and more detailed search would doubtless increase the area over which it is known to occur. Already, its observed distribution is rather widespread.

The question now arises, as to the significance of this widespread conglomerate. It may be interpreted as: First, an intraformational conglomerate, similar to those of the Davis formation; or second, as basal conglomerate of the Bonneterre, resting unconformably on the eroded surface of the marble.

In general, there is sharp lithologic contrast between the beds above the conglomerate and those below. The beds above are commonly very coarsely granular and dolomitic. Those below are chiefly dense, approaching lithographic in texture, and are for the most part non-dolomitic.

At the one point where the conglomerate was actually found in place, there is above and between it and the coarsely crystalline typical Bonneterre, thin-bedded red shaly limestone closely resembling the red marbles below the conglomerate bed. These beds seem to be an indication that the material above belongs stratigraphically with that below. However, the basal beds of a new series, above an unconformity, are not infrequently red, and especially so if the series below is red. And above an unconformity, the basal beds of a limestone series might be expected to be less pure, and show shaly phases. Therefore it is not believed the presence of these red beds above the conglomerate horizon affords any particular evidence either way.

Somewhat more suggestive is the presence, interbedded with the marble below the conglomerate, of very coarsely crystalline dolomite beds, very similar in texture and general appearance to the typical overlying Bonneterre. This is a somewhat disturbing element in any interpretation of a break between the marble and the undoubted Bonneterre above. It must not be forgotten, however, that many cases are known of beds separated by undoubted unconformities, in which almost identical phases occur. There is a remarkable similarity between certain beds in the Bonneterre and others in the Eminence, though the two are separated by a considerable unconformity, and by several hundred feet of intervening beds. Likewise many beds of the Eminence and the Gasconade are wholly indistinguishable on lithologic grounds, though there is a widespread unconformity between them. Consequently the presence of the coarse dolomitic beds below the unconformity is less convincing than might be desired.

It must also be admitted that the conglomerate horizon, although widespread, was not found at all points, and particularly, it could not be located in the exceptionally good exposure in the S. ½ sec. 24, T. 32 N., R. 4 E., on Marble Creek, in Iron County, where it was not possible to draw any satisfactory line between beds of the marble series, and overlying coarsely crystalling beds interpreted as Bonneterre. In fact, here, and in the next section east, seems to occur the best evidence yet seen, of the possible conformable sequence of the marble with higher Bonneterre.

Nevertheless, it must be remembered that two unconformable series of limestone or dolomite beds may show so little evidence of a break, that for years the unconformity escapes detection. In fact, many profound unconformities are very obscure. To be more specific, no conglomerate has ever been found at the contact where the Potosi rests with certain unconformity on the Bonneterre, even though the contact has been traced over many square miles, and in spite of the fact that many new road cuts expose it admirably. Even in fresh cuts, it is almost impossible to locate the exact contact, though at least 250 feet of beds are missing. And at only one place has it been possible to show a clearly definied channel in the Bonneterre, in which Potosi rests.

In general, the Eminence-Gasconade unconformity is more easily detected, though in the Potosi quadrangle, field work had been going on for a year, before the contact, unconformable as it is, was exactly located.

At one point in the Potosi quadrangle, near the center of the east line of sec. 23, T. 37 N., R. 1 E., along state Highway No. 8, where there are particularly good exposures, it was suspected that the Eminence-Gasconade contact was perhaps 10 feet above the valley bottom. Still a very careful search gave not the slightest evidence either of basal conglomerate or uneven erosion surface, and it was not until, in the construction of the new highway, a rock cut was made, that the presence of the break was shown, both by a very thin conglomerate, which had wholly escaped detection on natural exposures, and by undoubted fossils that demonstrated the age of the beds.

The examples cited above afford good evidence that failure to find the conglomerate at certain localities carries no convincing argument against an important break at this horizon.

A feature that seems to the writer of particular interest is the lithologic character of the conglomerate itself. At the place where it was first discovered, there were, associated with the marble pebbles, abundant and large pebbles of rhyolite, and still more interesting, a few pebbles of quartzitic sandstone. At every point where this conglomerate has been found, there have been pebbles of rhyolite porphyry associated with those of marble. To be sure, at every point, the outcrops of rhyolite are in close proximity, but on the other hand, the beds above and below this conglomerate are singularly free from the rhyolite, and the incursion of rhyolite pebbles at this particular horizon suggests movements at this time, and fits well with the idea of a measurable break. Also from what source, if there were not a break at this horizon, and the conglomerate is merely intraformational, were the quartzite pebbles derived?

Even more suggestive, in the writer's opinion, is the abundance of quartz sand in the matrix of the conglomerate. This sand consists of quartz grains, mixed with fragments of porphyry. Many of the quartz grains are very perfectly rounded, and in this respect are in sharp contrast to the fragments of rhyolite, which are at most, only sub-angular to sub-round. Many of the finer sand grains, probably derived locally from the porphyry, also show very little if any rounding. A careful examination of the marble beneath the conglomerate does not reveal any quartz grains coarse enough to have been the source of the coarser sand in the matrix, the few grains noted on digesting a sample of the marble in acid being much finer than those in the conglomerate.

There would, then, seem to have been an influx of sand from some foreign source, at the time of the formation of this conglomerate.

The geographic distribution of the marble would also seem to demand some explanation. It is quite noteworthy that nowhere has it ever been noted *above* undoubted Lamotte. If it is a local basal phase of the Bonneterre, it would hardly be expected that it would nowhere appear in the area where Bonneterre is known to rest on Lamotte. If, on the other hand, it is stratigraphically below Lamotte, that situation would afford entirely adequate explanation of its failure to be found where Lamotte outcrops. At the first locality noted, in the N. ½ SE. ¼ sec. 35, T. 36 N., R. 2 E., the marble pebbles occur in the Bonneterre, at the contact with a porphyry knob. Not over 200 yards away where Bonneterre rests on Lamotte, no evidence of the marble beds occur at the contact between these formations.

Moreover, although the marble is notably similar in lithologic character, from Reynolds County across Iron and into Madison, still its distribution is extremely erratic, and in many places where beds very low in the Bonneterre lap against the porphyry, it is not found at all. If it is a phase of the Bonneterre this would seem to indicate very local areas of development, not at all consistent with its remarkably uniform character across the entire St. Francois range. On the other hand, if it were a once continuous bed, partly removed before Bonneterre deposition, its present local distribution would be perfectly explained.

Its stratigraphic position, likewise, is apparently erratic. In the W. ½ NW. ¼ sec. 11, T. 33 N., R. 1 E., not to exceed 60 feet of Bonneterre intervenes between the top of the marble, and the base of undoubted Davis. And in the NE. ¼ SE. ¼ sec. 34, T. 34 N., R. 1 E., there certainly is not over 20 feet of Bonneterre between it and undoubted Davis. On Little Tom Sauk Creek, on the other hand, a much greater thickness of Bonneterre, probably in excess of 200 feet, lies above the marble. This situation is capable of two interpretations. If the marble is part of the Bonneterre then it occurs at more than one horizon, one of which is high in the formation. If, on the other hand, the marble consists of remnants of a once more widespread and continuous formation, upon which the Bonneterre was laid unconformably, then as a result of the uneven surface on which the Bonneterre was laid, any horizon of that formation might rest on the marble, just as all horizons of the Bonneterre lap against the porphyry.

This point is further emphasized in the results of the recent drilling[1] near Shepard. Hole No. 2, in the W. ½ SW. ¼ SE. ¼ sec. 11, T. 34 N., R. 1 E., shows 219.6 feet of typical Bonneterre, resting on marble, a total thickness of 46½ feet of which intervenes between the Bonneterre and the porphyry. Hole number 3, less than a half mile northeast shows 260 feet of Bonneterre resting on characteristic Lamotte transition beds. Hole number 4, less than a half mile to the southwest shows 256 feet of Bonneterre also resting on typical Lamotte transition.

In neither of these is there anything resembling the marble, though the hole midway between them shows marble about 35 feet higher than the normal position for the base of the Bonneterre. If this marble is a phase of the Bonneterre, the 46½ feet of it shown in hole number 2 certainly pinches out with surprising rapidity in both directions.

In hole number 5 of the same series (center of SW. ¼ sec. 14, T. 34 N., R. 1 E.), red limestone intervenes between the top of the porphyry, and the base of the Bonneterre, only 148 feet below the top of the Bonneterre formation.

In deep holes at Saco, in Madison County, drilled by the St. Louis Smelting and Refining Co., the cuttings of which are on file in the office of the State Geological Survey, dense-textured, red, only slightly dolomitic limestone underlies gray dolomite, of undoubted Bonneterre age, and rests on porphyry conglomerate. The contact of the red material within the overlying gray Bonneterre is very sharp, the two not being interbedded. On the other hand Muilenburg[2] has examined drill cores from Marble Creek, in Iron County, in which he reports that this marble-like material is intimately interbedded with coarse granular gray dolomite, apparently identical with typical Bonneterre.

Furthermore, not a single occurrence of the marble has ever been found, except in the immediate vicinity of exposed porphyry. This might, conceivably, be interpreted to mean that the igneous rock exerted some influence on the type of deposition, were it not for the fact that in hundreds of localities, normal Bonneterre rests against the porphyry. Another possible explanation is that the relation to the igneous knobs is merely that of erosion remnants protected against the old slopes, on the pre-Bonneterre surface.

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[1]Data furnished by E. T. Campbell.

[2]Muilenburg, G. A., Personal communication.

These data seem more or less conflicting, but recent drilling on the Schulte property, south of Fredericktown, in sec. 27, T. 33 N., R. 7E., cuttings of which have been carefully examined by both Bridge and McQueen, seems to throw light on the problem. They both agree that marble, essentially identical with that on the outcrop, is interbedded with characteristic gray Bonneterre, overlying typical Bonneterre transition beds, which in turn overlie ordinary Lamotte. This Lamotte seems to have been traced with sufficient continuity to be convincing, into the type area, by means of drilling.

These recent data seem to establish beyond much doubt that the marble is merely a phase of the Bonneterre. There are left unanswered, however several very insteresting and puzzling questions in sedimentation, suggested in the preceding paragraphs, but for the further discussion of which there is neither time nor space, in this report.

Age and correlation.—The marble is undoubtedly younger than the rhyolite porphyry, since on the head of Little Tom Sauk Creek, between the two intervenes a thin sandstone, the base of which is an arkosic conglomerate with abundant rhyolite pebbles. Quite as clearly the marble underlies typical Bonneterre, which in turn passes underneath characteristic fossiliferous Davis, so that, in spite of the close lithologic resemblance to the Davis "marble-bowlder" horizon, there can be no doubt whatever that the marble in question is older than the main body of the Bonneterre formation. For some time after the discovery of the marble beds, there persisted a feeling that they might be a phase of the Davis, dropped to their present position by faulting. Careful tracing of the contacts between the marble and the Bonneterre, however, soon showed that there was no possibility of any interpretation other than that the beds actually passed below the main Bonneterre.

It is possible that they are a conformable downward extension of the Bonneterre, and only older in the sense that the base of any formation is older than the top.

Except for one brief reference[1] to metamorphic limestone in Iron County, no mention has thus far been found of limestones or quartzites in the pre-Cambrian of this general region. If Pumpelly is right in his contention that the limestones he found

[1]Pumpelly, Raphael, Iron Ores and Coal Fields; Geol. Survey of Missouri, 1872, pt. 1, pp. 23-26. Also cited by Van Hise and Leith, Pre-Cambrian Geology of North America; Bull. U. S. Geol. Survey, no. 360, 1909, pp. 735-736.

are interlayered with rhyolite, they can hardly be the equivalent of the beds herein described, which are obviously unconformable on the porphyry.

Davis Formation.

Name.—The name of the formation is derived from Davis Creek, a tributary of Flat River. Winslow[1] includes this and the overlying Derby-Doerun in his St. Joseph limestone, and Keyes[2] defines his Fredericktown formation in the same terms.

Nason[3] places much of the Davis and all of the Derby-Doerun in the Potosi. His interpretation of the base of the Davis has already been indicated under the discussion of the Bonneterre.

Bain and Ulrich[4] propose the term Elvins for "the shales, shaly limestones, and more or less earthy dolomites in St. Francois County that intervene between the shaly top of the underlying Bonneterre limestone and the cherty limestones of the Potosi group above." As already pointed out, in the discussion of the Bonneterre, they include in that formation about 100 feet of beds now classed as typical Davis.

In the report on the geology of Ste. Genevieve County, Ulrich presents[5] a list of fossils said to come from "15 feet beneath the so-called 'Marble Bed'—only a few feet above the base of the Davis shale." It is thus evident that as late as 1928, he still places the contact at the same horizon drawn by Bain and Ulrich in 1905. So far as known, Buckley[6] was the first to give a satisfactory description of these beds, and apply the name Davis to them.

Distribution.—In the Potosi quadrangle, the outcrop of Davis is limited to a narrow belt, in the southeast third of the map. A small area of it occurs near Hunters Mill, in the angle between the two main branches of the Palmer fault, largely in

[1]Winslow, Arthur, Lead and zinc deposits; Mo. Geol. Survey, vol. VI, 1894, p. 331.

[2]Keyes, Charles Rollin, A report on Mine LaMotte sheet; Mo. Geol. Survey, vol. IX, 1895, sheet report no. 4, pp. 48-52.

[3]Nason, F. L., The geological relations and age of the St. Joseph and Potosi limestones of St. Francois County, Missouri; Amer. Jour. Sci., 4th ser., vol. 12, 1901, pp. 358-361.

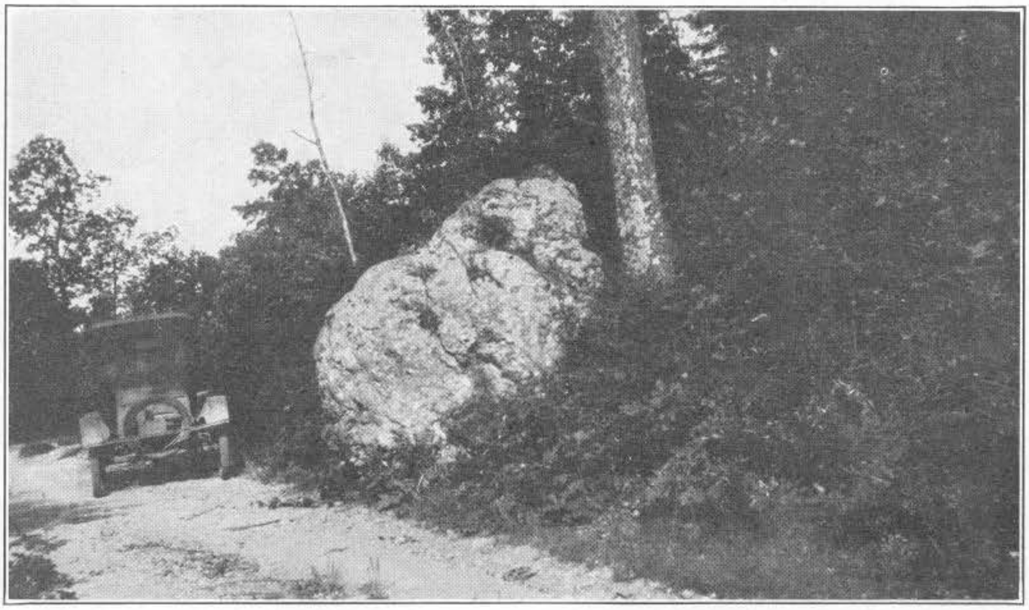
[4]Bain, H. Foster, and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, no. 267, 1905, pp. 21-26.

[5]Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, pp. 50-51.

[6]Buckley, E. R., Am. Min, Cong. Rept., Proc. 10th Ann. Session, 1907, p. 286.

Buckley, E. R., Geology of the disseminated lead deposits of St. Francois and Washington Counties; Mo. Bur. Geol. and Mines, vol. IX, 2nd ser., 1908, pp. 33-44.

A. Thin-bedded Davis shale and limestone, showing small fault, SW. ¼ SW. ¼ sec. 12, T. 35 N., R. 1 E.



B. Large boulder of Gasconade chert, just east of the sheet edge, on the Graniteville and Munger road.

sec. 25, T. 36 N., R. 2 E., but extending into adjacent sections to the east. The main area, however, is a narrow belt west and south of Belgrade, passing through Sunlight, where it forms the slope of a ragged east-facing escarpment overlooking the Bonneterre plain. In all, it probably does not occupy more than 10 square miles, on the Potosi map.

On the Edge Hill quadrangle, there is an important area bordering, on the west and south, the large Bonneterre plain about Belleview. It is practically a continuation of the belt west of Belgrade and Sunlight, from where it can be traced continuously, except for the interruptions produced by several porphyry knobs, to Belleview. This belt contains about 8 to 10 square miles of the formation. Most of the deeper valleys on the Edge Hill sheet expose more or less isolated patches or strips of the Davis, and the total area on the sheet is about 30 square miles.

Thickness.—Over much of the Edge Hill sheet, the full thickness of the Davis is not present, all of the overlying Derby-Doerun, and portions of the Davis itself having been removed by pre-Potosi erosion. Locally, even the entire thickness of the Davis has been cut away, so that at some point the Potosi rests directly on the Bonneterre. This is particularly true over much of the southeast portion of the Edge Hill quadrangle.

Even in those places, however, where the succession is perfectly normal, with the Davis resting between Bonneterre and Derby-Doerun it is not easy to get a satisfactory estimate of the thickness. Two elements, particularly, make such determinations difficult. First, there is considerable faulting, and, second, the dips about the porphyry knobs are decidedly erratic. Where the dips are lowest, and the structure most regular, between Belgrade and Sunlight, a number of observations point to about 165 feet as a fair average. About 3 to 4 miles west of Belleview, also, where the contact with the Bonneterre and the Derby-Doerun are both exposed, the average thickness seems to be about 160-170 feet.

At several points south of Sunlight, the interval between the top of the Bonneterre and the base of the Derby-Doerun does not appear to be much over 60 or 80 feet. Although there is doubtless some thinning in the vicinity of the porphyry, it is probable that much of the variation is apparent only, as a result of the erratic dips in that locality.

In the deep hole at Palmer, Buckley[1] correlates 175 feet of strata with the Davis. In the city well at Potosi McQueen assigns 165 feet to that formation (see log, p. 226). There was during 1926 considerable drilling in the vicinity of Sunlight, by the St. Joe Lead Co. Only a few of their holes, however, started as high as the top of the Davis, and therefore, few of them show the full thickness of that formation. Below is a list of those that start at the top of the Davis or higher.[2]

TABLE OF HOLES PENETRATING THE ENTIRE DAVIS.

No. of hole.	Location.	Depth to top and bottom of Davis.	Thickness of Davis.
16	NE. ¼ SE. ¼ sec. 4, T. 35 N., R. 1 E......	17–175	158
17	NE. ¼ SE. ¼ sec. 3, T. 35 N., R. 1 E......	54–218	164
7	NE. ¼ SW. ¼ sec. 35, T. 36 N., R. 1 E.....	21–201	180
22	S. ½ NW. ¼ sec. 21, T. 36 N., R. 1 E.....	575–790	215
10	SE. ¼ NW. ¼ sec. 25, T. 36 N., R. 1 E.....	89–191	102
5	NE. ¼ SE. ¼ sec. 26, T. 36 N., R. 1 E.....	74–163	89
3	N. ½ NW. ¼ sec. 36, T. 36 N., R. 1 E.....	0–171	171

Hole No. 22 is closely adjacent to a major fault zone, and there may be some tilting of the beds, resulting in the unexpectedly large figure. Holes numbers 5 and 10 start well above the top of the Davis, and the usual thinness of that formation demands some explanation. Since, however, the top of the Davis carries very massive beds, which, even on the outcrop, are repeatedly mistaken for Derby-Doerun, it is quite probable that where such massive beds are encountered in drilling, they are assigned to the higher formation, thus causing the Davis to be reported as unusually thin. There does not seem to be any valid evidence that would indicate any considerable variation in the thickness of the Davis, where it lies between Bonneterre below and Derby-Doerun above.

[1]Buckley, E. R., Disseminated lead deposits, pp. 55-57.
[2]Correlations by Larson, personal communication.

The abnormal thinness of the Davis in the Ste. Genevieve County area[1] may quite possibly be accounted for, also, by the fact that the upper more massive beds are included in the Derby-Doerun.

Lithologic character.—The term "Davis shale" is distinctly misleading, unless accompanied by a detailed description of the formation. It is more properly a complex of thin-bedded limestones (mostly dolomitic), and shales, with considerable limestone conglomerate, and subordinate amounts of very fine-grained sandstone. Since, however, it is the only notably shaly horizon in the Cambro-Ordovician of the Ozark region, it is commonly spoken of as the Davis shale, or by drillers as "the shale." To determine more carefully the composition of the formation in the type area, the extremely detailed section given by Buckley[2] was totaled in two portions, the one portion including all the material he classed as limestone, the other all he classed as shale. The results show approximately $\frac{2}{3}$ limestone (mostly somewhat magnesian) and $\frac{1}{3}$ shale. While it was not possible to measure any complete section, in the area of the Potosi and Edge Hill quadrangles, the proportion of shale is even less. In the southwest corner of sec. 23, T. 34 N., R. 1 E., on the west side of Ottery Creek, a cliff of nearly 100 feet of Davis, every foot of which is exposed, does not show a single inch of shale, although it immediately overlies undoubted Bonneterre, and shows by color, texture, and general position that it is undoubted Davis. This is usually the most shaly part of the formation.

The shales of the Davis are almost invariably bluish or greenish in tint on fresh surfaces, but weather to shades of light gray, yellow and brown. Thin layers of magnesian limestone occur erratically throughout the shale horizons, largely as discontinuous lenses.

The magnesian limestone beds of the Davis, usually thin and thin-bedded (Pl. X, A), carry many discontinuous shale seams, or lenses. The limestones themselves vary from dense fine-grained or earthy to coarsely-crystalline, and range through shades of green, light and dark gray, buff, pink, and rich reddish-brown, the latter tint being quite unusual, and so far as known, entirely restricted to the Davis horizon. Near the base of the formation there are beds of very coarse, granular, highly glau-

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[1]Weller, Stuart, and St. Clair, Stuart, Geology of Ste. Genevieve County, Missouri; Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, p. 46.

[2]Buckley, E. R., op. cit., pp. 39-43.

conitic dolomite, closely resembling certain beds in the underlying Bonneterre, but separated from it by shale beds. This is particularly well exposed along the road in the S. ½ SE. ¼ SE. ¼ sec. 34, T. 35 N., R. 2 E., on the Edge Hill sheet. Edgewise conglomerates of the well-known Davis type in which thin flat limestone pebbles, some angular at the edges, others rounded, stand at high angles to the bedding in a limestone matrix, are fairly common. Some of these pebbles are as much as six inches in diameter, and less than half an inch thick, although such proportions are exceptional. They seem to represent the breaking up of very thin-bedded limestones already consolidated, and their cementation in an accumulating lime ooze. Much of the conglomerate, however, is better described as "flat-pebble," the pebbles being thin flat discs, but not standing in the edgewise position. In places, the pebbles are simply irregularly-rounded fragments of limestone, without even the flattened shapes. The distribution of the flat-pebble conglomerates is distinctly erratic. In some sections not a single bed of it could be found, in others, several beds are present. Nowhere in the area, however, is it as abundant as in the type locality near Flat River.

The famous "Marble Bowlder" horizon was not identified anywhere in the Potosi quadrangle, nor in the north half of the Edge Hill sheet. Strangely enough, however, it is found in extremely typical development in the area from Redmondville southwest on to Strother Creek, particularly in sections 30 and 31, T. 33 N., R. 1 E., as well as in portions of adjacent sections. In this area its appearance and association with "edgewise" conglomerates is practically identical with that in the Lead Belt. In this locality the bed averages perhaps two feet thick, and consists, as in the type section, of dense, finely-crystalline, bluish-gray, nearly pure non-magnesian limestone, which weathers to a dead white. The bowlders are much more rounded on the upper than on the lower surface, and show evidence of having once been a continuous bed. In fact, in some cases, the lower portions of certain "bowlders" are still connected. Obviously they have been separated by solution, but whether contemporaneously or later, or while submerged or emerged, is not clear.

It is of interest to note that the Davis carries much less shale, and a larger proportion of dolomitic limestone, in the area among the porphyry peaks, than in the Lead Belt to the north, or in the Redmondville area, to the southwest of the St. Francois Mountains.

This is distinctly contrary to the usual conception of the igneous peaks as an active source of Paleozoic sediment, and points to a derivation of the muds of Davis time from some more distant source, and indicates that bottom conditions in the narrow inter-porphyry lowlands were too well protected to permit of their invasion by the mud-laden currents that were responsible for the more shaly Davis bordering the mountain archipelago.

It is also of interest to note that in those sections in which shale is less abundant, the limestone becomes rather more magnesian, as indicated by the lack of effervescence in cold acid. This suggests that the presence of impervious beds might be a factor in preventing dolomitization.

The Davis, like the Bonneterre, is almost wholly free from chert.

Much of the soil from the weathering of the more shaly Davis shows a peculiar ashy gray tint. An abundance of thin shale flakes of gray or greenish color is, even in the absence of outcrops, almost certainly indicative of the presence of that formation.

The highest beds of the formation are very massive, in places as much as 20 feet of outcrop locally showing hardly a trace of bedding. This situation becomes more striking to the south, and on the Edge Hill sheet the boundary between the Davis and the Derby is drawn with the utmost difficulty, and could not be drawn at all, were it not for certain rather striking fossil zones that persist through abrupt lithologic changes.

Very massive upper Davis outcrops just east of an old shanty on the east side of the valley, near the center of the W. ½ sec. 18, T. 34 N., R. 3 E.; at the extreme south tip of High Top Mountain (Pl. XI, A), near the center of the NE. ¼ sec. 8, T. 33 N., R. 2 E.; about 200-300 yards south of an old saw mill, in the SW. ¼ NE. ¼ sec. 9, T. 34 N., R. 2 E.; and adjacent to the prophyry in the center of the N. ½ sec. 32, T. 35 N., R. 2 E. The most massive exhibit of the Davis noted occurs on the west side of Ottery Creek, in the extreme southwest corner of sec. 23, T. 34 N., R. 1 E. In all but the last of these localities, the definite identification of the formation resulted from the presence of the Eoorthis bed (p. 90). All of the localities mentioned are on the Edge Hill sheet, but even on the Potosi quadrangle, much trouble was encountered in drawing the upper contact, and after the position and persistence of the Eoorthis bed were discovered, a portion of the contact as earlier delineated, had to be redrawn.

In reporting drill records, particularly from churn drilling, these massive beds are rarely classed with the "shale" (Davis), and their erratic development is doubtless largely responsible for the great variation in thickness of the Davis, commonly reported in drilling.

Locally the Davis carries very thin beds of very fine-grained sandstone. As a rule these are sufficiently limey so that where unweathered they would doubtless be classed as limestones, but where leached at the surface, they are distinctly sandy. Such sandy beds have been noted near the center of sec. 1, T. 35 N., R. 1. E.; near the center of the south line of sec. 20, T. 35 N., R. 2. E.; in the NE. ¼ SW. ¼ sec. 20, T. 35 N., R. 2 E.; in the SW. ¼ NE. ¼ sec. 14, T. 35 N., R. 1 E.; and near the center of the NW. ¼ sec. 15, T. 35 N., R. 1 E. Very similar thin-bedded sandstone was also found in the Davis of the Crooked Creek area of Crawford County, near the center of the SW. ¼ NW. ¼ sec. 17, T. 36 N., R. 4 W. Similar sandstone has also been found in what is believed to be Davis at Decaturville, near the center of the SW. ¼ sec. 7, T. 36 N., R. 16 W. McQueen reports sandstone in the formation in the log of the Potosi hole.

Locally, also, the upper part of the Davis consists of thin wavy-bedded layers of light buff to light gray argillaceous dolomite ("cotton rock"), reaching a total thickness of at least 30 feet, and possibly more. In general lithologic character, it very closely resembles the Doerun, from which it is distinguished only by its position below the more massive, hackly-weathering Derby. This phase of the Davis is well exposed in the SW. ¼ sec. 2, T. 35 N., R. 2 E.; in the SE. ¼ sec. 11, T. 35 N., R. 2 E.; on the north slope of the isolated knob in the SW. ¼ sec. 14, T. 35 N., R. 2 E., where it is exceptionally well developed; in a valley (not shown on the map), bisecting the hill through the center of the N. ½ sec. 32, T. 35 N., R. 2 E.; and in the SW. ¼ sec. 5, T. 34 N., R. 2 E.

In the table on page 70 is presented an analysis of the peculiar reddish-brown beds of the middle Davis. The proportion of magnesia to lime is lower than in the underlying and overlying formations, though the rock is highly magnesian. The content of ferric oxide is higher than in any other sample analyzed. The high content of silica is also noteworthy, though the formation is not a chert-maker. Microscopic study of insoluble residues from the Davis shows that much of the silica is in the form of very fine sand, rather than as minutely disseminated chert, the form in which it occurs in the Potosi, Eminence and Gasconade.

Topographic expression.—Where the Davis occurs in the complexly faulted area, it has no distinctive expression, but west of Belleview, Belgrade and Sunlight, where it dips gently and rather regularly to the west and southwest, its position as a weak formation, between more resistant beds, results in a definite, though rather ragged, east- to north-facing excarpment, the crest of which is formed by the more resistant Derby-Doerun or Potosi, the lower slopes occupied by the shale, which also floors the western edge of the broad plain characteristic of the Bonneterre. Where the Davis occurs along the bottoms of various valleys, over the southern portion of the Edge Hill quadrangle, there is no distinctive topographic expression.

Stratigraphic relations.—As already described, under the section devoted to Bonneterre, the relations at the base of the Davis are nowhere satisfactorily exposed. The top of the formation suggests gradation from thin-bedded to more and more massive layers. In fact, the contact is more or less indefinite, and a good deal of difficulty was encountered in drawing the boundary. The contact between the Davis and Derby may be best seen on the high knob through the E. ½ sec. 8, T. 35 N., R. 2 E.; along the south side of the hill in the SW. ¼ sec. 2, T. 35 N., R. 1 E.; on the north slope of the knob in the SW. ¼ sec. 14, T. 35 N., R. 1 E., where it is very well exposed; and at the south tip of High Top Mountain, near the center of the NE. ¼ sec. 8, T. 33 N., R. 2 E., where the exposures are exceptionally good. No reason whatever was found for believing the contact to be anything other than perfectly conformable. The closeness of the relation between the two is, in fact, indicated by Ulrich's use of the formation name Elvins, to include both.

At a few points, the Davis overlaps the Bonneterre, and rests against the porphyry. The only place where a good porphyry conglomerate was found at the contact is just back of an old house near the center of the south line of sec. 10, T. 35 N., R. 1 E.

Paleontology.—Beecher[1] identified a collection of fossils made by Nason from the shale and conglomerate horizon of his lower Potosi (now the Davis). His determinations are as follows:

DAVIS FAUNA REPORTED BY BEECHER.

Ptychoparia sp.
Ptychaspis sp.
Chariocephalus sp., cf. *onustus* Whitfield.
Crepecephalus sp.
Billingsella sp.
Acrotreta sp.
Lingulella sp.
Hyolithes primordalis Hall.
Platyceras sp.

Beecher[2] also reports a Eurypterid which he described under the name of *Strabops thatcheri* Beecher, "from the lower members of the Potosi limestone, Flat River, St. Francois County, Mo." Since the lower members of the old Potosi group along Flat River make up the present Davis, this species is probably from that formation.

Branson[3] figures *Eoorthis remnicha* (N. H. Winchell) as a Cambrian index fossil from Missouri, but does not state from what horizon it is reported.

Walcott[4] gives two lists of brachiopods from the Elvins formation. The first list is from the "basal Elvins," or "Edgewise beds," and is clearly a Davis fauna:

BASAL ELVINS FAUNA REPORTED BY WALCOTT.

Obolus matinalis ?
Lingulella acutangula
Lingulella similis
Lingulella sp.
Linnarssonella girtyi
Acrotreta microscopica missouriensis
Billingsella coloradoensis
Eoorthis wichitaensis

Walcott's other list comes from higher Elvins beds, undifferentiated, and probably contains both Davis and Derby-Doerun species. The list follows:

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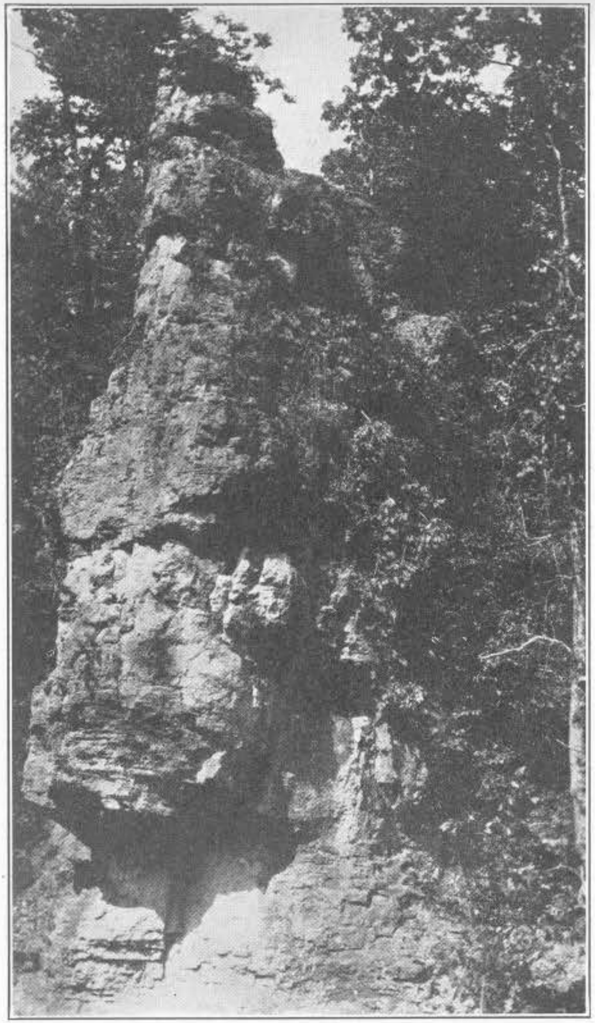
[1]Beecher, C. E., Note on the Cambrian fossils of St. Francois County, Missouri; Am. Journal. Sci., 4th ser., vol. XII., 1901, pp. 362-363.

[2]Beecher, C. E., Discovery of Eurypterid remains in the Cambrian of Missouri; Am. Jour. Sci., 4th ser., vol. 12, 1901, pp. 364-366.

[3]Branson, E. B., Geology of Missouri; Univ. of Mo. Bull., vol. 19, no. 15, 1918, pp. 96-97.

[4]Walcott, C. D., Cambrian Brachiopoda; Mon. U. S. Geol. Survey, vol. 51, pt. 1, 1912, p. 137.



A. Massive beds of the upper Davis, at the junction of Imboden Creek and East Fork of Black River, NE. ¼ sec. 8, T. 33 N., R. 2 E. The Eoorthis bed occurs at the base of the cliff.

B. Cryptozoons in the upper Davis, W. ½ NW. ¼ sec. 3, T. 35 N., R. 1 E.

UPPER ELVINS FAUNA REPORTED BY WALCOTT.

1. *Obolus ismene*
2. *Obolus matinalis?*
3. *Lingulella acutangula*
4. *Lingulella texana*
5. *Linnarssonella girtyi*
6. *Billingsella coloradoensis*
7. *Billingsella major?*
8. *Eoorthis indianola*
9. *Eoorthis remnicha texana?*

Of these, *Lingulella acutangula, Billingsella coloradoensis* and *Eoorthis remnicha texana?* are reported in a single collection (Walcott, p. 178), 50 feet above the "edgewise beds," and are clearly the main Eoorthis bed described later. In none of the other citations of locality, are the data specific enough to permit of any discrimination whatever between species collected from the upper Davis and those from the Derby-Doerun.

Tarr[1] collected a few fossils from the Elvins, which were identified by D. K. Greger as follows:

ELVINS FAUNA REPORTED BY TARR.

Eoorthis remnicha texana
Obolus matinalis
Obolus ismene?
Lingulella similis.

There are no date given which will permit of any discrimination between forms from the Davis, and those from the Derby-Doerun, nor are any specific fossil localities given.

No fossils were reported from the Davis in Ste. Genevieve County, but Ulrich has supplied two brief lists for that report,[2] of forms collected near Flat River. The first fauna is reported from a thin limestone 15 feet below the "marble bowlder" bed, and "only a few feet above the base of the Davis shale." If it came from 15 feet below the "marble bowlder" bed, it is approximately 100 feet above the base of the shale, as that formation is defined by Buckley. The faunal list follows:

[1]Tarr, W. A., The barite deposits of Missouri; Univ. of Mo. Studies, vol. III, No. 1, p. 22.

[2]Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, pp. 50-51.

DAVIS FAUNA FROM SHAW BRANCH OF FLAT RIVER.

Lingulepis aff. *acuminata* (Hall).
Linnarssonella girtyi Walcott.
Agnostus sp.
Irvingella sp. 1.
Irvingella sp. 2.
"*Saratogia*" cf. *hera* Walcott.
Plataegis n. sp.
Housia n. sp.
Three small new trilobites of undetermined generic relations.

The second fauna is reported to occur 26-36 feet above the top of the massive Bonneterre, and is listed herewith:

DAVIS FAUNA FROM JUST SOUTH OF FEDERAL SHAFT NO. 4.

Pterocephalia sp.
Dokiomorphalus gregeri Walcott.
Elvinia roemeri (Shumard).
Elvinia texanus (Walcott).
Elvinia large n. sp.
Linnarssonella girtyi Walcott.
Wilbernia sp.
Five or six new species of an undescribed genus closely allied to *Taenicephalus*.
Undetermined trilobites.

During the summer of 1923, Mr. F. L. Seiver made a collection of fossils from basal Davis, in the N. ½ sec. 1, T. 35 N., R. 1 E., about a mile east of Sunlight. During the summer of 1926 Mr. Ronald Mabrey and the writer revisited the locality, and made a large and very important collection from the same beds. The locality is more exactly described as on the south side of Brock Creek about 200 yards west of a house not shown on the Potosi sheet, along the Belgrade and Sunlight road, relocation since the Potosi sheet was mapped, in the E. ½ NE. ¼ NW. ¼ sec. 1, T. 35 N., R. 1 E., in a shallow rock cut, near a galvanized iron pipe culvert. Many of the rock masses shot out of the road are rich in fossils. The forms consist chiefly of primitive, conical gastropods, and seem to be limited to a single bed, about two feet thick, of very hard, fine-grained, crystalline, brownish-gray limestone, with occasional vugs. The bed occurs just above a shaly horizon, about 10 feet above what is taken to be the top of the Bonneterre.

The first reference to this fauna to appear in print is the bare announcement of its discovery made in December, 1926, before the Geological Society of America, and mentioned in the Bulletin.[1] Prof. Bridge identified the following forms:

[1]Bridge, J., Occurrence of the *Hypseloconus recurvus* fauna in Missouri; Bull. Geol. Soc. America, vol. 38, No. 1, 1927, p. 231.

DAVIS HYPSELOCONUS FAUNA.

Hypseloconus capuloides, Berkey.
Hypseloconus cornutiformis, Berkey.
Hypseloconus cylindricus, Berkey.
Hypseloconus franconensis, Berkey.
Hypseloconus recurvus (Whitfield).
Hypseloconus recurvus, var. *attenuatus*, Berkey.
Hypseloconus recurvus, var. *erectus*, Berkey.
Hypseloconus recurvus, var. *marginatus*, Berkey.
Capuloid gasteropods, 3 undetermined species, related to *Triblydium*.
Undetermined trilobite, cf. *Maryvillia arion*, Walcott.

In the NW. ¼ NE. ¼ sec. 23, T. 34 N., R. 2 E., very near the north line of the section, low outcrops in the creek bed yielded a considerable collection consisting chiefly of small brachiopods, and primitive gasteropods. The outcrops are so isolated that it is almost impossible from the field relations to get any idea of whether the horizon is high or low in the Davis. From this locality, the following forms were secured and were identified by Bridge:

Billingsella coloradoensis (Shumard).
Hypseloconus sp.
Tryblidium sp.
Various conical gastropods, apparently undescribed.

The abundance of *Billingsella coloradoensis* suggests that the beds are fairly high in the formation.

Near the center of the SW. ¼ sec. 8, T. 35 N., R. 2 E., on the north slope of a small valley, and perhaps 15 feet above the valley bottom, is a low outcrop of reddish-brown limestone, the weathered surface of which is literally packed with a single species of brachiopod shell identified by Bridge as *Eoorthis remnicha.* This bed lies topographically about 30-40 feet above the Davis-Bonneterre contact, but since it is in close proximity to a porphyry knob, dips are such as to allow a considerably greater thickness of beds than that figure would indicate to intervene between the top of the Bonneterre and the Eoorthis bed. It also lies topographically farther below the base of the Derby, over 100 feet, than in any of the localities found later, but with the irregular dips, its exact position in the section is uncertain.

Soon after the discovery of this locality, Mr. E. Taylor Campbell, geologist for the St. Louis Smelting and Refining Co., sent in a collection of the same species from the SW. ¼ NE. ¼ sec. 22, T. 33 N., R. 1 E., and another from the SW. ¼ NW. ¼ sec. 23, T. 34 N., R. 2 E. In neither of the localities reported by Mr. Campbell, do we know the interval between the Eoorthis bed and either the base or the top of the Davis.

In the summer of 1926, the writer found abundant fossils at a rock-walled spring, at elevation 1230 feet, in a steep gully on the north side of the valley, near the center of the NW. ¼ sec. 7, T. 34 N., R. 3 E. The striking lithologic similarity of the rock, and the extraordinary abundance of the single species of *Eoorthis* suggested that we here had a valuable horizon marker, and it was decided to visit the type section at Elvins, described in so great detail by Buckley,[1] and see if the exact horizon of this bed could be determined. After a little search, the *Eoorthis* bed was located, probably bed number 10 from the top of Buckley's section, p. 39. This would place it about 32 feet below the base of the Derby. This horizon has proved to be of very great value in mapping the Davis-Derby contact.

In the NW. ¼ SW. ¼ sec. 2, T. 34 N., R. 2 E., the *Eoorthis* bed occurs at an elevation of 1190 feet, on the south slope of the saddle, and the base of the Derby appears to be at 1230 feet, giving an interval of about 40 feet, whereas it seemed to be about 32 feet at Elvins. One-fourth mile east, the base of the Davis is at about 1090, but the interval between the top of the Bonneterre and the *Eoorthis* bed is probably more than 100 feet, since there is considerable west dip. Near the center of the NW. ¼ sec. 7, T. 34 N., R. 3 E., near a rock-walled spring in a steep gully on the north side of the valley, the *Eoorthis* bed is 100 feet above the Bonneterre. The dips are not known. Here the Potosi rests on Davis, so the interval to the Derby is not known.

Just west of a house, near the center of the S. ½ sec. 20, T. 36 N., R. 2 E., the *Eoorthis* bed is 82 feet, by careful hand level measurement, above the creek level. Davis is exposed, all the way down, though the Bonneterre is exposed in the creek, both to the north and the south. There are fairly strong west dips, so that the interval from the Bonneterre to the Eoorthis bed is doubtless something over 100 feet. At least 20 feet of fossiliferous Davis occurs, above the *Eoorthis* bed, though the interval to the base of the Derby is uncertain.

In the NE. ¼ NW. ¼ sec. 32, T. 35 N., R. 2 E., fairly massive beds occur in the head of the valley, dipping steeply away from the porphyry against which they lap. But for a fortunate discovery of the *Eoorthis* horizon in these beds it is doubtful whether they would have been recognized as Davis.

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[1]Mo. Bur. Geol. and Mines, 2nd ser., vol. IX, pt. 1, 1908, pp. 39-43.

Erratic dips and covered areas make it impossible to determine any intervals at this point. Loose slabs carrying abundant *Eoorthis* were found in the head of the valley in the southeast corner of sec. 5, T. 33 N., R. 1 E., about 30 feet above the "marble bowlder" bed, at an elevation of about 970 feet.

In the valley in the SW. ¼ NE. ¼ sec. 9. T. 34 N., R. 2 E., very massive beds at elevation 1180 feet, up creek 200-300 yards from an old saw mill, were first mapped as Derby, but later were found to represent a massive facies of the *Eoorthis* bed.

At the extreme south tip of High Top Mountain, near the center of the NE. ¼ sec. 8, T. 33 N., R. 2 E., the *Eoorthis* bed outcrops at creek level, in the angle between the two forks, at the ford. Probably at no point found, is it more packed with fossils than here. At this point, the beds certainly would never have been called Davis, had it not been for the presence of this valuable and persistent fossil zone. Above the *Eoorthis* horizon at this locality is 60 feet of massive beds, within which it is difficult, if not impossible, to see any contact. By a fortunate coincidence, at the top of the exposure, just 60 feet above the *Eoorthis* bed, occurs a bed of dolomitic limestone full of small round masses, varying in size from 0.2 to 0.6-inch in diameter, that resemble pisolites (p. 102). In the type section at Elvins this bed, which seems to be remarkably persistant, occurs about 35 feet above the top of the Davis, or near the contact of the Derby and the Doerun. If the contact of the Davis and Derby, therefore, be drawn midway between the *Eoorthis* bed and this nodular horizon, the intervals check very closely those found in the type section at Elvins.

Although the lithology of the Upper Davis varies greatly from place to place, and in places the *Eoorthis* bed is in a thin limestone interbedded with shales while at other points it occurs in a very massive limestone in which is almost no trace of bedding, still the color and texture of the actual rock in which the *Eoorthis* is embedded is rather constant. It is moderately crystalline limestone, with a peculiar reddish-brown, more rarely pinkish, tint.

The layer that is so rich in *Eoorthis* seems to be confined to a bed a foot or two in thickness, though the form is found sparingly through possibly 10 or 15 feet of the overlying rock.

The persistence of the bed is very striking. That the horizon is so thin is probably sufficient explanation for the fact that in many localities, its outcrop could not be found. At only one place where intervals could be determined was it found less than 30 feet below the base of the Derby, and in every locality but one, it is 100 feet or more above the top of the Bonneterre. The slight variation in apparent intervals may represent minor changes in thickness of beds, but may also quite as easily be accounted for on the basis of local dips, since in this area of extensive porphyry knobs, structure is very erratic.

Thus far, no single section has yielded this fossil in more than one zone. The single striking variation from the regularity noted above seems to occur near the center of the SW. ¼ sec. 8, T. 35 N., R. 2 E., on the north slope of a small valley, where the Eoorthis bed lies topographically about 40 feet above the Bonneterre contact, and 100 feet or more below the base of the Derby. This, however, is in a very small sedimentary basin, almost surrounded by porphyry knobs. Dips may be expected to be very irregular, and thicknesses somewhat variable. The fossils were collected from what is without much question actual outcrop, and seems to indicate that *Eoorthis* sometimes occurs lower in the formation than the persistent *Eoorthis* bed. Nevertheless that bed is a constant horizon of great value in mapping. It should be recognizable in drill cores, and probably, with microscopic study, fragments of the plications could be identified in cuttings. In fact, since the above was written, a careful study of the cuttings in hole No. 3 of the St. Louis Smelting and Refining Co., at Black, in the NE. ¼ SE. ¼ sec. 22, T. 33 N., R. 1 E., shows fragmentary plications of Eoorthis in chips from a depth between 10 and 15 feet, at 140 to 145 feet above what was already identified as the Bonneterre-Davis contact.

Associated with the *Eoorthis* bed are rocks that carry abundant smaller brachiopods. In the type section at Elvins, about 200 yards south and a little west of the intersection of the Illinois Southern and Mississippi River and Bonneterre Railroads, in a cut on the latter road, in the SE. ¼ sec. 13, T. 36 N., R. 4 E., at the north end of the cut, in dense brownish gray limestone, between shale beds, in layers thought to correspond with the 14th and 15th beds from the top of Buckley's section, on p. 39, Vol. IX, 2nd ser., Mo. Bur. Geol. and Mines, and 4 to 6 feet below the Eoorthis bed, Prof. Bridge and the writer made a collection. The forms identified from this and succeeding localities are listed in the table of Davis fossil localities, on p. 96. All of the identifications are by Bridge.

On the south side of the saddle in the NE. ¼ SE. ¼ sec. 3, T. 34 N., R. 2 E., just two feet above the main *Eoorthis* bed, a collection of smaller brachiopods was made, and another from five feet above the last collection, or seven feet above the Eoorthis bed (see table).

On the slopes just northwest of the knob marked by the 1180-foot closed contour near the center of the NW. ¼ sec. 4, T. 34 N., R. 2 E., faint markings suggestive of Eoorthis were noted in a very massive rock, forty feet below the base of the Derby. In the same rock, other small brachiopods were collected. Beds thirty feet higher, or 10 feet below the base of the Derby, also yielded a small collection (see table).

In the W. ½ NW. ¼ sec. 3, T. 35 N., R. 1 E., at the west line of the section, about 400 feet downstream and on the opposite bank from a house, about 4 feet above creek level, several brachiopods were collected from a limestone ledge just above a shale bed. Ten feet higher on the hillside, a collection was made from a float boulder (see table). The relation of the two collections reported above to the main *Eoorthis* bed is not known.

In the saddle near the center of the W. ½ sec. 35, T. 36 N., R. 1 E., fragmentary brachiopods were collected, and again the relation to the *Eoorthis* bed was not established (see table).

West of the house, on the east slope of the hill, in the NE. ¼ SW. ¼ sec. 20, T. 35 N., R. 2 E., the *Eoorthis* bed itself yielded smaller brachiopods, and eighteen feet, higher on the hillside, occurs a very thin-bedded, sandy-appearing horizon, apparently a leached sandy limestone, in which are abundant impressions (see table). Since the beds are dipping rather strongly west, this interval is probably 20 feet, or more, instead of 18, as suggested above. This same sandy material also occurs on the south point of the hill, about at the center of the south line of the same section (sec. 20, T. 35 N., R. 2 E.), where it yields the same fossils (see table).

In the center of the E. ½ sec. 22, T. 35 N., R. 1 E., along a secondary road on the north bank of Telleck Creek, about where the creek crosses the 55 minute meridian, 2½ feet above the water, in a 6-inch limestone bed, overlying blue-gray shale, are abundant brachiopods, from which a collection was made (see table). The relation to the *Eoorthis* bed was not determined, but the horizon is about 35 feet below what was taken to be the base of the Derby.

Near the center of the E. ½ sec. 32, T. 35 N., R. 2 E., small brachiopods were collected, from a low ledge in an open field, about 200 yards northeast of the house (see table).

Near the center of the W. ½ NW. ¼ sec. 26, T. 35 N., R. 1. E., a collection was made, about 30 feet below what was taken to be the base of the Derby (see table). The *Eoorthis* bed was not located.

In a small valley on the east side of Kaolin Creek, in the E. ½ SW. ¼ sec. 1, T. 34 N., R. 1 E., at an elevation of about 1130 feet, a small collection was made, from beds believed to be Davis (see table). The relation to other known zones was not made out. Another small collection, the horizon of which is not known, was made at elevation 960 feet, on the northwest side of the valley, in the SE. ¼ SE. ¼ sec. 32, T. 34 N., R. 1 E. It is probably fairly high in the Davis, or possibly in the Derby. The forms are listed in the table.

The fact that most of the collections described above come from near the top of the Davis formation is explained largely by the fact that to determine the contact between the Davis and the Derby-Doerun, and to establish the overlap of the Potosi onto various horizons of the Davis, study was concentrated on the topmost beds of the formation. It is not to be assumed, therefore, that the lower beds of the Davis are barren, but simply that time did not permit of as extensive a study of the entire formation.

In the NE. ¼ SW. ¼ sec. 20, T. 35 N., R. 2 E., a thin-bedded sandstone with trilobites occurs 50 feet below the main *Eoorthis* bed, which should be about 80 feet from the base of the Derby. The forms identified are listed in the table.

In the center of sec. 1, T. 35 N., R. 1 E., and exactly 75 feet above the *Hypseloconus* bed, occurs a thin very fine-grained sandstone that also carries imperfect remains of trilobites. Apparently it is not the same faunule as that of the preceding paragraph. In the same locality, small collections of brachiopods were made at 135 feet, 150 feet and 160 feet respectively above the *Hypseloconus* bed. The forms collected are listed in the table. The *Eoorthis* bed was not located in this section.

A thin sandstone with trilobite fragments too imperfect for identification was also noted about 90 feet below the base of the Derby in the SW. ¼ NE. ¼ sec. 14, T. 35 N., R. 1 E. It is probably the same bed as the trilobite bearing layer in the preceding paragraph. The interval of 75 feet above the *Hypseloconus* bed, or 85 feet above the top of the Bonneterre, and 90 feet below the base of the Derby, would place it very near the middle of the formation, which averages about 175 feet in thickness.

A sandstone lithologically quite similar, also carrying trilobite remains, was discovered by Prof. Bridge, near the center of the SW. ¼ NW. ¼ sec. 17, T. 36 N., R. 4 W., in the Crooked Creek area of Crawford County, where he made considerable collections (see table).

TABLE OF FOSSIL LOCALITIES IN THE DAVIS.
Identification by J. Bridge.

Locality	At Elvins, SE. ¼ sec. 13, T.36 N, R. 4E.	NE. ¼ SE. ¼ sec. 3, T. 34 N., R. 2 E.	Cent. NW. ¼ sec. 4, T. 34N., R. 2E.	Same as preceding column.	W. ½ NW. ¼ sec. 3, T. 35N., R. 1E.	Same as preceding column.	Cent. W ½ sec. 35, T. 36N., R. 1E.	NE. ¼, SW. ¼ sec. 20, T. 35N., R. 2E.	Same as preceding column.	NE. ¼ SW. ¼ sec. 20, T. 35N., R. 2E.	Cent. S. line sec. 20, T. 35N., R. 2E.	Cent. E. ½ sec. 22, T. 35 N., R. 1E.	Cent. E. ½ sec. 32, T. 35N., R. 2E.	Cent. W. ½ NW. ¼ sec. 26, T.35N., R. 1E.	E. ½ SW. ¼ sec. 1, T. 34N., R. 1E.	Cent. sec. 1, T. 35N, R. 1 E.	NE. ¼ SW. ¼ sec. 1, T. 35N., R. 1E.	NW. ¼ SW. ¼ sec. 1, T. 35N., R. 1E.	NW. ¼ SW. ¼ sec. 1, T. 35N., R. 1E.	Crooked Creek, SW. ¼ NW. ¼ sec. 17, T. 36 N., R. 4 W.	SE. ¼ SE. ¼ sec. 32, T. 34N., R. 1E.	Cent. S. line, sec. 8, T. 33N., R. 2E.	S.Side Black R., W.line sec. 2, T. 33 N., R. 2E.
Locality number.	82.5a	81.2d	81.9a	81.9	74.33	74.33a	74.32	81.8a	81.8	81.8b	81.11	81.12	81.13	81.25	81.26	74.2b	74.2c	74.2d	74.2e	73.7	81.27	90.5	90.7
Horizon with respect to the Eoortnis bed	4-6 ft. below	7 ft. above	Uncertain, probably 5-10ft. below.	Uncertain, 30 ft. above preceding.	Unknown.	Unknown, 10 ft above preceding.	Unknown.	In Eoorthis bed.	18-20 ft. above.	50 ft. below.	Probably same horizon as 81.8.	Uncertain, about 35 ft. below base of Derby.	Unknown.	Unknown.	Unknown.	Unknown, 75 ft. above Hypseloconus bed.	135 ft. above Hypseloconus bed.	150 ft above Hypseloconus bed.	160 ft. above Hypseloconus bed.	Unknown.	Unknown.	Unknown.	Unknown.
Cystoidea																							
Cystoid stems								+				+											
Brachiopoda																							
Billingsella coloradoensis (Shumard)		+		+	+	+	+					+	+		+		+	+	+		+	+	+
Billingsella major (Walcott)																	+	+					+
Eoorthis indianola (Walcott)	+																	+					
Eoorthis remnicha (N. H. Winchell)		+						+															+
Eoorthis wichitaensis (Walcott)	+							+										+				+	
Eoorthis sp.									+		+												
Linguiella acutangula (Roemer)			+																				
Obolus matinalis (Hall)			+											+									
Gastropoda																							
Hypseloconus sp.															+								
Tryblidium (?) sp.															+						+		
Trilobita																							
Dunderbergia sp.										+													
Housia sp.																+				+			
Iddingsia sp.										+													
Pseudagnostus josepha (Hall) (?)																+				+			
Taenicephalus shumardi (Hall)									+														
Unidentified Trilobites								+															

A collection was also made from very massive beds, undoubtedly fairly high in the Davis, at the bridge over Castor River, on Highway 61, near the center of the south line of sec. 21, T. 33 N., R. 8 E. The forms are too imperfectly preserved for safe identification.

Many of the thin limestone and shale beds of the Davis are covered with small branching ridges, usually referred to as fucoid markings. They are presumed to be stems of some sort of marine plant, though nothing definite is known as to their character.

Some of the limestone beds of the formation are packed full of small stems, probably those of cystids, or perhaps even of crinoids, though no heads were found, during the course of this work.

The weathered surfaces of certain beds carry very abundant and distinct concentric markings, thought to be a species of *Cryptozoon*. These are well exposed below the small spring, near the center of the NW. ¼ sec. 7, T. 34 N., R. 3 E., in the steep gully on the north wall of the main valley. Here there are two horizons of these cryptozoons one ten and the other 25 feet below the main *Eoorthis* bed. Near the center of the west line of sec. 2, T. 34 N., R. 2 E., similar beds with cryptozoons occur on the south side of the saddle, at about elevation 1190 feet, and perhaps 10 feet below the Eoorthis bed.

In the W. ½ NW. ¼ sec. 3, T. 35 N., R. 1 E., south of the main road, and 20 feet above the creek, on the southwest bank, in open pasture, is a low flat ledge of limestone showing a very fine development of *Cryptozoons* (Pl. XI, B). There is another occurrence in the saddle in the NE. ¼ NW. ¼ sec. 36, T. 36 N., R. 2 E. In these two localities, the horizon with respect to the *Eoorthis* bed is not definitely known.

Age and correlation.—The unique lithologic character of this formation, together with nearly perfect continuity into the type area, serve to establish without question its identity with the original Davis. This has long been classed as upper Cambrian in age.[1]

Ulrich, in his Revision, has correlated the Elvins with the Nolichucky of Virginia and Tennessee, with the uppermost Conasauga of Tennessee and Alabama, and tentatively with the

[1]Bain and Ulrich, op. cit., p. 12.
Ulrich, loc. cit.
Buckley, op. cit., p. 19.

Mendota limestone of Wisconsin and the basal Arbuckle of Oklahoma. In a later unpublished correlation table, however, he indicates that he believes the Davis to be equivalent to the Dresbach and Franconia of Wisconsin, to the upper part of what he calls Cap Mountain and all of the Honey Creek of Oklahoma, and to the upper part of the Cap Mountain and all of the Wilberns of Texas.

The presence of the *Hypseloconus* fauna (p. 89) certainly suggests a fairly close correlation of the basal Davis with the Upper Dresbach *Hypseloconus* zone described by Berkey[1] in the Geology of the St. Croix Dalles.

There seem to be very good grounds for correlating the Davis with the Gallatin (Upper Deadwood) of the northern Rocky Mountains. During the summer of 1916, the writer was engaged in mapping in northwestern Wyoming. At that time, he collected from the upper thin-bedded member of the Gallatin, interbedded with "Edgewise" limestone conglomerates, fossils closely allied to the Davis fauna from Missouri. Quoting from an unpublished report on the Wyoming work, "In unsurveyed territory, but in what is approximately the center of sec. 19, T. 55 N., R. 104 W., above the typical scarp of the lower massive Gallatin, and just below a typical flat-pebble conglomerate, occurs a considerable thickness of greenish shale and conglomeratic limestone, from which the following fossils, identified by Mr. Edwin Kirk, were collected:

GALLATIN FAUNA.

Billingsella coloradoensis (Shumard).
Ptychoparia sp.
Trilobite genus?".

Quoting again from the same unpublished report: "On the north side of Clark Fork Canyon, near the center of sec. 7, T. 56 N., R. 103 W., there are about 300 feet of slope, above the scarp of the massive lower Gallatin. About 50 feet of interbedded limestone conglomerates and green shales outcrop near the middle of the slope. Fossils were collected, and submitted to Mr. Edwin Kirk, who reported the following:

GALLATIN FAUNA.

Eoorthis desmopleura (Meek).
Billingsella coloradoensis (Shumard).
Ptychoparia sp.
Trilobite genus?".

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[1]American Geologist, vol. 21, 1898, pp. 270-294.

Walcott[1] reports *Eoorthis remnicha*, *Eoorthis remnicha texana*, *Eoorthis wichitaensis*, and *Billingsella coloradoensis* from the Gallatin; and *Lingulella similis*, *Linnarsonella girtyi*, and *Eoorthis wichitaensis* from the upper Flathead.

The Davis is also, probably, to be correlated with the Wilberns formation of central Texas, which is described[2] as gray, greenish and pinkish flaggy limestone, some shale, and limestone conglomerate. Some of the limestone beds, of which the writer has seen only hand specimens, greatly resemble, lithologically, the "marble-bowlder" horizon of the Davis. According to Buehler,[3] there are beds of typical "edgewise" conglomerate, with the thin, slightly rounded limestone pebbles so abundant in the Davis. From this locality, and presumably from this horizon, Walcott[4] lists the following forms:

WILBERNS FAUNA.

Obolus matinalis	*Acrotreta microscopica*
Obolus nundina	*Billingsella coloradoensis*
Obolus sinoe	*Eoorthis indianola ?*
Lingulella upis	*Eoorthis remnicha texana*
Lingulepis acuminata	*Eoorthis wichitaensis*
Lingulella acutangula	*Linnarsonella girtyi*

The close lithologic resemblance, and the striking similarity in fauna seem to suggest a rather close correlation between the Davis of Missouri, the Wilberns of Texas, the upper Deadwood, and the Gallatin of the northern Rocky Mountains of Wyoming and Montana.

Derby-Doerun Formation.

Name.—These beds were formerly included with the Davis (see p. 87), first as part of the St. Joseph of Winslow, then as part of the Fredericktown of Keyes, later as a portion of the Potosi of Nason, and finally as part of the Elvins of Ulrich. They were first adequately described by Buckley,[5] who assigned the name Derby from the Derby Mine, and the name Doerun from the Doe Run Lead Company. The two do not seem to be sufficiently developed to warrant mapping them separately in

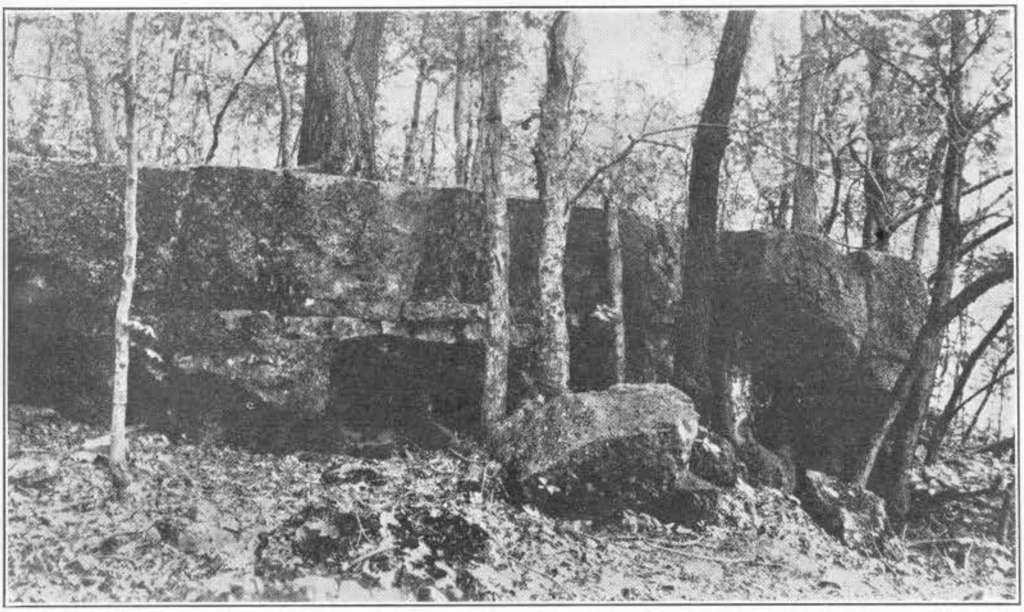
[1]Cambrian Brachiopoda, U. S. Geol. Survey, Mon. 51, 1912, pp. 161 and 296.
[2]Paige, Sidney, U. S. Geol. Survey, Llano-Burnett Folio, No. 183.
[3]Buehler, H. A., Personal communication.
[4]Cambrian Brachiopoda, U. S. Geol. Survey, Mon. 51, pp. 184 and 212-213.
[5]Buckley, E. R., Am. Mining Cong. Rept., 10th Ann. Session, 1907, p. 286.
Buckley, E. R., Geology of the disseminated lead deposits of St. Francois and Washington Counties; Mo. Bur. Geol. and Mines, vol. IX, 2nd ser., 1908, pp. 44-49.

the area of the Potosi and Edge Hill quadrangles. Therefore the dolomitic horizon occupying their stratigraphic position between the Davis below and the Potosi above has been delineated together under the compound name of Derby-Doerun.

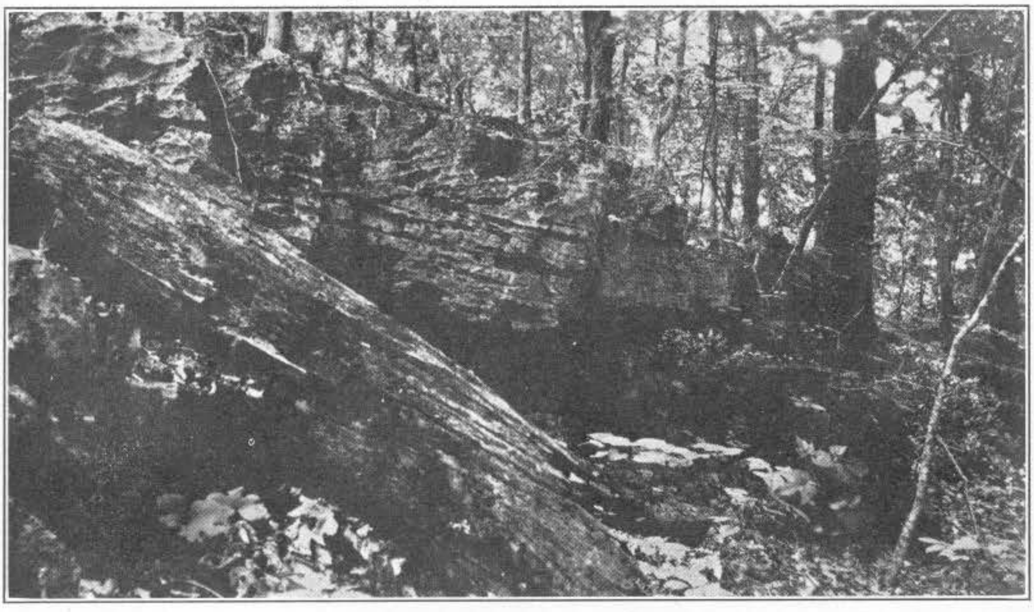
Distribution.—On the Potosi quadrangle this formation has a distribution not greatly different from that of the Davis, though its belt of outcrop is for the most part considerably narrower. There is a small patch of it near Hunter's Mill, in sec. 25, T. 36 N., R. 2 E., and sec. 30, T. 36 N., R. 3 E., in the angle between the two main forks of the Palmer fault. Farther southwest, in the vicinity of Belgrade and Sunlight, it forms the crest of the ragged east-facing escarpment, already described, the lower slopes of which are occupied by the Davis. There are also isolated strips of the formation, along the lower reaches of Trace and Cub creeks, near the southwest corner of the map, and small "windows" of it showing in the backslope of the escarpment, in secs. 32 and 33, T. 36 N., R. 1 E., and secs. 9 and 10, T. 35 N., R. 1 E. Its total area of outcrop on the Potosi sheet probably does not greatly exceed four square miles.

On the Edge Hill quadrangle, its distribution is much more erratic. Along the continuation of the escarpment described above on the Potosi sheet, it is present only well toward the northwest end, being removed, farther east, by pre-Potosi erosion. On the north and east face of this escarpment, it covers about two square miles. Over the remainder of the quadrangle, it is exposed at many isolated points, in the deeper valleys, the total area of outcrops being about four or five square miles on the Edge Hill sheet.

Thickness.—The fact that there has been pronounced post-Doerun pre-Potosi erosion results in a great variation in thickness of the Derby-Doerun. In fact, over much of the southeast portion of the Edge Hill sheet, these beds are entirely wanting, the Potosi lapping across onto the eroded surface of the Davis and Bonneterre. Over most of the remainder of this sheet only the Derby is present, the Doerun having been cut away before Potosi time. Another element of uncertainty in determining the thickness of these beds is that the weakly resistant, argillaceous, thin-bedded Doerun may easily be badly masked by heavy Potosi druse float. This fact complicates the situation greatly, because at localities where the first thing observed above the Derby is heavy Potosi float, one can never be certain whether the Doerun is really missing, or only obscured by the heavy



A. Typical outcrop of massive Derby, NE. ¼ SW. ¼ sec. 8, T. 35 N., R. 2 E.



B. Cross-bedded Derby, at above locality.

Potosi residuum. It is quite probable that the actual base of the Potosi is much more irregular than it has been mapped and the thickness and distribution of the Derby-Doerun much more variable than the mapping would indicate. It was, however, thought to be unsafe to assume that the Derby-Doerun was absent at all points where it failed to outcrop.

A greater thickness of these beds is undoubtedly present in the Potosi than in the Edge Hill quadrangle. In the general vicinity of Belgrade and Sunlight, where the greatest thickness seems to occur, the interval from the top of the Davis to the base of the Potosi varies topographically from as low as 40 to as high as 140 feet. Both extremes, however, seem to be influenced by local dips, adjacent to the porphyry knobs, and an average seems to be about 60 to 80 feet.

In the city well at Potosi, McQueen,[1] who has studied the cuttings very carefully, assigns 240 feet to the combined Davis and Derby-Doerun, of which he tentatively correlates the uppermost 75 feet with the latter formation.

In the Palmer well, Buckley[2] assigns 101 feet to the Derby-Doerun, and in the St. Joe Lead Company's hole number 22, in the S. ½ NW. ¼ sec. 21, T. 36 N., R. 2 E., Larson[3] assigns 110 feet to that formation. This is in the faulted area, however, and the Bonneterre and Davis also show exceptional thicknesses.

In hole No. 2, near Black, in the northeast corner of NW. ¼ SW. ¼ sec. 26, T. 33 N., R. 1 E., the situation is somewhat anomalous. The hole starts on Derby-Doerun, seemingly some distance below the top. The Lamotte sandstone was reached at a depth of 615 feet, of which 25 feet was reported as residual material[4]. This would leave a thickness of 590 feet for Bonneterre, Davis, and Derby-Doerun combined. A careful study of the cuttings[5] seems to throw 315 feet into the Bonneterre, and 275 feet into the combined Davis and Derby-Doerun. Since the hole starts well below the top of the latter formation, the figure seems to be very excessive. The figure for the Bonneterre is also rather too high, and the explanation may be repetition or tilting in close proximity to the Black fault.

Lithologic character.—The Derby consists essentially of thick-bedded to massive, non-cherty dolomites, usually light

[1]Personal communication.

[2]Buckley, E. R., Disseminated lead deposits, pp. 55-57.

[3]Personal communication.

[4]Log furnished by E. T. Campbell.

[5]By T. D. Murphy.

gray to buff in color, but with occasional dark gray phases. In texture, it varies from finely crystalline to earthy, and is commonly dense, though locally beds show vugs. It rarely exhibits the granular, or sandy-appearing weathered surfaces so characteristic of the upper Bonneterre and of portions of the Eminence.

Exposures, usually rough-weathering and pitted, are locally as craggy as those of the Eminence, and as certain phases of the Bonneterre, but more commonly outcrop in a series of steps, or low, regular cliffs (Pl. XII).

Very near the top of the Derby, in the type section near Elvins, is a bed that shows a nodular character, the rounded masses resembling pisolites. As nearly as can be made out from Buckley's detailed section,[1] this must be the fifth bed from the top of the Derby, as given on page 46 of his report. This same bed is remarkably developed, on the point between the two valleys, along the north line of the N. ½ NE. ¼ NE. ¼ sec. 35, T. 36 N., R. 1 E., where the nodules reach as much as 0.6 inch in diameter, and make up the main bulk of the rock. It is sparingly developed at the extreme south tip of High Top Mountain, near the center of the NE. ¼ sec. 8, T. 33 N., R. 2 E., where it occurs just 60 feet above the *Eoorthis* bed of the Davis. In the type section, it is about 67 feet above the *Eoorthis* bed. Thin sections of these nodules show them to be essentially without either radiating or concentric structure.

Cross-bedding is a conspicuous feature of many outcrops of the massive phases of the Derby (Pl. XII, B). Except for local occurrences of this structure in the upper Davis, the Derby is the only conspicuously cross-bedded dolomite the writer has encountered in the area. Exceptionally good exposures of this structure occur on the hill in the SE. ¼ sec. 8, T. 35 N., R. 2 E., and near the center of the NW. ¼ sec. 15, T. 35 N., R. 1 E.

The Doerun has but small development in the Potosi quadrangle, chiefly, it is believed, because it was removed by pre-Potosi erosion. Its development in the Edge Hill quadrangle is even less. In the small tributary valley, draining south, in the W. ½ SW. ¼ sec. 2, T. 35 N., R. 1 E., there occurs, above the Davis, 40 feet of very massive, pinnacled, hackly-weathering dolomite, which was considered typical Derby. Above that is about 50 feet of thin-bedded, argillaceous, smooth-weathering light buff to light gray dolomite, quite typically Doerun. Above

[1]Buckley, E. R., op. cit., p. 46.

that, heavy Potosi druse float continues to the top of the hill. This is by far the best exhibit of the Doerun in the Potosi quadrangle.

In the valley, above the house, in the center of the NE. ¼ sec. 22, T. 35 N., R. 1 E., Edge Hill sheet, above massive beds believed to be Derby, are thinner-bedded rocks of more argillaceous character, probably Doerun. Locally there occur in the upper portion of the Davis, certain white argillaceous dolomites, very similar to the Doerun, which have caused much difficulty in mapping (see p. 84), since in isolated exposures, it was very difficult to know which horizon was encountered.

Between the typical Derby-Doerun and the typical Potosi, there occur at several points, beds the relations of which are very obscure. They consist of coarsely crystalline light brown to gray non-drusy dolomites. Locally they show a faint greenish tint, and somewhat resemble the more granular phases of the Bonneterre. They outcrop quite extensively on Cub Creek for a mile or two above the mouth of Trace, especially in sec. 12, T. 35 N., R. 1 W. Similar beds were noted at Black, in the N. ½ NE. ¼ sec. 28, T. 33 N., R. 1 E., and they have their most striking development (not to exceed 30 feet, maximum) on the south side of the main valley through sec. 32, T. 35 N., R. 2 E. In the valley near the center of the S. ½ sec. 31, T. 34 N., R. 1 E., similar granular beds occur about 100 feet above the marble bowlder bed of the Davis. Material of about the same general character is to be seen near the center of the NW. ¼ sec. 11, T. 34 N., R. 1. E.; in the S. ½ NW. ¼ sec. 22, T. 34 N., R. 1. E.; and in the S. ½ SW. ¼ SW. ¼ sec. 4, T. 33 N., R. 1 E. They may possibly belong to the Derby-Doerun. If so, however, they are a local development of that formation, since the type section carries nothing at all comparable to these beds. It is entirely possible, on the other hand, that they represent a light-colored, non-drusy phase of the Potosi, present only locally along the unconformity at the base of that formation.

In the table, on page 70, is given an analysis of the typical massive craggy phase of the Derby. This rock, though not a chert-maker, yielded the highest silica content (7.5%) of any sample analyzed from the entire area. The alumina is also the highest encountered, though it would doubtless run much higher in some of the more shaly beds of the Davis. The rock is essentially a dolomite.

Topographic expression.—West of Belgrade and Sunlight, the Derby-Doerun, overlying as it does the much weaker Davis, forms the crest of a ragged but conspicuous east-facing escarpment which exists in response to a low regional west dip. The raggedness of the escarpment is the combined result of faulting, the irregular dips associated with the porphyry knobs, and recession from unequal erosion. Elsewhere than along this escarpment, outcrops of the formation are so limited that they control the general topography only to a negligible degree.

Cedar "glades" are a striking feature of the landscape, throughout the area of outcrop of the formation on the Potosi quadrangle.

Stratigraphic relations.—As already pointed out, no evidence of any break between the Davis and the Derby-Doerun was noted, the appearance being that of perfect gradation and conformity.

The relations with the Potosi are less simple. Again, contacts are poorly exposed, and practically no direct evidence was noted. Within the area of the Potosi quadrangle, the thickness of the Derby-Doerun seems to be notably variable. At a very few points, however, has the base of the Potosi actually been observed, the contact being drawn chiefly on the basis of heavy Potosi druse float, above the Derby-Doerun. Since the Doerun, being very thin-bedded, is rather weakly resistant, there is always the possibility that failure to outcrop does not mean absence, but only masking by the very heavy Potosi residue. In the earlier mapping, it was assumed that the entire thickness of the Derby-Doerun was everywhere present, and the base of the Potosi was drawn in accordance with that view. Later discoveries of the Potosi, in place, resting on Derby, and even on Bonneterre, farther to the south and east, outside the Potosi quadrangle, have led to the belief that the Doerun is quite generally absent, and that the total thickness of the Derby-Doerun is much more variable than was at first supposed, and than was indicated on the Potosi sheet. Since, however, the mapping of the contact continued to rest chiefly on float evidence, it was not thought advisable to re-map the contact.

It is firmly believed, however, that the Doerun is only locally present, and the base of the Potosi much more uneven than the map shows, though it is difficult, if not impossible, to prove this within the area of the Potosi sheet.

A very careful study of the main St. Francois Mountain region to the south and east, reveals the fact that the Potosi, over large areas, rests directly on the Bonneterre, and in places on the Davis. This would seem to indicate an important break in sedimentation near the close of pre-Potosi time.

The contact of Potosi on Bonneterre is well shown on the south side of Twelve-mile Creek, at its junction with St. Francois River, about a mile below Saco, in Madison County, in the W. ½ sec. 13, T. 31 N., R. 5 E. Here 50 to 75 feet of Bonneterre is exposed, with good outcrops of Potosi next above. An even more striking contact is to be seen in the SW. ¼ sec. 20, T. 31 N., R. 7 E., about a mile northwest of Buckhorn, Madison County, on the Coldwater road, on the northeast side of the road, extending back into the small valleys draining south and southwest. Here the contact is rather uneven. An even better example of its uneven character is to be seen near where the main road northeast from Higdon crosses the north line of sec. 4, T. 33 N., R. 8 E. Here, on the north side of the road, and in close proximity to a granite knob, the Potosi is clearly seen resting on a very uneven surface of the Bonneterre.

The actual plane of contact is perhaps best exposed in the SE. ¼ sec. 22, T. 32 N., R. 3 E., about two miles north of Sabula, Iron County, along the state highway, in a newly-made road excavation. Here the Bonneterre is coarse-grained light gray dolomite, with greenish patches, and is typical of this formation over wide areas in the St. Francois Mountains. The Potosi is dark-colored, with abundant druses, and has the characteristic foetid odor of the formation. At this locality, the contact, only a few feet of which is actually exposed, seems to be rather regular and is marked by about four inches of white sand and greenish shale. There is no sign of a conglomerate, probably because there is little or no cherty or other resistant material in the Bonneterre, from which a conglomerate would be likely to form. At numerous points along the new state highway both north and south of Annapolis, the contact of Potosi on Bonneterre is well exposed.

Over most of the area between Castor River on the east and Black River on the west, and from Ironton south to Piedmont, the Potosi rests directly on the Bonneterre. There are several localities, however, where thin shaly limestones or shales occur below the Potosi, and these may, perhaps, represent remnants of the Davis, though some of them may possibly be shaly phases of the Bonneterre. The most significant of these areas is quite probably the one along the east side of Castor River, near Hahns Mill, in sec. 16, T. 33 N., R. 8 E., and on Combs Branch, in the W. ½ sec. 15, T. 33 N., R. 8 E. There is at least 75 feet of this material in Combs Branch, and while no fossils were found, nor any of the limestone conglomerates so characteristic of the Davis, still the material has the peculiar texture and color of Davis, and is strongly suggestive of that formation. From Combs Branch these beds may be traced south under more massive limestones that outcrop at the Castor River bridge on Highway 61, near the center of the south line of sec. 21, T. 33 N., R. 8 E., from which Davis fossils have been collected. Other localities where the Potosi rests on similar thin-bedded limestones, possibly Davis, are on Funks Branch, not far from the center of sec. 5, T. 30 N., R. 3 E., in Iron County; along the Lesterville and Glover road, just west of the Mill Spring School, near the center of the N. ½ sec. 14, T. 32 N., R. 2 E., and again about four miles northwest of Marquand, on the Fredericktown road.

The nature of the unconformity is perhaps still better indicated, by the situation in the southeast one-fourth of the Edge Hill sheet. Near the center of the south line of sec. 28, T. 33 N., R. 2 E., the Potosi seems to rest directly on Bonneterre, since no outcrops could be found above the Bonneterre and below the heavy druse float of the Potosi. Less than 4 miles north, up the East Fork of Black River at the south tip of High Top Mountain, near the center of the NE. ¼ sec. 8, T. 33 N., R. 2 E., the *Eoorthis* bed, packed full of the most typical Davis fossil we know, occurs at creek level, and 60 feet higher, Potosi is resting in place on Derby. Only a mile north of this, in the E. ½ SW. ¼ sec. 5, T. 33 N., R. 2 E., perhaps ¼-mile south of the Lower Imboden School the first thing above the Bonneterre is again heavy Potosi druse float.

Occurrences of this sort indicate rather definitely that even here, in the very heart of the porphyry ranges of the St. Francois group, the Davis and Derby were actually deposited, and that this deposition was followed by emergence, and removal of the beds locally down to the Bonneterre, before the Potosi was laid down.

There would thus seem to be abundant evidence that the base of the Potosi, throughout the St. Francois Mountain area, is marked by a definite and fairly important unconformity.

Paleontology.—No fossils were found in the Derby-Doerun, in the area of the Potosi quadrangle. On the Edge Hill quadrangle, a single trilobite glabella was taken from beds believed to be about 60 feet above the top of the Davis, or probably in the lower part of the Doerun, in the SE. ¼ NW. ¼ sec. 21, T. 33 N., R. 1 E. It appears much like species found in the Davis, but is too incomplete for satisfactory identification.

At the south tip of High Top, in the center of the NE. ¼ sec. 8, T. 33 N., R. 2 E., just 60 feet above the *Eoorthis* bed, and in the pisolitic bed of the Derby already described (p. 102), fragmentary fossils were found. Among them is a single specimen of a planispiral gastropod, with a very rapidly expanding whorl, apparently quite unlike anything else thus far found in the Elvins group. With it is a very imperfectly preserved discoidal brachiopod, suggesting an *Obolus*. Other fragments occur, but nothing else that could possibly be identified.

Mr. E. T. Campbell also sent in slabs of argillaceous dolomite carrying abundant specimens of *Obolus matinalis* Hall (?), from the SE. ¼ NE. ¼ sec. 22, T. 33 N., R. 1 E. Lithologically, the horizon resembles basal Doerun, though similar beds are known in the upper Davis, and the species probably ranges through both horizons.

From the base of the Doerun, in the type section, near Elvins, near the center of the NW. ¼ sec. 19, T. 36 N., R. 5 E., thin-bedded very argillaceous dolomite yielded abundant specimens of *Obolus* sp.

Buckley[1] reports *Finkelnburgia osceola* Walcott, from the Doerun of the Lead Belt region.

Age and correlation.—Even though the Derby-Doerun of the Potosi-Edge Hill area varies considerably from the Derby and Doerun of the type area, its nearly perfect continuity into these area, and its stratigraphic position between the highly distinctive formations of the Davis below and the Potosi above, serve to establish its essential identity with the original Derby and Doerun. It is the upper portion of Ulrich's Elvins[2] formation, which he considers the highest true Upper Cambrian of Missouri.

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[1]Buckley, E. R., The geology of the disseminated lead deposits of St. Francois and Washington Counties; Mo. Bur. Geol. and Mines, 2nd ser., vol. IX, 1908, pt. 1, p. 49.

[2]Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, no. 267, 1905.

Since practically no faunal lists are available for the Derby-Doerun, little can be said of its broader relations, except that it is conformable with, and hence immediately follows the Davis, the correlation of which seems to be fairly well established.

Potosi Dolomite.

Name.—The formation was named from the town of Potosi. According to an early correlation table by Winslow,[1] it would appear that he applied it to beds in southeast Missouri, equivalent to the Jefferson City and Moreau (Roubidoux) of the central Ozarks. A careful study of his reports, however, makes it clear that his Potosi included much more than the present equivalents of Roubidoux and Jefferson City, as they are known to occur in the southeast part of the state.

According to Winslow's table, all the strata in southeast Missouri lying between the Lamotte below and the Crystal City (St. Peter) sandstone above, both of which units seem to have been defined about as at present, are assigned to two formations, the St. Joseph limestone and the Potosi limestone. Since the base of the St. Joseph and the top of the Potosi are thus closely defined, it remains to ascertain where he meant to place the boundary between them. On page 347 of the same report, he says:

"Overlying this (the Lamotte) is a series of limestone beds in which the ore is found. Near the base of these are the shales, containing the oft-referred to Linguelella shells. This limestone is estimated to be as much as 200 feet thick here. Above this massive limestone, which we correlate with the St. Joe (St. Joseph?) limestone of St. Francois County, there are recognized in the hills a series of cherty magnesian limestone beds which are assigned a thickness of nearly 300 feet."

In another paper[2] the St. Joseph limestone is reported to carry "shale beds .... in the upper part along Flat River" which are quite probably the Davis. Also "no chert or drusy quartz is found in the formation."

In contradistinction to this, Winslow reports, the "thickness of the 'cherty' limestone—which is essentially the same as the Potosi—at 270 feet" and further speaks of the Potosi as characterized by "irregularly shaped masses ...... of amorphous chalcedonic silica covered with quartz crystals on the free surfaces."

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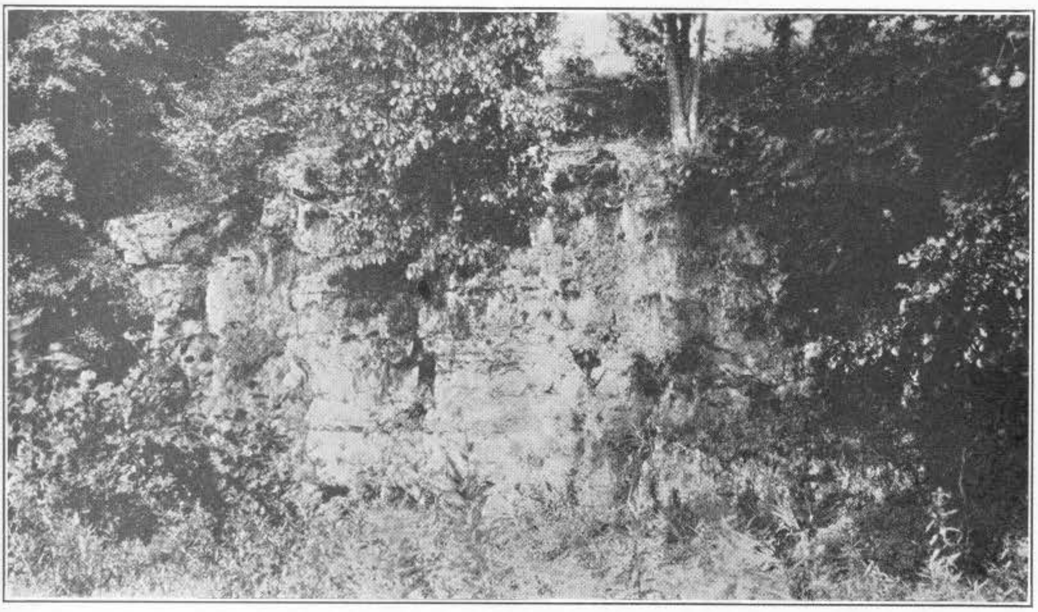
[1]Winslow, Arthur, Lead and zinc deposits; Missouri Geological Survey, vol. VI, 1894, p. 331.

[2]Winslow, Arthur, The disseminated lead ores of Southeastern Missouri; Bull. U. S. Geol. Survey, no. 132, 1895, pp. 13-18.



A. Cliff of very massive Potosi, Fourche a Renault Creek, SW. ¼ sec. 13, T. 38 N., R. 1 E.

B. Potosi druse in road ditch on Highway 21, at Old Mines.

From the above descriptions, it is clear that Winslow's St. Joseph limestone is essentially the equivalent of the Bonneterre and the Davis, and that his Potosi formation began either with the Derby-Doerun, or with the present Potosi at the base, and included the beds up to the base of the St. Peter.

His correlation table, already referred to,[1] is now known to be in error, in that his Lamotte sandstone and St. Joseph limestone are both older than any part of the Proctor, which he correlates with the Lamotte. Inasmuch as the Gasconade is actually the youngest formation to outcrop extensively in the immediate vicinity of the "Lead Belt," it is quite probable that in actual practice the term Potosi was not applied to beds younger than Gasconade, and was in general restricted to the true Potosi of present definition.

Nason,[2] in his use of the Potosi, includes in its base the equivalent of the Davis shale, which from his descriptions, it is thought Winslow placed in the St. Joseph. To the St. Joseph thus restricted, he applied the term Bonneterre. He does not appear to define the upper limits of the Potosi.

Bain and Ulrich[3] apply the term "Potosi group" to all the formations between the Elvins (Davis and Derby-Doerun) below and the St. Peter above, ruling the shale horizon out of the Potosi. This seems to come more closely to the intent of Winslow, in his usage. In their report, the Potosi as now defined is considered to be the basal unit of the Gasconade.

Since, however, the true Potosi of modern usage, which carries the abundant druse or "mineral blossom" of the prospectors, is the only really conspicuous member of the so-called "Potosi group" in the immediate vicinity of the Lead Belt, local usage came to confine the application of Potosi to that particular stratigraphic unit, and when, some years later, Buckley[4] prepared his detailed report on the district, he wisely decided to restrict the term to include only beds to which the name was actually being applied in practice, that is to the very drusy horizon that yielded the abundant "mineral blossom" of the local miners.

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[1] Mo. Geol. Survey, vol. VI, 1894, p. 331.

[2] Nason, F. L., The geological relations and the age of the St. Joseph and Potosi limestones of St. Francois County, Missouri; Am. Jour. Sci., 4th ser., vol. XII, 1901, pp. 358-361.

[3] Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, No. 267, 1905.

[4] Buckley, E. R., loc. cit.

Buckley was not familiar with the Eminence formation, proposed by Ulrich from the county seat of Shannon County, and unwittingly included a considerable amount of Eminence in the Potosi as mapped on the Bonneterre quadrangle. As the term is defined at present, it includes the brownish very drusy, almost unfossiliferous dolomite lying above the Derby-Doerun, and below the Eminence, which is lighter in color, more cherty than drusy, and carries an abundant fauna.

Distribution.—In the Potosi quadrangle, the area of Potosi outcrop is exceeded by both the Eminence and the Gasconade. The formation occurs most extensively in the southwest and northeast portions. From the southeast, it has been widely removed by erosion, and in the extreme northwest only the deeper valleys penetrate to it, in the region of doming about Little Pilot Knob. Its area of outcrop approximates 47 square miles on the Potosi quadrangle. The formation also outcrops widely over the Edge Hill quadrangle, the most extensive area being in the northwest portion of the sheet, where it caps all but the highest hills. Over the remainder of the area it makes up the intermediate slopes, and it has a total exposure of perhaps 48 square miles in the quadrangle.

Thickness.—Nowhere in either quadrangle are the top and bottom of the formation both exposed in a single section, so that no exact measurements can be made. At several points in the southwest fourth of the Potosi sheet, hills 200 feet high show Potosi outcropping at the base, and abundant druse float on the hill tops, so that the formation exceeds that thickness.

From the presence of abundant Eminence float on some of the higher of these hills, at an elevation of about 250 feet above the Derby-Doerun and Potosi contact, one might be led to think that 250 feet is not far from the maximum, though the top of the formation is undoubtedly somewhat higher than the float would indicate. There does not seem to be any way of determining how far this Eminence chert may have slumped below its original position, thus masking the contact, but there is reason to believe that the amount of slump is appreciable.

In Buckley's[1] interpretation of the core from the deep hole at Palmer, he reports that the boring starts in Potosi, and goes out of it at 274 feet, which would give the formation a thickness in excess of 274 feet. If this is the flowing well still

[1]Buckley, E. R., op. cit., pp. 55-57.

visible along the Palmer-Potosi road, then it probably started at least 30 or 40 feet below the top of the Potosi, which would give a thickness of over 300 feet. The elevation of 922 feet at the sleeve given by Buckley, suggests strongly that it is the flowing well. The identity of the hole is now uncertain. Some of the holes near Palmer started in Eminence.

Hole number 22 of the St. Joe Lead Company, drilled in 1926, in the S. ½ NW. ¼ sec. 21, T. 36 N., R. 2 E., about 3 miles northeast of Belgrade, starts on the Eminence formation, and in it, Mr. Larson[1] reports 295 feet of the Potosi, the Eminence-Potosi boundary having been established by the writer, from an examination of the core before the Derby-Doerun was reached.

The city well at Potosi starts about 80 feet below the top of the Potosi formation, and probably passed into Derby-Doerun at a depth of about 310 feet, giving to the Potosi formation a thickness of about 390 feet. This seems somewhat excessive, but it must be remembered that most of the formations thicken somewhat, out in the center of these sedimentary basins, away from the porphyry ranges, and the city of Potosi occupies such a locality.

In the northwest corner of the Edge Hill quadrangle, the Potosi formation reaches approximately its full development of well over 200 feet. Over most of the southeastern part of the area, however, it is clearly much thinner, perhaps averaging under 100 feet. Since outcrops are exceedingly rare in this area, and since both its upper and lower contacts are established almost wholly by the distribution of the float, it is impossible to give any very satisfactory figures. This thinning may be explained as the result of the fact that over most of this portion of the quadrangle, pre-Gasconade erosion has allowed the removal of the entire Eminence, and most of the Potosi, before the Gasconade was laid down. In consequence of this, the thickness of the Potosi is greatly variable, and in a few places, it seems from the lack of float, to be entirely eroded away, and the Gasconade laps directly across onto the Bonneterre. Such seems to be the case in much of the Tom Sauk Country, in the southeas portion of T. 33 N., R. 2 E.

Since there is also unconformity at the base of the Potosi, its variable thickness may in part result from the suppression of basal beds, never laid down in the heart of the St. Francois

[1]Personal communication.

Mountains. Unfortunately, as yet no means have been found of distinguishing horizons within the Potosi, so we do not know, in those areas where it is so thin, what part of the formation we are dealing with.

Lithologic character.—The Potosi is lithologically one of the most distinctive formations of the entire Cambro-Ordovician section in the state. In its most characteristic phase, it consists of light to dark brown, moderately crystalline, medium to fine-grained, almost non-bedded, very drusy dolomite, commonly with a pronounced foetid odor on freshly broken surfaces.

The dark color and foetid odor are characteristic, and presumably result from the presence of organic matter. Shades of light and dark brown are most abundant, and as a rule, the deeper the color, the more pronounced the organic odor. At a few localities, lighter colors, with faint tints of pink and green, were noted, and locally the color is light to dark gray. No large body of Potosi has thus far been seen, however, in which brown shades did not predominate. The white Potosi described by St. Clair[1] from Ste. Genevieve County has been studied at several localities, and has been found in all cases to be typical Eminence. Identification of this material as Eminence has been verified by diagnostic Eminence fossils.

The texture of the Potosi, though ordinarily ranging from medium to finely-crystalline, is in places distinctly earthy. An almost white, even-textured true "cotton rock" occurs near the Potosi-Eminence contact, in the NE. ¼ NE. ¼ sec. 34, and NW. ¼ NW. ¼ sec. 35, T. 38 N., R. 2 E. It is uncertain to which horizon it belongs. As a matter of fact, lithologically it more closely resembles the basal Van Buren, though the only way it could possibly be of that formation is through profound unconformity or faulting, since fossils pronounced Eminence by Ulrich occur on the hill top, at least 80 or 100 feet higher. There does not seem to be any evidence of abnormal structural relations, though outcrops are not sufficiently continuous to be at all certain. Similar light-colored, fine-grained, argillaceous dolomite occurs in the Potosi-Eminence transition beds on the Mineral Point road, about a mile southeast of Potosi.

A very similar "cotton rock" outcrops along the Trace Creek road in the E. ½ NE. ¼ sec. 1, T. 35 N., R. 1 W., about

[1]Geology of Ste. Genevieve Co., Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, p. 55; also pp. 58-61.

at the contact of the Potosi on Derby-Doerun. In the center of the NW. ¼ sec. 6, T. 35 N., R. 1 E., this is seen to be underlain by a bed (thickness unknown) of brown drusy dolomite, such as characterizes the typical Potosi. In the absence of fossil evidence, this might be assigned to either formation, as the cotton-rock is quite as foreign to the typical Potosi as the dark drusy rock is to the Derby-Doerun. This alternation of beds suggests conformable gradation, but the evidences pro and con are more completely summed up, under the "age and correlation" of the Derby-Doerun, where the unconformable relations are clearly brought out. Very similar fine-grained argillaceous dolomites are also exposed along the creek in the E. ½ sec. 24, T. 36 N., R. 2 E., possibly rather low in the Potosi, though because of the complex faulting in this area, their precise horizon could not be determined.

In cliff exposures of the Potosi, bedding planes are seen to be few, widely spaced, and rather irregular or undulatory (Pl. XIII, A). On gentler slopes, the formation not uncommonly outcrops in pinnacles (Pl. XIV, A), that closely resemble those of the Eminence, except that they are smoother and more rounded. Locally, well-bedded, even thinly-bedded phases have been noted. This is particularly true of the base of the formation on Cub and Trace Creeks, in the southwest portion of the quadrangle. Rather thin-bedded phases were also noted along the creek in the E. ½ sec. 24, T. 36 N., R. 2 E.

The weathered surface of the outcrop is usually rather smooth, sometimes slightly pitted, and very rarely granular or sandy-appearing.

Sandstone and shale beds are conspicuous by their absence from this formation, not a single one having been noted within the limits of either quadrangle. Some sandstone in the soil was observed in tiff (barite) pits in the SE. ¼ sec. 33, T. 38 N., R. 2 E., the horizon of which may possibly be in the Potosi, but it is more likely that it is residual from some higher horizon.

Probably the most striking single characteristic of the formation is the abundance of druses. These, in their most typical development, consist of irregular large and small masses of banded chalcedony coated on the convex surfaces with quartz crystals.

The chalcedonic banding is usually parallel to notably botroyoidal surfaces, the individual bands varying in thickness. What appear, with the naked eye, to be separate and distinct bands, are themselves resolved, by magnification, into still more minute layers. In some cases, the bands of chalcedony are separated by layers of minute quartz crystals, but more commonly the quartz-crystal layer is limited to one surface only of the chalcedonic material. Fourteen distinct bands were counted with the naked eye, in a layer ¼-inch thick. Upon magnification, one of these proved to consist of quartz crystals, standing at right angles to the banding. A single one of these 14 layers was resolved, with a lens, into 7 thinner bands.

The layers range in color from white through various shades of red, brown and purple. When broken, many of the druses show very white botryoidal surfaces. The crystals of the quartz coating range from microscopic up to a half-inch or more in length, and more rarely aggregate 2 or 3 inches in thickness. Though the crystals are commonly clear and glassy in appearance, they may range from milky white through shades of red, purple, and brown.

In general, the darker colored the dolomite, the more extreme the development of the druses. It is also very noteworthy that on steep slopes, and in cliff exposures, druses are sparingly developed, and are commonly small. On more gentle slopes, they become more abundant, though large ones are rare in unweathered outcrops. Where deep residual soils are the rule, the druse shows its most extreme development, and road excavations that cut into badly decayed brown Potosi dolomite, show it to be honeycombed, and in places almost completely replaced, with great masses and ledges of druse (Pl. XIII, B). This condition would seem to indicate that the development of the druse is chiefly a weathering phenomenon; and such a conclusion is borne out by the fact that deep drilling and mining operations reveal rock only slightly drusy, except along openings such as enlarged joints or other solution channels, where druse seems to become more abundant. It is believed that during the weathering process, silica already present in the formation in disseminated form is gradually segregated into druse on the exposed surface. Why it should form as druse in the Potosi, and as chert in the Eminence, is not understood.

Locally the Potosi druses are small, and sparingly developed, even where the dark color and foetid odor are pronounced. This is particularly true of the upper 100 feet of the Potosi in the NW. ¼ sec. 28 and the SW. ¼ sec. 21, T. 38 N., R. 1 E. The Potosi is also much less drusy in northern Wayne County, near Patterson and Piedmont, than in the Potosi quadrangle.

That some of this druse was formed very early in the geologic history of the region, is clearly shown by the fact that in the St. Francois Mountains where the Gasconade rests directly on the Potosi, the basal conglomerate in places yields pebbles of perfectly-rounded and water-worn Potosi druse, the silification of which must have been completed during the pre-Gasconade erosion interval. Such conglomerates have been noted as float at the Gasconade-Potosi contact in the southwest corner of sec. 27, T. 33 N., R. 1 E., and in the saddle in the extreme northeast corner of the same section. They have not been noted in place. The facts previously cited, however, would certainly seem to indicate that druse formation is still going on with the progressive weathering of the Potosi dolomite, and that a large part of the druse seen on the present erosion surface is of recent origin.

A large proportion of the barite (tiff) of the Southeast Missouri barite district is produced from the Potosi formation, though considerable quantities are also secured from the base of the overlying Eminence.

Some rusty porous chert has been noted in place in the Potosi. Much of that found in the float, however, may well be residual from the overlying Eminence. There does not thus far seem to be much possibility of distinguishing between the residual chert of the two formations, except in cases in which the Eminence cherts are fossiliferous. Cherts with scattered pellets resembling oolites, only larger, occur near the Potosi-Eminence contact, but are probably Eminence. At a single locality, a fragment of black chert was found attached to a typical Potosi druse in place, in the W. ½ sec. 19, T. 36 N., R. 3 E. Black chert is also known in the Eminence.

The soil from the weathering of the formation is characteristically a deep red, rather sticky clay, locally termed "tallow-clay." Very similar red clay results from the weathering of the overlying Eminence, but is rare throughout the area of the Gasconade, though not unknown. On the whole, the soils from the Potosi and Eminence are hardly to be distinguished, except through the presence or absence of the typical Potosi druse, or the characteristic Eminence chert.

At the barite pits near Westover, in Crawford County, the country rock seems to be Gasconade, though the barite is there associated with "tallow-clay" as red and sticky as that from the

Potosi or Eminence formations. As a rule, however, the soils from the Gasconade are more yellowish-brown than deep red.

Two samples of the Potosi, one from about the middle of the formation, the other from near the top, were analyzed, and the results are presented in the table on page 70. They are both essentially dolomites. The low silica content is particularly conspicuous, especially in a formation that yields such large quantities of druse and chert during weathering.

Topographic expression.—Much of the area immediately underlaid by the Potosi is characterized by very rugged topography, with deep narrow valleys, steep rocky hillsides, and narrow ridge tops. The soils are for the most part stony, and but little of the area is suited to cultivation, except the narrow strips of flood plain, along the larger streams. To the north, in the De Soto quadrangle, between Shibboleth and Fertile, and to the east in the Bonneterre quadrangle, in the vicinity of Mineral Point and Cadet, certain of the uplands on the Potosi formation are sufficiently open and rolling to permit of considerable farming.

Stratigraphic relations.—As already pointed out there is no evidence, within the confines of the Potosi quadrangle, to indicate that the contact between the Derby-Doerun and Potosi is anything but a perfectly conformable gradation. However, a larger view of the relations, throughout the St. Francois Mountain area, gives clear evidence of an unconformity, with Potosi resting on Davis and on Bonneterre.

The relations with the overlying Eminence are much more easily made out. At numerous localities in the vicinity of the town of Potosi, good sections are exposed across the contact, and show it to be a perfectly conformable gradation. As the upper limits of the formation are approached, the deep brown color gradually gives way to lighter shades, not uncommonly with a mottled phase, consisting of light brown splotches, on a background of gray.

With the change in color from brown to gray, comes an accompanying gradual decrease in the size and number of druses, which are practically absent in the light gray rock of the basal Eminence, and even in some of the light brown gradational phases.

Along with the loss in color and depletion in druses, usually comes an increase in the coarseness of texture of the dolomite, the Eminence, on the average, being coarser than the Potosi.

Accompanying these changes, there is an increase in the amount of non-drusy chert, much of that in the typical Eminence being fossiliferous.

The above changes range through a thickness of perhaps 40 feet which is strictly gradational, but which is classed with the Potosi, on the basis that the brown color and presence of druses are the distinguishing feature of that formation. It is quite probable, however, that the practice in mapping has not been strictly consistent, especially as there are occasional brownish or mottled layers in the Eminence, more commonly in the creek beds, where it has been water soaked. Attention should be called, in fact, to the prevalence of dark colors in practically all water-soaked exposures of all the dolomites of the area. Where color becomes a criterion in mapping, this caution is important.

Further, there are occasional druses in the Eminence some of which closely resemble those of the uppermost Potosi. Nevertheless, even though the contact is hard to locate precisely, the distinction between the main bulk of the two units is very easy to make, and they certainly constitute valid formations, the separate delineation of which makes possible much structural mapping that otherwise could never be accomplished.

Paleontology.—Fossils are very scarce in the Potosi. According to St. Clair,[1] up to the time he did his work, two imperfect cryptozoons, and one poorly preserved gastropod were the sum total of the known occurrences, which are probably of little diagnostic value.

During the course of work in the Potosi quadrangle, Mr. Jewell, one of the field assistants, collected two small and very imperfectly preserved gastropods, apparently identical forms, from undoubted Potosi in place, in the SE. ¼ SE. ¼ sec. 33, T. 38 N., R. 2 E. They appear to be internal moulds of a low-spired, loose-coiled species, very closely allied to forms found abundantly in the Eminence. They have been identified by Bridge as *Scaevogyra* cf. *swezeyi*, Whitfield.

The writer also broke out one imperfect fragment of a much larger gastropod from undoubted Potosi chert in place, near the center of the SE. ¼ SE. ¼ sec. 2, T. 36 N., R. 1 W. It is identified as the same species.

From the mottled transition beds, in this case in dolomite, the writer secured a fragment of a trilobite, identical with a

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[1]Op. cit., p. 58.

common Eminence species. This occurrence is about ½-mile southeast of the town of Potosi, on the Mineral Point road. It is referred by Bridge to *Plethometopus* sp.

Prof. Bridge found three fairly well-preserved gastropods in a typical Potosi druse at Davisville in Crawford County. They are also identified as *Scaevogyra cf. swezeyi*, Whitfield.

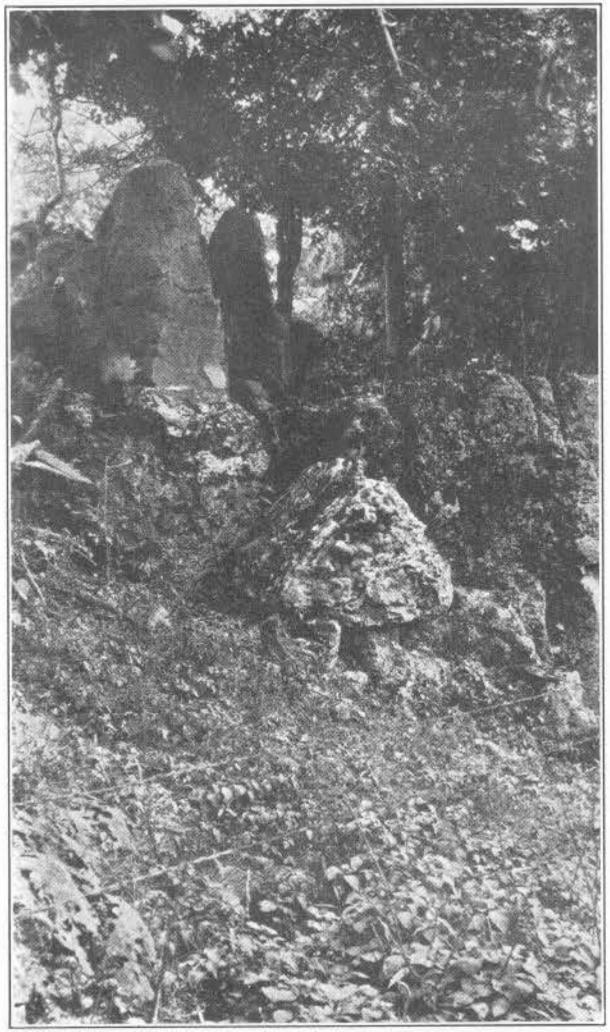
From Potosi chert one-third mile west of Piedmont, Wayne County, St. Clair obtained a very poorly preserved *Dirhachopea*, which has been made the holotype for the species *D. dubia* by Ulrich and Bridge.[1]

Age and correlation.—The upper boundary of the Potosi does not appear to have been very exactly defined, heretofore. On the map of the Bonneterre quadrangle, Buckley[2] shows the entire northwest quarter of the sheet as immediately underlain with the Potosi formation, and states in the text[3] that the Eminence "does not occur in the southern, western and eastern parts of the Ozark region which have been the special fields of study of the writer." This was soon after Ulrich had first announced the Eminence, and before there were available any descriptions of the formation. As a matter of fact, most of the hill tops in the northwest quarter of the Bonneterre quadrangle, where Buckley shows only Potosi, are actually capped with a considerable thickness (up to at least 140 feet) of very typical Eminence. At the road fork in the W. ½ SE. ¼ sec. 32, T. 38 N., R. 3 E., at least 40 feet below the top of the hill, characteristic Eminence fossils were collected from a light gray, coarsely crystalline dolomite, strictly in place. Their identification as Eminence is concurred in by Bridge of this survey, and by Ulrich of the United States Geological Survey.

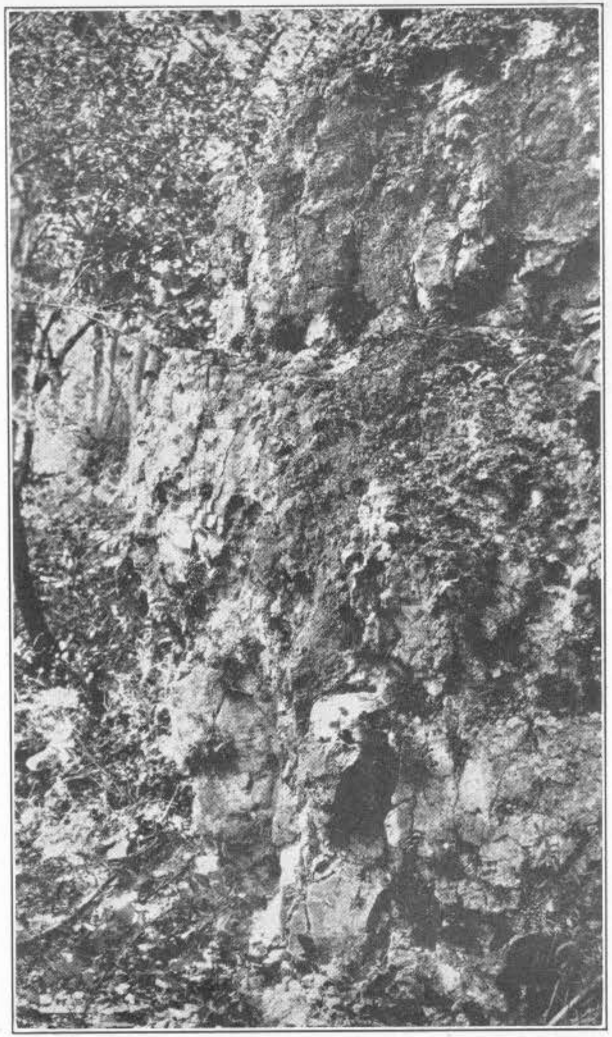
Although not separately delineated on the map, certain slightly cherty dolomites south of Valles Mines are referred by Buckley to the Proctor. It is probable that these are also Eminence and perfectly continuous with the beds definitely identified above by their fossil content.

This entirely natural error on the part of Buckley is probably in part responsible for a similar error in the mapping of Ste. Genevieve County. In that work, St. Clair[4] concluded that there was little Eminence in Ste. Genevieve County, the rather

[1]Personal communication.
[2]Buckley, E. R., op. cit., pt. 2, map.
[3]Pt. 1, p. 58.
[4]Op. cit., pp. 58-61.



A. Smooth Pinnacles of Potosi, SE. ¼ NE. ¼ sec. 4, T. 37 N., R. 1 E.



B. Very massive Gasconade on Highway 8, just off the west border of the Potosi sheet. Compare with Plate XVII, A.

abundant Eminence fauna, so he thought, being limited chiefly to residual cherts at the unconformable Potosi-Gasconade contact. Certain very light gray granular dolomites mapped as Potosi and described in the text as an unusual light-colored phase of that formation, are especially well exposed in the extreme northwest corner of sec. 25, T. 38 N., R. 6 E., where 120 feet of the material forms a bald hill on the east side of the creek. From it, in place, were collected typical Eminence fossils.

According to Buehler,[1] there is, in central Texas next above the beds that carry the "Edgewise" conglomerates (the Wilberns) certain very drusy beds. The writer has seen samples of the druse from these beds, and it is certainly highly suggestive of the Potosi. Since the next horizon above the Wilberns is the Ellenburger, this suggests a possible correlation of the Potosi with beds low in the Ellenburger limestone.

None of the fossils found thus far in the Potosi are of much diagnostic value. In the Revision,[2] Ulrich correlated the formation with the Potosi of Alabama, now known as the Bibb[3] dolomite. Since both formations are essentially unfossiliferous, they were correlated on similarity of stratigraphic position. In his most recent unpublished correlation table, the Potosi is placed as the equivalent of what he has called the Fort Sill limestone and Royer dolomite of Oklahoma; of the Mendota of Wisconsin; and of the Brairfield of the Appalachian Valley. The Bibb, on the contrary, is now placed as a partial equivalent of the Eminence. The Potosi constitutes the lowermost formation of Ulrich's Ozarkain System.

Eminence Dolomite.

Name.—In 1905, the Eminence formation together with the Potosi, as that unit is now defined, were still included by Ulrich[1] in the Gasconade, a term proposed by Nason[2] for "the great series of limestone beds, interstratified with thin beds of sandstone, which underlie the Roubidoux sandstone." Nason quite correctly recognized the widespread distribution and importance of the "Second Sandstone" or Roubidoux, as he called it, throughout the Ozarks, though he was mistaken in assuming

[1]Buehler, H. A., Personal communication.

[2]Ulrich, E. O., Revision of the Paleozoic Systems; Bull. Geol. Soc. America, vol. 22, 1911; pl. 27.

[3]Geological Survey of Alabama, Special Report No. 14; The Geology of Alabama, 1926, pp. 83-84.

it to be the equivalent of the First (St. Peter) sandstone. It is evident that he intended to limit the top of the Gasconade at its contact with the overlying Roubidoux, and apply the term to the dolomite beds outcropping so prominently on Gasconade River. The base, he left in doubt. Ulrich, in 1905, made the base of the Gasconade the contact with the top of the Elvins, of which the Derby-Doerun is the highest member.

In 1908, Buckley's report[3] defined the Potosi, which was split off the base of the Gasconade of Nason and Ulrich, and although Buckley included the Eminence with the Potosi, on the map of the Bonneterre quadrangle, this was done unwittingly, since in his text he clearly indicates the position of the Eminence between the Potosi below and the Gasconade above. At that time, apparently, Ulrich had just made the separation, and these reports of Buckley's seems to be the first reference in print to the newly separated unit. In 1911, Ulrich[4] first described, very briefly, the Eminence formation as "a very cherty dolomite, ...the interval between the top and bottom being not less than 200 feet in Shannon County." The name, of course, is derived from the town of Eminence, the county seat of Shannon County.

Distribution.—On the Potosi quadrangle, the Eminence has the greatest surface distribution of any of the formations, the VanBuren-Gasconade and Potosi following in the order named. In the immediate vicinity of Potosi, and for some distance to the northwest, the valley bottoms are floored with the Potosi formation, and the intermediate slopes and all but the very highest hills are capped with Eminence. It also has an extensive development in the vicinity of Palmer, where, as a result of complex faulting, the Potosi and Eminence are intimately intermingled, in a very confusing way. The total outcrop of the Eminence, on the Potosi quadrangle, probably slightly exceeds 70 square miles, or nearly one-third of the quadrangle.

Little if any Eminence is exposed on the Edge Hill sheet. Over most of the sheet, the formation, if it was ever laid down,

[1]Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, no. 267, 1905.

[2]Nason, F. L., Iron ores of Missouri; Geol. Survey of Mo., vol. II, 1892, pp. 114-115.

[3]Geology of the disseminated lead deposits of St. Francois and Washington Counties; Mo. Bur. Geol. and Mines, 2nd ser., vol. IX, p. 51. See also Buckley, E. R., Am. Min. Cong. Rept., Proc. 10th Ann. Session, 1907, p. 286

[4]Ulrich, E. O., Revision of the Paleozoic Systems; Bull. Geol. Soc. America, vol. 22, 1911, pp. 630-631, and tables.

was thoroughly stripped off, in the pre-Gasconade interval of emergence and erosion. It is only on the extreme west side of the sheet that we may expect to find any of the formation wedging into the section, probably in very irregular fashion. No Eminence has been shown, on the quadrangle, though it is probable that some of the residual cherts of the west portion of the area mapped as Gasconade may include some of that formation. If so, however, the quantity is very small. In the SW. ¼ sec. 31, T. 35 N., R. 2 E., in a cut along Highway 32, very rusty cherts that have a strong Eminence aspect yielded a small collection of fossils that are quite certainly Eminence. On the entire Edge Hill sheet, this is the only patch of residual chert that can with any confidence be referred to that formation. It probably occupied a sink structure on the pre-Van Buren erosion surface.

Thickness—Because of the unconformity between it and the overlying Van Buren, the Eminence is distinctly variable in thickness. Ulrich[1] assigns to it over 200 feet in Shannon County, and Bridge[2] reports a maximum of 250 feet, along Current River. On the Potosi quadrangle, the maximum thickness seems to occur in the northwest, where it varies between 160 and 200 feet, with an average of perhaps 175 feet. Farther east in the vicinity of Potosi, the average seems to lie between 120 and 160 feet.

Drilling in progress at the time this report went to press, gives additional data on the thickness of the Eminence.[3] Several holes in the vicinity of the Big Bill Mine, in sec. 24, T. 37 N., R. 1 E., start on Eminence, and pass out of that formation into undoubted Potosi at depths varying from 150 to 175 feet. The writer established this contact by careful examination of cuttings from five different holes. The variation in depth to the Potosi is owing to the varying elevation at the curb of the wells. The holes start only slightly below the base of the Van Buren, and the entire thickness of the Eminence in this locality is clearly not much over 175 feet.

South of the Palmer fault, however, the thickness suddenly becomes very erratic. At one locality, there may be as much as 140 feet of it present, and a few hundred yards away, patches of mixed Van Buren-Gasconade float may rest directly on Potosi. It was a considerable time after the mapping was started before the identity of these patches of float on the Potosi was recog-

[1]Ulrich, E. O., loc. cit.
[2]Personal communication.
[3]Information made available through the courtesy of T. J. Mateer.

nized. At many places, however, they have yielded good *Cryptozoons*, and more rarely other fragmentary fossils, so that there can be no doubt of their horizon.

At this stage in the field work, the importance of the unconformity at the base of the Van Buren was not suspected, and various explanations were sought, for the anomolous position of these patches of float. The first was that they might be Tertiary gravels containing Van Bureu and Gasconade material. Their very fresh and unworn appearance, and the lack of other debris among them soon caused this explanation to be discarded.

Another suggestion was that they might represent old sinks, into which overlying strata had been dropped from higher levels. This view was accepted for some time. However, as the work was carried south and east into and across the heart of the St. Francois range, it was soon seen that very large areas of this float rested directly on the Potosi, or even overlapped across onto the Bonneterre. It is true that no outcrops of Van Buren or Gasconade were actually seen in this relation, but the large size, great thickness, and general regularity of elevation of this mantle of float left no reasonable doubt that it actually overlapped and was deposited on the Potosi and older beds.

The fact that north of the Palmer fault, the Eminence is regularly more than 150 feet thick, whereas, immediately south of that line, it is extremely variable, and within ten miles south of the fault zone, disappears entirely, strongly suggests that there was a belt of post-Eminence, pre-Van Buren faulting, along the main line of the Palmer disturbance. Of course, it must be understood that many of the faults now in evidence belong to a later period of deformation which involves beds as young as the Roubidoux and perhaps very much younger. That a period of later deformation should thus follow somewhat closely a zone of earlier disturbance is not at all surprising, and the assumption of a period of post-Eminence and pre-Van Buren sharp deformation, probably involving faulting, certainly most satisfactorily explains this abnormally sudden dropping of the Eminence out of the section. Along this zone, the north side would, of course, be the dropped block, with the Eminence preserved in nearly normal development. The south side, upthrown but with some minor faulting, would account for patches of Eminence on the upraised side near the fault, and its total elimination but a short distance south.

Lithologic character—Dolomite.—The Eminence consists essentially of light gray, moderately granular, rather massively-bedded cherty dolomites.

The color of the formation is distinctly lighter than that of the Potosi. On the average it is light gray to almost white. Dark gray is rare, and brown almost unknown, whereas the Potosi is dominantly brown, less commonly gray. Locally the Eminence is splotched with green, probably from glauconite, though much less commonly so than the Bonneterre, which it much resembles in color and texture.

The Eminence is, on the average, more coarsely crystalline than either the Potosi or the Gasconade, and much coarser than the Van Buren. On deeply weathered surfaces, it commonly looks "sandy," from the abundance of coarse, loosely-aggregated dolomite crystals. The only other formation in the area that shows this characteristic at all extensively is the Bonneterre.

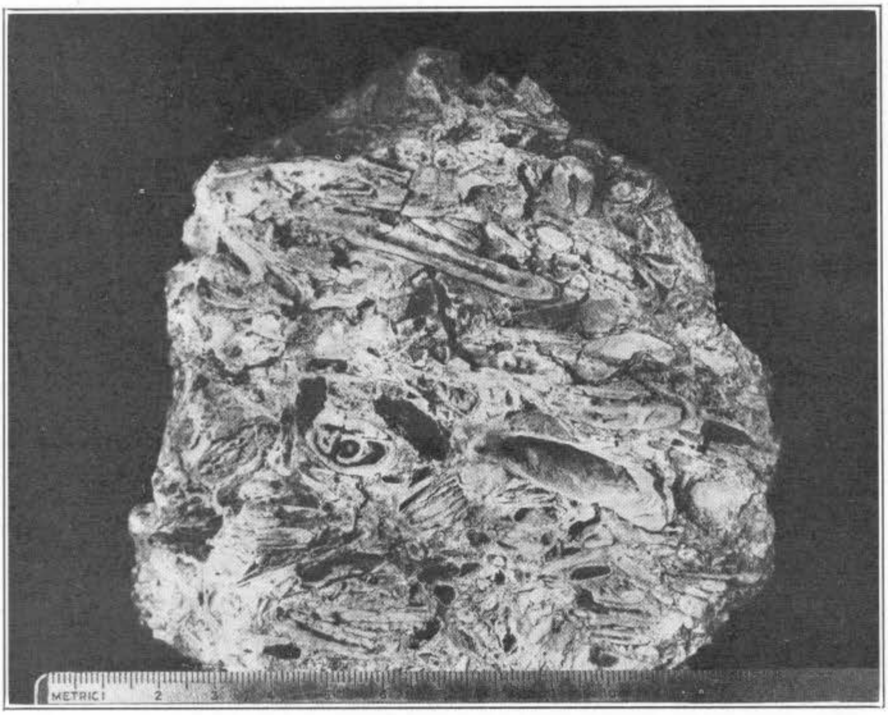
The lower part of the formation is particularly massive, and outcrops in irregular crags and pinnacles, somewhat like those of the Potosi, except that they are more rugged and cavernous (Pl. XVI, B), while the pinnacles of the Potosi are more rounded and smoother (Pl. XIV, A). The surfaces of the Eminence crags are usually rough and pitted. The crag and pinnacle outcrop of the Eminence is especially well shown north of the road on the south slope of the hill near the center of the S. ½ sec. 33, T. 38 N., R. 1 E. Other typical outcrops occur in the E. ½ SE. ¼ sec. 34, T. 38 N., R. 1 E.; at the common corner of secs. 26, 27, 34 and 35, T. 38 N., R. 2 E.; and west of the creek in the NE. ¼ sec. 23, T. 36 N., R. 2 E. These should be compared with the outcrops of the Proctor between the postoffice and the lake at Hahatonka (Pl. XVI, A). The upper part of the Eminence is more thinly and regularly bedded, and in that respect somewhat resembles the Gasconade, though on the average, the Eminence is much less perfectly bedded than the higher formation, this being one of the helpful field characteristics for distinguishing between the two.

At a few localities, curved markings, believed to be cryptozoons, are clearly seen in the dolomite, particularly where the road crosses the 920-foot contour in the E. ½ NW. ¼ sec. 24, T. 36 N., R. 2 E. Somewhat similar markings in the dolomite occur 137 feet above the creek in NE. ¼ NE. ¼ sec. 5, T. 37 N., R. 1 E. They are mostly easily seen at the road fork on Highway 21, in the E. ½ NE. ¼ sec. 26, T. 37 N., R. 2 E., about 2½ miles south of Potosi. They are less perfect here, however, than in the other localities cited. They are not silicified, in any of these occurrences.

Shale and sandstone.—Shale beds are very rare in the Eminence. One thin green seam, perhaps four inches thick, is exposed in a road cut, about 60 feet above the base, at elevation 990 feet, along the main road, about two miles due northwest of Potosi. At only one point was argillaceous dolomite, approaching that known locally as "cotton rock," noted. It occurs in the NW. ¼ NW. ¼ sec. 35, T. 38 N., R. 2 E., on the south side of the hill, about at the Potosi-Eminence contact, and it is uncertain to which formation it really belongs, since it is distinctly foreign to both. It looks much more like basal Van Buren, but since Eminence fossils are found nearly 100 feet higher on the hill to the north, only some very unexpected structural relation could possibly cause Van Buren to outcrop here.

Sandstone beds have rarely been observed in the Eminence formation within the Potosi or Edge Hill quadrangles. About in the center of the W. ½ sec. 3, T. 37 N., R. 2 E., in the road ditch along the main road at about 940 feet elevation, perhaps a foot of reddish sandstone occurs, which is probably in place, and interbedded in the lower few feet of the Eminence. This is at the same locality where the shale of the preceding paragraph is exposed.

Chert.—Chert is a very abundant constituent of the formation, occurring as beds, and also as irregular, branching masses. In general, the cherts of the Eminence are rusty, porous, and old-looking, in contradistinction to the remarkably white, dense, fresh-looking varieties of the overlying Van Buren. This contrast is of much diagnostic value in the rapid field separation of the formations. There are, to be sure, some very dense white cherts in the Eminence, and some porous, rusty ones in the Van Buren. For instance, along the old Potosi-Caledonia road, at an elevation of about 1030 feet, just down the hill from bench mark 1110, near the center of the SE. ¼ sec. 2, T. 36 N., R. 2 E., is a ledge of dense white chert, with structure resembling cryptozoons, that was mistaken for Van Buren, although Eminence fossils were later taken in place, from just above the bed in question. Nevertheless the contrast in chert float, on passing from the Eminence to the overlying formation, is ordinarily a very striking one, most of the Van Buren hillsides being literally strewn with small fragments of dense white chert.



A. Eminence chert with flat pebbles, ¼ mile east of Stone Hill, in Dent County.

B. Same as above, with the pebbles leached out, NW. ¼ NE. ¼ sec. 34, T. 29 N., R. 4 W., Shannon County.

A fairly common type of chert characteristic of the Eminence may be described as branching, or perhaps as tubular, with the columns between the openings faintly banded, suggesting somewhat the banding in the Potosi druses. This variety breaks up into masses an inch or two in diameter, and at many places, the red residual clay is literally packed with the fragments.

Some dense black chert occurs in the Eminence formation. It is fairly abundant in the float on the hillside in the NE. ¼ NE. ¼ sec. 34 and the NW. ¼ NW. ¼ sec. 35, T. 38 N., R. 2 E., just above the Potosi contact. It was also noted at several other localities, a few of the more striking of which are listed herewith; Near the center of the SE. ¼ sec. 15, T. 36 N., R. 2 E., on the tip of the hill at an elevation of about 990 feet; along the Potosi-Caledonia road, near the center of the NE. ¼ sec. 23, T. 37 N., R. 2 E.; and on the isolated knob, in the SE. ¼ sec. 2, T. 37 N., R. 2 E. Similar black chert is also known from the Potosi; but is exceedingly rare, if present at all, in the higher formations.

Oolitic chert, which is so highly characteristic of the Roubidoux and Gasconade, is less common in the Eminence. A very small lens of typical silicious oolite was found in place over 100 feet below the top of the formation, at the Jacks Fork bridge, near Eminence, in Shannon County. Considerable oolite, usually very rusty in color, and carrying fragments of fossils, occurs near the top of the formation.

A peculiar chert with pellets, or oolities, present, but few in number, less closely spaced and somewhat larger than ordinary oolites, though showing the same concentric structure, occurs near the Potosi-Eminence contact at several places, especially in the NE. ¼ NE. ¼ sec. 34 and the NW. ¼ NW. ¼ sec. 35 ,T. 38 N., R. 2 E., and also in the SE. ¼ sec. 2, and the center of the N. ½ sec. 4, T. 37 N., R. 2 E. This pellet chert may possibly occur in the top of the Potosi, but is believed to be characteristic of the base of the Eminence.

Locally over the Eminence areas, there occur large blocks of chert, some of them several feet in diameter, usually gray on the weathered exterior, and somewhat rusty and porous, even on freshly-broken surfaces. A few of these chert masses have yielded typical Eminence fossils. Others are unfossiliferous. Similar large blocks are also strewn over the surface of the Van Buren and Gasconade, at some points, and these, too, are locally fossil-bearing, and locally not. The blocks, therefore, that are found strewn on the surface of the Eminence may be either

Eminence or higher, especially where the erosion surface coincides closely with the top of the older formation. In the absence of fossils, then, the source of these large blocks is rarely certain.

Many of the masses, especially near the Eminence-Van Buren contact, seem to consist of chert breccias, which are more probably in actual fact chert congolmerates, both pebbles and matrix completely silicified, marking the unconformable base of the younger formation on the older. If this interpretation is correct, the presence of Eminence fossils would prove their Eminence age, only in case the fossils occur in the matrix, and not in the pebbles. This might, in some cases, where the chertification of the matrix is very complete, be difficult, or even impossible to determine, and might easily lead to incorrect inferences as to the age of the chert masses.

An exceptionally fine exhibit of these large cherts, presumably Eminence in age, may be seen along the north side of the Belgrade-Palmer road in the SE. ¼ NW. ¼ sec. 21, T. 36 N., R. 1 E. Another good occurrence was noted just south of the old Palmer-Potosi road, where it goes up the high hill in the W. ½ sec. 8, T. 36 N., R. 1 E.; and still others in the N. ½ sec. 14, T. 36 N., R. 2 E.; the NW. ¼ sec. 26 and the N. ½ sec. 27, T. 38 N., R. 2 E.

A peculiar type of chert has been noted at several localities, strewn over the surface of the ground, on outcrops of Eminence, but usually at, or only slightly below, the base of the Van Buren. It consists of a matrix of chert, containing numerous disc-like bodies of chert, ranging from ¼-inch to 1 inch in diameter, and from $^1/_{16}$-inch to ¼-inch in thickness. Whether they are pebbles, or concretions, is somewhat uncertain. Broken surfaces of some of the discoidal bodies show concentric banding, resembling concretionary structures, but it is possible that this banding is a weathering phenomenon, as such banding is sometimes produced in pebbles, during weathering. Not uncommonly a difference exists in resistence to solution, in some instances the matrix being partly removed, so that the discs stand out in relief (Pl. XV, A). In other cases the matrix has resisted, the discs being wholly or partly removed, leaving discoidal cavities (Pl. XV, B). This peculiar type of rock has a wide distribution. A list of the more important localities is appended, herewith:

SE. ¼ sec. 33, T. 38 N., R. 1 E., along S. slope of hill, elev. 1000 ft.
¼-mi. W. of Stone Hill, Dent Co., 60 feet above highway, on N. side.
Center W. ½ sec. 36, T. 36 N., R. 1 W., west slope of 1220-foot knob.
1/8 to ½-mile east of Berryman, Washington Co., on hill 75 ft. above highway.

Center sec. 2, T. 39 N., R. 3 W., near crest of hill east of Blue Spring. Also reported by Bridge from Eminence quadrangle.

At no locality has this peculiar chert been seen in situ, and its horizon may be either topmost Eminence, or basal Van Buren. It is very different, however, from the usual basal conglomerate of the Van Buren, and to date, does not seem ever to have been found above the Eminence-Van Buren contact, where that plane has been definitely located, a fact which seems to point to its Eminence age. Unsilicified flat-pebble conglomerates, of which these are probably the chertified equivalents, are reported by Bridge from the upper part of the Eminence, in the Eminence-Cardareva area.[1] A very similar type of material has been collected from the Roubidoux. The similarity in form of these cherts to the famous flat-pebble and edgewise conglomerates of the Davis is somewhat suggestive of a common origin.

The soil from the weathering of the Eminence is essentially like that from the Potosi, consisting of a deep red, very sticky clay. It differs from the deep red Bonneterre soils, in that the latter contain little or no chert, and may be distinguished from the typical Potosi red clays by the abundance of chert and the absence of druse. It is in striking contrast to that of the Van Buren, which, in the area of these quadrangles, is more commonly gray or yellowish-brown.

Two samples of the Eminence, one from near the base, the other from near the top of the formation, have been analyzed. Results are presented in the table on page 70. The rock is essentially a dolomite. It shows the lowest content of silica of any formation analyzed in the course of this work, in spite of the fact that on the weathering surface, it produces much chert. The two samples, so widely separated stratigraphically, are remarkably similar in composition.

Topographic expression.—With but few exceptions, the area underlain by the Eminence is rugged and stony, and very poorly suited to agriculture. In fact, the topographic expression of the Potosi and the Eminence are nearly identical.

Stratigraphic relations.—Attention has already been called to the fact that all available evidence points to perfectly conformable gradation between the Potosi and the Eminence.

[1]Geology of the Eminence-Cardareva quadrangles; Mo. Bur. Geol. and Mines, in press.

At the base of the Van Buren, on the other hand, occurs one of the most conspicuous unconformities within the entire Cambro-Ordovician of the Ozark region.

The most outstanding evidence for this unconformity is the way the Van Buren formation laps across the truncated older beds from Eminence down to Bonneterre. Unfortunately, in the area of this great overlap, outcrops of the Van Buren and Gasconade are not found, but the widespread distribution of heavy chert float, resting upon successively older and older beds, as the core of the St. Francois Mountains is approached, seems to be wholly convincting.

Facts have already been cited which seem to suggest very strongly that in the interval between the Eminence and the Van Buren, there was faulting along the present trend of the Palmer fault zone, the south side being raised, and the Eminence largely planed off, before the younger beds were deposited. Evidence presented elsewhere (p. 181) also suggests pre-Van Buren movement and planation along the Black fault.

Over the area from Caledonia south to Piedmont, and from Lesterville east to Fredericktown, the Eminence seems to be wholly missing, and the younger float rests extensively on the Potosi, and more locally on older beds, even down to the Bonneterre; the latter situation being especially conspicuous in the vicinity of Higdon, just north of the large granite knob, in sec. 5, T. 33 N., R. 8 E., and at several points immediately north and west of Buckhorn, in Madison County. Heavy Van Buren-Gasconade float also rests widely on Bonneterre along Tom Sauk Creek, in the southeast portion of T. 33 N., R. 2 E., on the Edge Hill sheet.

Throughout the area of the Potosi quadrangle, the base of the Van Buren is marked by a very persistent, though thin and inconspicuous, basal conglomerate. This conglomerate is very well shown, in place, in the bed of the creek, north of the road, at the east end of the prominent knob, near the center of the N. ½ sec. 23, T. 37 N., R. 1 E. At this point the underlying beds cannot be seen, but similar conglomerate is well exposed along the north side of Highway 8, just east of a house with a high concrete retaining wall, near the center of the E. ½ sec. 23, T. 37 N., R. 1 E. Here perhaps 6 or 8 feet of the underlying Eminence is exposed. The same conglomerate is also exposed in place, at about elevation 1090 feet, on the north side of an old road, near the center of the east line of sec. 29, T. 37 N., R. 2 E.

Another well-marked occurrence is in the small gully heading north of the road, in the NW. ¼ NW. ¼ sec. 13, T. 36 N., R. 1 E.; and still another in the N. ½ NW. ¼ sec. 18, T. 36 N., R. 2 E. West of the quadrangle it is exposed in place where Highway 8 crosses Huzzah Creek, back of the house east of the creek and north of the road, about 90 feet above creek level, in the SE. ¼ sec. 25, T. 38 N., R. 3 W.; also about a mile east of Steelville, just above the creek bed, and south of the road, in the SW. ¼ sec. 27, T. 38 N., R. 4 W.; also 200 yards north of the Benton Creek School on east side of the road, near the center of sec. 5, T. 36 N., R. 5 W. The conglomerate also occurs on the tip of the hill between Indian and Little Indian Creeks, at their junction, where it is perhaps 50 feet above water level, in the SW. ¼ sec. 32, T. 41 N., R. 1 E.

Careful search, at almost any locality where the Eminence-Van Buren contact outcrops, will yield blocks of the conglomerate among the float. The pebbles consist of well-rounded fragments of chert, commonly from ¼ to ½-inch in diameter, but more rarely reaching 2 or 3 inches. The entire bed is not often more than 3 or 4 inches thick. Most of the pebbles are white or light gray, but black cherts are fairly common.

Where outcrops of the horizon are exposed, the matrix is usually limestone, but where the material has been seen as float the matrix is usually silicified.

Paleontology.—The cherts of the Eminence are usually fossiliferous, locally highly so. Except in the cherts, organic remains are very rare, an occasional silicified gastropod being found attached to the weathered surface of the dolomite, in place. Most of the faunules collected are from the residuum, and any study and comparison of published lists must take this fact into account, since such collecting involves grave danger of mixtures with the forms from the overlying beds.

Of course all possible precautions were taken against such a contingency, but in spite of the greatest care, some of the first collections seem to have been mixed. Apparently, this was the cause of the earlier view that cephalopods were an element in the Eminence fauna. A very careful study, however, of all the collections made has thus far failed to reveal a single case of a cephalopod associated, in an individual fragment of chert, with other undoubted Eminence forms. As a consequence, it is now quite certain that the Eminence faunas carry no cephalopods.

Trilobites and gastropods furnish by far the larger number of species. The trilobites vary greatly in size. Individual heads range from not over $^1/_8$-inch to almost 1½ inch in diameter. High, smooth, frequently more or less globose glabellae are the rule, and pustulate forms are much rarer than in the younger formations. In general, the trilobites seem to have Cambrian rather than Ordovician affinities.

The rarity of gastropods in beds older than Eminence, and their abundance higher in the section, serve to link that formation more closely with the younger units. And it is true that certain of the genera are very closely related to Van Buren and Gasconade forms. There is, however, a complete absence of *Ophileta*, a genus very characteristic of the Gasconade.

Inasmuch as many of the genera and most of the species diagnostic of the Eminence are as yet undescribed, faunal lists of significance cannot be given. At the present time, Ulrich is preparing a paper on the trilobites, and Ulrich and Bridge one on the gastropods of the Ozarkian and Canadian, in which most of these new forms from the Eminence are to be described. Lists of names would be more or less meaningless, until these descriptions appear, and would only serve to embarrass those authors, in cases where the names now proposed prove to be unsuitable. It seems most desirable therefore, not to attempt any further discussion of Eminence paleontology, other than to list some of the more important localities.

At the road fork, elevation about 970 feet, in the W. ½ SE. ¼ sec. 32, T. 38 N., R. 3 E., on the Bonneterre quadrangle, silicified gastropods were taken from an outcrop of dolomite, in place. Ulrich pronounced the forms typical Eminence. The writer would place the Potosi-Eminence contact about 40-50 feet lower, giving at this point not far from 100 feet of Eminence beds. This is not a good locality for collecting, but is significant, for two reasons. First, it establishes definitely the Eminence age of certain beds mapped formerly as Potosi;[1] and second, it is one of the few localities in which Eminence fossils have been found in place.

About 100 yards northwest of the southeast corner sec. 14, T. 37 N., R. 1 E., just above a group of old test pits, silicified gastropods were taken in place from dolomite outcrops. These

[1]Mo. Bur. Geol. and Mines, 2nd ser., vol. IX, pt. 2, map of Bonneterre quadrangle.

are about 10 feet below a thin, very locally developed sandstone believed to mark the base of the Van Buren formation. This collection is significant, also, for two reasons. First, it was secured in place; and second, it comes from the very top of the Eminence, and, according to Bridge, is rather more closely related to the Proctor fauna than are many of the Eminence collections.

A faunule very similar to the one mentioned above was collected in residual chert, just below a very abnormal development of Gunter sandstone, at Shady Dell Spring, southwest of Greenville, Wayne County, just west of the abandoned railroad bridge across Castor River. This faunule, too, is more closely related to the Proctor than are most of the collections from the Eminence.

According to Bridge, who has examined all available collections, there appear to be at least two fairly distinct and characteristic faunas in the Eminence formation. The lower one of these is dominated by very abundant specimens of a trilobite with an extremely high, nearly globose, very smooth glabella, belonging to the genus *Stenopilus.* For convenience it has been referred to as the *Stenopilus* fauna, but further study shows that Stenopilus runs through the upper fauna, as well. For the time being, therefore, this lower horizon will be referred to as the main faunal zone. One of the best collections that the writer has made from this horizon occurs west of the Edge Hill sheet, in cherts, presumably very nearly in place, about a mile northeast of Bixby, Iron County, on the old Bixby and Goodwater road, at an elevation of about 1300 feet. At this point, the fauna occurs about 80-100 feet above the Eminence-Potosi contact. In this section the higher horizons of the Eminence seem to be missing, because the interval between the top of the Potosi and the base of heavy Van Buren float seems to be only 120 feet.

On the north side of the road, back of a house with a good spring, in the SW. ¼ sec. 34, T. 33 N., R. 2 W., in Reynolds County, Eminence is exposed at creek level, and up through an interval of 100 feet. Above this is about 60 feet of covered slope, and from chert float at the very top of the hill, was made a small collection, in which *Stenopilus* is represented. This form, therefore, ranges up at least something over 160 feet above the base of the formation.

The same horizon, with the main faunal zone very well developed, occurs in Ste. Genevieve County, along the road, near the center of the south line of sec. 10, T. 36 N., R. 8 E., in beds mapped by St. Clair[1] as Gasconade, and about 100 feet above what he shows as the Potosi-Gasconade contact. The collections were made from bedded cherts essentially in place in the road ditch. Above them is a thin sandstone, without much doubt the Gunter. Evidently, the higher beds of the Eminence had been removed by pre-Gunter erosion. At this point, the Potosi-Eminence contact has not been satisfactorily established, but the fossil zone is probably about 100 feet up in the formation.

Again, very good collections were secured from the same horizon, in the road at a little spring, near the center of the NW. ¼ sec. 12, T. 36 N., R. 6 W., about ¼-mile south of Wesco, in Crawford County. At this point, the base of the Eminence is not exposed, and there is no field evidence as to the stratigraphic position of the zone within the formation.

Float bowlders about 50 feet above the Potosi contact yielded a fairly good representation of this fauna at the road fork in the W. ½ SE. ¼ sec. 32, T. 38 N., R. 3 E., on the Bonneterre quadrangle.

The same fauna is represented in collections from residual cherts, in Madison County, about ³/₈ of a mile southwest of Albright Postoffice, where the road to Gravelton climbs the big hill. The beds are Eminence down to the flood plain of Castor River, and the fossils were collected about 50 feet above the river. They are, therefore, over 50 feet above the Potosi contact, but beyond that, their stratigraphic position could not be determined.

On the Steelville and Scotia road, about ¼-mile south of the Scotia store, near the center of the E. ½ sec. 11, T. 38 N., R. 3 W., imperfect specimens of *Stenopilus* seem to be sparingly represented in a collection from residual cherts 80 feet above Huzzah Creek, and about 40 feet below the basal conglomerate of the Van Buren. The base of the Eminence is not exposed.

Definitely above the lower faunal zone, but with an interval about which, as yet, little information is available, occurs a well-marked horizon characterized by a great abundance of trilobites of the genus *Plethopeltis*, and for convenience, spoken of as the *Plethopeltis* zone.

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[1]Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, map.

A fair collection from this zone was made in residual cherts, along temporary Highway 32, at elevation 1220 feet on the first high hill west of Howe's Mill, in Dent County. This is about 150 feet above the bottom of the valley, which does not expose Potosi. As a result, it is not possible to say how much more than 150 feet the zone is above the base of the Eminence formation. It is about 30 feet below the Gunter sandstone.

About 1½ mile east of Stone Hill, Dent County, on temporary Highway 32, the same horizon also yielded excellent collecting. The section exposed is not sufficient to afford any field evidence as to the stratigraphic position of the zone, except that it is very close to the base of the Van Buren.

Near the center of sec. 2, T. 36 N., R. 2 E., at elevation 1080 feet, cherts essentially in place, yielded fossils which Ulrich in the field identified as characteristic Eminence. This is one of the few places in the Potosi quadrangle, where brachiopods were found in the Eminence formation. There are many other localities in and near the Potosi and Edge Hill quadrangles, from which Eminence fossils were collected, but it seems worth while to list only those in which collecting proved to be especially good, or the collections particularly significant.

Age and correlation.—The formation has been traced with almost perfect continuity into the Eminence of the type region in Shannon County, with which it is a unit both lithologically and faunally. In both areas, also, it occupies the interval between the Potosi below and the Van Buren above.

Its relationship to beds mapped as Proctor by Ball and Smith[1] in Miller County has long been a disputed problem in Missouri stratigraphy. The Proctor is, lithologically, remarkably like the Eminence in color, texture, massiveness of bedding, pitted weathering, and craggy character of outcrop. As a matter of fact, each resembles the other far more closely than it resembles any other formation in the entire Ozark region. To be sure, the Proctor carries very little chert, and the Eminence a great deal. What little chert the Proctor does yield, however, is very similar to that from the Eminence formation.

Both lie next beneath the Gunter sandstone. The base of the Proctor, as originally defined, is nowhere exposed. Ulrich, however, in his Revision[2] states that the Eminence is exposed

[1]Ball, Sidney H., and Smith, A. F., The geology of Miller County; Mo. Bur. Geol. and Mines, vol. I, 2nd ser., 1903, pp. 23-25.

[2]Bull. Geol. Soc. America, vol. 22, 1911, p. 630.

(beneath the Proctor?) "in some of the deep valleys near the Osage, in the northern part of Camden and the southern part of Morgan counties."

Most Missouri geologists who have seen both formations in the field, have been strongly inclined to believe that they were equivalents, but Ulrich has steadily maintained that the Proctor is younger than the Eminence. This has not been based on faunal evidence, because at the time this view was advanced, no fossils had ever been described from the Proctor. In the fall of 1922, however, Prof. Bridge and the writer made a small collection from a few feet below the Gunter sandstone, on the island at Hahatonka. In the summer of 1925, the writer discovered two additional localities, and made considerable collections, which have been augmented on more recent occasions.

The Proctor fauna, according to Bridge, is more closely related to that of the Eminence than to that of any other formation in the sequence. Particularly it shows close affinities to certain forms from the topmost Eminence collected near Shirley, and near Greenville, in Wayne County.

Although Ulrich has, at various times, expressed to the writer the belief that a hiatus exists between the two formations, there has not been found, during the field work on this problem, the slightest physical evidence that such a break exists. In fact, it is altogether probable that the two, so long described as separate formations, are practical equivalents. It is, perhaps, true that the highest Proctor is only locally present in southeast Missouri, but the main bulk of the formation, as exposed along the Niangua River, where 160 to 180 feet are known, is almost certainly to be correlated with the upper portion of the Eminence, as mapped in southeast Missouri.

McQueen[1] finds that in deep drilling in south Missouri, beds are encountered below the Gunter sandstone, and above the typical Eminence, which he correlates with the Proctor. These beds, on the outcrop, have been mapped as Eminence, and have yielded Eminence fossils. Likewise, deep drilling on the northwest flank of the Ozark dome shows undoubted Eminence of the southeast Missouri type, beneath the less siliceous Proctor. It may be shown by further detailed studies, that the two can be separated in the field, but as yet, this has not seemed feasible. If, however, the separation is ever made, it is almost certain

[1]McQueen, H. S., Insoluble residues as a guide in stratigraphic studies; Mo. Bur. Geol. and Mines, 56th Biennial Report, 1931 (published Mar., 1930).

that Eminence will not be found exclusively on the southeast flank of the Ozarks, and Proctor exclusively on the northwest, each corresponding to a hiatus on the opposite flank, but that both will be found to occur in both areas, the Proctor with somewhat the more limited distribution, as befits its position next beneath the unconformable base of the Van Buren.

The beds which in south Missouri McQueen assigns to Eminence and Proctor are in this report all included in the Eminence. They are without much doubt the partial equivalent of the so-called Proctor of the northwest flank of the dome, though it is probable that somewhat higher beds occur in the original Proctor area than any in the Eminence of southeast Missouri.

The Eminence, as mapped in the Potosi quadrangle, is the full equivalent of the beds mapped by Tarr[1] as Proctor, in Washington County. In his report, he suggests that there may be Eminence beneath the Proctor in the area, and hints at an unconformity between the two. The writer has, however, found undoubted Eminence fossils in the top of the beds mapped by Tarr as Proctor, immediately beneath the Van Buren contact. There is, then, no reason whatever for assuming two formations between the Potosi and the Van Buren, and the supposed unconformity would fall in the middle of the Eminence where there is no indication of any break. The boundary between Eminence and Proctor, if these divisions are ever made in this region, must, on faunal evidence, be drawn very near the top of Tarr's so-called Proctor, because, as pointed out above, typical Eminence fossils have been found almost immediately below the base of the Van Buren, leaving very little room for other beds, except locally.

It is interesting to note that these beds, which carry typical Eminence faunas, identified as such by Ulrich, have been assigned without question, by Tarr, to the Proctor. This in itself shows how strikingly similar the two formations must be. The chief reason for using the term Eminence, rather than the older name, is the fact that the fossils assure correlation with the type Eminence, whereas there are no described faunas from the Proctor of Proctor Creek and vicinity, and the correlation rests on lithologic similarity, and similarity of stratigraphic position.

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[1]Tarr, W. A., Barite deposits of Missouri, Univ. of Missouri Studies, vol. III, No. 1.

In the Revision[1] Ulrich reported that Eminence faunas had also been found in the lower part of the Copper Ridge of Tennessee, and in the lower part of the Oneota of the upper Mississippi Valley. In the accompanying correlation table however, the Eminence was made the equivalent, not of the Oneota, but of the Jordan. In his latest unpublished table, he indicates that his recently named Signal Mountain formation of Oklahoma is a partial equivalent, as is also the Bibb of Alabama. The base of the formation, he considers to be represented in Wisconsin by the Madison.

In the Geology of Alabama,[2] the Copper Ridge faunas are assigned a horizon *above* the Eminence and *below* the Proctor of the Missouri section. The peculiar significance of this correlation will at once be noted, in the light of the preceding paragraphs. In Ulrich's recent correlation table, however, the base of the Copper Ridge is made the equivalent of the Proctor, instead of being above that formation.

The Eminence is upper Cambrian in age, or if Ulrich's classification is accepted, Ozarkian. It forms the highest unit of the lower Ozarkian, as Ulrich now delimits that division.

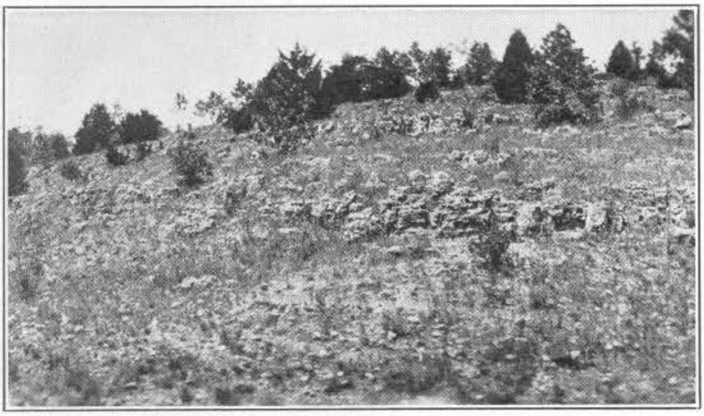
ORDOVICIAN SYSTEM.

Van Buren Formation.

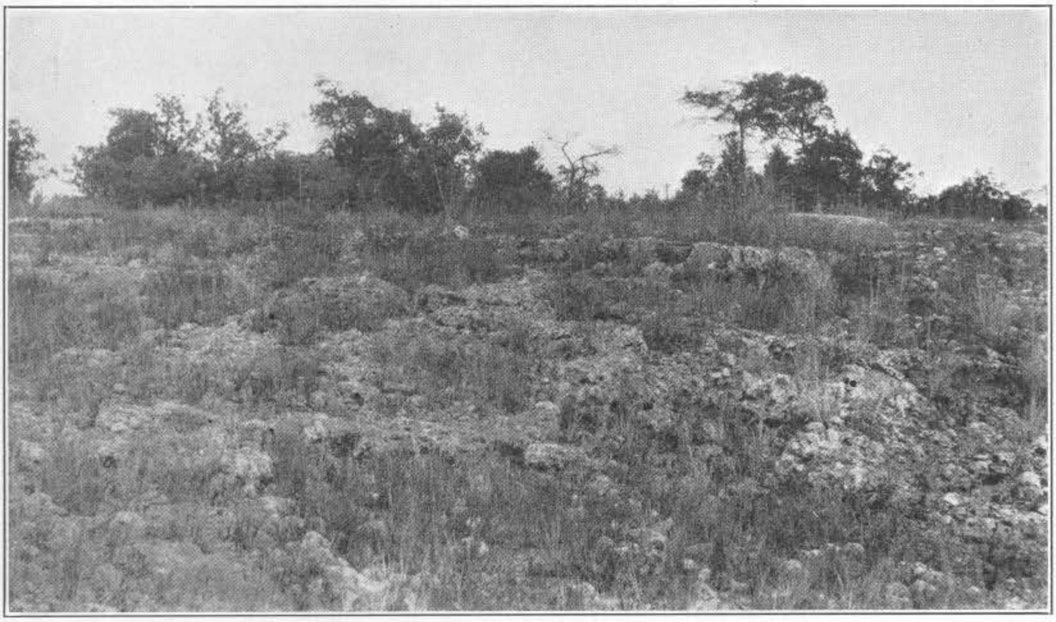
Name.—The beds herein called Van Buren are those formerly referred to by Ulrich as the Upper Eminence. Within a short time after work in the area was begun it was found that these beds were separated from the Eminence proper (until then called Lower Eminence) by a pronounced unconformity. Still further study showed conclusively that they had in general been assigned, by Missouri workers, to the lower part of the Gasconade, and this policy was followed during the course of most of the field work for this report. Ulrich, however, pointed out that these strata carried a fauna quite distinct from that of the higher divisions of the Gasconade, and insisted that the differences were sufficient on which to base a new formation. In 1923 the writer accompanied him on an extended reconnaissance trip

[1]Bull. Geol. Soc. Am., vol. 22, 1911, pp. 630-631.

[2]Adams, G. I., Butts, Charles, Stephanson, L. W., and Cooke, Wythe, Geology of Alabama; Geol. Survey of Ala., Special Report No. 14, 1926, p. 87.



A. Crags of Proctor at Hahatonka. Compare with the Eminence, below.



B. Characteristic rough pinnacle outcrop of Eminence on Highway 21, just north of Potosi. Compare with Proctor, above.

across the southeastern Ozarks. During this trip he made collections from the cherts of the strata in question along U. S. Highway 60, west of Van Buren, in Carter County, and proposed for them the name Van Buren. This term has been used by him constantly in his correspondence, and in his unpublished correlation tables, since that time. So far as known, the first reference to the name in print is by McQueen,[1] who discusses the recognition of the unit in deep drilling.

The beds in question do not outcrop at all in the immediate vicinity of the town of Van Buren, which is built on outcrops of the Eminence formation. The nearest exposures are on the tops of the nearby hills, and no good sections are known anywhere in the vicinity. Since the name has appeared in print, however, it does not seem wise to attempt to substitute another.

No exposures of the formation occur in the Edge Hill quadrangle, though the characteristic residual cherts from it are present. Even in the Potosi quadrangle good sections of the Van Buren are rare.

Since, in so much of the area mapped by the writer, both the Van Buren and the Gasconade are represented only by chert residuum, which it was practically impossible to differentiate no attempt was made to map them as separate units, but both were shown in one color, and included under the older and more widely used name, Gasconade.

The only area in the two quadrangles in which it is probable that field separation could be satisfactorily made is in the Shirley syncline, between the Shirley and Palmer faults, and in all does not embrace over a township and a half. The best sections which the writer has seen occur in Shannon County, where the beds are well exposed.

The field mapping of the Potosi quadrangle had been completed before some of the most critical data from the Eminence region became available. This in turn was followed by extensive subsurface studies by McQueen, which indicated a probability that the Van Buren and Gasconade might be separated over wide areas. Before the decision had been reached to attempt a separation in the field, the map of the Potosi-Edge Hill quadrangles was already off the press, and consequently it is impossible to show the separate distributions of the formations, on those sheets. This, however, is of comparatively small moment

[1]Loc. cit.

since the area in which separations could possibly be made is so very limited. It has been thought best, however, to give such separate descriptions of the two units as is possible. Since no satisfactory contact has as yet been drawn between the two, in any part of the Ozarks, these descriptions may overlap somewhat. It is likely to be some time, however, before another opportunity will be available, to present what is known of the distinctions between the units, and as a consequence the best descriptions possible are given herewith.

Distribution.—On the Edge Hill sheet, cherts of the lithologic type of the Van Buren occur residual, mixed with residual cherts of undoubted Gasconade, and there seems to be no question but what both units once overspread that quadrangle. Since separations were absolutely impossible, however, the distribution of the two, undifferentiated, is discussed, under the younger formation. In the Potosi quadrangle, practically all of the Gasconade shown east of the 50-minute meridian is residual, and cannot be separated, but west of that meridian, and between the Shirley and Palmer faults, the basal portion of what is shown as Gasconade comprises the beds now split off and designated under the name Van Buren.

In this area, it is probable the two could be mapped separately, but any boundary drawn would, at this stage of our knowledge, be purely arbitrary.

Thickness.—Since no satisfactory contact has as yet been established between the Van Buren and the overlying Gasconade, it is impossible to give any very satisfactory estimate of the thickness of the formation. The greatest distance above the top of the Eminence at which cherts with a definite Van Buren fauna have been found in the Potosi quadrangle is about 80 feet. This is along Highway 8, near the crest of the divide, in the SW. ¼ sec. 18, T. 37 N., R. 2 E. This would indicate that at least the basal 80 feet of what is shown on the map as Gasconade is referable to the Van Buren. Whether the formation reaches a greater thickness than this is not known. Perhaps it should be noted at this point that Ulrich, in the field, identified beds exposed less than 10 feet below the Roubidoux along Highway 8, in the SW. ¼ sec. 21, T. 37 N., R. 1 E., as Van Buren. The identification was on purely lithologic grounds. This would indicate a thickness of 200 feet or more with no Gasconade at all in the section. Later discoveries, however, throw serious doubt upon this interpretation, inasmuch as the main cryptozoon reef of the Gasconade is exposed in place below the Roubidoux about 2½ miles south, in the NW. ¼ SW. ¼ sec. 3, T. 36 N., R. 1 E. The base of the Roubidoux here is badly obscured by slump, so that its elevation is hard to determine, but the reef is undoubtedly at least 30 feet if not more, below the top of the highest exposed Gasconade chert float. Embedded in the reef are diagnostic upper Gasconade fossils, a definite indication that it is not the variety of cryptozoon which Ulrich reports to be restricted to the Van Buren. In the Eminence quadrangle, Bridge[1] finds this reef 70 feet below the base of the Roubidoux. It is therefore evident that but little of the Gasconade was removed by pre-Roubidoux erosion in the area mentioned above. In the Eminence region typical Gasconade faunas, using the term in the restricted sense to exclude the Van Buren, have been found *in situ* at least 50 feet below the main cryptozoon reef, which would show that the Van Buren contact cannot be higher than 50 feet below that marker. This would indicate that at least 80 feet, and probably more, of the beds below the Roubidoux in the Potosi quadrangle are definitely Gasconade. If 80 feet of the basal beds are Van Buren, this would leave, from a total thickness of 220 feet between the Eminence and Roubidoux, some 60 feet, still unassigned to either formation, in which it is not possible as yet to draw a satisfactory contact.

Lithologic character—Sandstones.—Although the Gunter sandstone member, at the base of the Van Buren-Gasconade sequence, has been widely traced by the writer over the Ozark region, in Morgan, Miller and Camden Counties, on the northwest; in Shannon, southern Reynolds, Carter and Wayne, on the south; and in Ste. Genevieve on the east; nevertheless it is generally absent in the area of the Potosi and Edge Hill sheets, and over the most of that part of Crawford County in which the base of the overlying dolomite is exposed. The precise contact between the Eminence and the Van Buren has been located at many points in the Potosi quadrangle, and at only two localities, closely adjacent, was any sandstone observed. One is in the southeast corner of sec. 14, T. 37 N., R. 1 E., where there is perhaps a foot or less, which can be traced only a few yards, lying between typical fossiliferous Eminence below, and characteristic Van Buren dolomite above. The other is in the S. ½ SW. ¼ sec. 18, T. 37 N., R. 2 E., on the north side of the Shirley-Potosi road, where perhaps 2 or 3 feet of sandstone occurs at the

[1]Geology of the Eminence-Cardareva quadrangles; Mo. Bur. Geol. and Mines, in press.

contact, but again it can be traced only a few yards, before it seems to pinch out.

Thin, discontinuous sandstone beds, rarely over a few inches in thickness, occur immediately overlying the Eminence contact at several points along Highway 32 in Dent County; particularly about a mile west of Stone Hill.

To the south of the St. Francois Mountains, however, the basal sandstone thickens rapidly. A very interesting section was measured, about ¼-mile south of Mill Spring, Wayne County, along the railroad. It is appended below:

SECTION ¼-MILE SOUTH OF MILL SPRING, WAYNE COUNTY

	Ft.	In.	
Van Buren, possibly including some Gasconade, 122 + ft.	75		Covered slope, white chert float.
	15		"Cotton-rock," smooth-weathering, light-gray, fine-grained.
	10		Covered.
	3		Dolomite, yellowish-gray, very granular.
	10		Covered.
		6	Dolomite, coarsely-crystalline, gray.
	5		Covered.
	3		Dolomite, coarsely-crystalline, massive, gray.
		6	Chert, white, oolitic.
Gunter member of the Van Buren, 28 ft.	2		Sandstone, coarse-grained, gray, in conspicuous rounded ledge.
	1	2	Dolomite, coarsely-crystalline, gray.
	2		Covered.
		4	Chert, gray.
	1		Dolomite, very coarsely-granular, gray.
	1	6	Covered.
	1	4	Sandstone, thin-bedded, gray, very prominent outcrop.
	3		Dolomite, massive, crystalline, pitted, gray, with white chert stringers.
	3		Dolomite, thin-bedded, crystalline, gray.
	1		Dolomite, massive, pitted, crystalline, gray.
		6	Dolomite, very thin-bedded, crystalline, gray.
	1		"Cotton rock," white, thin-bedded, argillaceous.
	1		Sandstone, thin-bedded, calcareous.
		8	Dolomite, gray, crystalline.
		10	Sandstone, thin-bedded, gray.
	1		Sandstone, massive.
	6		Covered.
		8	Sandstone, gray.
Eminence, 71 + ft.	24		Dolomite, massive, pitted, very crystalline, gray, outcropping in crags.
	2		Dolomite, thin-bedded, crystalline, gray.
	1		Dolomite, massive, crystalline, cherty, gray.
	12		Covered.
	2		Dolomite, moderately-crystalline, pitted, gray.
	3		Covered.
	15		Dolomite, coarsely-granular, very pitted, gray.
	8		Dolomite, fine-grained, thin-bedded, gray.
	4		Dolomite, massive, crystalline, gray.
			Bottom of section at railroad track.

The lower 71 feet of the above section is undoubted Eminence. The next 28 feet is basal Van Buren, and may probably all be referred to the so-called Gunter horizon. If so, the Gunter at this point is unusually thick. This abnormal development of the basal sandstone beds seems to be characteristic of much of Wayne, Carter and southern Reynolds Counties, but has not been observed in northeastern Reynolds, in the area of the Edge

Hill Sheet. The propriety of using the term Gunter for this sandstone is discussed in the section on age and correlation, on page 148.

Much of the sandstone reported by St. Clair[1] from within the Gasconade of Ste. Genevieve County, is actually Gunter, the error having arisen from including considerable Eminence in the base of his Gasconade. The sandstone, therefore, is not well up in the Gasconade, as his mapping shows it, but at the base of the formation, between it and the underlying Eminence. A single specific instance is cited. Along the road over the top of the hill, across the SE. ¼ sec. 10, T. 36 N., R. 8 E., the map accompanying the Ste. Genevieve report shows nearly 100 feet of Gasconade (unrestricted). The hill top is capped with considerable sandstone residuum, which seems to have been interpreted as a lens in the Gasconade. As a matter of fact the cherts along the road, just beneath the sandstone carry an abundant fauna that is typically Eminence, and has been so identified by both Ulrich and Bridge. There is no doubt, then, of the Gunter age of the sandstone. The same error accounts for the apparent absence of the Gunter, in places where it has been believed to represent beds higher in the Gasconade.

Occasional residual masses of sandstone at or near the base of the residual chert mapped as Gasconade on the Edge Hill sheet, may possibly be Gunter, but are perhaps more probably Roubidoux, since such patches occur all the way from the base of the heavy chert float to the tops of the highest Gasconade hills, and are suggestive of old sink structures. Because no Van Buren or Gasconade has been found in place on the Edge Hill sheet, it is impossible, however, to say with certainty that none of these residual masses are Gunter.

Where the basal Gunter sandstone is not present, its horizon is usually marked by a thin but very persistent conglomerate, the pebbles of which are white, gray, and black chert. Commonly the matrix is dolomite, or sandy dolomite, though at many localities where the congolmerate is found as float, the matrix is also chertified. The detailed distribution of this conglomerate has already been outlined.

Sandstone beds within the Van Buren and Gasconade, above the Gunter horizon, are distinctly rare. The writer has not seen a single one in place, within the area of the two quad-

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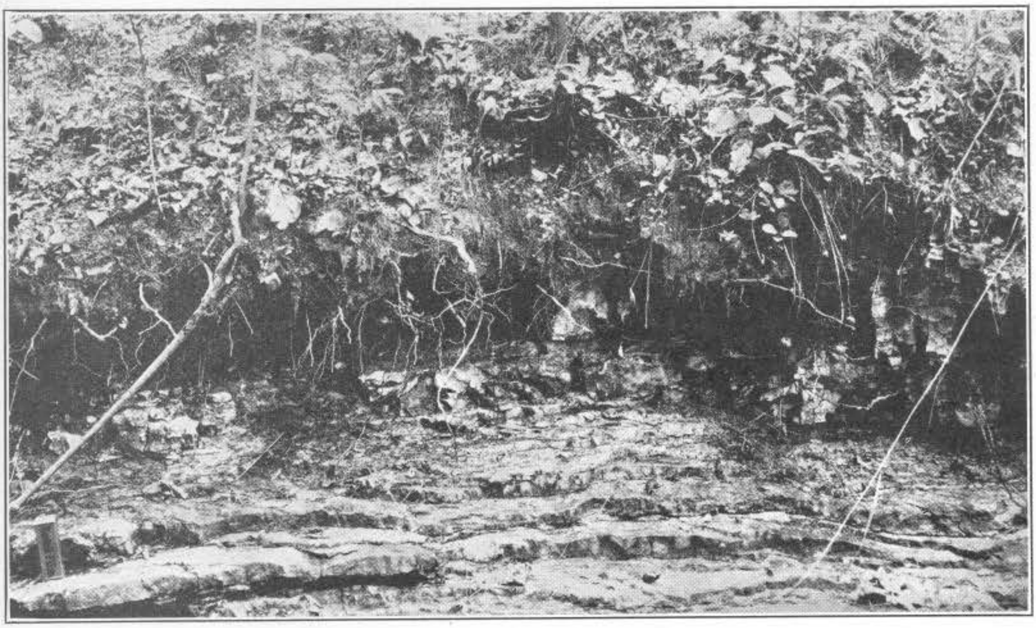
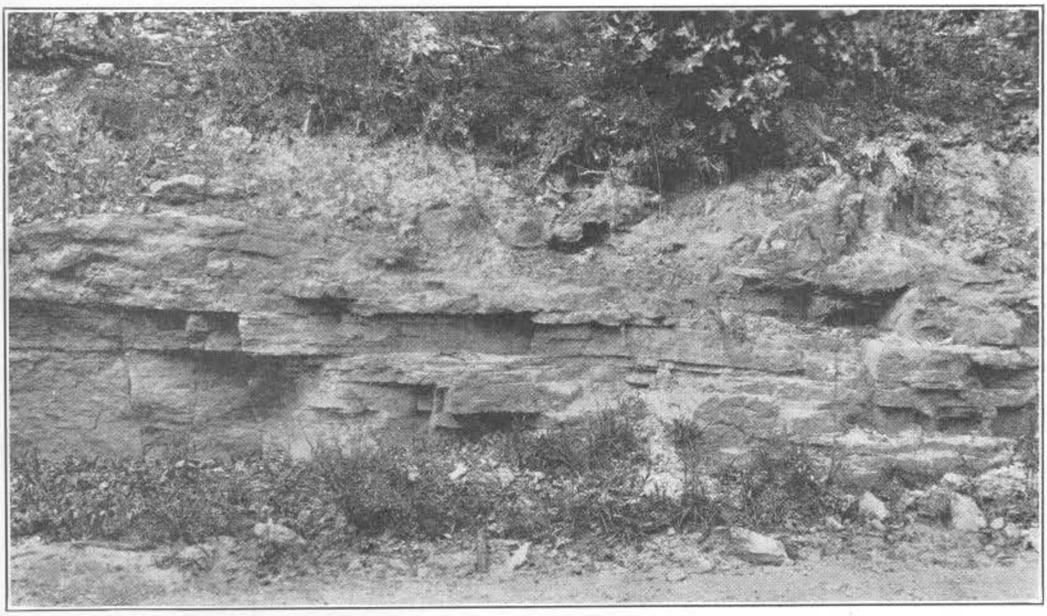
[1]The geology of Ste. Genevieve Co., Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, pp. 63 and 66.



A. Very thin-bedded basal Van Buren, cent. N. ½ sec. 23, T. 37 N., R. 1 E. Compare with Plate XIV, B.



B. Well-bedded Roubidoux sandstone in road cut, NW. ¼ sec. 20, T. 37 N., R. 1 E.

rangles. There are, to be sure, many patches of sandstone float, at various horizons, from the base to the top of the two formations. These have already been described as probably remnants of Roubidoux, preserved in sinks. The fact that none of these can be traced far as definite beds greatly strengthens this conclusion. The writer would, of course, hesitate to say that there are no sandstone beds in the formations, within the Potosi quadrangle, but it is his firm belief that the lenses of sandstone reported by Tarr,[1] for instance, are for the greater part Roubidoux remnants in sinks.

Dolomites.—At the base of the formation, there is commonly a considerable section of thin-bedded, fine-grained, light gray argillaceous dolomite of the type locally known as "cotton rock" (Pl. XVII, A). In places this carries thin seams of grayish to greenish shale. Its thin-bedded character, the light gray to nearly white color and dense earthy texture are features that serve to distinguish it from the underlying Eminence. This phase of the Van Buren is very similar to many beds of the Jefferson City formation, in adjacent areas.

The thin-bedded character of this rock is emphasized by the partial section, appended below, measured in the NE. ¼ SE. ¼ sec. 15, T. 37 N., R. 1 E. The exact position in the formation is not known, though it is not far above the base.

PARTIAL SECTION OF BASAL VAN BUREN.

Ft.	In.	Character.
8		Dolomite, slightly cherty, in beds 1 inch to 6 inches thick.
3		Dolomite, massive, in overhanging ledge.
1		Dolomite, very soft, white, argillaceous, very thin-bedded.
5		Chert, with some dolomite, massive, white, brecciated.
8		Dolomite, wavy, very thinly bedded, gray.
5		Dolomite, in beds 1 inch to 2 inches thick.
2		Covered.
	8	Chert, dense, light gray, brecciated.
2		Covered.
	8	Dolomite, light gray.

The thin-bedded argillaceous "cotton rock" of the Van Buren is well exposed along the south side of the valley draining east through the center of sec. 5, and the W. ½ sec. 4, T. 37 N., R. 1 E.; and on the west side of the hill in the SW. ¼ sec.

[1]The barite deposits of Missouri; Univ. of Mo. Studies, vol. III, no. 1, p. 35.

14, T. 37 N., R. 2 E. Similar "cotton rock" is exposed in the base of the Gasconade (undivided) just above the Gunter, near the castle at Hahatonka, and also farther north along Niangua River, near where Highway 54 (temporary) crosses the Niangua on the suspension bridge. Just east of this bridge, near the crest of the big hill, these beds are so highly argillaceous that they were mistaken for Jefferson City, and both Ulrich and Buehler were also confused regarding their identity, until undoubted Gasconade fossils were found overlying them, which served to fix their stratigraphic position. Similar argillaceous beds are common just above the Gunter sandstone, near Eminence, in Shannon County.

This basal, thin-bedded, fine-grained member gradually gives way upward to much more massive, coarser-grained crystalline gray dolomite, which probably could be distinguished from the Eminence only with the greatest difficulty, if at all, except for the intervening beds, and for the difference in the accompanying chert.

A sample of the typical basal Van Buren "cotton rock" was analyzed, and the results are included in the table on page 70. It is high in both silica and alumina. The ratio of magnesia to lime is practically that of a true dolomite.

Cherts.—The cherts of the Van Buren constitute one of its most distinctive features. The lower slopes of the formation are usually strewn with rather finely-broken, sharply-angular blocks, ranging up to several inches in diameter, of a very dense white, fresh-looking chert, that affords a very striking contrast to the old-looking, rusty, porous cherts of the Eminence. This dense white chert carries a few fossils locally, though on the whole, it is very barren. At many localities, these white cherts are so finely fragmented that the soil consists of sharply-angular, fine-textured residual gravel, in places many feet deep, admirably suited to road construction. Some of the finest driving surfaces on southeast Missouri highways consist of this natural gravel in place, on the hill tops.

Locally, the lower Van Buren carries banded chalcedony druses, very similar to certain kinds found in the Potosi. There is not, however, the variety of types characteristic of the older formation. These druses usually coat dense white chert, of the sort common in the Van Buren. The chalcedony is very thinly banded, the entire druse coating usually being thin, and the quartz crystals very fine. These druses were first noted in place along the east side of the valley in the NE. ¼ NE. ¼ sec. 9; on the south side of the valley in the NW. ¼ NW. ¼ sec. 10; and on the south side of the valley in the SW. ¼ NW. ¼ sec. 4, T. 37 N., R. 1 E. The beds in question were first mapped as Potosi, but the lack of any Eminence overlying them and the discovery of similar druses in other parts of the state above the Gunter sandstone soon forced the conviction that they were Van Buren. They are evidently very low in the formation, although, since its base is not here exposed, it is impossible to know their exact horizon. Similar drusy beds in place were noted near the center of the north line of sec. 5, T. 38 N., R. 1 E., on the De Soto quadrangle. In both localities they are overlain by very thin-bedded argillaceous dolomitic "cotton rock" characteristic of the lower Van Buren.

Entirely similar druse was noted in the basal Van Buren just above the Gunter sandstone, at several localities near Eminence, in Shannon County, and just above the Gunter sandstone on Niangua River, at Hahatonka, and for several miles down the river from that point. They are also, very significantly, abundantly developed just above the Gunter, at Proctor Creek, the type locality of the Proctor, where they occur associated with smooth-weathering argillaceous dolomites, in the base of the Gasconade (unrestricted).

Topographic expression.—So far as type of topography is concerned, the Van Buren and the Gasconade are so absolutely a unit that they will be discussed together, under the latter formation.

Stratigraphic relations.—As already pointed out at considerable length, the Van Buren rests on the older formations from Eminence down to Bonneterre, with obvious unconformity. No satisfactory contact has been established between it and the overlying Gasconade. Certainly no evidence has been yet observed in the field that would indicate anything other than a perfectly gradational and conformable contact, though it must be admitted that examination has not yet been sufficiently thorough to justify a final conclusion. McQueen[1] believes that an upper member of the Van Buren not represented in southeast Missouri wedges in between the lower member and the Gasconade, in the south central basin. The evidence is exclusively from drill records and cuttings. It is this interpretation, doubtless,

[1]Op. cit., p. 20.

which causes him to infer an unconformity between the Van Buren and the Gasconade. If such a break occurs, it is very obscure on the outcrop.

Paleontology.—The only collections thus far secured from the Van Buren are from residual cherts. Nowhere have fossils been taken from the formation in place. The fauna consists almost exclusively of gastropods and cephalopods. For the most part it is very sparingly developed, the Van Buren being much less fossiliferous than the Eminence below or the Gasconade above.

The gastropods are much like those of the Eminence formation, but the cephalopods introduce an entirely new element, not present in the older beds.

Like the Eminence faunas, the Van Buren assemblage consists for the most part of undescribed forms, and for the same reason, it has not seemed advisable to present faunal lists. The forthcoming paper by Ulrich and Foerste on the Ozarkian and Canadian cephalopods, and the one by Ulrich and Bridge, on the gastropods, will include descriptions of the characteristic Van Buren forms.

The most extensive collection from the Van Buren made during the course of this work comes from the SE. ¼ NW. ¼ sec. 19, T. 36 N., R. 3 E. Unfortunately this is in a complexly faulted area and the stratigraphic relations cannot be made out. Also, the material is mixed with fossiliferous chert from other horizons, so that the value of the collection is considerably lessened. Its position is sufficiently identified, in other and more complete sections, however, to characterize it as dominantly Van Buren. The same forms were also collected in the E. ½ SE. ¼ SE. ¼ sec. 19, T. 38 N., R. 1 E. These collections were both submitted to Ulrich before the name Van Buren had been proposed, and he designated both as "between the upper Eminence and the lower Gasconade."

A considerable collection was made, also from residual cherts, along Highway 8, in the SW. ¼ sec. 18, T. 37 N., R. 2 E., about 80 feet above the top of the Eminence formation. Ulrich was present at the time this collection was taken, and characterized the material as typical Van Buren. At the same locality, but a little higher on the hill, collections were identified by him as diagnostic of the Gasconade.

Smaller collections of Van Buren forms were made at numerous other points, on the Potosi quadrangle, but at no other point were fossils sufficiently abundant to merit special mention.

Outside the quadrangle, another good Van Buren collection was secured from residual cherts nearly two miles southwest of Goodwater, on the road to Bixby, probably in lot 4, NW. ¼ sec. 5, T. 34 N., R. 1 W., just at the foot of a big hill. The cherts here are badly slumped, and again there is no possibility of any safe conclusions as to stratigraphic position.

Along temporary Highway 32, just at the crest of the first big ridge east of Howe's Mill, small but very characteristic collections of Van Buren forms were made from dense white residual chert, just above a very thin representative of the Gunter sandstone.

Age and correlation.—The beds described in this report as Van Buren are those formerly referred by Ulrich to the Upper Eminence. Heretofore they have been included by Missouri geologists in the basal Gasconade. They have been split off chiefly on faunal grounds.

They are believed, on the basis of the great abundance of highly characteristic dense white chert, to be represented in the heavy mantle of residual cherts so widely overspreading the St. Francois Mountains, in Iron, Madison and Wayne Counties. It is true that as yet no Van Buren fossils have been reported from this mantle of residue, whereas Gasconade fossils have been found. In the entire area, however, where outcrops of the two formations are missing, and their residue so extensively developed, not above a dozen specimens of identifiable Gasconade fossils have been reported, and the Van Buren cherts are normally so sparingly fossiliferous, compared with the Gasconade, that the absence of a Van Buren fauna is not surprising, even though the formation spread entirely across the area.

Another lithologic indication that the Van Buren is probably represented in this area of extensive chert residue, is the abundance, immediately above the Potosi, of thinly-banded druse coating dense white chert, a type very common in the base of the Van Buren, both in the Potosi and in the Eminence quadrangles, where its position is known in actual outcrop.

The beds next above the Gunter sandstone in the area about Hahatonka and Proctor Creek, in Camden and Morgan Counties show the same type of thin-bedded, smooth-weathering argillaceous dolomite and an abundance of the same type of druses that mark the Van Buren in the Potosi and Eminence quadrangles. They also carry the same abundant dense white chert. On this basis, they are tentatively correlated with the Van Buren. They constitute the lower part of the Gasconade, as the name has heretofore been applied in that area. It is true that in this region, these cherts have thus far yielded no identifiable faunas, but there seems to be very little doubt but what they are essential equivalents.

The validity of this correlation is greatly strengthened by the fact that in deep wells in the intervening areas, residues assigned unhesitatingly by McQueen[1] to the Van Buren are found in beds immediately above the Gunter sandstone, and have made possible nearly continuous tracing of the Van Buren from the one area to the other.

Ulrich has questioned vigorously the propriety of using the term Gunter for the basal sandstones of the next younger beds above the Eminence in southeast Missouri, on the grounds that they are not of the same age as the Gunter at the type section at Hahatonka. Since these beds are the basal deposit of an encroaching sea, over an eroded landmass, it is to be presumed that they are not everywhere of exactly the same age, any more than, for example, the basal beds of the St. Peter are everywhere contemporaneous. That these sands, do, however, mark the base of a single encroachment of the sea, seems to the writer to be rather clearly established. This seems to be borne out, as stated above, by nearly continuous tracing in deep wells, in which typical Van Buren residues are recovered from just above a sandstone that occupies the stratigraphic position of the Gunter.

There is probably greater variation in the age of the Eminence (including Proctor) beds on which the sandstones rest, than there is in the age of the Van Buren which in turn rests on them. The overlying beds everywhere from Ste. Genevieve County on the east, through Shannon on the south, to Camden on the west, are remarkably similar in their thin-bedded character, content of light-gray, fine-textured, argillaceous dolomite (cotton rock), and abundance of dense white very fresh-looking chert, as well as of druse.

It is believed, therefore, that the usage of the term Gunter for the sandstone lying between the Eminence (including Proctor) and the Van Buren is quite justified, in southeast Missouri.

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[1]Personal communication.

In his latest unpublished correlation table, Ulrich considers the Van Buren to be the equivalent of the upper part of the Copper Ridge of the Appalachian Valley. According to him the same fauna is represented in Oklahoma but is not found in Wisconsin.

Gasconade Dolomite.

Name.—The name Gasconade was proposed by Nason[1] in 1892, to "be applied to the great series of limestone beds, interstratified with thin beds of sandstone, which underlie the Roubidoux." Although he expresses a belief that the Roubidoux and Crystal City (St. Peter) sandstones are equivalents, an idea now known to be in error, it is still very evident that he intended to delimit the top of the Gasconade just as we do now, at the base of the sandstone-chert complex which occurs so widely over the uplands of the central Ozarks. The base of the formation, he does not appear to have defined.

Winslow[2] in 1894, presents a correlation table which makes the Gasconade include everything from the base of the Crystal City (St. Peter) sandstone, down to the Iron Mountain conglomerate. This is based, of course, on the mistaken correlation of the Roubidoux of Nason, with the St. Peter, an error which Nason himself actually intimated. In practice, however, the term Gasconade does not appear to have ever included any beds above the base of the Roubidoux, as we now use that term.

Ball and Smith,[3] in their report on Miller County, seem to have been the first to define the base of the Gasconade, which they limit at the top of the Gunter sandstone, next overlying the Proctor dolomite.

Bain and Ulrich,[4] two years later, revert to the older usage, and include in the Gasconade, all beds between the top of the Derby-Doerun (upper Elvins) and the base of the Roubidoux.

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[1]Nason, F. L., Iron ores of Missouri; Geol. Survey of Mo., vol. II, 1892, pp. 114-115.

[2]Winslow, Arthur, Lead and zinc deposits; Mo. Geol. Survey, vol. VI, 1894, p. 331.

[3]Ball, Sydney H., and Smith, A. F., The geology of Miller County; Mo. Bur. Geol. and Mines, vol. 1, 2nd ser., 1903, pp. 30-50.

[4]Bain, H. Foster, and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, no. 267, 1905, pp. 28-31.

Marbut[1] slightly modifies the usage of Ball and Smith, including the Gunter as the basal member of the Gasconade, but otherwise following their definition of the formation.

Buckley[2] follows Marbut in including the Gunter as the basal member of the Gasconade, and Ulrich,[3] in 1911, accepts that usage, which has been consistently followed, up to the time of the present report. In this volume, as already pointed out, the basal portion of the Gasconade has been split off, and described separately, under the name Van Buren.

Distribution.—In the Potosi quadrangle, the Gasconade and Van Buren together outcrop over not far from 50 square miles, chiefly occupying a trough running diagonally from the south central to the northwest portion of the sheet. On the north and east sides of this belt, it caps the hills, whereas to the west, it is exposed in the valley bottoms. South of the Palmer fault, only very small patches of residual chert occur. Inasmuch as the boundary of the Van Buren and Gasconade has not been satisfactorily located, it is not possible to say how much of this 50 square miles is Van Buren. On the Edge Hill sheet, neither Gasconade nor Van Buren are actually known to outcrop, though heavy residual chert float from them, caps most of the higher uplands, widely, except in the extreme north. The total area where the older formations are completely masked by Van Buren-Gasconade float on the Edge Hill sheet is probably about 60 square miles, or more than one-fourth of the quadrangle.

Throughout the area of the St. Francois Mountains, from Castor River on the east to Black River on the west, and from the Lead Belt on the north to Piedmont on the south, almost all of the higher hills that are not made up of porphyry are capped with this heavy Van Buren-Gasconade residuum, although to date not an outcrop of either formation has been found in the St. Francois area.

Thickness.—Owing to the unconformity at the base of the Van Buren and possibly to one at the top of the Gasconade as well, the combined thickness of the two formations is distinctly variable. Nowhere on either sheet, does a single section expose

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[1]Marbut, C. F., The geology of Morgan County; Mo. Bur. Geol. and Mines, vol. VII, 2nd ser., 1907, pp. 26-32.

[2]Buckley, E. R., Geology of the disseminated lead and zinc deposits of St. Francois and Washington Counties; Mo. Bur. Geol. and Mines, vol. IX, 1908, 2nd ser., pp. 59-60.

[3]Ulrich, E. O., Revision of the Paleozoic Systems; Bul . Geol. Soc. America, vol. 22, 1911, pp. 631-632.

both the base and the top of the combined sequence in sufficiently close proximity to eliminate the influence of local dips. From the bottom of the deepest valley that exposes Van Buren along its course, to the top of the highest adjacent hill that shows Gasconade float, is not over 200, or possibly 220 feet. This thickness, probably the greatest now remaining in the area of the two quadrangles, is attained in the west central portion of the Potosi sheet, in the northeast corner of T. 37 N., R. 1 W. and the northwest corner of T. 37 N., R. 1 E., in the synclinal trough between the two main porphyry areas of the Potosi sheet.

As already pointed out, the uncertainty as to the proper boundary between Van Buren and Gasconade makes it impossible to assign to each formation its true proportion of this total of 200 or 220 feet. There is reason to believe that some 80 feet, at least, contain the Van Buren fauna, and if this is true, the thickness of the Gasconade alone cannot be much in excess of 140 feet, and it may be less.

Toward the eastern side of the quadrangle there is a very great apparent thinning of the combined Van Buren and Gasconade, the interval between the top of the Eminence, and the base of the numerous residual patches of Roubidoux decreasing to less than 100 feet. How much of this may be due to unconformities at base or top of the sequence it is impossible to say, but there is reason (p. 162) to believe that most of these patches of Roubidoux occupy the sites of old sinks, into which the sandstone has settled far below its normal position, with the gradual solution of the underlying dolomite. Then, as erosion reduced the general level, all the Roubidoux was stripped away except that occupying the very deepest sinks. This has resulted in an *apparent* thinning of the underlying beds. Practically everywhere that the formation occupies the uplands in southeast Missouri, this process has acted extensively. That it is a plausible explanation seems to be borne out by the fact that in many areas where the Roubidoux-Gasconade contact is still well enough preserved to be easily located, many patches of sandstone, consisting of broken and jumbled blocks, occur a hundred feet or more below the normal contact, in obvious sinks.

No Van Buren-Gasconade outcrops have been found on the Edge Hill Sheet, but the float from these formations is very widespread, and apparently very thick. From the base of this chert float to the tops of the highest hills capped with the same material, is an interval reaching, in some localities, as much as 200 feet. Along Little Brushy Creek in secs. 7 and 8, T. 33 N., R. 1 E., and in secs. 24 and 25, T. 33 N., R. 1 E., the float of these formations is perhaps as strikingly developed as in any part of the area. Of course, it is quite probable that the contact at the base, drawn as it is wholly on the occurrence of float in the Edge Hill quadrangle, is too low. And there may quite probably be cores of the dolomite in place, below the residuum. It is open to question therefore whether there is actually at any point, 200 feet of unconsolidated Van Buren-Gasconade chert float. This cherty mantle, however, is known to be remarkably thick.

Three drill holes of the St. Louis Smelting and Refining Co., in Madison County[1] (hole number 4, in the NW. ¼ SW. ¼ SW. ¼ sec. 24, T. 33 N., R. 7 E.; number 5 A, in the SW. ¼ NE. ¼ NE. ¼ sec. 26, T. 33 N., R. 7 E.; and number 21, in the SW. ¼ NW. ¼ NW. ¼ sec. 29, T. 33 N., R. 8 E.), show respectively 184, 182½, and 181 feet of residuum. Judging by what is known of the distribution of the formations in the immediate area, only a fraction of this is Van Buren-Gasconade, the remainder being Potosi, but the records of these three holes attest the great thickness that the cherty residuum attains in the St. Francois Mountain area.

If there is anything even approaching 200 feet of Van Buren-Gasconade chert residuum in the St. Francois Mountains it certainly implies abnormal conditions, and demands, it might seem, one of three possible explanations. (1) That the Van Buren-Gasconade was much thicker there than elsewhere, or (2) that the formations contained a much higher proportion of original silica there than elsewhere, to leave so great an insoluble residue, or (3) that the ground waters circulating through the formations and largely responsible for their solution, were highly charged with soluble silica from sources outside, which replaced the lime as it was removed, leaving a large insoluble residue. In deciding between these possibilities, little direct evidence is available, since outcrops of the Van Buren-Gasconade, from which its character might be judged, are not to be found, within the main St. Francois region, where the abnormal thickness of residuum occurs. A fact to be considered is the observed scarcity of silicious material in the Bonneterre and Davis, in the same area. If circulating waters charged with silica from outside

[1]Logs furnished by E. T. Campbell.

sources replaced the dolomites, during their removal, why were not the older formations also chertified? If, on the other hand there were exceptional amounts of silica in the Van Buren-Gasconade, when it was laid down, the destruction of the formations has obscured the evidence.

There is, however, some reason to believe that the Van Buren-Gasconade may originally have been thicker, perhaps considerably thicker, in the St. Francois area, than about its border. This evidence lies in an analysis of the probable topographic conditions, when that sea encroached. The Potosi and Eminence formations had been laid down over the area, which had then been domed, and from which those formations had been stripped, as evidenced by the fact that the Van Buren-Gasconade laps across onto Bonneterre and Davis, with the Eminence wholly missing and the Potosi present only in patches. The highly cherty Potosi and Eminence, then, should have formed an inward-facing escarpment about the dome, with lowlands on the weaker Davis and Bonneterre, out of which the porphyry knobs rose as fragments of a central upland. In other words, the Van Buren-Gasconade sea may more than probably have entered a lowland, comparable to the present plain about Fredericktown between the Avon escarpment to the east and the porphyry ranges to the west. Any sea encroaching over that lowland at present, would deposit earlier beds there than on the adjacent highlands. Similarly, older Van Buren may have been deposited in the lowland between the porphyry and the Potosi-Eminence escarpment than was laid down on the surrounding upland. Consequently, there is good reason for thinking that the sequence in this area may have been considerably thicker than that some distance back, where the cherty Potosi and Eminence still held up surrounding uplands.

Because, however, the central St. Francois region was domed in post-Gasconade times, until that formation constituted the hill tops, it has been very thoroughly leached, and little if any of it left, except the cherty relatively insoluble residue.

In the area west of the Potosi quadrangle, near Scotia, Wesco, and Steelville, all in Crawford County, where the entire section from the underlying Eminence to the overlying Roubidoux is exposed continuously, there seem to be places where the full thickness of the Van Buren-Gasconade sequence is less than 180 feet, and possibly not over 150 feet. This is the least thickness that has been reported where both contacts have been directly observed.

Lithologic character—Dolomite.—The Gasconade consists essentially of light gray, moderately crystalline, very cherty dolomites. The color of the beds averages slightly darker than those of the Eminence, but much lighter than the Potosi. It is somewhat less coarsely granular than the average of the Eminence, but not as fine as the typical Van Buren.

It is somewhat more regularly bedded than the Eminence, but more massive than the Van Buren. Like the Eminence, it has a tendency to weather into pitted and cavernous outcrops (Pl. XIV, B), but does not produce as striking crags as those characteristic of the older formation. Its character of outcrop can best be studied where Lost Creek leaves the west border of the Potosi quadrangle, in the S. ½ sec. 13, T. 37 N., R. 1 W., along Highway 8.

The soils from the weathering of the Gasconade are more reddish than those of the Van Buren, but are very rarely the deep red so typical of those from the Potosi and Eminence.

A sample of the Gasconade, from the top of the formation was analyzed, and the result is shown in the table on page 70. The sample is lower in both silica and alumina, and carries a somewhat lower ratio of magnesia, than the sample of the Van Buren.

Shale and sandstone.—Shale beds have not been noted in the Gasconade, within the area of the Potosi quadrangle, nor have there been noted any of the argillaceous dolomites known as "cotton rock," so characteristic of the basal Van Buren.

Sandstone beds are very rare within the formation. As already pointed out, under the discussion of the Van Buren, the sandstone layers mentioned by Tarr[1] as characteristic of the Gasconade, seem rather to be residual patches of Roubidoux, filling sinks.

There are, however, outside the area mapped, a few thin sandstones in the Gasconade. A case in point is in the 890-foot saddle near the center of the NW. ¼ sec. 3, T. 37 N., R. 6 W., on the Meramec Springs quadrangle, where a thin sandstone 4 to 10 inches thick outcrops 35 feet below a very massive sandstone bed that is undoubtedly Roubidoux. Considerable question existed as to where the contact should be drawn, but careful

[1]Op. cit., pp. 34-38.

search revealed Gasconade fossils in the cherts of the 35-foot dolomite member above the thin sandstone, so there seems to be little doubt that this thin sandstone bed is actually in the upper Gasconade. It has been traced into sec. 4, T. 37 N., R. 6 E., and north into sec. 33, T. 38 N., R. 6 E. In places it is hardly a true sandstone, but rather a somewhat sandy dolomite, at other points it is almost pure sand.

Cherts.—Cherts are a very important constituent of the formation. They may, in general, be distinguished from the dense white types of the Van Buren, by being porous, and weathered, and superficially, at least, more closely resembling those of the Eminence. They are likely to be much more abundantly fossiliferous than those in the Van Buren. Very close to the top of the Gasconade is a peculiar variety that looks like interlaced stems. Though no definitely identifiable organic structure has been detected in these "stems," it seems quite probable that they represent some type of marine plant.

Chertified cryptozoons are very abundant in the Gasconade, and have been observed as ledges in place, and widely scattered through the residual cherts. There is considerable variation in the types occuring in the area.

The dominant type is a reef-building form, some of the reefs being so regular and persistent that they can be traced for miles, and they constitute one of the best horizon markers in the formation. These consist of rather regularly-spaced vertical columns, connected by thin curved laminae or plates, convex upward. They have been called festoon cherts. Of these Ulrich points out two distinct varieties, one in which the columns are not more than 2 to 4 inches apart, and another in which they are from 6 to 10 inches. In general, he believes the smaller type occurs high in the true Gasconade, the larger type belonging to the Van Buren. Unfortunately, the writer has never seen the two as distinct reefs in a single section. Furthermore, both the large and the small varieties may sometimes be found in a single block. Moreover, no well-developed reefs have as yet been seen in place in undoubted Van Buren, where identification has been checked by fossils. It is by no means clear as yet, that the two are distinct and diagnostic.

Rarely this structure can be seen in unsilicified dolomite but is much more distinct in the chertified beds, and is most clearly seen where there has been considerable weathering since chertification. Not infrequently these masses, in the chert residuum, show curved lamellar plates, separated by curved lamellar interstices, caused apparently by leaching out of less completely silicified laminae.

Extremely large bowlders of chert, similar to those seen in many places on the surface of the Eminence, occur thickly distributed over the Edge Hill quadrangle, in areas where the chert float is mixed Van Buren-Gasconade. The peculiar texture of many of these bowlders strongly suggests that they may be masses of recomposed chert residuum at the unconformable base of the Van Buren, in other words, essentially a basal conglomerate. In a few localities, this origin is quite definitely indicated by fragments of Potosi druse within the mass. Large bowlders just north of Highway 32, in the SW. ¼ sec. 32, T. 35 N., R. 2. E., are clearly of this origin.

A very fine exhibit of these large bowlders, with less evidence of conglomeratic character, occurs in the SW. ¼ sec. 6 and the NW. ¼ sec. 7, T. 34 N., R. 3 E.; another on the ridge top in the W. ½ sec. 22, T. 34 N., R. 2 E.; still another in the NW. ¼ NE. ¼ sec. 26, T. 35 N., R. 1 E.; and a particularly striking area just off the east edge of the Edge Hill sheet, on the Graniteville-Munger road, in the S. ½ sec. 21, T. 34 N., R. 3 E. (Pl. X, B). The latter is without doubt the finest exhibit yet noted in the St. Francois Mountains which can be seen along a main road, and is easily reached by automobile.

The most striking development of these chert bowlders the writer has seen anywhere is in a very inaccessible region, where the topography is poorly mapped, about in the SW. ¼ SW. ¼ sec. 31, T. 34 N., R. 3 E. The whole hillside here is strewn with these gigantic masses of chert, the largest single bowlder of which measures about 40 feet long, 30 feet wide, and 30 feet high.

Topographic expression.—For the most part, the Gasconade areas are very rugged, deeply dissected, with narrow valleys steep and very stony hillsides, and narrow rocky uplands, quite unsuited to agriculture. In this respect they resemble the region of Potosi and Eminence outcrop. Over most of the area of the Gasconade, the slopes are very stony, the chert residuum being extensively developed.

Stratigraphic relations.—As already pointed out the contact between the Van Buren and Gasconade has not yet been satisfactorily established, thus far no physical evidence has been found in the field, that would indicate anything but perfect conformity. The relations with the overlying Roubidoux are also somewhat confusing. Within the area of the two quadrangles mapped, the contact is so poorly exposed that no direct evidence is available. In other localities there is definite evidence of some erosion at this horizon. Along Highway 66, near Arlington, and near Hooker, the new road cuts show a thin conglomerate of chert pebbles at the contact of Roubidoux on Gasconade. Similar conglomerate was noted at and somewhat above the base of the Roubidoux, just south of the Gasconade River bridge on the main road between Linn and Belle. These conglomerates, however, are no more conspicuous than others within the Roubidoux itself. There are also well-developed conglomerates in the lower part of the Roubidoux along Highway 63, in the vicinity of Westphalia.

Ulrich[1] points out what he interprets as proof of the widespread removal of the Gasconade from southeast Missouri, before the Roubidoux was laid down. The writer accompanied Dr. Ulrich on the trip to which reference is made, in the above-named article, and interprets the field conditions differently. It is a striking fact that most of the area over which the upper beds of the Gasconade appear to be missing is that in which the Gasconade occupies the hill tops, with only a thin cap of Roubidoux still preserved. Since the overlying Roubidoux is a very permeable formation, constituting an excellent water-gatherer, resting on the formation most famous throughout the entire Ozark area for its extensive development of caves, sinks, and unusually large springs, there is no doubt but what solution has been exceptionally active at the contact, and has resulted in the widespread removal, *by solution*, of the higher beds of the Gasconade, and the consequent settling, very unevenly, of the overlying relatively insoluble sandstone. Hundreds of observations of sink structure at the Gasconade-Roubidoux contact, with large slumped areas of Roubidoux far below the normal level of that formation, within sinks in the underlying dolomite, have been reported by others, or noted by the writer, and attest the extreme development of the process described above. The higher the contact rises on the hillsides, and hence above the ground water level, the more numerous these dropped masses become. They are found in their maximum development in those areas where

[1]Ulrich, E. O., Notes on new names in table of formations and on physical evidence of breaks between Paleozoic systems in Wisconsin; Trans. Wis. Acad. Sci., Arts and Letters, vol. XXI, p. 103, 1924.

only a moderate thickness of Roubidoux remains capping the hill tops. The extensive development of iron ore deposits at this horizon has led to a close study of the distribution of this phenomenon.

That much of the removal of the upper Gasconade has been brought about by this process, rather than by pre-Roubidoux erosion of the formation, seems rather clearly to be indicated by the fact that along the main drainage lines of the area in question, the upper Gasconade seems quite definitely to thin out and in places to disappear *towards the present valleys*, the thickening and thinning being in direct response to the present topographc situation. No such relation should exist if the removal were by emergence and pre-Roubidoux erosion.

The writer doubts whether the Gasconade has been removed as widely from southeast Missouri by pre-Roubidoux erosion as Ulrich has indicated.

The unconformity at the base of the Roubidoux certainly is much less conspicuous in Missouri than that at the base of the Van Buren-Gasconade sequence. The one at the base of the Roubidoux was not accompanied by much warping since the Roubidoux everywhere rests on Gasconade, though the highest beds of that formation may locally be absent in southeast Missouri. This apparent absence, as explained before, is most probably largely a matter of post-Roubidoux solution. The break at the base of the Van Buren-Gasconade, on the contrary, was marked by sufficient local deformation so that the formations lap across all the older beds from Eminence down to Bonneterre. At Decaturville, in Camden County, there even seems to be marked discordance in dip, between the Gasconade (unrestricted) and older beds.

That the unconformity at the base of the Roubidoux is inconspicuous in Missouri, does not necessarily indicate that it is local, however. Widespread emergence with relatively little warping might produce the results observed. That the unconformity may be of greater significance than local conditions would seem to imply is suggested by Ulrich's statement that in the Appalachian mountains, hundreds of feet of sediment wedge into the section, between the equivalents of the Gasconade and Roubidoux.

Paleontology.—The fauna of the Gasconade is much larger than that of the underlying Van Buren. It consists chiefly of gastropods, cephalopods, trilobites, and brachiopods. The following list was prepared by Ulrich for the Ste. Genevieve County report.[1]

FAUNA OF THE GASCONADE FORMATION.

Eoorthis n. sp.
Sinuopea obesa (Whitfield).
Sinuopea regalis Ulrich.
Rhachopea grandis Ulrich.
Gasconadia putilla (Sardeson).
Chepultepecia leiosomella (Sardeson).
Helicotoma uniangulata (Hall).
Ozarkotoma acuta Ulrich.
Ozarkispira typica.
Ozarkispira valida.
Ozarkispira complanata.
Ophileta supraplana Ulrich.
Ophileta, at least six other undescribed species.
Camaroceras huzzahensis Ulrich and Foerste.
Walcottoceras shannonense Ulrich and Foerste.
Buehleroceras compressum Ulrich and Foerste.
Clarkoceras crassum Ulrich and Foerste.
Clarkoceras obliquum Ulrich and Foerste.
A number of tuberculated trilobites of or related to the genus *Hystricurus*.

It seems, according to Bridge, who has carefully studied not only his own collections from the Eminence-Cardareva quadrangles, but also those of the writer, from the Potosi-Edge Hill area and vicinity, that there are within the Gasconade three fairly distinct faunal zones. The highest of these is characterized by an abundance of *Helicotoma uniangulata*, and may for convenience be called the *Helicotoma* zone. It immediately underlies the Roubidoux contact, but it is not possible as yet to indicate how many feet of beds this zone occupies, because the residual cherts slump far down the hillsides, and few collections of importance have been made in situ.

A collection from the center of the SE. ¼ NE. ¼ sec. 25, T. 38 N., R. 1 W. yielded well preserved forms characteristic of the *Helicotoma* zone. An excellent collection from the same horizon was secured near a small pond in the SW. ¼ NW. ¼ sec. 17, T. 41 N., R. 1 W. A good representation of this horizon was collected from float about two miles east of the Salem courthouse, on Highway 32 (temporary), at elevation about 1180 feet, some 50 feet below the Roubidoux contact. Along the same road, about 4¼ miles east of Salem, on the west side of the valley and about 40 feet below the Roubidoux contact, is another locality from which a good representative of this fauna was collected from residual chert.

A good collection from this zone was also secured from residual chert at Elm Spring, Franklin County, in the NW. ¼ sec. 11, T. 40 N., R. 2 W., about 150 feet below the Roubidoux, but it may be slumped.

[1]Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, p. 68.

This zone is also well represented at Meramec Springs and at Yancy Mills, in Phelps County.

Somewhere below this zone but above the Van Buren fauna, is a horizon characterized by an abundance of a new genus for which Ulrich proposes the name *Euomphalopsis*, and which may be called the *Euomphalopsis* zone. Near the mouth of Proctor Creek, in Morgan County, this horizon occurs about 100 feet above the Gunter sandstone. The Roubidoux is nowhere exposed, in the immediate vicinity, but the Gasconade is here reported to be about 290 feet thick, which would place the zone about 190 feet below the base of the Roubidoux. Nowhere else has it been located quite so definitely in the section, though it occurs widely in southeast Missouri.

The *Euomphalopsis* zone is well represented in a collection from near the center of sec. 18, T. 37 N., R. 2 E., along Highway 8, at the top of the hill. The material all occurs as chert residuum. A still better collection from this zone, undoubtedly the best in the Potosi quadrangle, came from near the center of the S. ½ sec. 4, T. 37 N., R. 2 E., on the east side of the 1140-foot knob. The same horizon is also well represented in collections from near the center of the south line of sec. 31, T. 41 N., R. 1 E.; and again, in the SW. ¼ sec. 30, T. 37 N., R. 3 E., at elevation 1180 feet.

The third zone, characterized by an abundance of the genus *Ozarkispira*, has not been so definitely located, but probably lies somewhere between the other two.

It has already been suggested that the fauna of the Gasconade is more closely related to that of the overlying beds than it is to that of the Eminence. This conclusion is based on the following facts. First, the Eminence contains no cephalopods, whereas the Van Buren and Gasconade carry them in abundance, and in considerable variety. Second, the trilobites of the Eminence are in general very unlike those of the Gasconade, those of the older formation having closer Cambrian affinities, those of the younger being of more typically Ordovician aspect. Third, the Gasconade fauna carries an abundance of *Ophileta*, of various species, a form typically Ordovician, and wholly lacking in the Eminence. On the other hand, many of the gastropods of the Eminence are closely related to Van Buren and Gasconade forms, and have no counterpart in the earlier formations.

Age and correlation.—The beds called Gasconade in this report have been traced with practical continuity into the

Gasconade of the type region. In addition they carry the same faunas as the beds next below the Roubidoux throughout the Ozark region, so that there seems to be no question at all as to their identity.

In his Revision[1] Ulrich correlated the Gasconade with the Chepultepec of Alabama; in part with the Oneota of Illinois, Wisconsin, Iowa, and Minnesota; and more doubtfully with the basal Arbuckle of Oklahoma. In his latest unpublished correlation table, he makes the Gasconade the full equivalent of the Oneota, and of the Chepultepec. He indicates that it is a partial equivalent of his recently named McKenzie Hill formation of Oklahoma. It constitutes the highest formation of the Upper Ozarkian, as that system is now delimited by Ulrich.

Roubidoux Formation.

Name.—Nason[2] was the first to apply the name Roubidoux to the complex of chert, dolomite and sandstone "overspreading the Ozark region from Cabool to Gasconade City and from Salem to Doniphan." He says of it: "It embraces much, if not all of what has been called the Second Sandstone, and will undoubtedly include the areas of the so-called First Sandstone as well." From the localities which he cites, it is obvious that he meant to apply the term primarily to the Second sandstone, that is to the beds now called Roubidoux. He was, of course, wrong in his suggestion that these were the equivalent of the First (St. Peter) sandstone.

Winslow,[3] in his correlation table, uses the term Moreau for what is now known as Roubidoux, next beneath the Jefferson City, and restricts the term Roubidoux to beds above the Jefferson City, equivalent to the Crystal City (St. Peter).

Ball and Smith,[4] writing several years later, ignore Nason's term Roubidoux and introduce the name St. Elizabeth for the Second sandstone of Miller County, although accepting Nason's term Gasconade for the underlying beds. They do not even mention the name Roubidoux, and it is not clear why they used one of Nason's terms and not the other.

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[1]Bull. Geol. Soc. America, vol. 22, 1911, pl. 27.

[2]Nason, F. L., A report on the iron ores of Missouri; Geol. Survey of Mo., vol. II, 1892, pp. 114-115.

[3]Mo. Geol. Survey, vol. VI, 1894, p. 331.

[4]Ball, S. H., and Smith, A. F., The geology of Miller County; Mo. Bur. Geol. and Mines, 2nd ser., vol. 1, 1903, pp. 50-51.

Van Horn[1] follows Ball and Smith in calling the beds St. Elizabeth. The same year, however, Bain and Ulrich[2] reintroduced Nason's term Roubidoux, with a clear understanding of the fact that it does not include the First or St. Peter sandstone, thus for the first time formulating the present exact definition of the formations.

Marbut[3] accepts this use of the term, and from that time on it has been used consistently for the chert, dolomite and sandstone complex lying between the Gasconade below and the Jefferson City above.

Distribution.—On the Potosi quadrangle the Roubidoux occupies about 16 square miles, chiefly in the west central portion of the quadrangle, though numerous small outliers, believed to be chiefly remnants preserved in structural sinks, are to be found in the east central portion.

On the Edge Hill sheet, the total area is very much less, probably not greatly exceeding a square mile. The only actual outcrops are in the extreme southwest part of the quadrangle. Scattering very small patches of residual sandstone blocks, usually associated with Gasconade chert residuum, occur widely over the southern and western portions. Many of these are too small to map, but many of the larger ones have been indicated. Some of them are almost certainly residual Roubidoux preserved in sinks. Some of them may possibly be local developments of the Gunter. Others are quite probably Pennsylvanian. In the absence, however, of any positive method of discrimination, and in view of the wide distribution of known Gasconade float, they have been shown as Roubidoux. For a further discussion of the possibility that some, at least, of these patches are Pennsylvanian, see pages 169-172.

Thickness.—Since no younger formation than the Roubidoux occurs in situ, on either quadrangle, no exact limits for the original thickness of the formation can ever be determined in this area. The maximum thickness remaining occurs on the Potosi quadrangle, in the Shirley syncline, west of the post office of Shirley, near the west central border of the map. Here the difference in elevation between the lower contact and the tops of the highest

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[1]Van Horn, F. B., The geology of Moniteau County; Mo. Bur. Geol. and Mines, 2nd ser., vol. III, 1905, p. 21.

[2]Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri; Bull. U. S. Geol. Survey, no. 267, 1905, p. 12 and p. 18.

[3]Marbut, C. F., The geology of Morgan County; Mo. Bur. Geol. and Mines, 2nd ser., vol. VII, 1907, p. 32.

hills capped with Roubidoux float is about 120 feet. Some part of this may be accounted for by local dips and slump, but certainly not far from 100 feet of the formation still remains.

To the south the formation is cut off abruptly by the Palmer fault, but to the north and east, it thins gradually, as a result of truncation by the present erosion surface.

Of course no figure can be given for the remnants preserved in the structural sinks, since these masses consist of tumbled blocks dropped far below their normal position.

The exceptional thickness reported by St. Clair[1] in Reynolds County is rather surprising. Careful investigation in the County by the writer has failed to show more than 50 or 75 feet of Roubidoux, capping the higher hills. The explanation seems to be that the abnormal development of the Gunter in the southern and western part of the County has led to the inclusion of everything from the base of the Gunter up to the top of the Roubidoux in the latter formation.

Lithologic character.—With the possible exception of the Davis, there is no more variable formation in the entire Ozark region than the Roubidoux. To the northwest, in Miller[2] and Morgan[3] Counties, one gathers, from the detailed descriptions, that dolomite and chert make up considerably the larger part of the formation. In Dent and Crawford Counties, on the contrary, sandstone is by far the most abundant constituent. To the southeast, in Ste. Genevieve County,[4] chert and dolomite again become conspicuous elements of the formation, and still farther southeast, in Bollinger County there are sections in which dolomite is dominant, and sandstone only a subordinate constituent.

In the Potosi quadrangle, sandstone is the most conspicuous element of the Roubidoux. The color in unweathered masses is almost invariably white to gray, but where deeply weathered, it is commonly reddish brown.

Individual beds vary from a few inches to a few feet in thickness (Pl. XVII, B), and in areas of normal development, the residual blocks are for the most part well-bedded and distinctly angular. In areas where the formation has undergone much disturbance, either by faulting, or by large-scale slumping

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[1]Weller, Stuart, and St. Clair, Stuart, The geology of Ste. Genevieve County; Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, p. 70.

[2]Ball and Smith, op. cit., pp. 50-68.

[3]Marbut, C. F., op. cit., pp. 33-39.

[4]Weller and St. Clair, op. cit., pp. 69-74.

into sinks, it is firmly cemented, far more massive, and occurs in more rounded bowlders (Pl. IX, B). As a result it is more difficult to distinguish it from the massive Pennsylvanian remnants (Pl. XVIII, A).

The grain size is slightly smaller than that of the Lamotte, and quite similar to the better-known St. Peter. Screen analysis of a sample from Buick, Iron County, about 8 miles west of the Edge Hill sheet, is presented in the table on p. 47.

Quartz enlargement is a very conspicuous feature of the sandstone, and is more evident on weathered than on fresh samples, as though such enlargement were, in part at least, a feature of the weathering process.

Two thin sections of the Roubidoux were prepared, for microscopic study, and brief descriptions follow.

1. This sample is from near the center of sec. 2, T. 36 N., R. 2 E., where it occurs as tumbled blocks, believed to be Roubidoux, occupying a sink. The original grains were very perfectly rounded, but have undergone extreme secondary enlargement, until now the sand appears to be sharply angular. One or two grains were noted that seem to be very fine intergrowths of quartz and feldspar, and are probably fragments of some fine-grained igneous rock.

2. This sample, from the NW. ¼ sec. 19, T. 37 N., R. 1 E., was taken from outcrop, very near the base of the formation. The rock is moderately friable. The grains are much more sharply angular than those of the preceding sample, and show only faint traces of secondary enlargement. They are minutely roughened, as though by solution, subsequent to deposition.

Cross-bedding, both on large and small scale, is very abundant, as are also ripple marks of both current and oscillation types. Slabs showing an intricate network of raised ridges, obviously fillings of mudcracks in more shaly layers, are not uncommon.

Case hardening is very common, invariably accompanied by a much deeper reddish or brownish tint on the hardened surface, than in the more friable interior of the rock. Some beds of the sandstone are almost quartzitic.

Certain beds seem to be strikingly conglomeratic, the pebbles usually chert in a chert matrix. Concentric banding in some of the so-called pebbles suggests that the masses may be concretions rather than pebbles. A flat-pebble conglomerate similar to that described in the Eminence (p. 126) was found in the NW. ¼ SE. ¼ sec. 28, T. 37 N., R. 1 E., as an abundant float, without doubt derived from the Roubidoux.

A wide variety of chert occurs in the formation. Some is dense white like that common in the lower Gasconade but is much less abundant than it is in the lower formation. Oolitic chert is also very common. A globular type of Cryptozoon is fairly common, and another type, much like that in the Gasconade has been observed. A cellular chert, somewhat resembling honeycomb, the open pores averaging about $^1/_8$-inch in diameter, is not uncommon.

At only two localities in the entire area, both occurrences on the Potosi quadrangle, were dolomite beds actually observed interbedded with the Roubidoux sandstones. One is on Little Lost Creek, in the NW. ¼ SE. ¼ sec. 25, T. 37 N., R. 1 W., where Shipton measured the following section.

PARTIAL SECTION OF ROUBIDOUX.

5.	Covered slope.	
4.	Crystalline dolomite	10 ft.
3.	Sandstone	1 ft.
2.	Covered	5 ft.
1.	Crystalline dolomite, base not exposed.	

It is believed that still other sandstones pass below No. 1 of the above section, and that the entire section is Roubidoux. Since the base of the formation is not exposed in this valley, at least on the quadrangle, or for some distance west, it is impossible to say where within the formation, these dolomite beds fall. Lithologically, they resemble the Gasconade very closely.

In the NE. ¼ NW. ¼ sec. 6, T. 36 N., R. 1 E., occurs a bed of dolomite about 6 feet thick. The rock is finely crystalline, gray, cherty, and somewhat brecciated. It is underlain and overlain by sandstone. The dolomite may be traced some distance down Johns Creek. Still farther down the valley, in sec. 36, T. 37 N., R. 1 W., Shipton reports several thin dolomite lenses, intercallated with sandstone. Nowhere else except on John's Creek and Little Lost Creek, were any dolomite beds seen in the Roubidoux, though it is quite probable they occur elsewhere, since the Roubidoux sandstone float is such as to rather completely mask outcrops of thin dolomite beds.

Source of the sandstones.—As has already been pointed out, the present distribution of the Gasconade chert residuum is such as to indicate that by far the greater number, if not all, of the porphyry peaks were completely buried before Roubidoux time, so that it can be said with much certainty that the St. Francois Mountains cannot be looked upon as a source for the sand of the Roubidoux formation. The writer has elsewhere indicated his belief that the sands were derived from northern sources.[1]

[1]Dake, C. L., The problem of the St. Peter Sandstone; Mo. Univ. School of Mines Bull., vol. 6, no. 1, 1921, pp. 11-12, and 200-206.

Topographic expression.—Only in the area west of Shirley on the Potosi quadrangle, are the Roubidoux outcrops extensive enough to have any very distinctive topographic expression. In this area, they serve as a gently dipping resistant cap, so that the area is less sharply dissected than the bordering Gasconade terrane.

Though the actual relief is less, in the Roubidoux than in bordering areas, the region, in its minor features, is rather rugged. The hill slopes are heavily covered with large blocks of chert and sandstone, the soil is sandy, springs and flowing streams are few, and the region has little value for agriculture. Pines are a conspicuous feature of the landscape.

Where the Roubidoux is present only as small residual patches, each patch constitutes a particularly stony local area.

Stratigraphic relation.—The relations of the Roubidoux to the underlying Gasconade have already been discussed in detail. Except for a few residual patches of Pennsylvanian, which rest with obvious unconformity on the older beds, the Roubidoux is the youngest consolidated formation in the two quadrangles, and wherever present, constitutes the existing erosion surface.

Paleontology.—Along Highway 8, about three miles west of Shirley, near the center of the N. line of sec. 19, T. 37 N., R. 1 E., from a ledge in place the writer collected an imperfect specimen of a gastropod which Ulrich, who was present at the time, pronounced *Lecanospira* sp., a genus highly diagnostic of the Roubidoux.

On the 1240-foot ridge in the SE. ¼ sec. 31, T. 33 N., R. 1 E., in the extreme southwest corner of the Edge Hill sheet, is thick and abundant sandstone float and occasional ledges. Above the sandstone float is much chert float, from which imperfect fossils were taken, identified as *Lecanospira* sp. The material was too fragmentary for specific identification, but there is no question about the sandstone being Roubidoux.

In the valley in the N. ½ NE. ¼ sec. 10, T. 36 N., R. 1 E., there is abundant chert float carrying beautifully preserved specimens of *Lecanospira* of two or three species. At few localities has the Roubidoux been found to be more highly fossiliferous.

Along the ridge road, at elevation 1130 feet, in the SE. ¼ sec. 1, T. 37 N., R. 1 W., occurs an abundance of a very small species of Lescanospira, hitherto unfamiliar, in a very porous, iron-stained chert.

From the topmost two feet of the Roubidoux, in place, on Joachim Creek in the east edge of DeSoto, the writer secured slabs of chert literally packed with *Lecanospira*. The collection from this locality was submitted to Ulrich, who identified the following forms:

ROUBIDOUX FOSSILS FROM DE SOTO.

Lecanospira............................Two species.
Euconia or *Roubidouxia* n. gen.
Eccyliomphalus aff. *multiseptarius* Cleland.

According to Ulrich, these are all Roubidoux forms, and the last is known to occur in the Tribes Hill limestone of New York. The same horizon, richly fossiliferous, is exposed, about two miles farther south along the road, on the north side of McMullen's Branch, in the N. ½ sec. 11, T. 39 N., R. 4 E.

From Bollinger County, in the N. ½ sec. 3, T. 29 N., R. 8 E., the writer made a small collection, from chert float. This was also submitted to Ulrich, who reports the following, said to be of Roubidoux age:

ROUBIDOUX FOSSILS FROM BOLLINGER COUNTY.

Lecanospira sp.
Hormatoma aff. H. *artemesia* (Billings).
Lophospira, a small undetermined species.
A small round-whorled gastropod suggesting the genus *Holopea*.

In western Iron County, along the railroad track about 2 miles south of Bixby, an excellent specimen of a trilobite was secured from heavy chert beds, essentially in place. It was submitted to Ulrich, who pronounced it characteristic Roubidoux, but without further identification.

Near the center of the N. ½ sec. 30, T. 25 N., R. 7 E., in Cape Girardeau County, Ulrich and the writer collected the following fossils from beds in place, at the level of the Mississippi flood plain.

ROUBIDOUX FOSSILS FROM CAPE GIRARDEAU CO.

Lecanospira sp.
Roubidouxia sp.
Syntrophia sp.

Age and correlation.—The sandstone mapped as Roubidoux in these two quadrangles has been traced with perfect continuity into other Roubidoux areas to the north, west, and south. In his Revision,[1] Ulrich correlated it with the New Richmond and

[1]Bull. Geol. Soc. America, vol. 22, 1911, pl. 27.

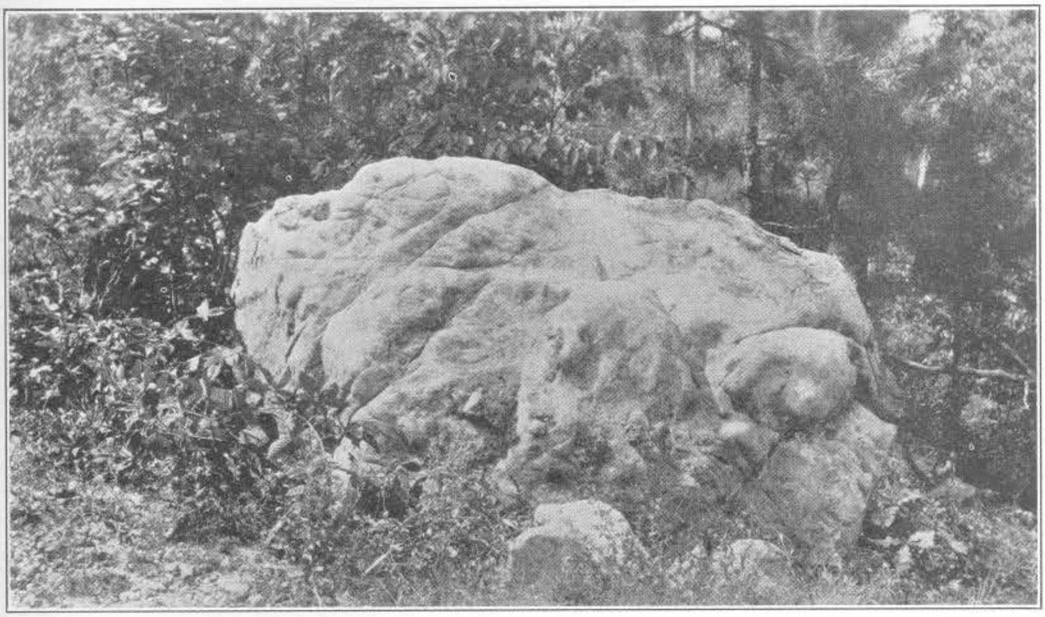
basal Shakopee of Wisconsin, Minnesota, and Iowa. In his latest unpublished table, however, he indicates his belief that it is not represented in the Upper Mississippi Valley. He notes its presence in Oklahoma, and correlates it with the Nittany of Pennsylvania. It is Lower Ordovician in age, being equivalent to beds fairly low in the Beekmantown. Ulrich, in the Revision, made it Upper Ozarkian, but he now makes it the middle division of his Canadian System (unpublished table).

MISSISSIPPIAN SYSTEM.

The abundance of residual cherts of Mississippian age throughout the Ozark region has naturally led to a close watch for similar material in the Potosi and Edge Hill quadrangles. The only place where anything was encountered which would even suggest the former existence of these beds in the area, is in the NW. ¼ sec. 4, T. 33 N., R. 1 E., where Lynch found a single fragment of chert, with a well preserved silicified coral, identified as *Zephrentis*, sp. undet. The state of preservation makes difficult, if not impossible, any more definite identification. The character of the chert, and the known distribution of the Burlington-Keokuk make almost certain the identification of the fragment as Mississippian. Mr. Lynch reported that he searched very thoroughly in the vicinity, without finding further fossiliferous material. It is not as much rounded or waterworn, as a pebble from a Tertiary gravel might be expected to be, but resembles normal residual chert. The evidence is too scant to permit any sweeping conclusions, but is in line with other evidence that points to practically complete submergence of the Ozark region by the Burlington-Keokuk seas.

PENNSYLVANIAN SYSTEM.

Distribution.—In the entire area of the two quadrangles the only Pennsylvanian rocks that have been identified with sufficient certainty, or in sufficiently large patches, to warrant mapping are in the vicinity of the old village of Shepard, in sec. 36, T. 35 N., R. 1 E., where the character of the material is well shown in recent cuts along the new location of Highway 32; in the saddle along the road between Enough and Maxwells Mill, near the center of the W. ½ sec. 32, T. 35 N., R. 1 E.; and in adjacent small areas west along Highway 32.



A. Bowlder of sandstone believed to be Pennsylvanian, in saddle, in old road, S. ½ NW. ¼ sec. 32, T. 35 N., R. 1 E.

B. Highly brecciated Eminence in cut on Highway 21, at Big River bridge, about three miles north of Caledonia.

It is believed, however, that many of the patches of sandstone bowlders shown as Roubidoux, especially on the Edge Hill sheet, may quite probably be Pennsylvanian. This is particularly true in the north central portion of the quadrangle, and especially so of those patches in which the bowlders are abnormally massive.

Among the many localities where Pennsylvanian is suspected, a few of the more striking are listed below.

Near the center of the line between sections 3 and 4, T. 34 N., R. 1 E.; in the N. ½ sec. 10, T. 34 N., R. 1 E.; in the NW. ¼ sec. 36, T. 36 N., R. 1 W., where large bowlders of sandstone that look more like Pennsylvanian than like Roubidoux are associated with a patch of chert float, possibly Van Buren or Gasconade; in the SE. ¼ SE. ¼ sec. 7, T. 36 N., R. 1 E., where similar bowlders are again present in a patch of chert float almost certainly Van Buren and Gasconade; in the NE. ¼ sec. 25, T. 38 N., R. 1 W.; near the center of the west line of sec. 30, T. 38 N., R. 1 E.; near the center of the SE. ¼ sec. 31, T. 38 N., R. 1 E.; and in the S. ½ NE. ¼ sec. 29, T. 38 N., R. 1 E.

Southwest of the Edge Hill quadrangle, new road cuts along Highway 21, between Centerville and Ellington also strongly suggest residual Pennsylvanian, as do also materials in a road cut near the highest point of the same highway between Centerville and Lesterville, in secs. 15 and 16, T. 32 N., R. 1 E.

In this general region clay pits or prospects reported by Wheeler[1] are without much question of Pennsylvanian age. The following localities listed by him are in addition to those already described.

PENNSYLVANIAN CLAY PROSPECTS IN IRON CO.

Center sec. 36, T. 35 N., R. 1 E.
Center sec. 32, T. 35 N., R. 1 E.
NW. ¼ sec. 1, T. 34 N., R. 1 W.
NE. ¼ sec. 2, T. 34 N., R. 1 W.

PENNSYLVANIAN CLAY PROSPECTS IN REYNOLDS CO.

Sec. 14, T. 32 N., R. 3 E.
Sec. 26, T. 32 N., R. 2 E.
About 2 ½ mi. NE. of Centerville.

All of the patches of residual sandstone believed to be Pennslyvanian are without much doubt preserved in structural

[1]Wheeler, H. A., Clay deposits; Mo. Geol. Survey, vol. XI, 1896, pp. 178, and 181-182.

sinks, and this accounts for the intimate admixture of the sandstone and clay with Van Buren and Gasconade chert and in many cases also, probably with blocks of Roubidoux sandstone. Consequently in the absence of the characteristic Pennsylvanian clays, which naturally do not outcrop well among all this more resistant material, definite identification as Pennsylvanian is almost impossible.

Muilenburg reports a patch of sandstone bowlders resting directly on porphyry in the SW. ¼ SE. ¼ sec. 16, T. 33 N., R. 2 E., which has been shown on the map as Roubidoux. There did not seem to be anything, according to his statements, by which it could be identified. It may quite possibly be Pennsylvanian.

Lithologic character.—Since it is not only possible, but altogether probable, that in many of the occurrences, bowlders of Roubidoux and Pennsylvanian sandstone are actually intermixed, it does not seem to be very safe to attempt any description of textural differences. A very interesting study in sedimentary petrography could be carried out in this region, by a systematic sampling of the bowlders believed to the Pennsylvanian, and those believed to be Roubidoux, to see whether grain shape, grain size, and heavy mineral content would give any clue to a means of differentiation.

The sandstones believed to be Pennsylvanian weather in general into larger and more massive, as well as more rounded, blocks than do those believed to be Roubidoux (Pl. XVIII, A). This is especially true of the occurrences actually mapped as Pennsylvanian. Many of these bowlders exhibit almost no trace of bedding, and not a few of them reach four to six feet in diameter.

The sandstones of the supposed Pennsylvanian are usually gray in color, more rarely reddish-brown. Some of the bowlders contain many sharply angular fragments of chert, probably residue from the Gasconade, embedded in the unconformable base of the younger sandstone.

In the patches mapped (secs. 32 and 36, T. 35 N., R. 1 E.), the sandstone bowlders are intimately associated with flint clays of the type so common in the clay deposits of Phelps and Gasconade Counties. In the patch at Shepard, there are also suggestions of the peculiar purple tint so characteristic of many of the Pennsylvanian deposits of the northeastern Ozarks. It is, in fact, chiefly on the strength of the white clays, and the purple tint, that these patches are mapped as Pennsylvanian.

Another feature of these deposits is the presence of a very large amount of white flint, some of it leached and porous to the point where it resembles clay. This is probably the residue from the Van Buren and Gasconade formations, and owes its intimate admixture with the clay and sandstone, to the process of slump into the structural sinks which have been the chief means of its preservation.

Topographic expression.—The area of exposure of the Pennsylvanian residual material is so very limited that it has no individual topographic expression.

Stratigraphic relations.—The few patches of Pennsylvanian in the area rest with profound unconformity on the older rocks, probably overlying beds ranging in age from Potosi to Roubidoux. The absence of all the formations between the lower Orodovician and the Carboniferous attests the magnitude of the hiatus.

There are reasons for believing that farther to the northwest, at least, the topography of the Ozarks was quite rugged when the Pennsylvanian sedimentation was initiated. At Knobview, in Phelps County, for instance, in the NE. ¼ sec. 24, T. 38 N., R. 6 W., Pennsylvanian rests in place on horizontal Roubidoux, at an elevation of 1020 feet, while not over a quarter of a mile to the north, in the SE. ¼ sec. 13, T. 38 N., R. 6 W., Jefferson City or possibly Cotter, rises in regular sequence to 1180 feet. In sec. 3, T. 38 N., R. 5 E., not quite three miles farther northeast, the Pennsylvanian is again seen resting directly on Roubidoux, at an elevation of about 1030 feet. Everywhere in the area cited, the Roubidoux and Jefferson City or Cotter are essentially horizontal, and there is no evidence whatever of any important sink structure. It is believed, therefore, that this establishes the existence of abrupt relief of over 150 feet on the pre-Pennsylvanian surface.

There is no reason to think that the pre-Pennsylvanian surface in the Potosi-Edge Hill region was any less rugged, though the evidence is completely obscured by the heavy mantle of chert float. The present irregularity of altitude of the sandstone patches may result from deposition on a rugged surface, from later slump into sinks, or from both, and there does not seem to be the remotest possibility of determining the relative parts played by these factors.

There does not seem to be much doubt that the Roubidoux was stripped off portions of the area, before the Pennsylvanian was laid down, since, where the Pennsylvanian residue rests on, or is mingled with, the Van Buren-Gasconade residue, at Shepard, there is certainly very little, either of chert or sandstone, that one would be tempted to call Roubidoux.

In fact, in this region, patches of the sandstone are actually in contact with Potosi. Since, however, it is intimately mixed with chert believed to be Van Buren-Gasconade, it is possible that some of those formations were still present, when the Pennsylvanian was laid down. It is quite possible, however, in fact even probable, that locally, at least, Potosi was actually exposed on the pre-Pennsylvanian erosion surface. The fact that over much of the region, the Gasconade is represented by residuum only, with no rock known in place, makes interpretation difficult.

Paleontology.—No fossils, except imperfect fragments of included older forms, in the cherts, have been found in this region, in the rocks of supposed Pennsylvanian age.

Age and correlation.—On the basis of the massive character of the sandstone, the association with characteristic flint clays, and the presence of the peculiar purple tint already described, these patches of residual material are correlated with some assurance with the remnants of Pennsylvanian of the northeast Ozarks, particularly in Phelps, Crawford, and Gasconade Counties.

This has usually been considered to be Cherokee. As the basal Pennsylvanian sedimentation encroached upon the Ozark upland, it is believed that the basal beds were successively suppressed by overlap so that, while the beds in question in Phelps and Crawford Counties, are locally basal, they actually are very high in the Cherokee. This is borne out by recent unpublished information secured in the field by McQueen.[1]

There does not seem to be any way to determine whether the patches in the Edge Hill quadrangle are the precise equivalents of those farther northwest about Cuba and Rolla, but they are provisionally referred to the uppermost Cherokee.

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[1]McQueen, H. S., Personal communication.

QUATERNARY DEPOSITS.

It is not possible, in the area of the Potosi and Edge Hill quadrangles, to distinguish between deposits of Quaternary and those of Recent age, so the two are described together. There are only two well recognized types of such deposits, within the area, residuum and alluvium.

Residuum.

The character of the soil derived in situ from the weathering of each formation has been described under the section devoted to the lithologic character of each, since it constitutes one of the very helpful bits of evidence, in the identification of the formation. In general, in the Edge Hill sheet, and in the St. Francois Mountains at large, of which the Edge Hill area is a representative portion, the residuum is much deeper, and masks the underlying formations much more completely, than in the areas either to the east or west of the St. Francois uplift.

There are two formations, in particular, in the region, outcrops of which are very deeply masked by residuum, in spite of the fact that the same formations outcrop well, in bordering areas. These are the Van Buren-Gasconade and the Potosi, and the Van Buren-Gasconade is far more completely masked than the older formation.

The reason for the exceptionally complete removal of the soluble portions, and the extreme accumulation of the insoluble residue, from the Van Buren-Gasconade, in the St. Francois as compared with surrounding regions, is believed to be the fact that here it has been raised higher above the general level of ground water and exposed for a far longer period of time, than in the bordering area.

Obviously solution, as contrasted with erosion in the larger sense, has been the chief factor in the removal of the limestones from the considerable areas where the exceptionally deep chert mantle now exists.

That the Potosi has been less completely removed, and less absolutely masked, results, perhaps, from the fact that it occurs lower in the section, and consequently lower topographically, and is less completely exposed to leaching and removal by solution.

Since such a heavy mantle of chert residuum may slump far down the hillsides, and deeply mask not only the outcrops of the formation from which it was derived, but also those of non-cherty or less cherty beds below, it is almost impossible to form any reasonable estimate of its true thickness. Over very large areas however, hillsides are so completely masked with Van Buren-Gasconade chert, that nothing else can be seen, through a vertical interval of from 100 to 200, and in some cases over 300 feet, so it would seem that the residuum is very thick.

As already pointed out (p. 152), drilling in Madison County, where the situation seems to be essentially the same as in the Edge Hill area, has demonstrated an actual thickness of nearly 200 feet of unconsolidated residual chert and clay.

The residual material so widely developed in the St. Francois Mountain area is characterized by an extreme development of chert, frequently in enormous masses (Pl. X, B). As already emphasized, bowlders of chert up to 5 feet in average diameter are not uncommon, and much larger ones are known, up to 15 and even 30 feet. In general the more complete the removal of the dolomites, the larger the residual bowlders, and the most striking occurrences are to be found where actual outcrops of the Gasconade no longer exist.

Similarly, the druse of the Potosi formation is most abundant and largest where the formation is most deeply weathered (Pl. XIII, B).

An extensive study of cores and cuttings from both the Potosi and Van Buren-Gasconade seems to indicate that where the formations are deeply buried and unweathered, large masses of chert or druse are very rare, except along lines of active circulation of aereated waters. Both formations are siliceous, and leave, on digestion with acid, insoluble silica residues. Most of the silica, however, is inconspicuous, even with mircoscopic examination, until the dolomite is dissolved.

One is forced, from the above facts, to the conclusion that as the dolomites are leached away, the minutely disseminated silica is gradually dissolved, and reconcentrated in larger and larger masses, thus developing the very huge chert bowlders that are so common a feature of the chert residues of the area in question (Pl. X, B).

It should be kept clearly in mind that it is not proposed to explain the origin of all chert by the above process, but to the writer, it seems proven beyond question of doubt, in spite of profound earlier conviction to the contrary, that most of the large masses of chert strewn over the central Ozark area, where the Cambro-Ordovician formations outcrop, are secondary, and developed by segregation of formerly disseminated silica, *as the formations weather*. This question is considered at greater length, in the discussion of the origin of the lead and barite deposits.

Alluvium.

No terrace deposits of consequence are known in the area, and the deposits properly referred to as alluvium are confined to two types. (1) Alluvial fans bordering the higher porphyry knobs, and (2) the material accumulating on the present flood plains of the streams.

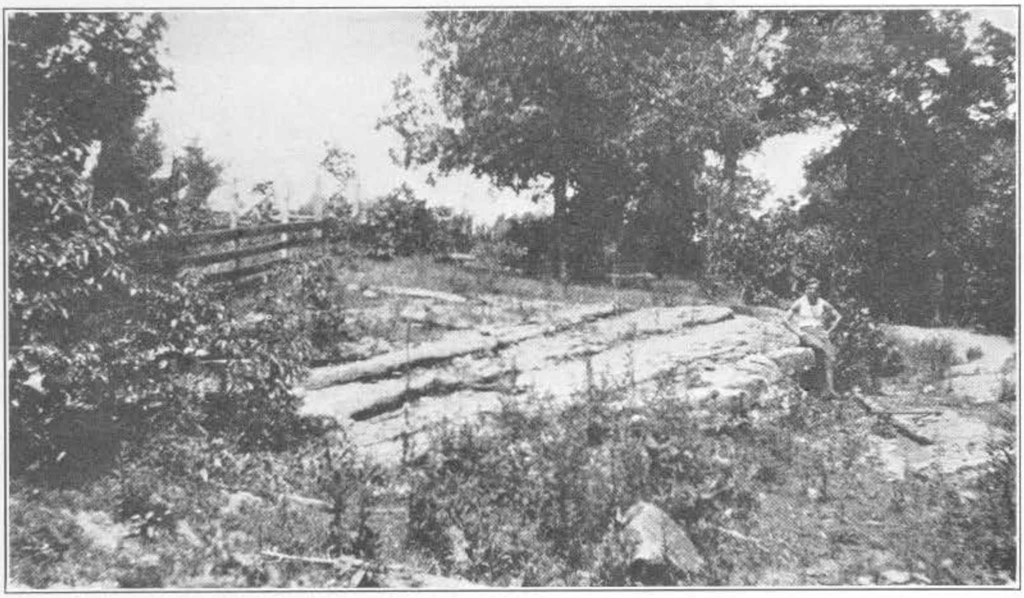
1. At the bases of many of the higher porphyry knobs, the very high-gradient gullies of the porphyry slopes open out onto much flatter areas, where they pass onto the Cambrian sediments that floor the inter-porphyry valleys. Over such areas exists a considerable accumulation of rounded, or sub-rounded, prophyry bowlders, which actually laps out for some distance over the bordering Cambrian sediments. To these accumulations, the term alluvial fan seems properly to be applied. In a few instances these fan deposits are now trenched by sharp gullies that show the mass of porphyry bowlders actually resting upon the Cambrian sediments.

Such deposits occur at the southwest extremity of Little Pilot Knob, in the N. ½ sec. 36, T. 38 N., R. 1 W.; around the group of high porphyry knobs in the north central part of the Edge Hill sheet, especially adjacent to Johnson Mountain; and at many localities bordering mountains like Bell, Lindsay, High Top, Little Tom Sauk, Wildcat, and others.

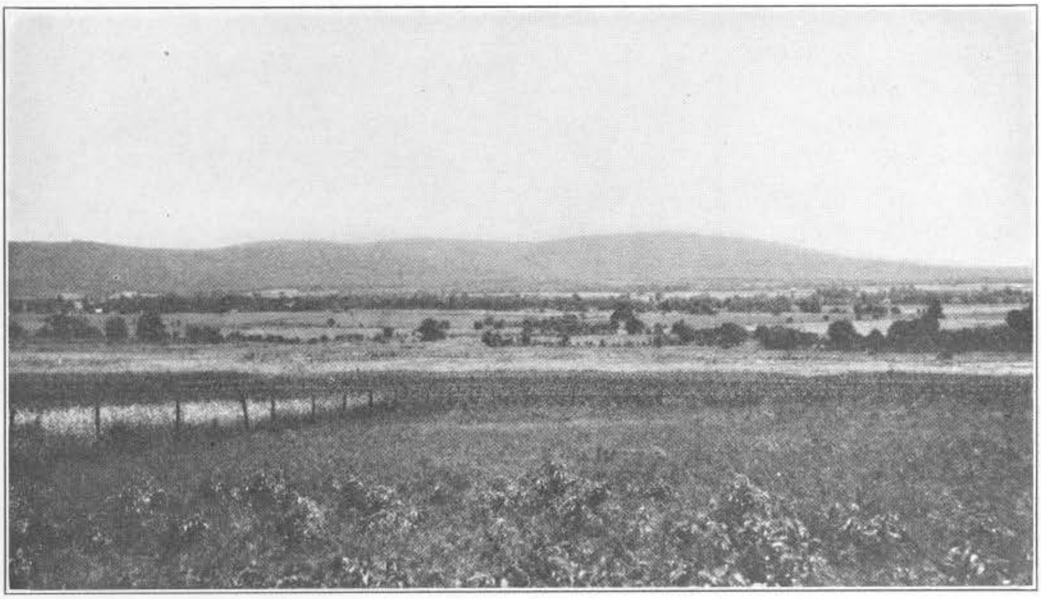
2. The flood plains of the area are floored chiefly with chert gravel, most of it angular to sub-rounded. The presence, at certain localities, of ledges of rock in the beds of the streams, suggests at first thought, that the gravel is very shallow. It must be noted, however, that such ledges commonly occur in the stream beds, only where they are close to one or the other wall of the valley. Little is actually known of its depth, in the broader valleys, not a single record of drilling through it being available. Holes located in some of the smaller valleys, in which are reported a considerable depth of "surface," probably

penetrate undifferentiated alluvium and residuum, rather than the true flood plain accumulations.

The material shown as alluvium in many of the smaller valleys, still topographically too youthful to have true flood plains, is actually residuum that has crept and washed down the hillsides and accumulated temporarily along the course of the main valley. While it obscures the rock of the valley floor, it is not exactly a true flood plain deposit.



A. Steep dips in the topmost beds of the Bonneterre, adjacent to a porphyry knob. E. ½ NE. ¼ sec. 22, T. 35 N., R. 1 E.



B. Looking east from near Belleview, at a porphyry ridge. The west face of this ridge is so straight that it suggests a pre-Cambrian fault line.

CHAPTER III.

STRUCTURE.

Regional.

The Potosi-Edge Hill area borders the St. Francois Mountains, the structural center of the Ozark dome, on the northwest, west, and southwest. Consequently it is characterized in general by a westerly regional dip. The uniformity of this inclination is broken by faults, and by the initial dips about porphyry knobs, and is, therefore, so irregular that it is hardly possible to give for it a significant figure.

It is perhaps most regular through the central portion of the Potosi quadrangle. At the center of the east border of the sheet, the base of the Van Buren is at an elevation of about 1140 feet. At the center of the west border, the top of the Gasconade is at nearly 860 feet. If the Van Buren-Gasconade is 250 feet thick, probably an excessive figure for this area, the due west component of the dip, in that distance, about 13½ miles, is 530 feet, or approximately 40 feet per mile.

This is, however, far higher than the average dip on the west flank of the Ozarks. For instance, as just cited, the top of the Eminence is at about 1140 feet, near the center of the east line of the Potosi quadrangle. At Steelville, nearly due west, the same contact is at somewhere near 740 feet, or a drop of 400 feet in about 35 miles airline distance. That would be not to exceed an average of 12 feet per mile.

The situation cited above is entirely characteristic, the outward dips being much greater, as a rule, near the St. Francois core, than the average for the Ozark dome as a whole.

Just west of Sunlight, the base of the Potosi is at 1120, while where Trace Creek leaves the west border of the map, a distance of 3½ miles, it is at 980, a west component of 40 feet to the mile.

On the Edge Hill sheet, the structure is still more erratic, owing to the large number of porphyry knobs exposed, and average figures mean still less. Near Belleview (sec. 6, T. 34 N., R. 3 E.) the top of the Potosi is at about 1400 feet, whereas due west, at the west border of the map, it is at about 1200, a west component of 200 feet in about 14 miles, or roughly 15 feet to the mile. At the southwest corner of the map, the same contact is at nearly 1000 feet, a due south component of about 200 feet in 14 miles, or again approximately 15 feet to the mile.

Folds.

Throughout the area, high dips are limited to two types of situations, drag along fault planes, and quaquaversal dips off the pre-Cambrian knobs. Nothing that would, in the ordinary sense of the word, be termed folding, has occurred. The more gentle dome-and-basin areas, outlined in general by dips of less than one-half degree, are probably largely depositional, intensified in some measure by compacting and solution.

The only definite structure of this sort that cannot be certainly shown to be related to the old pre-Cambrian topography, is the broad shallow basin which has been responsible for the preservation of the area of Roubidoux west of Shirley, in the Potosi quadrangle, to which the name Shirley Syncline has been applied. Even this basin seems quite probably to be initially depositional, between two porphyry ranges, the northern of which is represented most visibly by Little Pilot Knob in sections 25 and 36, T. 38 N., R. 1 W., and the southern even more conspicuously by Johnson Mountain, in sections 13, 23, and 24, T. 35 N., R. 1 E. The basin character of the area has been further intensified by the Palmer and Shirley faults.

Faults.

The faults of the area fall naturally into three groups, the Shirley fault and the Palmer fault zone, on the Potosi quadrangle, and the Black fault zone, in the Edge Hill sheet. In all three, the major movement is clearly post-Roubidoux. Along the Palmer and Black zones, however, there are also some indications which suggest post-Eminence and pre-Van Buren movement. Each of these will be discussed separately.

The Shirley fault.—This fault passes within about a mile and a half northeast of the postoffice of Shirley, from which it is named. It has been traced about eight miles, from the W. ½ sec. 31, T. 38 N., R. 1 E., to the W. ½ sec. 19, T. 37 N., R. 2 E., striking about N. 50 W. It has not been possible to trace it definitely beyond these two points, in either direction.

The southwest side has been dropped, the maximum throw, in secs. 10 and 14, T. 37 N., R. 1 E., dropping Roubidoux on the southwest side to the level of middle or lower Eminence on the northeast. Allowing at least 200 feet for the thickness of the intervening beds, and a known 100 for that portion of the Eminence exposed, the maximum displacement is not less than 300 feet, or perhaps a little more.

The apparent disregard of the fault for hills and valleys, suggests that the plane dips steeply, though no direct observations could be made.

Where the fault cuts dolomites it is usually deeply soil covered, and few outcrops of breccia or dragged beds are to be seen, but where it cuts the Roubidoux, the sandstone has been rendered more veined and quartzitic, and beautiful drag dips, slickensides, and masses of breccia are exposed. The most striking one noted occurs in the SW. ¼ NW. ¼ sec. 14, T. 37 N., R. 1 E., in the valley bottom.

This fault and adjacent shatter zones seem to be responsible for a certain amount of mineralization, both of zinc and lead. The Big Bill diggings occur almost on the fault, in the NE. ¼ sec. 24, T. 37 N., R. 1 E. Other diggings, near the center of sec. 2, T. 37 N., R. 1 E., said to be on a considerable shatter zone, are over a mile from the main fault, and no displacement could be found in the vicinity.

The Black fault zone.—This fault passes about a mile northeast of the village of Black, from which it has been named. It has been rather definitely located, striking about N. 35 W., from the center of sec. 26, T. 33 N., R. 1 E., to where it leaves the west border of the Edge Hill quadrangle, in the NW. ¼ sec. 36, T. 34 N., R. 1 W.

No effort was made to trace it northwest beyond the limits of the sheet, but high dips in the vicinity of Goodwater suggest that it may extend at least that far, and it is thought highly probable that it continues northwest to join the Palmer zone. To the southeast it is lost in an area of very heavy Gasconade float. No effort was made to trace it beyond the south border of the quadrangle.

The southwest side has been dropped. Since the faulting involves the Potosi, both the upper and lower contacts of which are unconformable, resulting in extreme variations in thickness, exact measurements of the throw are nearly impossible. The greatest amount that can be determined from surface outcrop is in sections 15, 16, and 22, T. 33 N., R. 1 E., where Potosi is dropped to the level of the Bonneterre. Near this point, the Davis is about 180 feet thick, and there seems to be nearly 60 feet of Derby. Some 20 feet or more of Bonneterre is exposed against Potosi, so that the throw is probably not less than 250 feet. The results of the drilling at Black show that in hole No. 4, on the southwest side of the fault, the top of the Lamotte is some 290 feet lower than in hole No. 5, on the northeast side. This is in the NW. ¼ sec. 22, T. 33 N., R. 1 E. The check is reasonably close. In holes Nos. 1 and 2, in the NW. ¼ sec. 26, T. 33 N., R. 1 E., the throw on the Lamotte is about 210 feet. Between hole No. 10, near the center of the north line of sec. 16, T. 33 N., R. 1 E., and hole No. 11, near the center of the south line of sec. 8, T. 33 N., R. 1 E., the top of the Lamotte drops about 335 feet, but since the holes are about a mile apart, a portion of this difference is probably the result of regional dip, the throw of the fault being less than 335 feet, by the amount of such dip.

As in the case of the Shirley fault, no direct evidence of the inclination of the fault plane could be discovered, but one would naturally infer, from the way it cuts in a straight line across rather rugged topography, that it is very steep. At no place along the fault were exposures sufficiently good so that the actual plane could be seen, and drag dips, breccia, and slickensides were only noted at a very few localities, one of the best being near the center of the W. ½ sec. 26, T. 33 N., R. 1 E.

A branch fault joins the main trace in the NW. ¼ NW. ¼ sec. 16, T. 33 N., R. 1 W., and has been traced in a very irregular westward trend for about a mile. The north side drops Van Buren-Gasconade to the valley bottom, with Potosi rising 200 feet on the ridges to the south. The north side has, therefore dropped at least 200 feet. The Van Buren-Gasconade is identified wholly as float, not an outcrop being observed, so that some uncertainty may be felt, about the validity of the mapping, though faulting affords the most plausible explanation of the relations just described.

About at the SW. cor. sec. 17, T. 33 N., R. 1 E., this branch fault seems to turn abruptly to a bearing about N. 10°-15°W., in which direction it seems to run about two miles and die out. The entire evidence for this part of the fault consists of four small patches of druse float, believed to be Potosi, in the heads of the valleys, otherwise cut in Van Buren-Gasconade residuum throughout. This fault, if it actually exists, is upthrown on the west side.

One of the most puzzling features of the Black fault zone is the remarkably sudden change in the thickness of the Potosi, from an average of over 200 feet, west of the fault to an average of less than 100 feet, east of that line.

Of course it must be admitted that the upper contact of the Potosi is drawn wholly on float, that is no Van Buren-Gasconade occurs in place. This, however, is true on the west side of the fault, as well as on the east. And it seems quite inconceivable that any possible development of sink structure could leave patches of Van Buren-Gasconade float so widely distributed, above so uniformly thin a layer of Potosi, on the east side, and leave the Potosi so thick on the west.

The writer thus far can find only one plausible explanation of the observed facts, and that is that along the line of the present Black fault, there was a zone of sharp disturbance, either abrupt monoclinal dips to the west, or even more likely a zone of faulting, with the west down thrown, that was completed and peneplained in post-Potosi and pre-Van Buren time, so that east of this line, the Potosi was much thinner than west of it, before the Van Buren was laid down. Then when the latter was deposited, it was laid across the fault, resting on thick Potosi to the west, whereas to the east, it lapped onto much thinner Potosi, and even locally onto Davis and Bonneterre.

In post-Roubidoux times further raising of the east side, along this zone of weakness, again followed by active erosion, completed the structure as it is now found. Very similar conditions occur along the Palmer fault zone.

Palmer fault zone.—The main fault of this zone passes about 2½ miles north of the village of Palmer, from which it takes its name. The belt enters the east side of the Potosi quadrangle in secs. 19, 30, and 31, T. 36 N., R. 3 E., strikes about N. 75° W., and leaves the western side in sec. 36, T. 37 N., R. 1 W., and secs., 1, 12, 13, and 24, T. 36 N., R. 1 W. Within the belt, however, are faults that strike in almost every possible direction. The width of the faulted zone varies from 2 to 5 miles, and within it are local areas of very complex structure.

East of the Potosi quadrangle, the north branch of the Palmer fault has been traced in a northeast direction entirely across the Bonneterre quadrangle, to the vicinity of French Village, in St. Francois County, where it seems to become a part of the great fault zone that crosses Ste. Genevieve Co. In the western area of the Bonneterre quadrangle, this branch forks again, sending another shoot to the southeast corner of the quadrangle. This fork is quite probably a continuation of the Mine la Motte fault. The south branch of the Palmer zone leaves the Potosi quadrangle in sec. 31, T. 36 N., R. 1 E., and passes out of the southeast side of the Bonneterre quadrangle in sec. 11, T. 35 N., R. 3 E., beyond which point it has not been traced.

West of the Potosi quadrangle, the Palmer zone has been traced continuously into the famous Crooked Creek area of Crawford County, near Wesco. There it turns north, passing west of Cuba, where it has been known as the Cuba fault. This branch has been traced northwestward to the Gasconade River, near Mt. Sterling. It is quite probable that the fault observed along Highway 8, west of Berryman is a branch of the Palmer zone, and that it, in turn, connects with the fault just east of Leasburg, known as the Leasburg fault.

In general, the north side of the zone is the depressed area, though within the belt, are minor displacements in the opposite direction. At the west border of the quadrangle, the zone as a whole throws Roubidoux on the north to the level of Potosi on the south, though the total movement is distributed through several faults. This would be an aggregate throw of something over the full thickness of the Van Buren-Gasconade, and Eminence, which cannot be determined with certainty, in this area, but is probably more than 400 feet.

At the east side of the quadrangle, the aggregate movement brings Lamotte to the level of Eminence, a total of not less than the full thickness of the Bonneterre, Davis, Derby-Doerun, and Potosi, certainly not less than 800 feet, and probably more. Here also, the movement is distributed through several faults.

The entire zone is characterized by a number of long and very narrow dropped blocks, between pairs of faults. One such block, perhaps the most striking one in the belt, drops a wedge of Van Buren-Gasconade, and Roubidoux less than a quarter of a mile wide and over four miles long against Eminence on the north and Bonneterre and Davis on the south. This block has been traced across secs. 19, 20, 22, 27, and 26, T. 36 N., R. 2 E. In the latter section it is cut off by the main fault which here occupies the flood plain of Big River. At this end of the block the main fault throws Roubidoux on the northwest wall of the valley to the level of Lamotte, on the southeast wall. This is the greatest movement observed anywhere within the entire Palmer fault zone, and is probably not less than 1200 feet.

The most complicated structure encountered in the entire area of the two quadrangles is probably that which occurs about two miles north of Belgrade, in secs. 19, 20, 21, 28, 29 and 30, T. 36 N., R. 2 E., where seven or eight faults may be observed in a distance of less than half a mile.

South of the main Palmer fault, throughout the western half of the faulted zone, is an extensive area of Potosi and Eminence, in which outcrops are less abundant than elsewhere. In this area, many of the faults are mapped chiefly on the evidence afforded by the distribution of the Eminence and Potosi float. In the mining district north of Palmer, the structure is almost certainly more complicated than has been shown on the map. The scarcity of outcrops, except in the valleys, and the fact that much of the characteristic float has been worked over in mining operations and mixed with materials brought up from unknown depths, has made the use of float less certain than elsewhere. At the time the field work was done, not a single mine was in operation, many were badly caved, and all were full of water, so that it was impossible to enter them. As a result of this scarcity of evidence, it is almost certain that many minor faults have been entirely missed and it is not unlikely that portions of others have been incorrectly connected.

Except where the faults cut the Roubidoux, they are usually deeply soil covered, and good outcrops of steep drag dips, brecciated zones, or slickensided masses are rare. Perhaps the best exposures of breccia in dolomite, are to be seen in the SW. ¼ SW. ¼ sec. 36 T. 37 N., R. 1 W.; in the E. ½ NE. ¼ SE. ¼ sec. 24, T. 36 N., R. 2 E.; in the S. ½ SW. ¼ sec. 14, T. 36 N., R. 2 E.; near the center of the E. ½ sec. 15, T. 36 N., R. 2 E.; in the SE. ¼ NE. ¼ sec. 7, T. 36 N., R. 1 E.; and at the Big River bridge on Highway 21, about three miles north of Caledonia (Pl. XVIII, B).

Steeply dragged and strongly brecciated Roubidoux is beautifully exposed along the main fault, where it crosses the west line of sec. 6, T. 36 N., R. 1 E., and again in the valley near the center of the north line of sec. 1, T. 36 N., R. 1 W.

The Lamotte also shows high drag dips adjacent to the fault in the NW. ¼ SW. ¼ sec. 25, T. 36 N., R. 2 E.

The apparent disregard of the faults in this zone for topographic irregularities, the faults showing no shift in direction, in crossing high ridges and deep valleys, suggests rather steep fault planes, though no direct evidence on this point could be secured.

Type of faulting.—So far as the writer has been able to observe, the area is practically free from flexures such as would suggest active compression, and he would unhesitatingly refer the faults all to the type commonly called normal, or gravity. There does not seem to be the slightest evidence of thrust faulting, here, or elsewhere in southeast Missouri. Steeply dipping beds, adjacent to the fault, such as those mentioned on p. 183, are probably best explained as simple drag. Even the occurrence of slight overturn, next to the fault plane, such as that reported by Weller and St. Clair[1] is probably better explained as either extreme drag, or rotation of fragmented blocks between the fault walls, or between closely spaced minor faults.

Pre-Van Buren faulting.—Evidence has already been presented at length (p. 122) strongly suggesting that there may have been post-Eminence and pre-Van Buren movement, along the Palmer fault zone, the south side having been raised, and the Eminence largely removed, before the Van Buren was laid down. This is quite in line with the evidence just cited for pre-Van Buren movement along the Black fault.

Pre-Cambrian faulting.—No direct evidence has been secured of any faulting of pre-Cambrian age, but there are two lines of indirect evidence, which suggest pre-Cambrian fault movements.

First, there is the peculiar way in which the basic dikes end or are offset. Attention has already been called to the fact that the two small patches of basic dike, one near the center of the north line of sec. 16, and the other in the NE. ¼ NE. ¼ sec. 21, T. 34 N., R. 2 E., may very well be offset portions of the long dike just to the southeast. The dating of such movement depends on the dating of the dikes. It is, in any event, clearly pre-Potosi, and if the dikes are pre-Bonneterre, as has been suggested, is probably pre-Cambrian.

Second, there is, in the topographic arrangement of the pre-Cambrian hills, a hint of probable old fault or fault-line scarps. The rhyolite porphyries, in which evidences of stratification are usually quite obscure, are certainly not the type of rock in which one would expect a development of linear topographic features.

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[1]Geology of Ste. Genevieve Co.; Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, pp. 264-266.

Such a long, straight scarp as that bounding the porphyry ridge across secs. 22 and 28, T. 35 N., R. 2 E., is certainly suggestive of a fault feature. But there is not the slightest evidence of post-Bonneterre movement, so the faulting, if faulting it is, must be pre-Cambrian. Just east of Highway 21, and off the east edge of the Edge Hill quadrangle, on the old Iron Mountain sheet, is another such very straight border of the porphyry (Pl. XIX, B), along the southwest base of Buford Mountain, in secs. 19, 20, 28, 29, and 33, T. 35 N., R. 3 E. The parallel arrangement of the porphyry ridges and intervening valleys in the southeast portion of the Edge Hill quadrangle is also inconsistent with the massive character of the porphyry.

Initial Dips.

As pointed out in a previous publication,[1] the majority of the conspicuous dips in the Cambro-Ordovician sediments in that part of southeast Missouri in and adjacent to the St. Francois Mountains, are now known to be related definitely to the buried topography of the old pre-Cambrian erosion surface.

Many of the porphyry knobs of this old floor now protrude through the covering of Cambrian and Ordovician sediments which formerly entirely, or almost entirely, concealed them. In most instances the flanking sediments, which range in age from Lamotte to Gasconade, dip more or less steeply away from the protruding porphyry, in all directions.

The Lamotte is best seen in this relationship, in the general vicinity of Caledonia. One of the most conspicuous and easily accessible areas occurs along Highway 21, less than a half mile north of Caledonia, in about the center of the SW. ¼ sec. 1, T. 35 N., R. 2 E. Dips of from one or two, to over seven degrees are visible in the sandstone, to the east, south, and west of a small porphyry knob. To the north there are no exposures of any sort. The dips are characteristically quaquaversal, and if it were not for the fact that the porphyry core actually protrudes, the structure would undoubtedly be referred to as a small dome. To the south and west, the dipping Lamotte passes beneath Bonneterre at much lower elevations (20-30 ft.) than those at the top of the Lamotte near the porphyry.

[1]Bridge, Josiah, and Dake, C. L., Initial dips peripheral to resurrected hills; Mo. Bur. Geol. and Mines, Biennial Report, 1929, pp. 93-99.

Similar dips may be observed in the Lamotte on the south flank of a small pre-Cambrian exposure in the SE. ¼ NW. ¼ sec. 31, T. 36 N., R. 3 E.

There is a particularly interesting occurrence in the NW. ¼ SW. ¼ sec. 36, T. 36 N., R. 2 E. Here there is an unexpected exposure of the Lamotte, entirely surrounded by Bonneterre. On the north side, northerly dips, and west dips on the west side, at once suggest another such dome. No porphyry was actually exposed, but there is much porphyry float in the yard of the house on the west side of the road, and a dug well is reported to be bottomed on that rock, thus completely justifying the belief that this is a case wholly similar to the one at Caledonia.

Domal dips in Lamotte sandstone, in the NE. ¼ NW. ¼ sec. 35, T. 36 N., R. 2 E., also led to the suspicion of buried porphyry, and while no outcrops could be found, sufficient arkosic material and porphyry float were seen to bear out the suspicion.

Farther to the south and west, Lamotte does not outcrop, and Bonneterre occurs widely in contact with the pre-Cambrian.

A very fine example of domal dips in the Bonneterre, bordering such an old knob, occurs in the area surrounding the common corner of secs. 1, 2, 11, and 12, T. 35 N, R. 1 E. The region round about is Davis, but as a result of truncation of the dome by erosion, there is a ring of Bonneterre within the Davis, and in turn enclosing the central porphyry mass. The Bonneterre-Davis contact descends over 80 feet in a half-mile to the southeast, and about the same amount to the north in a similar distance, with pronounced crenulations or "V's" in the contact, where it crosses stream valleys, the "V" pointing downstream, because the beds dip downstream at an angle steeper than the stream gradient.

A similar dome occurs about the porphyry knob, in the W. ½ NW. ¼ sec. 14, T. 35 N., R. 1 E., but erosion has not cut deeply enough so that the Davis, the chief country rock of the immediate area, has been removed, even next to the porphyry, except on the north side, where a small stream cuts very close to the base of the porphyry knob. Here is a small inlier of Bonneterre, attesting clearly enough the domal nature of the structure.

In general, the dips in the dolomites are steeper than those in the Lamotte (Pls. VI, B and XIX, A). Along the valleys of Tom Sauk and Little Tom Sauk Creeks, in the southeast portion of the Edge Hill area, is perhaps the best place on the quadrangle to see steep dips in the Bonneterre, where it laps against the old buried hills. In the SW. ¼ SW. ¼ sec. 12, T. 33 N., R. 2 E., dips of between 20° and 25° were actually measured. Perhaps the most accessible point where the steep initial dips of the Bonneterre can be seen is in a road cut, on Highway 21, on the south slope of Tiptop (Pl. VI, B), south of Ironton.

The vertical element in these dips is large. For example in the main valley of the East Fork of Black River, undoubted, Davis, with characteristic fossils occurs at river level, elevation 940 ft., where the river crosses the east line of sec. 3, T. 33 N., R. 2 E., whereas a mile northwest, where the sediments lap against the porphyry near the center of sec. 34, T. 34 N., R. 2 E., Bonneterre, probably some distance below the top of the formation, outcrops at an elevation of 1240 feet, or 300 feet higher. This figure gives some conception of the structural relief on the Bonneterre-Davis contact resulting from deposition on the uneven surface of the old pre-Cambrian landmass. This relief certainly amounted, in this case, to well over 300 feet, and perhaps not far from 400 feet, in only a little more than a mile.

Another very striking case, only a little less extreme, occurs at the junction of Imboden Creek with the East Fork of Black River. In the angle between the two streams, at the south tip of High Top Mountain, near the center of the NE. ¼ sec. 8, T. 33 N., R. 2 E., the contact between the Davis and the Derby is at about 875 feet. A little over a mile due southeast, in the SE. ¼ SE. ¼ sec. 9, T. 33 N., R. 2 E., Bonneterre outcrops up to about 1050 feet. Allowing only 150 feet for the thickness of the Davis, considerably less than its known average, this would give a structural relief, on the Davis-Bonneterre contact, of over 300 feet in a little over a mile and a quarter.

So unfailingly true has the principle been proved to be, that the sedimentary contacts rise abruptly toward and over the old porphyry hills, that whenever, in this area, a contact was found exceptionally high, the proximity of porphyry was at once suspected. Perhaps the most striking verification of this supposition that was encountered has to do with the high knob in the W. ½ SW. ¼ sec. 13, T. 34 N., R. 1 E. On the southeast spur of this knob, in the adjacent section 23, the base of the heavy mantle of Van Buren-Gasconade chert, allowing duly for slump, seems to be at about 1140 feet. The writer climbed up this spur, to the high point, firmly expecting to find it capped with Roubidoux, or possibly even younger beds, and much to to his surprise, found nothing but Van Buren-Gasconade chert, entirely to the top, through a vertical interval of over 400 feet. It seemed incredible, of course, that the residuum could be that thick, and the suspicion was at once raised of a porphyry hill veneered with dip slopes, or near dip slopes, of the residuum. The finding of small patches of porphyry at valley heads on both the east and west sides of the hill, substantiated the hypothesis. (It should be noted here, parenthetically, that the larger porphyry knob, lying in the NW. ¼ sec. 24 and the NE. ¼ sec. 23, T. 34 N., R. 1 E., shown on the flank of the high knob, is actually topographically on a distinct and isolated hill by itself, separated from the higher point by a very pronounced saddle which the topographer has completely ignored.)

Other localities where formations are found abnormally high are at the 1539-ft. knob in the NE. ¼ SW. ¼ sec. 8, T. 34 N., R. 2 E., and the 1380-ft. knob in the center of the NE. ¼ sec. 33, T. 34 N., R. 1 W. It is confidently believed that these hills both have beneath them prominent but completely buried peaks of porphyry, though no direct evidence has been found.

The pronounced dips of the Potosi-Eminence contact to the north, east and south, in secs, 20, 21, 28 and 29, T. 38 N., R. 1 E., are believed to have exactly the same significance. The structural relief, on this contact, as a result of the supposed buried porphyry knob, is not less than 200 feet in three-fourths of a mile.

The top of the Potosi is unusually high in the saddle near the center of the south line of sec. 19, T. 33 N., R. 2 E., rising nearly 100 feet above its position in surrounding areas. Porphyry was at once suspected, and though no outcrops could be found, several porphyry pebbles were observed in the float in the valley draining east from this saddle, suggesting outcrops that escaped discovery, in the very thick brush of this area.

Again, in the SW. ¼ sec. 25, T. 34 N., R. 1 W., the Davis dips strongly northeast, and rises to an unusual height, suggesting porphyry to the southwest, beyond the limits of the map. No porphyry float could be found, in this valley head, but the fact that it outcrops somewhere in the vicinity is evidenced by the occurrence of pebbles of that rock, in the creek gravels of Strother Creek, at the west border of the map.

A particularly important corallary of the above facts is that in following up valleys toward porphyry knobs, one finds the normal sequence commonly reversed, successively *older* rather than younger beds being encountered, as the stream valley is ascended. This results, of course, from the fact that the beds are dipping downstream *more steeply* than the stream gradient. Unless this fact is kept clearly in mind, as being the usual situation in proximity to the porphyry knobs, it is easy to become very badly confused regarding the sequence of beds. The writer actually encountered much difficulty in this respect, until the above principle was clearly understood.

The best evidence that these dips are not the result of ordinary tangential deformation lies in their entire lack of any orderly alignment. On the contrary, they do very clearly follow the surface of the old pre-Cambrian topography. Nowhere is this better brought out than in the Tom Sauk country, in the southeast part of the Edge Hill sheet. In this area, the present valleys follow rather closely the main lines of pre-Cambrian drainage. This is shown quite clearly by the fact that Imboden Fork, East Fork of Black River, Tom Sauk Creek, and Little Tom Sauk Creek occupy valleys that are floored by considerable depths of Cambrian sediments. These valleys branch in an ordinary drainage pattern. Each valley is the axis of a syncline, toward the axial line of which the sediments dip, from the porphyry uplands on either side. These valleys, in turn, have minor tributary valleys, which were also clearly outlined by the pre-Cambrian erosion, since they, too are occupied by Cambrian sediments, also dipping, in each case, toward the axial line of the tributary. On Tom Sauk, for instance, two such tributaries enter from the north and one from the south, all three of them with typical synclinal dips toward the axis of the valley. Little Tom Sauk Creek shows several, and instances could be multiplied.

It is altogether beyond belief that any system of folding, no matter how complicated, could possibly have thus simulated the complex branching of a normal drainage system. And since, in the almost infinite number of directions of dip that have been observed, no single one seems to constitute a definite line, more conspicuous than the others, it seems wholly improbable that anyone of them has been appreciably intensified by later lateral compression. It, therefore, seems established beyond question that these dips, these pseudo-folds, are intimately and exclusively related to the buried, and now partly resurrected, pre-Cambrian topography.

That the dips are at least in partial initial, seems also to be quite obvious. Compacting and solution could play but little part, where the beds are coarse, arkosic grits and conglomerates, directly in contact with the porphyry. And in such situations very steep dips are observed. Shale, the type of rock in which compacting is presumed to be greatest, is wholly absent, in most of the area. The chief dolomite involved, the Bonneterre, it is true, is quite soluble, as shown by the numerous small openings encountered in mining operations, in the Lead Belt. But the almost complete absence of sinks, in the Bonneterre, either as topographic features, or filled with the slump of overlying formations, shows that it is far less subject to thinning by this process than the Potosi, Eminence, and Gasconade.

Evidence has already been presented[1] to show that the chief factor in these structures has been the initial angle of deposition. Bridge[2] has further elaborated on this discussion in a still later paper, and the problem will not be discussed at greater length in this report.

There are four chief items that render the porphyry area of southeast Missouri ideal, in fact perhaps the best in the United States, for the study of this particular type of structure. They are (1) the unusually large number of individual, more or less isolated peaks on the old pre-Cambrian surface; (2) the high relief, not far from 2000 feet, on that surface; (3) the fact that these peaks vary so greatly in their present degree of resurrection, from complete stripping to complete burial; and (4) the fact that the formations lapping against them are so thin that even slight dips result in the exposure of more than one formation in the resulting dome, so that the relations are obvious, even on the map.

These dips seem to have played a very important part in the stratigraphic history of the area. When, for example, the region emerged, at the close of Derby-Doerun time, that formation and the underlying Davis were much higher, immediately adjacent to the porphyry than elsewhere. As a result, regardless of any doming there may have been, they were more exposed, and more completely removed there than farther away from the buried hills. Consequently, with resubmergence, the Potosi lapped across the truncated older beds, toward individual porphyry peaks.

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[1]Bridge and Dake, loc. cit.

[2]The geology of the Eminence-Cardareva quadrangles: Mo. Bur. Geol. and Mines, in press.

The dropping of the Derby-Doerun, and even of the Davis out of the section, in close proximity to the porphyry knobs, is very strikingly shown at a number of localities on the Edge Hill sheet, perhaps nowhere better than on the west slope of Goggins Mountain, in secs. 2, 11, and 14, T. 33 N., R. 1 E., and on the East Fork of Black River, in secs. 1, 2, and 3, T. 33 N., R. 2 E., and 34, 35 and 36, T. 34 N., R. 2 E.

Similarly, when the region emerged in the pre-Van Buren interval, the formations were more exposed, and more completely removed next to the porphyry hills, so that close to the old peaks, the Potosi is not only thin, but not uncommonly missing, except for a very thin mantle of float, so that the Van Buren-Gasconade laps onto Davis, or even onto Bonneterre. This is clearly seen on Padfield Branch in secs. 2 and 11, T. 33 N., R. 1 E.; on Imboden Fork, in sec. 5, T. 33 N., R. 2 E., and particularly in the Tom Sauk Country, in the southeast corner of the Edge Hill quadrangle, where heavy Van Buren-Gasconade residuum rests widely on Bonneterre, with no sign of the intervening formations.

It would, of course, be impossible to say that doming played no part in this removal of beds, but the way the formations wedge out of the sections, in all directions, as the porphyry is approached, is in perfect accord with the idea that the beds were abnormally high as a result of deposition on prominences of the old erosion surface. Under such conditions, even uniform emergence would result in much greater exposure of the beds to erosion, in the areas where they had been deposited over "highs."

Solution Structures.

Although caves and sink holes, the more visible evidences of active solution, are not common in the Potosi-Edge Hill quadrangles, it is certain, nevertheless, that solution has played a very active part in the geologic history of the region.

Perhaps the most striking single evidence of the extreme importance the process is exhibited in the remarkably thick mantle of residual material so widely distributed over this and adjacent portions of the St. Francois Mountains. In highly soluble formations, such as the Potosi, Eminence, Van Buren, and Gasconade, the visible measure of the ratio of erosion to solution lies in the concentration of the insoluble residue. The fact that over areas of many square miles, this residue is over

100 feet thick, and in places not far from 200 feet, resting essentially in place, points to the extreme importance of removal of soluble constituents.

Unfortunately, in this area, there are two very important factors that make it extremely difficult to estimate the structural effect of this solution. One of them is the extreme structural relief on the various formations, as the result of deposition over the uneven surface of the pre-Cambrian topography. The other is the fact that the base of the Van Buren-Gasconade, the formation that has left the most extensive mantle of residual material, itself rests above a conspicuous erosion surface of older sediments. The present base of this float is actually very uneven. This irregularity, which under other conditions, might point to slump into sinks as a result of solution, may in this area quite as probably be the result of (1), structural relief inherited from the pre-Cambrian floor; (2), direct deposition of the Van Buren on an uneven erosion surface of the next older beds; (3), ordinary gravity slump, on oversteepened hillsides; (4) or the result of slump into sinks. It is actually believed that the observed irregularity in the base of the Van Buren-Gasconade chert mantle is the result of all four of the above factors, but it is quite impossible to determine how large a part solution has played.

In some ways, a still more striking phenomenon is the extreme vertical range of the patches of sandstone shown as Roubidoux (Pl. IX, B). Since, however, it is almost certain that some, and perhaps many, of these patches are actually Pennsylvanian, there again enters the question of possible deposition on a very uneven erosion surface. In spite, however, of this uncertainty, it seems altogether likely that most of these small tumbled masses of sandstone blocks, whether Roubidoux or Pennsylvanian, occupy the sites of solution sinks, into which they were dropped far below their normal stratigraphic position, and thus preserved from removal.

Still another aspect of solution in this relation to structure merits consideration. This is the question of the removal of soluble from beneath insoluble beds, in situ, with the resulting settling of the insoluble members. That this could take place consistently over any very large area, with the complete removal of the soluble member from beneath other beds, may be open to considerable doubt. That it does result in pronounced thinning of certain soluble members, *toward the outcrop*, even to their complete elimination, seems quite certain.

A horizon at which this phenomenon would be likely to be especially conspicuous would be the contact of the porous Roubidoux sandstone, an important collecting ground for water, above the very soluble dolomites of the upper Gasconade. That this is a zone of very active solution is attested by the frequency of large springs, by the great number of topographic sinks, by the abundance of large and small caves, and by the well known occurrence of the filled sink or cave iron ores, at this particular horizon.

These features are chiefly observed in the area where the Roubidoux is still present in large patches and moderate thicknesses. As one goes farther up the Ozark dome, to where the Roubidoux is left only as very small areas of thin capping on the higher divides, the springs have migrated to lower topographic levels, the caves and sinks have been largely filled with residuum, or cut away in the more dissected region, and the very soluble horizon greatly reduced in thickness.

The thinning of the upper Gasconade toward the St. Francois Mountains has been ascribed by Ulrich to unconformity, with removal of these beds by erosion, before the Roubidoux was laid down. The truth or falsity of this explanation has by no means been demonstrated. The fact, however, that much of this thinning is toward the present drainage lines, suggests that solution is an important factor.

CHAPTER IV.

GEOLOGIC HISTORY.

The geologic history of an area of this size is never adequately revealed by a study of the area itself, but must be pieced together from information assembled from adjacent and even more distant regions. The Eminence-Cardareva quadrangles mapped by Prof. Bridge and the Potosi-Edge hill area mapped by the writer are in such close proximity that most of the events in the geologic history are coincident, or at least very intimately interrelated. As a result, to write an exhaustive history for each separate area would involve excessive duplications and repetitions. It has been thought best, therefore, to present in each report only a brief skeleton of the sequence of events, with the hope of publishing, in the near future, in a joint paper, a more exhaustive and much broader treatment of the geologic history of the Ozark region as a whole.

The earliest known event in the history of the making of Missouri's framework was the extrusion of a great amount of rhyolitic lava and ash. This presumably took place in Algonkian time. This was later intruded by granite and granite porphyry, and presumably also in pre-Cambrian time by basic dikes. There is some reason for believing that these pre-Cambrian rocks may have been faulted, before the beginning of the Paleozoic.

Following the above events, erosion cut deeply into the old igneous rocks, and carved on them rugged mountains, the local relief of which did not fall far short of 2000 feet.

Next in the known sequence came a submergence which permitted the upper Cambrian seas to invade this mountainous area, first converting it into an archipelago, and possibly even overtopping it completely.

The partly reworked arkosic detritus from the deep pre-Cambrian weathering accumulated as a basal conglomerate, in some of the more protected embayments in considerable thickness, but was completely scoured away from the more exposed promotories. Then came a great influx of fairly clean sand, the Lamotte, seemingly derived from outside sources, since it is far too pure, too well sorted, and too abundant to have been derived from any possible local landmass. After this material had accumulated to a maximum known depth of perhaps 400 feet or 500 feet, almost entirely surrounding the moutain core, and penetrating the deeper valleys far back among the hills, the supply of sand became intermittent, and finally ceased, the seas became clear, and several hundred feet of limestone (the Bonneterre) accumulated, with only occasional arkosic phases, in some of the more protected embayments; over much of the area clean limestone resting in close proximity to the porphyry hillsides.

Another change in the more distant sources of sediment now began to introduce muds into the formerly clear seas, and for sometime alternating shales and limestones were laid down (Davis). With them are many beds of local limestone conglomerate, "flat-pebble" and "edgewise," that have usually been believed to indicate notable shoaling. The muds must certainly have been derived from outside sources, a fact clearly attested by the actual diminution in shale and increase in limestone, adjacent to and among the porphyry peaks. Gradually the waters became more clear, and slightly argillaceous limestones were deposited to the close of Derby-Doerun time.

It is quite probable that at this time many of the higher porphyry peaks still rose above the Cambrian seas, since the Davis and Derby-Doerun lap against the present peaks, far below their summits. Following the close of Derby-Doerun time, the region emerged, and either because of local warping, or because of original deposition over buried topographic highs, emergence was such that the Derby-Doerun, and even the Davis, were locally removed, exposing large areas of Bonneterre, and much porphyry.

Following this came the incursion of the Potosi seas, laying down limestones across the older eroded beds. Very similar marine conditions seem to have persisted without interruption into Eminence time, resulting in several hundred feet of marine limestone, which now almost completely buried the St. Francois range.

Again came a period of emergence and local doming of the St. Francois area, quite probably accompanied by some peripheral faulting. Again the area was deeply eroded, the faults being largely planed off, and the Eminence completely removed from the central area, in which beds as old as Bonneterre were once more exposed at the surface. There seems to have been developed on the very cherty Potosi over the weaker Davis, a pronounced cuesta, with escarpment facing the porphyry hills, and outward backslopes. The pre-Cambrian mountains were again widely uncovered, in the central area. This closes the events of the Cambrian, as the writer has seen fit to delimit that period.

With the influx of the Van Buren seas, Ordovician time was initiated. These waters found a surface on which were exposed beds ranging in age from the Eminence on the periphery of the uplift, to Bonneterre, in the central area, with many porphyry knobs looming above the general level. Again a considerable series of limestones were deposited, and by the close of Gasconade time only the very highest of the peaks were uncovered, if indeed any of the porphyry was still exposed. Then followed emergence, but essentially without warping, and the surface of the Gasconade was slightly eroded.

Changes in more distant sources of sediment again brought about a considerable but somewhat intermitted influx of sand (the Roubidoux), derived entirely from areas outside the Ozark region. Whether still younger Beekmantown sediments were laid down, within these quadrangles will probably never be definitely known, though it is highly probable that they were. If so, they have been completely removed.

From the known history of Ste. Genevieve County,[1] it is probable that the Potosi-Edge Hill area underwent many movements, and quite probably, several marine invasions, during middle and late Ordocivian, Silurian, and Devonian times. Definite evidence, however, is quite lacking.

The widespread distribution of residual cherts carrying a typical Burlington-Keokuk fauna, in bordering regions, suggests submergence of even this area by those seas, and the single fragment of a Mississippian coral found high on one of the hills is in line with this interpretation.

We have no evidence of the conditions in the area during the late Mississippian, nor earliest Pennsylvanian time, but the inference is that it was a land surface undergoing deep weathering and considerable erosion.

By late Cherokee time, the Roubidoux and any higher beds which may have been present were largely removed, and the

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[1]Weller, Stuart, and St. Clair, Stuart, The geology of Ste. Genevieve Co.; Mo. Bur. Geol. and Mines, 2nd ser., vol. XXII, 1928, pp. 267-312.

Gasconade widely exposed. It is even probable that still older beds may have been locally uncovered. It is reasonable to suppose that by this time many porphyry peaks were once more resurrected. The fact that near Knobview, Cherokee rests in place on undisturbed Roubidoux, and that near Shepard, Pennsylvanian is known on Potosi, is clearly indicative of the fact that the Pennsylvanian is lapping across successively older beds, as the St. Francois center is approached.

Although the Pennsylvanian in the vicinity of Shepard is probably preserved in sinks, it is not believed that any Roubidoux or Jefferson City were present there, when it was laid down, but that it was deposited on a surface not younger than Gasconade. The fact that Johnson Mountain, within two miles of these patches, rises over 400 feet above them is taken as a good indication that the porphyry was exposed, while the Pennsylvanian deposition was going on. It certainly would be unreasonable to assume that the Cherokee was laid down on beds which passed completely over the top of these highest porphyry knobs, and was dropped by sinks completely through these beds a distance of 400 feet or more, into contact with the basal Gasconade and and Potosi, without preservation of any remnants of the higher intervening formations.

There is but little evidence, and most of that indirect, from which to work out the post-Pennsylvanian history of the region, since no beds younger than Cherokee are known. Sometime after the Pennsylvanian, the region was widely peneplained, then rejuvenated, and a second younger and less perfect peneplain initiated, since which another period of uplift has set the streams to work entrenching themselves in the lower level.

CHAPTER V.

ECONOMIC GEOLOGY.

Barite Industry.

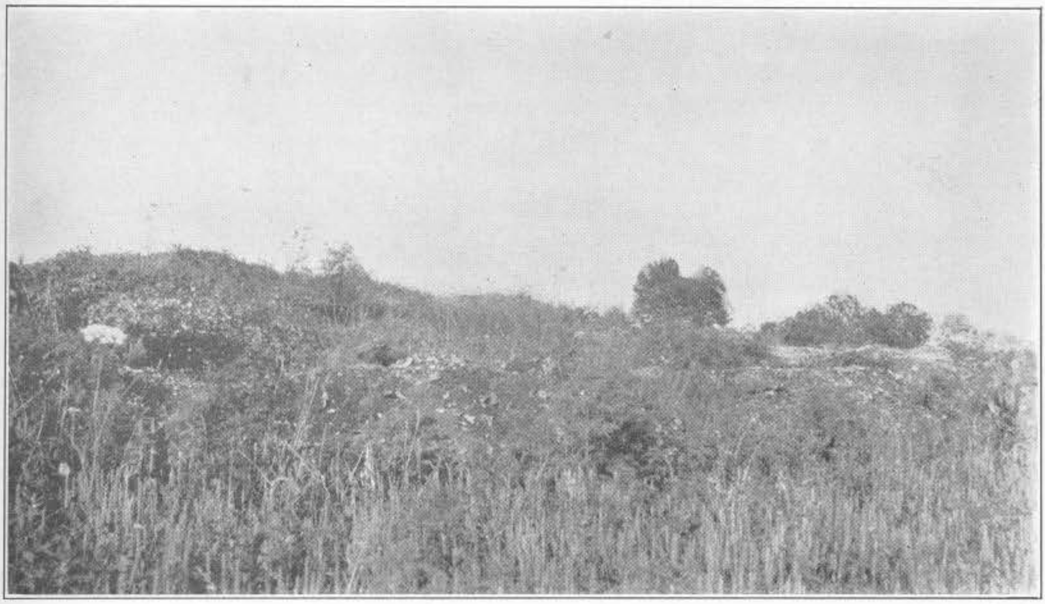
Importance of the barite industry.—For the year 1927, the latest complete statistics available, barite ranked eleventh in importance in the State's mineral resources, with a value of $797,465.00, being about one percent of the entire value of Missouri's mineral products. Over half of the total production for the United States comes from this state. Of this amount, about 85 percent is from Washington County. For the past 20 years, the price range has fluctuated between an extreme low of about 3 ¼ dollars and a high of about 10 dollars per ton.

To show the importance of the industry in Washington County, the following statistics are appended.

VALUE IN DOLLARS OF BARITE PRODUCED SINCE 1917.

Year.	Washington Co.	Entire State.
1917	274,414	391,363
1918	300,453	393,738
1919	....	640,398
1920	583,207	1,013,570
1921	194,898	217,913
1922	338,218	421,568
1923	484,307	629,097
1924	443,221	604,390
1925	660,693	749,927
1926	812,400	946,595
1927	....	797,465

Productive areas.—Less than one-fifth of the productive acreage of Washington County lies within the Potosi quadrangle, chiefly in the northeast corner (Pl. XXIV). Except for a few scattering areas of relatively little importance, the deposits now being worked lie north of an east and west line drawn two miles south of Potosi, and east of a north and south line drawn four miles west of that place. The most important exception to this is what may be designated as the Palmer district, lying chiefly within a radius of five miles of the old mining town of Palmer



A. Typical shallow barite diggings, SW. ¼ SE. ¼ sec. 9, T. 37 N., R. 2 E.

B. Hoisting barite with a hand windlass.

(Pl. XXV). Another occurs on Fat, Dry, and Furnace Creeks, in secs. 11, 14 and 15, T. 36 N., R. 2 E.

Potosi, the county seat, is the largest town in the district, and essentially the center of the industry. Other shipping points of importance are Mineral Point, Cadet, Tiff, and Blackwell.

Most of the good productive land has yielded 2000 to 6000 tons per acre, and some is reported to have exceeded that figure. Actual statistics, however, are very difficult to secure.

Mineralogy of the deposits.—Barite, the commercially important substance of the deposits, consists of barium sulphate ($BaSO_4$), known variously as barytes, heavy spar, and locally as tiff.

Except for the ever present red clay, the only substance universally associated with the barite is silica, either as chert, chalcedony, or quartz. The well known mineral blossom of the district consists of chalcedony in thin bands, coated with quartz, and usually termed druse.

Next in abundance, among the associated minerals, is probably limonite, which occurs as larger and smaller masses, sometimes intimately intergrown with the barite, and not uncommonly pseudomorphic after marcasite, more rarely after pyrite.

Probably next in abundance is Galena, also sometimes seen intergrown with masses of barite. It is usually present as well formed cubes, commonly called cog lead. In some of the deposits, enough lead is present so that it is recovered and marketed. In occasional masses, it is widely distributed.

Marcasite and pyrite are not common, only because most of the deposits are so completely oxidized. They sometimes remain as unaltered nuculei, at the centers of masses of limonite.

Other constituents are rare and insignificant in amount.

Mode of occurrence.—Practically all of the commercially important barite of the district occurs irregularly distributed through the deep red residual clays from the weathering of the Potosi and Eminence formations.

No information is available as to the proportions derived from the two horizons. There is no doubt that by far the larger amount is mined from the Potosi, but the quantity derived from the younger formation is by no means insignificant. The relation of the deposits to the Potosi-Eminence contact may be seen on Plate XXIV. No residual barite of commercial importance has, up to this time, been found in any other formation in the district.

The residual clays in which the barite chiefly occurs vary irregularly in depth from a few inches to many feet, as is the habit of residual deposits, and commercial barite is known from the grass roots to bed rock. The richest deposits, however, are usually found near the contact of the residual clay and the underlying rock. The maximum depth of mining rarely exceeds 20 feet, and is almost never over 30 feet.

In size, the particles of barite vary from minute grains to masses of several hundred pounds weight. More commonly however, the fragments recovered are from 1 or 2 up to 8 or 10 inches in diameter, and much of the finer material is lost.

The distribution of the barite in the clay is usually erratic, richer pockets, or streaks, sometimes termed leads, alternating with lean, or practically barren ground. This probably simply represents more active aggregation of the barite at certain points of emergence of underground water channels, although it has by some been taken to indicate areas of concentration of barite deposits, in the bed rock from which the residual material was derived.

Barite in bed rock.—At a few places, irregular veinlets of barite have been noted in the outcrops of the Potosi formation. The writer has seen no single body over 5 or 6 inches in width, and in most cases they consisted of minute stringers. Although both the Potosi and the Eminence formations, which have yielded almost all of the residual barite of the district, outcrop extensively in the area, certainly not over a couple of dozen stringers, all told, have been noted. It is quite certain that the observed distribution and abundance of veinlets is inadequate to account for the present quantities of residual barite occurring in the clays. One may occasionally see fragments up to an inch or so in magnitude protruding from the weathered surface of dolomite outcrops, but even such occurrences are rare.

The cuttings from the city well at Potosi[1] showed some barite. It is significant, however, that even where the rock was perfectly fresh, and unweathered, the barite was stained with red clay, similar to that seen at the surface. It is fairly certain that the barite was introduced from the surface, especially since the well is located at the base of a slope covered with old pits. No other record of drilling is available, in the barite district

[1]McQueen, H. S., Personal communication.

proper. Barite, in fragments of appreciable size, is not known within the *unweathered* body of the Potosi and Eminence formations.

Tarr[1] reports the occurrence of crested barite in caves. While he does not specify definitely, one would infer that these are not old cavities, completely filled, but typical modern caves, in which case they are doubtless related to the present erosion cycle, and the barite secondary.

Derivation of residual from bed rock types.—The residual barite, embedded in red clay, is rather obviously derived by weathering concentration from the bed rock type. There seems however, to be a very general misconception of the actual nature of formation of residual material. The enormous quantity of chert in the residuum of the district, for example, is far from being a simple mechanical concentration of insoluble material, in situ, by the removal of the dolomite in solution.

A very extensive study, made by McQueen, of well cuttings from the Gasconade and Eminence formations over almost the entire area of the Ozark uplift, shows only inconsiderable chert beds, as such, where the formation is below the active influence of surface circulation. These cuttings are siliceous, yielding, upon digestion in acid, an appreciable percentage of insoluble residue. The interesting feature, however, is that this residue consists, for the most part, not of large masses of chert, but of minutely disseminated particles. That it has not resulted from the grinding up by the drill of larger masses, is most conclusively shown by digesting in acid large blocks of dolomite which are, to the naked eye, entirely chert free. These yield essentially the same amount and quality of insoluble residue as is found in the average cuttings from deep drilling.

What, then, is the source from which the large blocks of residual chert in these two formations are derived? Obviously, as the limestone goes into solution, the silica is gradually aggregated into larger and larger particles. This, it seems, could only be accomplished by the actual solution and reprecipitation of the siliceous material. It is, therefore, improper to say that the chert is *not dissolved* because its solubility is inferior to that of the limestone, but rather that it is dissolved and quickly reprecipitated.

[1]Tarr, W. A., The barite deposits of Missouri; Univ. of Mo. Studies, vol. III, No. 1, pp. 65-66.

It is not meant to infer that there is no primary chert. Too many times geologists have gone sadly astray by assuming that all things that look alike have a common origin. The writer believes that there is such a thing as primary chert, but he also believes that the chert strewn so widely over the surface of the Gasconade and Eminence formations is most decidedly not primary, that it did not occur as these huge masses of chert deeply buried in the formations, to be left behind as such upon the removal of the soluble constituents, but that it has been gradually aggregated from minutely disseminated particles by solution and redeposition, during the process of weathering.

As stated above, these conclusions are borne out by studies of cuttings from a very large number of wells widely distributed over the Ozarks. The writer also had the opportunity of studying a Gasconade core, from near Bagnell, in Miller County. One considerable bed of chert occurred, at a shallow depth, where surface solutions had free access. Below that, the amount of chert was insignificant, and wholly inadequate to account for the immense amount of chert strewn over the adjacent hillsides representing the same thickness of beds.

In road cuts, and quarries, it is a very common thing to see beds that are very cherty at the old erosion surface grade laterally into less cherty or even non-cherty beds, within a very few feet, or even inches, back into the fresh exposure. From this fact, it may be safely inferred that much of this concentration takes place as replacement in the limestone very close to the weathered surface, where the silica-bearing solutions evaporate. It is quite probable, however, that many of the masses of chert continue to "grow" long after they are detached from the parent ledge, and become part of the residuum.

It is known, then, with a high degree of certainty that these formations do not carry enough chert, as such, in thick beds and huge blocks, to begin to yield the large amount of chert residuum observed, and consequently, that in spite of the alleged insolubility of silica in cold waters, perfectly enormous quantities of that substance are dissolved *during the weathering process by ordinary cold shallow ground water.*

What has been said of the formation of chert seems to apply equally well to the formation of the druse in the Potosi. Study of cuttings, again from a large number of wells, widely distributed, shows few large masses of druse where the formation is below the active zone of ground water movement. There is, on the other hand, a considerable content of silica, as shown by the amount and character of the insoluble residues.

The truth of these conclusions is verified by study of cores from the Potosi. In a hole penetrating that formation, north of the Palmer fault, near Belgrade, druse was observed sparingly, throughout, but not a single large mass was penetrated, though the nearest outcrops of the Potosi in all directions showed very heavy development of druse in the residuum. Another core through the Potosi in western Perry County showed only a sparing development of small druse. Rarely was more than an inch or two encountered. On the nearest outcrops, but three or four miles to the west, very large masses of druse occurred in the soil.

It is also conspicuously true that in steep cliffs as much as from 30 to 100 feet of Potosi has been observed, in which druse is either entirely absent, or minute and sparingly developed, whereas exactly the same horizon, a few rods away, on gentle slopes, where the weathering is deep, is completely honeycombed with large masses of druse.

Here again, then, is evidence of solution of silica, on a very large scale, by cold surface waters, and in this case, the reprecipitation has produced a tremendous amount of crystalline quartz, obviously of cold water origin.

The apparent lack of large masses of barite, either in veins, or as isolated bodies, in the Potosi and Eminence formations, certainly suggests that this substance, too, in spite of its "insolubility," may have been concentrated into larger and larger masses, replacing the weathered surface portions of the formation. The idea is somewhat strengthened by the fact that in several places in the deeply weathered "sandy" phase of the dolomite, large masses of druse and barite were so intimately intergrown as to indicate a strong probability that they were forming simultaneously.

Origin of the bedrock deposits.—The fact that little is actually known about the distribution and occurrence of the barite in the dolomites is quite distinctly a stumbling block in any adequate discussion of the problem. As already pointed out, direct observation has failed to reveal a sufficient number of veins in the district to adequately account for the known amount of residual material. Of course, it may be argued that the great majority of the veins are concealed beneath the residual clays and cherts. Naturally this argument can neither be substantiated nor refuted, but it is at least pertinent to inqure why veins might be supposed to be more numerous and larger in the covered areas than in the areas exposed to observation. Certainly no valid reason has as yet occurred to the writer. It is also pertinent to ask why such veins should be more numerous, and richer, in the almost wholly non-faulted barite district proper, than in adjacent faulted areas.

The erratic distribution of the barite in the clays, along the so-called "leads" of the miners, is probably the result of more active aggregation at the points of emergence of water channels, though it has been believed by some to indicate barite veins in the underlying bed rock.

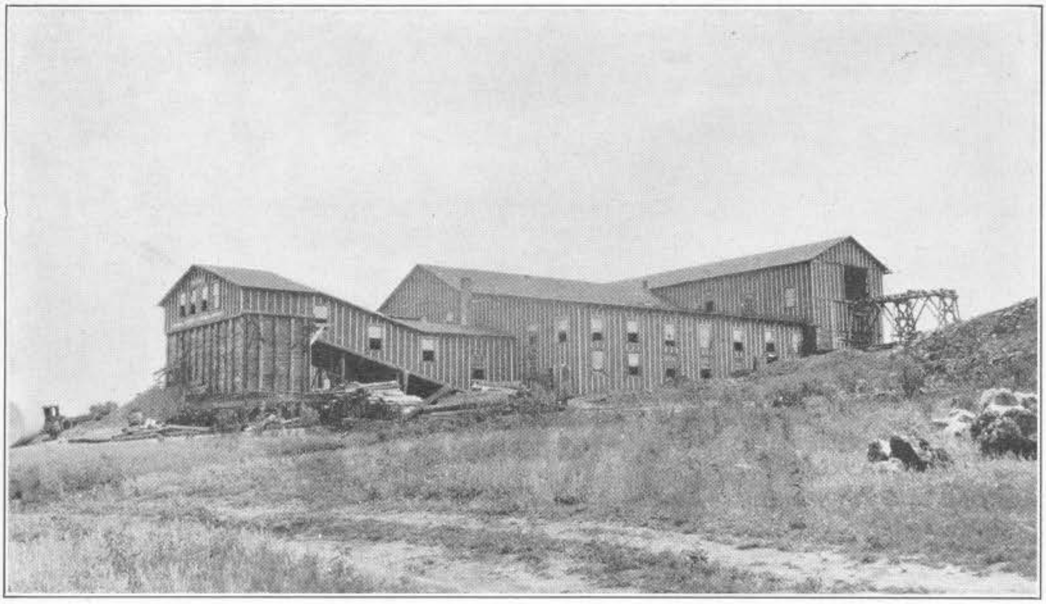
At least four possible theories might be advanced, to explain the origin of the barite in the dolomite. They are (1), descending cold solutions; (2), ascending cold solutions under artesian head; (3), ascending hot solutions from deep-seated hidden igneous sources; and (4), original deposition in colloidal form, along with the disseminated silica, from sea water.

It would seem that these four embrace the entire range of possibilities. To each one apparently unanswerable objections may be opposed, and it does not seem that any one of them can be accepted with confidence, until more precise information can be obtained than is yet available. It is possible, however, to point out the bearing that certain observed facts might have on each of the theories. Of these, the following seem pertinent.

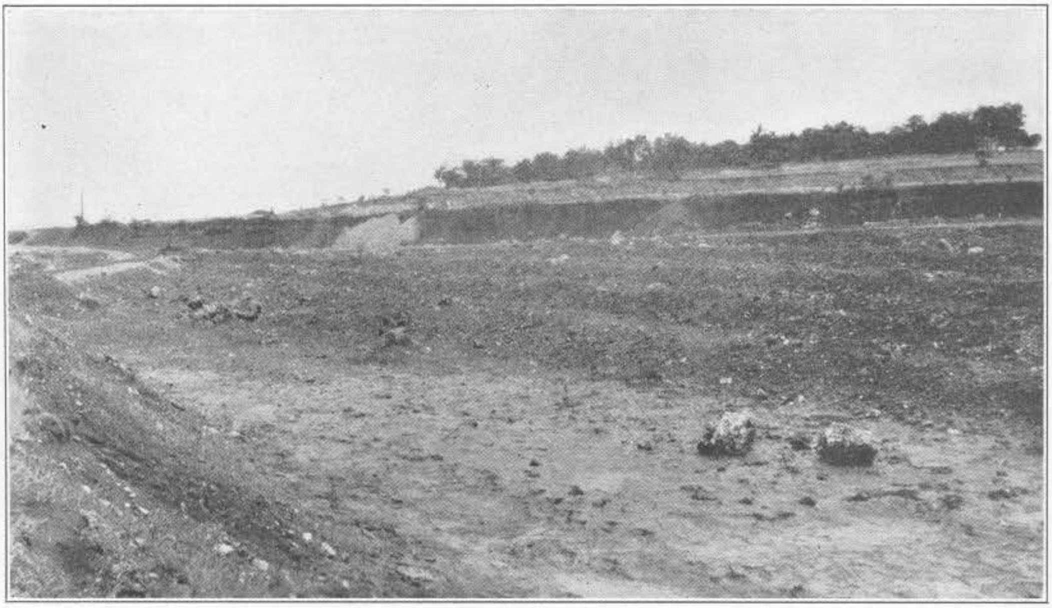
1. The Davis "shale" underlies the entire district. Although the formation is more largely limestone than shale, it is, nevertheless, the most completely impervious horizon in the entire geological column of southeast Missouri. There is in the aggregate, perhaps fifty feet of shale, in the formation, and that it plays an important part as a check to circulation is clearly to be seen in the distribution of springs and water seepages about the margins of its outcrop. Anyone who has travelled unimproved roads across the outcrop of the more shaly members of the formation can testify to the fact that water passes through it far less readily than through underlying and overlying dolomites.

To the south, east, and north of the barite district, the Davis shows the normal amount of shale, as it does also in the deep well at Potosi, in the very heart of the producing area.

The presence of this highly impermeable horizon continuously below the barite deposits would tend to argue rather strongly against ascending solutions, either hot or cold.



A. National Pigments and Chemical Company's barite mill, at Old Mines.



B. Open pit barite mines, at Old Mines.

Furthermore, it is to be noted that the barite district, though bounded by faults on all sides, at considerable distances, comprises, as a whole, one of the least faulted areas known in this general section of southeast Missouri. Such statements as that of Emmons[1] that "In the barite district faults are numerous," and that "The solutions could rise through the shale on account of the extensive faulting and fracturing of the area," do not represent the true conditions.

Actually there is far more faulting in the disseminated lead district, than in the barite district. It may, therefore, be inquired, quite pertinently, why the shale is invoked to prevent the lead from moving higher than the Bonneterre, in an area where it is strongly faulted, and still is said to permit the barite to pass up through it along faults, in an area where faults are actually far less common.

Within the Potosi quadrangle, not a single fault, with throw enough to measurably displace the formations, was found within the productive area. To the west, the nearest one is five miles distant; to the south, six miles away; and to the east, seven or eight miles. To the north, the area has been mapped in less detail, but thus far, no faults have been reported, for a distance of about ten miles beyond the limits of the quadrangle.

There certainly does not seem to be any increase in richness, towards the bordering fault zones. On the contrary, production actually falls off rapidly to the west and south, towards the faults. Since these areas are farther from transportation, this decrease may, however, be more apparent than real, owing to inadequate prospecting, and incomplete development. To the east, on the contrary, there is a real decrease, production falling off notably, even though the area is closer to transportation, and has been thoroughly combed. To the north, again, less information is available.

If the solutions came from below, and moved outwards from the faults, it certainly needs much explaining to show why they should produce the richest ground nearly in the center of the unfaulted block, approximately as far away from the main avenues of ascent as they could possibly get. If such is the case, it also remains to be shown why they did not produce rich deposits on the opposite sides of the faults, outside this block.

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[1]Emmons, W. H., The origin of the deposits of sulphide ores of the Mississippi Valley; Econ. Geol. vol. XXIV, 1929, p. 239.

These facts may or may not constitute adequate proof that the solutions did not move upwards, but at least they should not be ignored or misstated, and demand most serious consideration before any theory is accepted.

2. Another point that must not be overlooked, in working out any theory of origin of these deposits concerns the origin of the associated druse. The presence of so much crystalline quartz in the Potosi formation has been cited[1] as proof that the silica was introduced by hot waters. The writer has already pointed out evidence which he considers conclusive, that most of this druse, as it now occurs, is secondary, and developed by cold sufrace waters, during weathering. Microscopic study of insoluble residues from typical masses of Potosi that show no druse to the unaided eye, show that siliceous material, essentially microscopic druse, penetrates most intimately the entire formation. It is quite inconceivable that this very minute and all-pervading silicious material could possibly have been introduced subsequent to the formation of the dolomite, by any type of solution, hot or cold, ascending or descending. There would seem to be no other reasonable interpretation than that it was incorporated, probably in colloidal form, when the formation was laid down in the sea. The argument that the presence of quartz indicates hot solutions thus entirely loses its validity.

3. Again quite significant is the fact that masses of barite are found, intimately intergrown with, and coating, quartz chalcedony druses, strongly suggesting that barite has, at least in local cases, been transferred by the same cold surface waters that produced the druse, during weathering.

4. There is still another fact widely observed, that must not be overlooked. The almost entire absence of disseminated barite in the Gasconade residual soils seems to indicate that as a whole that formation does not contain barite under proper conditions to produce the typical residual deposits characteristic of the Potosi and Eminence. If the barite has been leached down from overlying formations, there would seem to be little reason for its not being present in the Gasconade, as well as in the older beds. Barite-rich veins are quite as well known in the younger formation as in the Potosi, for instance, but they *do not* result in widespread residual deposits of commercial magnitude. This

[1]Spurr, J. E., The southeast Missouri ore-magmatic district; Eng. and Min. Jour., vol. 122, 1926, pp. 968-975.

would seem to point to the fact that veins do not form an adequate source of the residual deposits.

The writer has suggested the possibility that the barite was precipitated as a colloid directly from sea water in minutely disseminated form, in the Potosi and Eminence beds, and later concentrated during the weathering process. Such a theory at once encounters, it is realized, difficulties quite as serious as those cited against the others. Not the least of these is why such original deposits were restricted to the limited areas known to carry barite. The question is legitimate, and no satisfactory answer has yet been offered.

It will also be objected that barite is insoluble in cold surface waters. To the writer, this objection is less valid. Silica has also been said to be insoluble under similar conditions. Nevertheless it has been leached from Lake Superior iron ores on a tremendous scale, in the process of their enrichment. And if the writer's interpretation of our residual cherts is correct, equally large amounts have gone into solution, moved short distances, and been reprecipitated, during weathering. Insolubility is only relative, at best, and if a substance as insoluble as chert can be moved in solution on so vast a scale, by cold surface waters, given time enough, and solvent enough the barite might also be so concentrated.

Much unsound geological reasoning has been postulated on supposedly well-established chemical principles, because of failure to realize the immensely important part played by time, degree of concentration of solutions, presence of minute amounts of possible catalytic agents, and other obscure factors. Instead, therefore, of reasoning from laboratory data to field facts, one should, the writer is convinced, make the fullest possible study of the available field data, and put forward the explanation that best fits the observed facts. The contemporary segregation of chert is no longer denied, simply because that substance was for years considered insoluble in cold waters. The field evidence is overwhelming, and with our constantly increasing knowledge of the widely varying conditions of chert, and of colloidal chemistry, the movement of silica in large quantity by cold waters is generally recognized.

Similarly the reputed insolubility of barite is undoubtedly based on an insufficient knowledge of a wide variety of modifying factors which it is impossible at present to evaluate, but which may quite conceivably profoundly influence the behavior of that substance in nature.

Methods of mining barite.—The very shallow depth and wide distribution of the barite deposits has resulted in extremely simple and primitive mining methods. Until recently most of the recovery came from shallow open pits, closely spaced. "Gophering," and "gopher-holing" are terms not uncommon (Pl. XX). The digging is by hand, with pick and shovel, and the fragments of barite are picked up by hand.

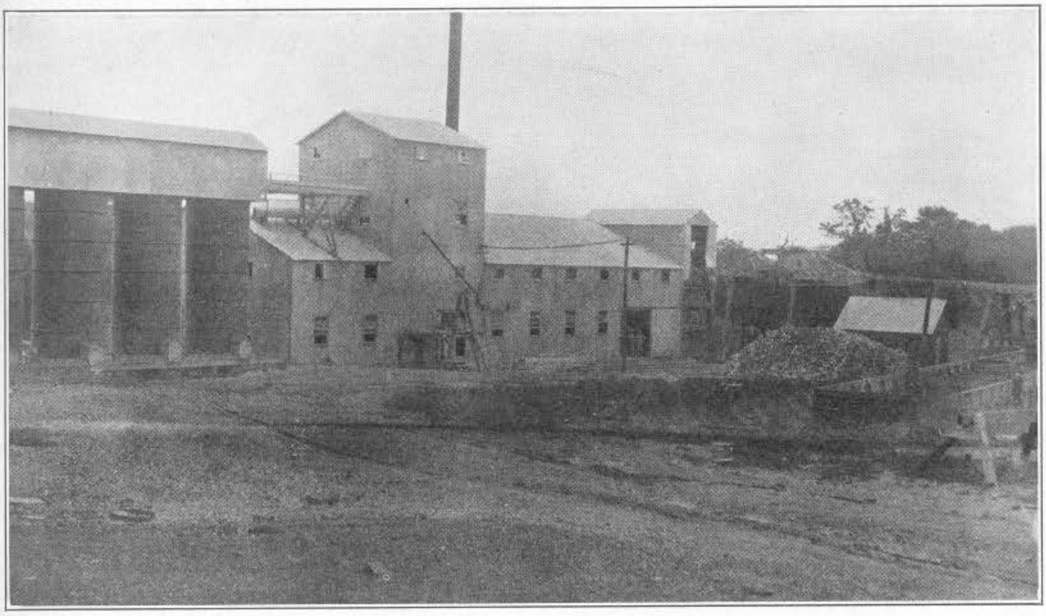
In those pits too deep to easily throw the barite out, a hand windlass and bucket are commonly used (Pl. XX, B). The deeper pits are often enlarged or undercut at the base, and in those deposits that show definite "leads," short drifts are sometimes driven. When caving begins, the shaft is usually abandoned, and another sunk, but rough timbering is sometimes employed.

So far as the writer knows, the first mechanical mining was started by the Eagle Picher Co., at Mineral Point about 1924. It is reported that earlier attempts were unsuccessful. Not long after, the National Pigments and Chemical Co. opened up plants at Fountain Farm and Old Mines, and the Superior Mineral Co. operates a plant near Cadet.

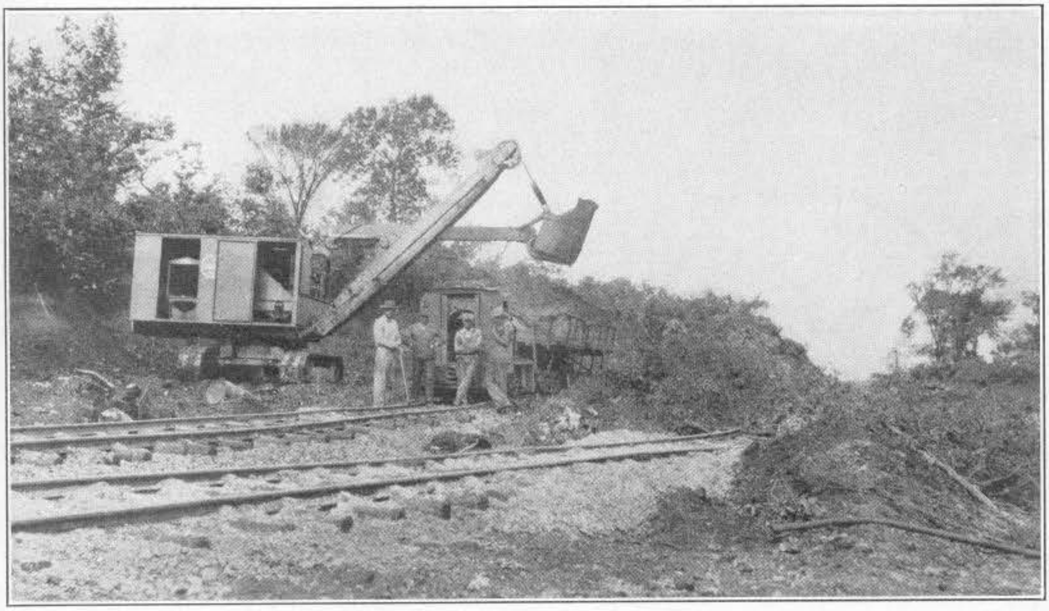
Gasoline, steam or electric shovels are used (Pl. XXII, B), operating to depths of 3 to 15 feet, without removal of overburden. In all cases, power haulage is employed. There are as yet no power operations within the area of the Potosi quadrangle.

Barite milling.—In all of the earlier operations, hand cleaning was employed, and is still used on most of the output from the Potosi quadrangle. The material is allowed to dry thoroughly as a result of which some of the clay falls off. The larger lumps are then cleaned with a hatchet or hammer, the smaller dumped in a "rocker" or "rattler" and violently agitated until much of the clay is jarred loose. Many of the rockers have a coarse screen bottom, so that the clay and fine barite drop out. Others must be dumped.

It is reported that small portable jigs and log washers are now coming into use. At the plants mentioned above more elaborate methods of milling are employed. The plant at Old Mines, visible from Highway 21, is typical (Pls. XXI and XXII, B). At Fountain Farm, there is in addition a plant (Pl. XXII, A), for the production of Baroid, a product employed in the so-called mud-laden fluid for use in drilling oil wells.



A. Baroid plant of National Pigments and Chemical Co., at Fountain Farm.



B. Digging barite with a power shovel, at Old Mines.

Milling practice varies somewhat, but in general, is about as follows. The ore first passes over a grizzly, from which the large bowlders and roots are removed by hand. From the grizzly the undersize goes to log washers from which the clay is discharged to a sludge pond. The ore and rock are then crushed, and delivered to jigs that make three products, a tailing discharged to the waste pile, a concentrate ready for market, and a middling that is further treated on tables.

Possible extension of the district.—The Eminence and Potosi formations outcrop widely in southeast Missouri. Their distribution in the Potosi and Edge Hill quadrangles is shown in the geologic map accompanying this report. Without question, the area of outcrop of those two formations constitutes the most favorable, and probably the only favorable, territory for the future extension of the producing barite district.

Unfortunately, outside of cultivated ground, actual outcrops of barite are rare, even in the heart of the present district. In the absence, then, of actual test pitting, it is difficult to form much of an idea of whether the Potosi residue carries values. On Trace and Cub Creeks and their tributaries, in the extreme southwestern part of the Potosi quadrangles, occasional pieces of barite were seen in creek beds, and because of the proximity to production in the Hazel Creek area, it is considered favorable territory. At present, however, it is too far from either railroad or highway to arouse much interest. In fact, this drawback holds for much of the area of outcrop of the Potosi and Eminence in the two quadrangles. From the viewpoint of transportation, the only areas that are really well located lie north of the Palmer fault, and east of the edge of the Gasconade outcrop, in the northeast part of the Potosi quadrangle, immediately adjacent to present production.

In the east half of the Edge Hill sheet, most of the Potosi has been removed by pre-Gasconade erosion, and much of what is left, is heavily masked by Gasconade float, so that the area is not promising. Greater thicknesses and better outcrops of Potosi occur in the west half of the quadrangle, but are so remote from transportation that they offer little encouragement.

Lead Deposits.

Importance of the lead industry.—Next to barite, lead has been the most valuable mineral product of the Potosi quadrangle.

So far as the writer could learn, there has not been any commercial production of that metal from the Edge Hill quadrangle.

The earliest report of lead in the area[1] refers to "Old Mine and Mine Renault, both in Washington County, respectively six miles N. and 8 miles N. W. of Potosi—discovered—between the years 1724 and '26." "In 1763—the Mine a Burton was discovered at what is now the town of Potosi.—Work was apparently started at once. ——About the same time, Mine a Robina, two miles southeast of Potosi, was discovered." The first reverberatory furnace was erected at Potosi, prior to 1802. Mine a Burton is reported to have employed in the neighborhood of 200 men, and to have produced, between 1798 and 1819 about 5430 tons of lead.

In 1814 the Fourche a Courtois Mines, later known as the Palmer mines, were opened, and finally became the most important in the present area of the quadrangle. By 1831 it has been estimated that 200 persons were employed in these mines. The first furnace at Palmer was built in 1832, and the Walton furnace began operations about 1840. After the properties were purchased by Palmer[2] in 1870, production increased rapidly, jumping from 275,000 pounds in 1872 to 833,000 pounds in 1873.

At the time that the field work for this report was being done (1922-1928), there was no systematic production anywhere in the quadrangle, though some lead was being bought by local dealers from farmers and barite miners, mostly from barite diggings. At only one place was actual underground work being carried on, at the Gulf prospect, near the northwest corner sec. 31, T. 38 N., R. 3 E., about 3 miles northeast of Potosi. At the time, a little lead was being stock-piled.

Authentic information about most of these old diggings is almost impossible to secure, at this late date, but enough is known to make it certain that the quadrangle once supported a thriving lead mining industry.

Productive areas.—The maximum production has centered around two main groups of mines, in the Potosi quadrangle, the Potosi or Mine a Breton group at Potosi, and the Palmer or Fourche a Courtois group, at Palmer (Pl. XXV). Two other groups are closely adjacent in the southern portion of the De Soto quadrangle. One is the Fourche a Renault area, in sec. 7, T. 38 N., R. 2 E., and the other at Old Mines, just off the north-

[1]Winslow, Arthur, Lead and zinc deposits; Mo. Geol. Survey, vol. VI, 1894, pp. 269-302.

[2]Mines, Metals and Arts, vol. II, no. 6, Oct. 15, 1874.

east corner of the Potosi sheet. Besides these, there are many other diggings, of lesser importance, widely distributed over the sheet, about the only areas that are devoid of them being the outcrops of the Bonneterre, Davis, Derby-Doerun, and Roubidoux formations. There are but few prospects, also, in the area of Gasconade outcrop.

Mineralogy of the deposits.—The chief ore is galenà (Pb S), but the oxidation product, cerussite, occurs sparingly. The most common associate is red clay in the residual deposits, and dolomite in the bedrock. Barite is an almost universal accompaniment. Quartz, when present, is usually coating chalcedony, in the form of druse. Calcite and pyrite are known but are not generally abundant. Limonite occurs as an alteration product. Sphalerite, or zinc blend, occurs in a few of the veins, but is more commonly absent. Calamine and anglesite have been reported.[1]

Mode of occurrence.—At the time the writer did his work in the area, not a single mine was open to observation. The following description of the occurrence therefore, has been pieced together by information gathered from personal conversation with old miners and other interested persons. Mr. T. F. Blount of Potosi, and Mr. B. G. Halbert, storekeeper at Palmer, were especially helpful. Their descriptions have been supplemented by Winslow's report, cited above.

At almost all the mines, the initial production has come from residual lead in the red clays, undoubtedly a concentration from the removal of the dolomite formerly enclosing the higher portions of the deposits. This in turn was followed by deeper mining and the production of lead from bed rock.

Most of the shafts were located well up on the hillsides, and in few cases were their bottoms as low as the level of the adjacent valleys. For the most part the ore occurred in bodies of greater horizontal than vertical extent. In fact, as a rule the vertical extent was from a foot or two up to 5 or 6 feet. The ore is usually described as occupying "runs" or "channels," presumably controlled by intersecting joints, but definitely occupying solution channels, rarely entirely filled, that were said to "interlace." Such bodies of ore sometimes occurred in several levels, but usually confined to horizons above or near the present water level. Inasmuch as facilities for handling water were usually inadequate, very little deeper mining was ever attempted, and it is not known whether such openings persist with depth. Since,

[1]Winslow, Arthur, Lead and zinc deposits; Mo. Geol. Survey, vol. VII, 1894, pp. 678, 685.

however, they are so obviously the result of solution by actively circulating waters, it is doubtful whether, except along zones of pronounced faulting, they extend far below the water level. In many localities, the ore is described as filling caves.

Occasional fissures, with definite strike, traceable for half a mile or more, have been reported, especially in areas close to the major faulting, but only a very small part of the ore of the region came from such lodes, by far the more important types filling caves and horizontal channels.

Description of mines.—Most of the individual mines were small, few maps were made, and still fewer preserved. Accurate descriptions have very rarely been published. And so far as scientific data are concerned, miner's memories are not often completely dependable. Winslow, in the paper just cited, has assembled not only his own observations, but also the more reliable of the earlier published descriptions, and the following details are largely taken from his report, supplemented by such additional data, meager enough, as the writer was able to secure in the field.

Palmer Mines.—This group of diggings, earlier known as the Fourche a Courtois mines, was first opened about 1814. By 1831 two hundred men were engaged in the operations. The first furnace was opened about 1832. The maximum annual production of which the writer has been able to find any record was 833,000 pounds of lead, in 1873. Between 1870 and 1891, about 10,000 tons of ore were taken out. In 1923, when the writer visited the area, not a single shaft was open. A few local miners were gopher-holing on the properties, and hauling some barite and a very little galena. At that date, the old town was almost entirely gone. A single store and a blacksmith shop represented the only industries, and most of the houses were vacant and falling into decay.

The present owners of the property are the Parole Mining and Mercantile Co. Their holdings comprise several thousand acres in one large and several smaller tracts, extending in all directions from the village of Palmer. The names and locations of the more important of the individual diggings are shown on Plate XXV.

These mines are located almost exclusively on the south side of, and in close proximity to, the main Palmer fault, and in a fairly complicated zone of minor faulting. The impossibility of entering the mines, and the heavy cover of residual druse and chert, have made it impossible to work out in full, the details of the structure, but several faults are indicated on the geological map.

The more important mines are on the hilltops from 200 to 300 feet above the main drainage lines. When Winslow visited the properties in 1892, the deepest shaft was about 145 feet, so that the main ore bodies lie well above the lower limit of active ground water circulation and solution.

The ore bodies occur at three levels, in a network of intersecting runs or channels, with great horizontal as compared with vertical dimensions. Judging by the character of the material on the dumps, the bulk of the ore occurred in the Potosi formation, though some seems to have been secured from the Eminence.

In general, the rock is very open, large solution cavities being not uncommon. Adjacent to these avenues of active circulation, and also embedded in the red clay that partially fills some of the openings, there is considerable quartz-chalcedony druse, or "mineral blossom."

Sand is described in the openings, below the ore. It is impossible to say, now, whether this material was actually sand, or whether it may not have been much disintegrated granular dolomite, which is very common on the outcrop, and is locally called sand or sandstone. If it is actually sand, it was probably washed into these solution channels, along connecting crevices, from the surface, prior to the ore deposition. The almost absolute lack of any sandstone layers in the Potosi, where that formation has been examined in detail, makes it quite unlikely that the reported sand is an integral part of the formation.

True veins, or vertical fissures carrying ore have been reported, but according to the most authentic information, only a very small part of the production came from such veins.

Considerable diamond drilling has been done in the area, in search of disseminated ore in the Bonneterre. The holes are all reported to bottom in the Lamotte. The indications are that nothing of value was encountered. The mention of one single speck of lead in the core studied by Buckley emphasizes this probability. One of the holes was cored the entire depth, and from this core Buckley[1] made up a detailed log, from which the following is condensed:

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[1]Geology of the disseminated lead deposits of St. Francois and Washington Counties; Mo. Bur. Geol. and Mines, 2nd ser., vol. IX, pt. 1, pp. 55-57.

CONDENSED LOG OF DIAMOND DRILL HOLE AT PALMER, MO.
Started 30 feet below top of Potosi formation).

	Feet.		
	From	To	Thickness.
Cambrian system:			
Ozarkian (of Ulrich):			
Potosi formation (total thickness 304 ft.)			
Dolomite, gray, coarsely-to finely-crystalline, small druses and some porous chert	0	100	100
Dolomite, gray, medium to finely-crystalline, some chert and druse	100	179	79
Dolomite, dark gray, finely-crystalline, druse especially abundant along fractures	179	238	59
Dolomite, gray, fine-to medium-grained, drusy, some "cotton rock"	238	274	36
Upper Cambrian (as restricted by Ulrich):			
Derby-Doerun formation (thickness 101 ft.):			
Dolomite, gray, fine-to medium-grained	274	276	2
Dolomite, yellowish to white, fine-to medium-grained	276	283	7
Dolomite, dense-to medium-grained, some druse	283	286	3
Dolomite, gray, hard	286	323	37
Dolomite, yellowish, soft, porous	323	350	27
Dolomite, like above, with thin green shale	350	375	25
Davis formation (thickness 179 ft.):			
Shale, green, with some dolomite	375	390	15
Shale, green, with less dolomite	390	422	32
Shale green, very little dolomite	422	455	33
Dolomite and shale laminae, wavy structure	455	528	73
Shale and dolomite, sandy	528	542	14
Shale and dolomite, platy, less sandy	542	550	8
Shale and granular dolomite, chloritic (glauconitic?)	550	554	4
Bonneterre formation (thickness 278 ft.):			
Dolomite, light gray, porous	554	627	73
Dolomite, coarsely-crystalline, irregular pockets and seams of green shale	627	675	48
Dolomite, some shale, porous, honeycombed	675	723	48
Dolomite, dark gray, crystalline	723	787	64
Dolomite, dark to light gray, medium-grained	787	810	23
Dolomite, dark gray, porous, no glauconite	810	832	22
Lamotte formation (penetrated 10 ft.):			
White sand	832	842	10

Potosi mines.—Lead was discovered in the immediate vicinity of Potosi, about 1763, at Mine a Breton. The various workings covered a large area, surrounding the present site of the town. Mining operations on any important scale, have long since ceased, and there is very little authentic information available as to the depth, character, and output of the innumerable local diggings. In fact, even the names and locations of many individual properties are now lost.

Most of the earlier production came from the red residual clays but later the ores in the dolomite were extensively exploited. A number of the shafts exceed 100 feet in depth. Some ore has been secured from the Eminence, but the great bulk came from the Potosi formation. As at the Palmer properties, most of the bed rock ore occurred in a complex network of interlacing channels, with far greater horizontal than vertical range. Two levels, at least, of these runs, have been worked. These ore bodies rarely exceed six feet in vertical dimension.

Vertical crevices, without reported displacement, are described but from all accounts, were exceptional features, and yielded only an insignificant amount of ore, as compared with the runs.

There is far less available information about this district, than about the Palmer area. The Mine a Breton, or Potosi mines, embraced several thousand acres, of varied ownership, on which there were many score of individual shafts and pits. No reliable statistics regarding output seem to be available. Among the better known individual mines, the Citadel, on the hill just south of the town of Potosi, is said to have been the first one opened up.

Old Mines.—Most of the shafts and pits of this district lie outside the borders of the quadrangle, though a few of the diggings extend from the village south into the extreme northeast corner of the sheet. These mines were opened in 1725. The area embraced in this group also covers several square miles, and the number of individual shafts and pits was very great. By far the larger part of the early development was concerned with the residual ores in the red clay. Later the ores in the dolomite were developed. Very little detailed information, and no authentic statistics, seem to be available. As in the other two districts, the bodies of ore are chiefly in the form of horizontal runs or channels and caves. Three levels are reported. Fissures, though known, were obviously of subordinate importance. The great bulk of the ore came from the Potosi formation. Although some shallow lead is still being picked up occasionally, in the area, the last important operations at the Old Mines seem to have been about 1901-1902, when some 700 or 800 tons of lead ore are reported to have been taken out.

Smith diggings.—These are chiefly shallow pits in the SE. ¼ sec. 4, T. 37 N., R. 1 E., which are said to have yielded considerable lead, about 1905. The deepest shaft is reported to be 70 feet. It starts low in the Eminence formation, and is on the upthrown side of the Shirley fault.

Heffner diggings.—This mine, located near the center of the W. ½ sec. 4, T. 37 N., R. 1 E., is said to have been operated as late as about 1920, but to have been drowned out by water. The pits, which start near the base of the Eminence formation, are reported to have been from 15 to 30 feet in depth. They occur close to and on the upthrown side of the Shirley fault.

Grainger diggings.—These diggings, located in the SW. ¼ sec. 2, T. 37 N., R. 1 E., are said to have produced a little in 1924. The shaft is claimed to be about 70 feet in depth, and occurs in the base of the Eminence formation.

Gulf prospect.—About at the northwest corner of sec. 31, T. 38 N., R. 3 E., is a shaft reported to be 70 feet deep, on a vertical lode which strikes about N. 30° W. From the character of the rock on the dump, when the property was seen in 1922, the shaft was still in the Eminence formation. Near the bottom of the shaft, the chief ore body was said to be nearly horizontal. It was reported at that date that the mine had produced about 50,000 pounds of lead, and about 300,000 pounds of barite. The writer did not have an opportunity to go underground.

Masson diggings.—In the SE. ¼ sec. 25, T. 38 N., R. 2 E., the writer visited extensive open pits, and one or two abandoned shafts, probably rather shallow, from which it is reported that considerable lead has been secured. The production was from the Eminence.

Bennings diggings.—Pits in clay, in the W. ½ sec. 25, T. 36 N., R. 1 E., are reported to have yielded considerable lead, about 40 years ago.

Nigger wool diggings.—These were clay diggings, located in the SW. ¼ SW. ¼ sec. 16, T. 36 N., R. 2 E., and operated about 45 years ago. They are said to have been exceptionally rich. The lead came from the Eminence formation.

Smith diggings.—A little lead is said to have been taken from clay diggings on Clear Creek, in the SW. ¼ sec. 18, T. 36 N., R. 2 E.

Forker (Forked?) diggings.—These occur on Forker Creek (not named on the map) in the W. ½ sec. 13, and the SE. ¼ sec. 14, T. 36 N., R. 2 E. There are several old shafts, said to be about 50 to 75 feet in depth, from which considerable production is reported. They all occur in the Potosi formation, and close to a branch of the Palmer fault. It is reported that the Federal Lead Co. drilled this tract.

Furnace Creek diggings.—These occur on Furnace Creek. On the map, this is shown as Flat Creek, but the latter name should be applied, according to all local reports, to the creek that flows southeast through the center of sec. 15, T. 36 N., R. 2 E. The Furnace Creek diggings occur in the SW. ¼ sec. 11, T. 36 N., R. 2 E., and are mostly shallow pits in clay, in the Potosi formation.

Plaffy diggings.—These are located near the cent. sec. 15, T. 36 N., R. 2 E. on Flat Creek. (Note that the creek shown on the map as Flat Creek is in reality Furnace Creek.) These diggings, which are reported to have yielded considerable lead, are in the Eminence formation. The tract is said to have been drilled by the Federal Lead Co.

Unnamed diggings.—Shallow pits are reported from the SE. ¼ SE. ¼ sec. 32, T. 38 N., R. 1 E., from which considerable lead is said to have been secured. Also near the center of the the E. ½ sec. 28, T. 38 N., R. 1 E., considerable lead is said to have been picked up, on the surface.

Origin of the lead deposits.—It is not proposed to enter into any lengthy discussion, in this report, of the origin of the lead deposits, but attention may be called to the fact that those arguments already presented, in the section devoted to barite, are for the most part quite as pertinent in consideration of the lead. The presence, continuity and thickness of the impervious Davis under the area is certainly not consistent with the activity of ascending waters. And in line with this point, is the absence, over most of the district, except in the Palmer area, of any appreciable faulting.

It seems highly significant, also, that even in the Palmer mines, the only group in the area in close proximity to faulting, deep drilling demonstrates the lack of lead in the underlying

Bonneterre. It is true, as Emmons[1] says, that the cores were not preserved. He seems, however, to have quite overlooked the extremely detailed log of the one hole that was cored throughout. In this log, Buckley[2] reports "one speck of lead along a thin shale parting at 803 feet." Regardless of whether the cores have been preserved or not, certainly no more conclusive evidence than this is needed, of the absence of lead deposits, in the Bonneterre of the Palmer district. If, however, this information is not considered sufficient, it is completely authenticated by the statement of Buehler,[3] who assisted Buckley in the examination of the other cores from the drilling in the area, that no lead of consequence was encountered.

The shape of the ore bodies, also, is of high significance. While fissures are not unknown, the great bulk of the ore at the Palmer Mines, the Potosi Mines, and at Old Mines, occurred in horizontal bodies, filling caves and channels of the type ordinarily resulting from solution by surface waters. The vertical extent rarely exceeded 6 or 8 feet, whereas the lateral dimension was many times as great. This is certainly far different from the type of body usually ascribed to ascending waters.

The type of gangue also demands consideration. Quartz, pyrite, and barite have been cited as probable evidence of hot waters. The only crystalline quartz present with the ores occurs as coatings of crystals on the chalcedony of the druses, and evidence of the secondary character of this mineral, developed by cold surface waters, during weathering, seems quite conclusive. Vein quartz is very rare, if present at all. It is not described in any of the mines listed by Winslow.[4] Nor has the writer seen evidence of it on any of the dumps.

Pyrite is present in sparing amounts, with marcasite much more abundant. While pyrite is a common gangue in the hot water deposits of the west, its wide occurrence in sedimentary rocks, especially coals, shows that it can form from cold waters, under shallow conditions. It is, therefore, not in the least diagnostic.

The possible significance of barite has already been discussed. It is certainly difficult to conceive of ascending

[1]Sulphide ores of the Mississippi Valley; Econ. Geol., vol. XXIV, 1929, p. 239.

[2]Disseminated lead deposits, Mo. Bur. Geol. and Mines, 2nd ser., vol. IX, pt. 1. pp. 55-57.

[3]Personal communication.

[4]Winslow, A., Lead and zinc deposits, Mo. Geol. Survey, vol. VII, pp. 678-683

solutions leaving lead below the Davis Shale in the Lead Belt, and carrying barite up through the Davis, in the barite district, which is actually less faulted than the Lead Belt. The close association of barite and lead in the flat bodies of ore also suggests surface waters. And the intimate intergrowth of barite and druse, the latter a cold water product, suggests that the barite, as well, has been in active movement in cold waters.

Of the other numerous gangue minerals common in thermal deposits, none are present.

Zinc Deposits.

Associated with the lead of the quadrangle is a little zinc, and locally there has been some production. Only a few of the ore bodies, however, carry zinc in appreciable quantities, and Tarr[1] states that sphalerite is confined to the vein deposits. Records of production are not available.

It is reported that a carload of mixed galena, blende (sphalerite) and barite was shipped to Joplin, from the Big Bill mine, also known as the Eye mine, in the NE. ¼ sec. 24, T. 37 N., R. 1 E., but that so much difficulty was encountered in separating the zinc and the barite, that there was no demand for the ore, and no further work was done. This mine, located close to the Shirley fault, and on the upthrown side, is close to the Eminence-Gasconade contact, and is probably in the Eminence throughout it entire depth.

In 1915 and 1916 about 15 cars of zinc carbonate ore (dry bone) were shipped from the Strawberry diggings of the Palmer district.

Mixed galena, barite and blende are reported in a vein at the Jumbo shaft,[2] in the NW. ¼ sec. 1, T. 36 N., R. 2 W., off the west edge of the quadrangle.

There seems to have been very little development of the sphalerite, largely because it is not easy to separate from the barite. Most of the actual production of zinc has been from residual clays, in the form of smithsonite, the carbonate. Several carbonate diggings are reported along the old Jefferson City road, about three miles northwest of Potosi. It is known that small quantities of carbonate ore have been recovered at many other diggings, though it is hard now to learn the exact localities.

[1]Barite deposits of Missouri; Univ. of Mo. Studies, vol. III, no. 1, p. 57.
[2]Winslow, op. cit., p. 638.

Copper Deposits.

So far as the writer has been able to learn, there has never been any actual copper production from the area of the Potosi or Edge Hill quadrangles. In the latter, however, are several old prospect shafts, opened in search for that metal.

One of these occurs in the NW. ¼ NE. ¼ sec. 27, T. 34 N., R. 2 E. The shaft, which was sunk on a basic dike, is now badly caved, and full of water, so that nothing but the dump could be examined. A little malachite stain is evident.

On the west side of the shut-in on Ottery Creek, in the E. ½ sec. 3, T. 33 N., R. 1 E., there is a shaft, long since abandoned, sunk in the pre-Cambrian rhyolite porphyry. The material on the dump is somewhat brecciated, and cut by a network of narrow quartz veinlets, in which occasional specks of chalcopyrite may be observed. A very little green stain, presumably malachite, was also noted.

In the shut-in on Shut-in Creek, in the NE. ¼ SE. ¼ sec. 30, T. 34 N., R. 2 E., openings have also been made in a zone of brecciated and veined rhyolite. Considerable galena, and smaller amounts of sphalerite and chalcopyrite, occur in the quartz veinlets. The presence of copper, zinc, and lead have been confirmed by qualitative tests.

There is nothing to indicate that any of these copper deposits will ever become of commercial importance.

Iron Deposits.

In Crane's[1] report on the Iron Ores of Missouri, mention is made of a limited production of iron southwest of Potosi from 1823 to 1832. A furnace was erected between Potosi and Caledonia. It has, however, been many years since any ore has been taken out in that area. There do not seem to be any records of iron production from elsewhere in either the Potosi or Edge Hill quadrangles.

The only pits that the writer saw during the course of the field mapping are located on the southwest slope of a knob in the NE. ¼ NE. ¼ sec. 27, T. 36 N., R. 2 E., closely adjacent to the Palmer fault. The ore occurs as large bowlders of spongy

[1]Mo. Bur. Geol. and Mines; vol. X, 2nd ser., 1912, pp. 343-346.

limonite. The pits were badly caved, and nothing of the relations could be made out.

A great abundance of bowlders of limonite, very perfectly pseudomorphic after marcasite, occurs on slopes of the Potosi formation near the center of the E. ½ sec. 27, T. 35 N., R. 1 E.

Abundant bowlders of rather spongy limonite occur as float along the contact of the porphyry and the Bonneterre, near the center of sec. 11, T. 33 N., R. 1 E.

In the area of the two quadrangles are the following reported occurrences of iron ore bowlders, listed from Crane.

OCCURRENCES OF IRON ORE BOWLDERS.

Washington County.

NW. ¼ NE. ¼	sec. 7, T. 35 N., R. 1 E.
SW. ¼ NW. ¼	sec. 7, T. 35 N., R. 1 E.
SW. ¼	sec. 7, T. 35 N., R. 1 E.
NW. ¼ NW. ¼	sec. 17, T. 35 N., R. 1 E.
NW. ¼ NE. ¼	sec. 18, T. 35 N., R. 1 E.
NE ¼	sec. 4, T. 35 N., R. 2 E.
	sec. 13, T. 35 N., R. 2 E.
NE. ¼ NE. ¼	sec. 14, T. 35 N., R. 2 E.
	sec. 16, T. 35 N., R. 2 E.
NE. ¼ NE. ¼	sec. 24, T. 36 N., R. 1 E.
NE. ¼	sec. 30, T. 36 N., R. 2 E.
NE. ¼	sec. 33, T. 36 N., R. 2 E.

Iron County.

sec. 7, T. 34 N., R. 1 E.
sec. 15, T. 34 N., R. 1 E.
sec. 1, T. 34 N., R. 1 W.
sec. 12, T. 34 N., R. 1 W.
sec. 20, T. 35 N., R. 1 E.
sec. 32, T. 35 N., R. 1 E.

Clay.

According to Wheeler,[1] the first white ware pottery in Missouri, and one of the earliest in the Mississippi Valley, known as the Poole pottery, was located at Foote, in the east part of lot 1, NW. ¼ sec. 1, T. 34 N., R. 1 W., which would be very nearly where present Highway 32 leaves the west border of the Edge Hill quadrangle. According to Wheeler, who wrote in 1896, it had at that date "been long since obliterated."

Its clays were derived from the immediate vicinity, in secs. 1 and 2, T. 34 N., R. 1 W., and also from the old town of Kaolin (now Shepard), in sec. 36, T. 35 N., R. 1 E. Prospects were also known near the cent. sec. 32, T. 35 N., R. 1 E.

[1]Wheeler, H. A., Clay deposits; Mo. Geol. Survey, vol. XI, 1896, p. 178.

Not far south of the border of the Edge Hill sheet, clay prospects have also been reported, in sec. 14, T. 32 N., R. 3 E., and in sec. 26, T. 32 N., R. 2 E., and another about 2½ miles northeast of Centerville.

The only one of these deposits to be examined in any detail is the one at Shepard, in sec. 36, T. 35 N., R. 1 E. The new cuts on Highway 32, both east and west of Shepard, on Kaolin Creek, expose a very heterogeneous mixture of sandstone blocks, chert, and impure, sandy clay. There is little doubt but what the material is Pennsylvanian, and occupies an old sink. The general occurrence is essentially the same as that of the larger deposits of Pehlps and Gasconade Counties, except that the Pennsylvanian has been much more completely stripped off this area, and consequently only the roots of once much larger deposits are left.

The clays vary from white to purple, as in other areas, and both plastic and flint types occur, but nothing definite could be made out as to their relations to each other.

Because erosion has stripped away the upper portion of these deposits, they are likely to be small, and very intimately mixed with chert and sand. Their remoteness from transportation, their small size, and their generally impure character make it quite unlikely that they can compete successfully with the larger, richer, and better located deposits of other parts of the state.

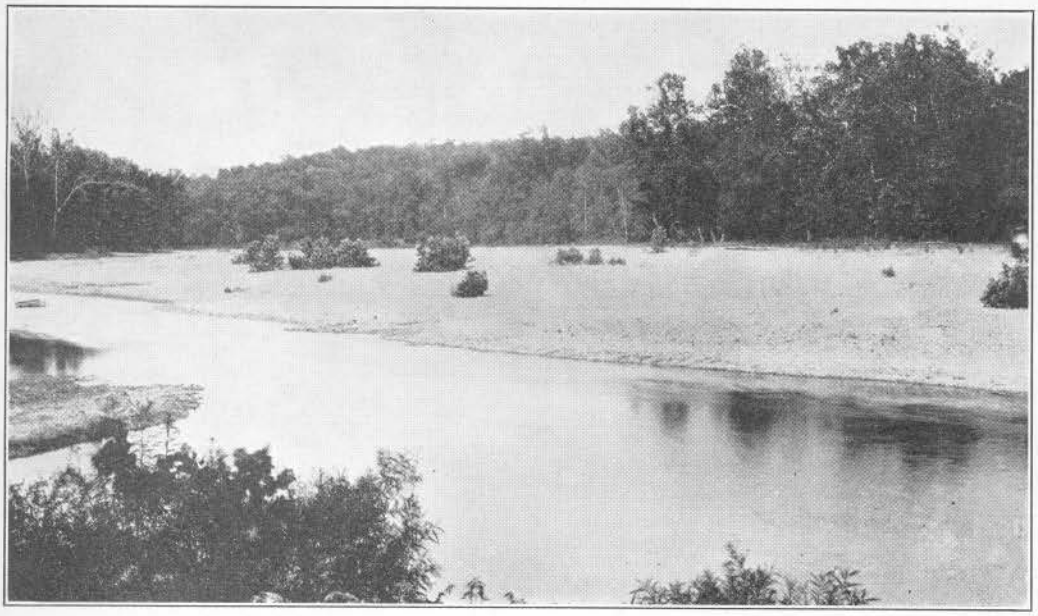
If, however, it is desired to prospect for further clay deposits, in this area, search should, in general, be concentrated in those localities showing patches of sandstone float, particularly in rounded bowlders. The sandstone is, for the most part, an indication of probable sink structure, and rounded bowlders are most characteristic of Pennsylvanian. These two conditions, therefore, point to places where Pennsylvanian remnants are most likely to be preserved.

Asbestos Deposits.

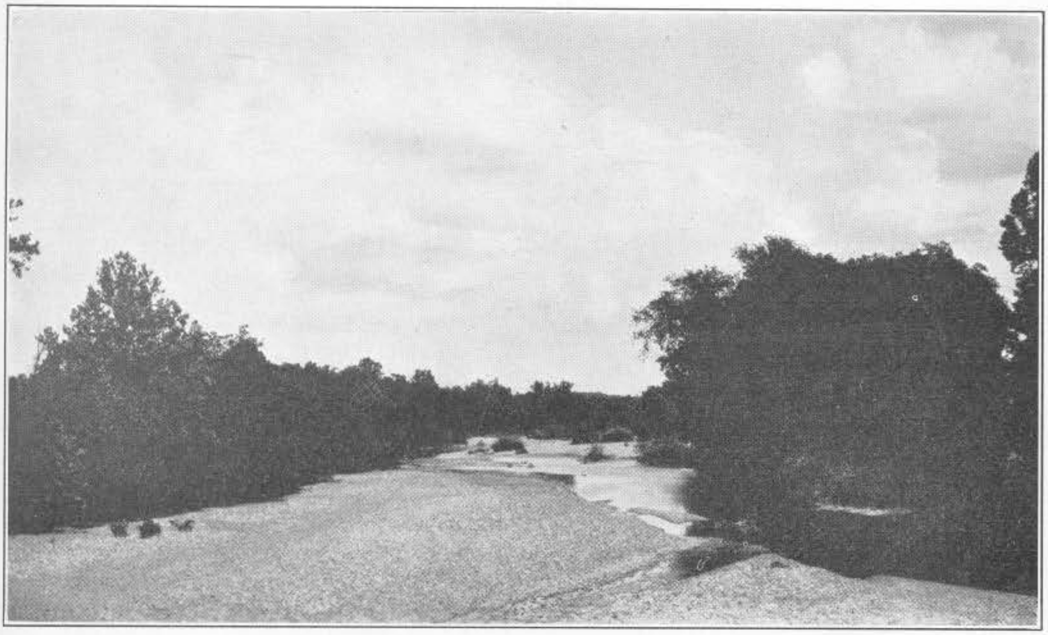
Asbestos has a very limited occurrence in Missouri. It has been reported associated with greenstone in Madison Co.,[1] in secs. 19 and 20, T. 32 N., R. 6 E., and also in sec. 17, T. 33 N., R. 5 E.[2]

[1]Report of the Geological Survey of Missouri for 1873-1874, pp. 51, 352 and 376.

[2]Haworth, E., The crystalline rocks of Missouri; Mo. Geol. Survey, vol. VIII, 1894, p. 120.



A. Gravel bar where Highway 8 crosses Courtois Creek, a few miles west of the Potosi quadrangle.



B. Gravel bar on Big River, on Highway 21, about three miles north of Caledonia.

Mention is also made[1] of actinolite asbestos in Iron and Crawford Counties, but no localities are mentioned, and no reference is made to sources of information.

In 1906 Dr. J. Q. Adams sent in to this Bureau samples of actinolite reported to come from a twelve inch vein on the farm of Robert Rich. The vein was stated to occur near the southeast corner of sec. 27, T. 34 N., R. 2 E. Though the location does not check exactly, the sample probably came from the deposit described in the following paragraph.

The writer visited a reported asbestos deposit in Iron County, near the SW. ¼ NW. ¼ sec. 26, T. 34 N., R. 2 E. The outcropping rock was a basic dike, cutting the rhyolite. At the locality to which he was conducted, nothing was visible except a little asbestiform actinolite, scattered through the residual soil from the dike. Its association was such as to indicate a vein in the dike, but no rock could be seen in place, and no definite relations were made out.

There is an old shaft in the extreme northeast corner of the SE. ¼ sec. 27, T. 34 N., R. 2 E., now badly caved, which was said to have been sunk on an asbestos vein. No sign of that mineral could be found on the dump, but a local resident reported that two small veins, the best one under 6 inches across, were formerly visible in the bottom of the shaft. He reported that the fiber ran the "long way of the vein," and varied from 2 to 3 inches in length. No shipments were ever made.

Gravel Deposits.

The smaller streams of the region carry the usual amounts of chert gravel, suitable for local uses. There are, however, larger streams, on which exceptional amounts of gravel occur. These are Big River, from Belgrade to the east edge of the Potosi quadrangle (Pl. XXIII, B), the Middle Fork of Black River, from Edge Hill to the south border of the Edge Hill quadrangle, the East Fork of Black River, near the south border of the sheet, and the Courtois, just west of the quadrangle (Pl. XXIII, A). The forks of Black River all carry enormous quantities of gravel, south of the quadrangle, near Lesterville.

The quality of the gravel is comparable to that of other typical Ozark streams. Most of the particles are chert, with a

[1]Biennial report of the State Geologist to the fourty-fourth Assembly, 1906, p. 35.

small admixture of porphyry. There is comparatively little sand, and almost no clay. Weak or decayed pebbles are rare.

Unfortunately, these gravels are too far from transportation to have any present market value, except for road work. They constitute, however, an excellent reserve for road construction, when the scenic attractions of this unexcelled tourist region result in any systematic development program.

Building Stone.

Although the Roubidoux has been used locally for foundations, furnaces, and chimneys, and the Davis for flagstones, there are no operating quarries in either quadrangle. It would appear that there is no rock in the area of sufficient value to indicate any future development, especially in the face of transportation handicaps.

Ground Water Resources.

The only sandstone in the area, that may be counted on to produce water is the Lamotte. North of the Palmer fault zone, this sandstone is probably everywhere present, except bordering the porphyry of Little Pilot, and adjacent knobs, in the northwest corner of the Potosi quadrangle. In the deep well at Potosi, it was reached at a depth of 905 feet, and penetrated for 55 feet. This is the only hole north of the Palmer fault, in the Potosi quadrangle, that is known to enter the Lamotte. On the Roubidoux uplands of the west central part of the quadrangle, the depth to the sand would probably be close to 1500 feet.

The deep well at Palmer entered the Lamotte at 832 feet. In the faulted zone north of Belgrade, the sandstone was encountered at depths varying from 200 to 1100 feet, depending on the position of the holes with respect to the faults. On the Roubidoux-capped hills in the extreme southwest corner of the Edge Hill sheet, it may be expected at about 1200 feet. On Kaolin Creek, south of Shepard, it was reached at less than 600 feet, and at Black between 400 and 600. In the southeast corner of the Potosi and the northeast corner of the Edge Hill quadrangles, Lamotte outcrops over a small area.

Among, or even in close proximity to, the porphyry outcrops, drilling may or may not reach the Lamotte, as a result of overlap of the younger formations directly against the buried pre-Cambrian hillsides. Some of the holes at Shepard (p. 55), and some of those at Black (p. 56), went directly from Bonneterre into porphyry, whereas others at both localities encountered the sandstone. More remote from the porphyry peaks, the sandstone is likely to be present everywhere below the Bonneterre. Wherever it is found, it may be counted on to yield an abundance of potable water.

Since the Roubidoux, where it is present at all, caps only the higher uplands, it cannot be expected to carry water, except very locally and in small amounts. Where the formation is deeply buried, in other parts of the state, it is an important ground water horizon.

Except in the west central part of the area, the Gasconade also caps the hills, and must not be expected to carry water, although, elsewhere in the state adequate domestic supplies can usually be secured, from the openings of this dolomite.

As a rule the Eminence, Potosi, and Bonneterre are sufficiently open so that wells penetrating them to any depth secure adequate supplies for local purposes. In thickly settled regions supplies from such openings in limestone or dolomite are particularly subject to contamination, but in most of this region, the danger is not great.

The Davis and Derby-Doerun are more argillaceous, less open, and would not be expected to yield much water.

Flowing wells, all of them drilled as lead prospects, are known at several points. One is located about a half mile southwest of Munger, in sec. 2, T. 34 N., R. 2 E. The curb is at an elevation of about 960 feet. Davis is the outcropping rock. The well was drilled about 1890 by the Laclede Land and Improvement Co., and is reported to be bottomed at a depth of 464 feet. Neither cores nor log are now available.

The flowing well at Palmer is in the S. ½ sec. 12, T. 36 N., R. 1 W. The hole started on Potosi, the curb is at 920 feet, the depth 842 feet, and it penetrated the Lamotte 10 feet.

Another flowing well is located near Black, in the NE. ¼ NW. ¼ sec. 26, T. 33 N., R. 1 E. The well started on Davis at an elevation of about 830 feet, is 502 feet deep, and penetrated the Lamotte 87 feet.

Another well near Black, in the SW. ¼ SE. ¼ NW. ¼ sec. 22, T. 33 N., R. 1 E., started on Derby-Doerun, and began to flow from a crevice at 250 feet, probably in the uppermost Bonneterre. The hole is 653 feet deep, the elevation at the curb about 765 feet. It went entirely through the Lamotte, which was 95 feet thick, and entered the porphyry. It is said that "no change in flow was noted on striking the sand."[1]

[1]Remark on log supplied by E. T. Campbell.

There is a flowing well on Flat Creek near the center of sec. 15, T. 36 N., R. 2 E., at the old Plaffy diggings, said to have have been drilled by the Federal Lead Co., but nothing could be learned about its depth, or the character of the formations.

Deep wells, except for the city well at Potosi, have been drilled exclusively for lead. The log of the deep well at Palmer is given on p. 214. Condensed summaries of other drillings are presented on pp. 53-56.

The city well at Potosi was put down by the Sewell Well Co., between Dec., 1926, and Feb., 1927. It started at an elevation of about 920 feet, on the outcrop of the Potosi formation, about 90 feet below the basal contact of the Eminence. The depth is 960 feet, and the well penetrated the Lamotte sand about 55 feet. It is said to yield about 65 gallons per minute. A condensed log of the well, compiled by H. S. McQueen of this Bureau, from an examination of cuttings, is given below:

CONDENSED LOG OF CITY WELL, POTOSI, MO.
(Started 90 ft. below top of Potosi dolomite.)

	Feet.		
	From	To	Thick-ness.
Surface	0	25	25
Cambrian system:			
Ozarkian (of Ulrich):			
Potosi formation (total thickness 400 ft.):			
Dolomite, brown, crystalline, some chert and druse	25	35	10
Dolomite, gray, crystalline, some chert and druse	35	150	115
Dolomite, light brownish-gray, crystalline, some chert and druse	150	310	160
Upper Cambrian (as restricted by Ulrich):			
Derby-Doerun formations (thickness 75 ft.):			
Dolomite, fine-grained, gray, argillaceous	310	385	75
Davis formation (thickness 165 ft.):			
Dolomite, gray to bluish-gray, fine-grained, some shale	385	420	35
Shale, grayish-green, hard, calcareous	420	450	30

Names and Locations of Lead Diggings Near Palmer

1. Booth
2. Williams
3. Pete Odle
4. Shores
5. Lost Creek Lode (beyond north edge of map)
6. Courtois
7. Duncan
8. Morris
9. New Coffee Pot
10. Doe
11. High Point
12. Kews
13. Bluff
14. Polecat
15. Water Hill
16. Coffman
17. Beers
18. Johns Creek
19. Skaggs
20. Kettle
21. Cole
22. Old Coffee Pot
23. Bridges
24. Clark
25. Picayune
26. Seed Tick
27. Blackwell
28. New Greasy
29. Locust
30. Possum
31. Old Greasy
32. English
33. Madden Hill
34. Galloway's Defeat
35. Sucker
36. Buckhorn Point
37. Meyers
38. Rock Spring
39. Pigeon Roost
40. Tucker
41. Cotton Point
42. Fords
43. Potato Patch
44. Brown
45. Bit Hill
46. Billy Brown
47. Black Hill
48. Flint Hill
49. Clompton
50. Snowdens Point
51. Strawberry
52. Nigger Hill
53. Noose
54. Coehorn
55. Trash Hill
56. Maury
57. Hutchins
58. Parole
59. Coon
60. Slit
61. Quinn
62. Peter Blount
63. Duncan
64. Midnight
65. New Ishmael
66. Turkey Hill
67. Snatch Back
68. Sand
69. Montgomery
70. Bunch
71. Peru
72. Copperhead
73. Waterloo
74. Crain
75. Boulder
76. Daylight
77. Tiger
78. Old Ishmael
79. Flint Point
80. Jackson Hill
81. Graveyard
82. Cales
83. Clemens
84. Tedder Hill
85. Old Tyler
86. Ground Hog
87. New Tyler
88. Sweezy
89. Klondike
90. Robinson
91. Fox
92. Tut
93. Tar Kiln
94. Grover

CONDENSED LOG OF CITY WELL, POTOSI, MO.—Continued.

	Feet.		
	From	To	Thickness.
Sandstone, extremely fine-grained, gray, argillaceous, calcareous, some shale	450	495	45
Dolomite, brownish, finely-crystalline, argillaceous, somewhat glauconitic	495	530	35
Sandstone, fine, calcareous, argillaceous	530	540	10
Dolomite, gray to brown, finely-crystalline, some shale	540	550	10
Bonneterre formation (thickness 355 ft.):			
Dolomite, brown to gray, finely-crystalline, some glauconite	550	650	100
Dolomite, bluish-gray, finely-crystalline	650	675	25
Dolomite, light gray, finely-crystalline, a little glauconite	675	810	135
Dolomite, bluish-gray, fine-grained, some glauconite	810	880	70
Dolomite, dark gray, finely-crystalline, sandy, some glauconite	880	895	15
Sand and dolomite, rounded grains, glauconitic	895	905	10
Lamotte formation (penetrated 55 ft.):			
Sand, fine, sub-angular to rounded	905	950	45
No samples	950	960	10

No exceptionally large springs, such as those that make the Ozark region famous, occur within the confines of the two quadrangles. Springs, however, are very numerous, especially on the outcrops of the Potosi and Eminence formations. Several of the more important ones are listed on pages 22-23.

Potosi is the only town in the entire area of sufficient size to have developed a municipal water supply. Analysis of the water is given below:

ANALYSIS OF WATER FROM CITY WELL, POTOSI.

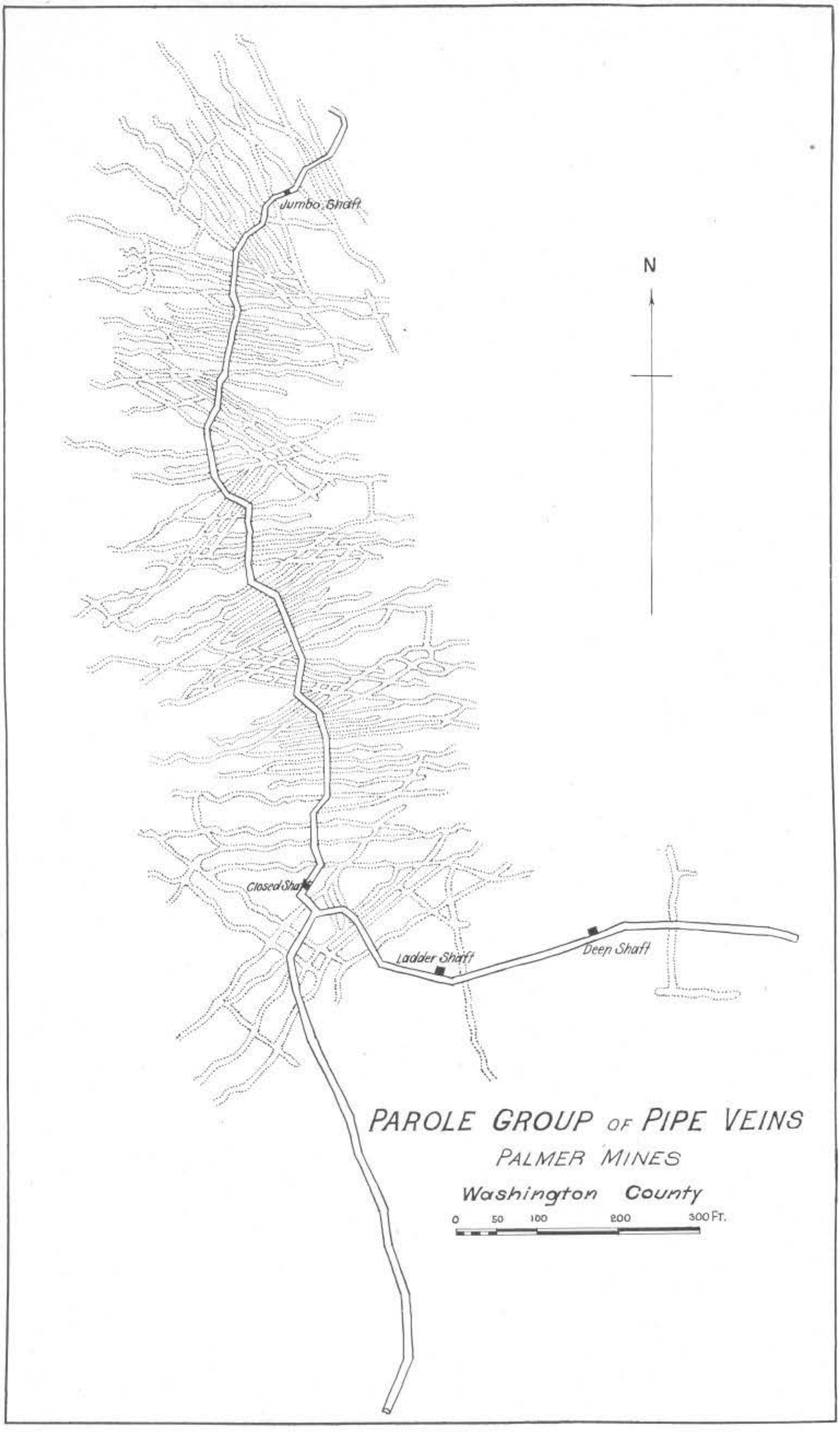
Location: Potosi, Washington County.
Owner: City of Potosi.
Well No. 2128.
Depth: 960 feet.
Received: 3-13-28.
Analyzed: 3-27-28.
Analyst: H. W. Mundt.
Collector: H. S. McQueen.
Sample from tap.

Constituents.	Parts per million.	
Silica (SiO_2)	4.4	
Iron (Fe)	0.47	
Calcium (Ca)	69.6	
Magnesium (Mg)	41.9	
Sodium (Na).. } as Na Potassium (K) }	3.8	
Carbonate radicle (CO_3)	16.8	
Bi-carbonate radicle (HCO_3)	373.0	183.21 CO
Sulphate radicle (SO_4)	10.1	
Chloride radicle (Cl)	3.7	
Nitrate radicle (NO_3)	0.76	
Sum of constituents	335.13	
Temporary hardness (as calcium carbonate $CaCO_3$)	....	307.0
Permanent hardness (non-carbonate hardness)	....	39.5
Total	....	346.5

Note: Temporary hardness is that removed by boiling.

This is a hard, alkaline water obtained chiefly from a crevice from 745-760 feet in the Bonneterre formation and from the Lamotte formation from 905 to 960 feet. Some water was no doubt obtained from small crevices in the dolomite above the Davis formation.

The analysis indicates that this water is suitable for human consumption, and that it meets the specifications of the U. S. Public Health Service for drinking water used in common carriers engaged in interstate traffic


Jumbo Shaft
N
Closed Shaft
Ladder Shaft
Deep Shaft
PAROLE GROUP OF PIPE VEINS
PALMER MINES
Washington County
0 50 100 200 300 FT.

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