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Geology of the Eminence
and
Cardareva Quadrangles

By Josiah Bridge

Vol. XXIV, Second Series

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Missouri Bureau of Geology and Mines
Rolla, Missouri
H. A. Buehler, *Director and State Geologist*

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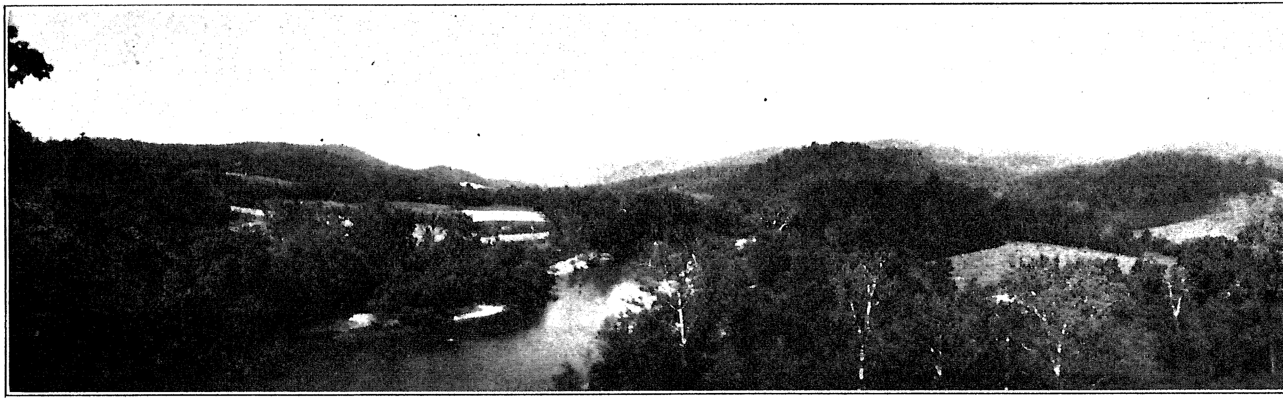

A. View of Current River looking upstream from the high cliff north of Cave Hollow, showing the open valley cut on the sedimentary rocks.

B. View of Current River looking upstream from the ridge east of Thorny Creek, showing the narrowing of the valley where the river passes between Coot and Blair Creek Mountains.

BOARD OF MANAGERS.

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Missouri Bureau of Geology and Mines,
Rolla, Mo., September 1, 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 Geology of the Eminence and Cardareva Quadrangles by Dr. Josiah Bridge. This, and the companion report on the Potosi-Edgehill Quadrangles treat of extremely interesting and important stratigraphic units in the southeast Ozark region and they are important contributions to our knowledge of the Ozark region.

Respectfully submitted,

H. A. BUEHLER,
State Geologist.

ACKNOWLEDGMENTS.

The writer gratefully acknowledges his indebtedness to Dr. E. O. Ulrich, who has at all times given him the benefit of his long experience and vast knowledge of Paleozoic stratigraphy and faunas.

Dr. Ulrich's connection with this Survey began nearly 30 years ago, when he made an extensive reconnaissance across southern Missouri and established the general stratigraphic succession for the entire Ozark region; an undertaking which had been attempted at various times by other workers, but which had never been successfully accomplished. His classification as originally proposed, has been revised, amended and amplified from time to time, partly as a result of his own researches, and partly as a result of detailed studies by members of this Bureau under his general guidance, but it has never been seriously modified.

It is impossible to give credit at the proper places in this report for all of the ideas which have been developed as a result of his observations. He was the first to call attention to the importance of the siliceous content of the dolomites; to point out the value of various types of chert as a means of discriminating between horizons; to show the concentration of silica along unconformities, and to emphasize the "insignificant appearance of great unconformities." He was also the first to show the presence of the large and interesting faunas in these older rocks and to undertake the great task of classifying and correlating them and most of our present knowledge of their composition, distribution and affinities is due to his efforts.

The citizens of the area discussed in this report, and particularly those interested in mining, have always shown great interest in the field work of the Survey, and many of them have materially aided these investigations. Especial thanks is due the late John W. McClellan, and also to Messrs C. Seaman, S. A. Cunningham and R. E. Carr, of Eminence, for information, and for access to documents relating to the early history of mining in this region.

The author is also deeply indebted to his colleagues on the Staff of the Missouri Bureau of Geology and Mines, and in the

Missouri School of Mines, for assistance on various problems connected with the investigation; and to the various students and former students, who have assisted in the mapping or have otherwise rendered service.

The broader stratigraphic problems, extending beyond the bounds of this region have been investigated jointly with Dr. C. L. Dake. Mr. H. S. McQueen has furnished much information regarding sub-surface correlation. Mr. C. O. Reinoehl prepared the final draft of the map, and drew the cross sections and text figures from preliminary sketches.

The author is also greatly indebted to Mr. W. O. Hazard, photographer, and Miss Frances Wieser, artist, both of the U. S. Geological Survey, who prepared the figures for plates XVIII to XXI.

Lastly the writer wishes to express his thanks to the members of the Faculty of the Department of Geology of Princeton University, under whose supervision this report was prepared.

INTRODUCTION.

SCOPE AND PURPOSE OF THIS REPORT.

This report presents the results of an investigation of the Geology and Economic Resources of the Eminence region. About a century ago small quantities of copper were produced near Eminence, and since that time many attempts have been made to mine and market the copper minerals found there. However, no production of any consequence was made and no extensive deposits discovered. During the World War, a number of these deposits were reopened and worked in the hope that the higher price of metal obtaining at that time would allow them to be operated at a profit. With this increased activity, which lasted until well after the war, came the demand for more accurate knowledge as to the distribution and size of these copper deposits, and it was largely to meet this demand that the present report was undertaken.

In addition to the economic problem just outlined, there are also purely scientific questions, concerning the age, classification, and correlation of the rocks found in this area. These problems are not confined to the Eminence region alone, but are concerned with the classification of the Upper Cambrian and Lower Ordovician rocks of the entire Ozark Uplift; and more particularly with those formations which Ulrich places in his proposed Ozarkian and Canadian Systems.[1] They have also been studied in Washington Co. by Dake, and this phase of the investigation has been carried on jointly with him.

PREVIOUS WORK.

Economic. In 1841, Hodge[2] visited the copper mines in Shannon Co. and the following year published a brief account of them. He describes the Slater Mine as it appeared shortly after the original mining operations had been discontinued This report constitutes the earliest published reference to the geology and mineral resources of the county.

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[1]Ulrich, E. O., Revision of the Paleozoic Systems: Bull. Geol. Soc. Amer., Vol. XXII, 1911., pp. 627-678.

[2]Hodge, James T., On the Wisconsin and Missouri Lead Region, (Silliman's Journal) Amer. Jour. Sci., Vol. 43, 1842.

Thirty-five years later, Dr. C. P. Williams, First Director of the Missouri School of Mines and Metallurgy, and ex officio, State Geologist of Missouri, visited the Slater Mine and published a brief report on Shannon Co., and its Copper Deposits.[1] His report includes a map of the surface workings of the Slater Mine, and also maps of Round and Alley Springs, and gives much information concerning the general geology of the region, as well as that of the mineral deposits.

In 1905 Bain and Ulrich[2] published a very brief notice of the Copper Deposits of Missouri, and followed it the same year with a much more detailed account.

These four reports comprise all that has been published on the copper deposits, but in addition to these there are a number of reports of professional geologists and mining engineers which have been submitted to various mining companies from time to time. Some of these are well prepared and contain much valuable information, especially as regards the mining being done at that particular time. Other reports were evidently written for promotion purposes, and contain many misstatements, and erroneous ideas.

In 1920-21 Bowles and Davidson[3] spent a few weeks in the region, and prepared a report upon the Copper deposits. They collected a considerable amount of valuable information concerning the mines, all of which were in operation at the time of their visit.

Stratigraphic. With the exception of the work of Bain and Ulrich[4] very little attention has been paid to the stratigraphy of this region. Swallow, Shumard and Broadhead make no mention of Shannon Co. in their reports, and it does not appear to have been visited by these early workers. Williams[5] assigned the igneous rocks to the Archean, and the sedimentary series to Swallow's "Second sandstones" and "Third limestone."

Nason[6] refers the sedimentary rocks to the Roubidoux and

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[1]Williams, C. P., Geol. Surv. of Mo., Industrial Report, 1875-6 (1877), pp. 159-67.

[2]Bain, H. Foster, and Ulrich, E. O., The Copper Deposits of Missouri, U. S. Geol. Surv. Bull. 260, 1905, pp. 233-35 and also, The Copper Deposits of Missouri, U. S. Geol. Surv. Bull. 267, 1905.

[3]Bowles, J. H., and Davidson, L. E., The Copper Deposits of Shannon Co., Unpub. Thesis, Library, Mo. Sch. Mines and Met.

[4]Bain, H. Foster, and Ulrich, E. O., The Copper Deposits of Mo., U. S. Geol. Surv. Bull. 267, 1905.

[5]Williams, C. P., Geol. Surv. of Mo., Industrial Rept., 1875-6 (1877), pp. 161-3.

[6]Nason, F. L., Report on Iron Ores, Mo. Geol. Surv., Vol. II, 1892, Chap. V.

Gasconade formations. He mentions the fact that copper has been found near Eminence, but gives no details.

Bain and Ulrich use Nason's nomenclature, but shortly afterwards, Ulrich[1] separated the Eminence formation from the Gasconade, and published a brief description of it.

No other published reports deal with the stratigraphy of this region, but all of the formations occurring in it have been recognized in other portions of the Ozarks, and there are many references to them in the publications and notes of the Bureau.

PRESENT WORK.

Field work was begun by the writer in the Eminence region in the summer of 1922 and was continued throughout the seasons of 1923 and 1924. During the season of 1923, Mr. E. T. Campbell was field assistant, and he mapped most of the Gasconade-Roubidoux contact in the western and southern portions of the Eminence quadrangle.

In this same season a reconnaissance was made of the area of the Cardareva quadrangle, and it was decided that it should be included in the final report. The United States Geological Survey began the topographic mapping of this quadrangle in the summer of 1923, but proof sheets were not available until late in the summer of 1926.

Little work was done in this region during the summers of 1925 and 1926. Most of these seasons were devoted to stratigraphic studies of rocks of equivalent age in other parts of the Ozark region, a large part of this work being done with Dake. Late in the season of 1926 geologic mapping was begun in the Cardareva quadrangle, and was continued throughout the summer of 1927 and completed in the middle of the sesaon of 1928.

During the season of 1927, the writer was assisted by Mr. C. D. Cordry. The following seasons, Mr. S. A. Lynch was field assistant, and he mapped the Eminence-Van Buren contact in the area east of the porphyry knobs and between Current River and Rogers Creek.

Mr. J. S. Cullison has done much of the work of preparing and identifying the paleontologic collections not only from the Eminence region, but from the Potosi-Edgehill area as well.

[1]Ulrich, E. O., Revision of the Paleozoic Systems, Bull. Geol. Soc. Amer., Vol. XXII, 1911, p. 630.

In addition to the regularly appointed assistants just named, Messrs. J. W. Hardy, R. D. Mabrey, J. D. Cameron and T. D. Murphy have assisted the writer at various times, both in the field studies and in the preparation of specimens.

Dr. E. O. Ulrich has been the guest of Survey parties in the field, for periods of about two weeks each during the seasons of 1923, '24, '26, '28, and '30. Each visit was devoted to a study of the stratigraphic problems of the Ozark region as a whole, and many areas throughout the entire uplift were visited and studied on these trips.

Dr. Dake has visited the Eminence region on several occasions, to compare the stratigraphic succession of this region with that of the Potosi area, and the writer has made similar visits to the Potosi region.

With the assistance of contoured road sketches prepared by Mr. C. O. Reinoehl, the geology of narrow strips connecting the Potosi, Eminence and Rolla areas has been done by Dake and the writer, and this has been of great assistance in bringing out the regional structural and stratigraphic relations.

CHAPTER I.

GEOGRAPHY AND PHYSIOGRAPHY.

LOCATION AND AREA.

The Eminence region, as the term is used in this report, is situated in the southeastern part of the Ozark Highland, and consists of the Eminence and Cardareva quadrangles, which are two standard 15 minute sheets of the United States Topographic Atlas. They have been published as a single sheet for this report.

The Eminence quadrangle lies wholly within the boundaries of Shannon Co., but the Cardareva quadrangle which lies to the east, includes portions of Shannon, Reynolds and Carter Counties. The area mapped is a rectangle 17.3 by 27.6 miles and contains about 478 square miles, of which 381 are in Shan-

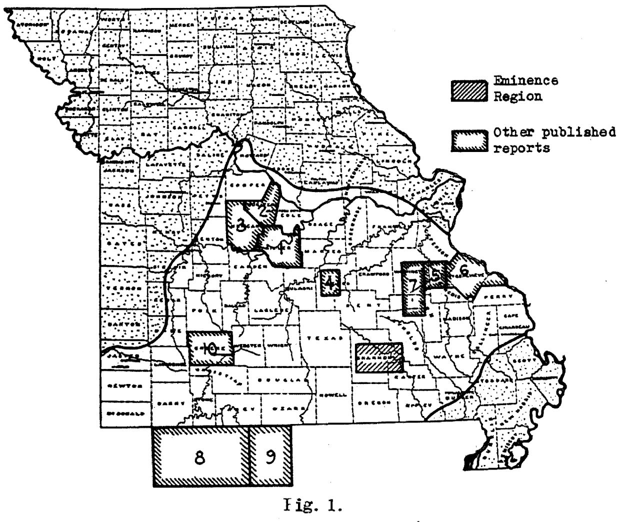


Fig. 1.

Index map showing the location of the Eminence region and other regions in the Ozarks for which there are published reports.

PUBLISHED REPORTS.

1. Miller County, Mo. Bur. Geol. & Mines, Vol. I, 2nd ser.
2. Moniteau County, Mo. Bur. Geol. & Mines, Vol. III, 2nd ser.
3. Morgan County, Mo. Bur. Geol. & Mines, Vol. VII, 2nd ser.
4. Rolla Quadrangle, Mo. Bur. Geol. & Mines, Vol. XII, 2nd ser.
5. Bonneterre Quadrangle, Mo. Bur. Geol. & Mines, Vol. IX, 2nd ser.
6. Ste. Genevieve County, Mo. Bur. Geol. & Mines, Vol. XXII, 2nd ser., 1928.
7. Potosi Region, Mo. Bur. Geol. & Mines, Vol. XXIII, 2nd ser., 1930.
8. Eureka Springs—Harrison quadrangles, U. S. Geol. Surv. Folio No. 202.
9. Yellville quadrangle, U. S. Geol. Survey, Prof. Paper 24.
10. Green County, Mo. Geol. Survey, Vol. XII, 1st ser.

non, 62 in Carter and 35 in Reynolds County. The location of these quadrangles, and their relation to the other areas in the Ozark region for which there are published geologic reports is shown in Fig. 1.

The boundaries of the Eminence region as thus defined are purely arbitrary and have no relation whatever to the political subdivisions, or to the geologic and geographic features of the country. Most of the features described in this report, extend far beyond its boundaries on all sides. Thus the geology of this area may serve as an index to the geology of much of the surrounding territory.

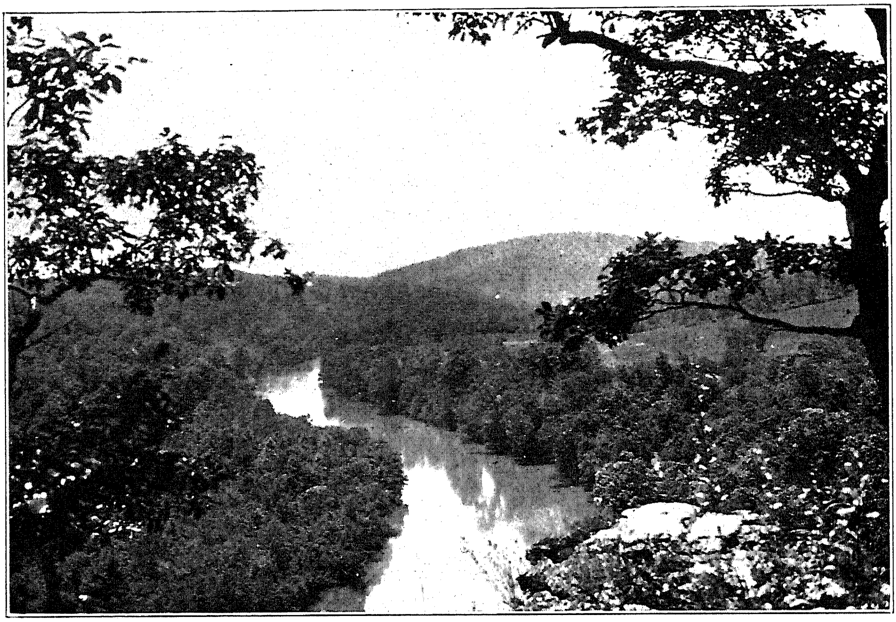
SCENIC ATTRACTIONS.

The Current River Valley, in which the greater portions of the Eminence-Cardareva quadrangles are located, has long been known as one of the most beautiful sections of the Ozarks. Until recently it has been almost inaccessible to the average tourist, and for that reason has not been greatly exploited. With the development and extension of the state highway system, the country has been opened to the motorist, and an increasing number of tourists visit it each year.

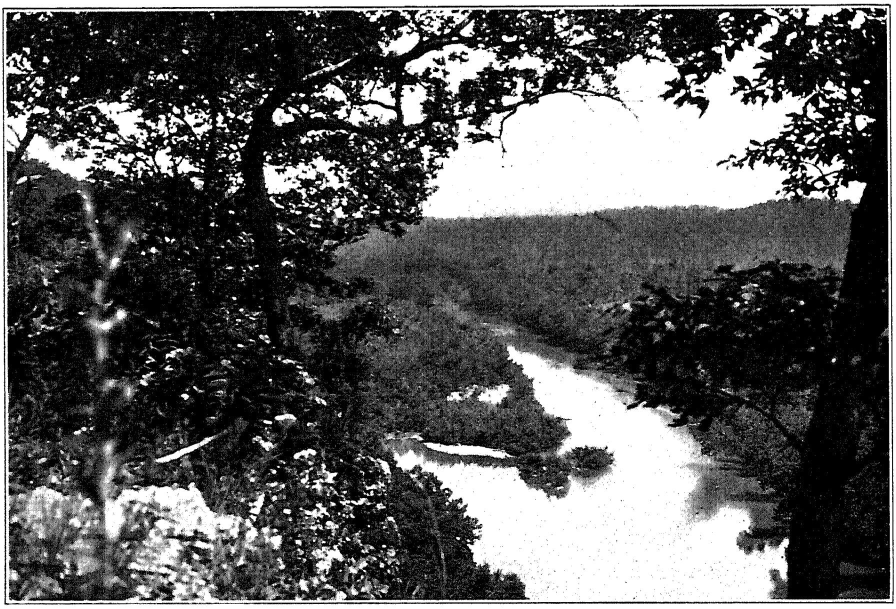
There are five State Parks in the Current River country. Four of these, Montauk Park, at the head of the river in Dent County; Round Spring Park 14 miles north of Eminence; Alley Spring Park 6 miles west of Eminence and Big Spring Park 5 miles southeast of Van Buren; have been set aside to preserve some of the beauty spots of the state for the pleasure of the public. Camping facilities are provided, but every effort is made to preserve the natural beauty of the parks and to avoid commercialization. Fishing is permitted, but dogs and guns are barred, and the parks thus serve the additional function of being game refuges.

Deer Run State Park is located in an extremely rugged and uninhabited section of the country lying between Ellington and Current River. It was set aside primarily as a game refuge, and the state is raising deer and wild turkeys here to restock the Ozark forests. A number of deer have already been liberated from this preserve, and it is occasionally possible to catch sight of one of these beautiful creatures, which a few years ago had all but vanished from the Ozark forests.

All of these parks have been created within the last few years, in fact, since the beginning of the field work upon which



A. View upstream (west) from the high cliff on the southeast slope of Blair Creek Mountain (SE. ¼ sec. 13, T. 29 N., R. 3 W.). Coot Mountain, a typical porphyry knob in the background.



B. View downstream (east) from the same point.

this report is based. Thousands of tourists visit them annually, though as yet, few of them venture off of the beaten trails to visit other less known, but fully as beautiful spots.

State Highway 19, the "scenic route of the Ozarks" crosses the center of the area, and gives ready access to its streams at several points. Throughout much of its course in Shannon County it winds along narrow ridge crests, and affords the motorist many magnificent views of the country. It passes through Round Spring State Park and close to Alley Spring State Park. State Highway 21 along the eastern border of the area is not as spectacular here as it is farther north where it passes through the St. Francois mountains, but it is an extremely beautiful drive, and has the advantage of being the direct route from St. Louis. By turning off of this highway at its junction with U. S. Highway 60, and following the latter for about 8 miles, Current River is reached at Van Buren. This is the gateway to Big Spring State Park, and to much of the lower Current River country. U. S. Highway 60 crosses the southern portion of the region, and from it many roads, among them state highways 19 and 17, lead northward to the river. Route 17 which lies just west of the area mapped, gives access to the upper reaches of Jacks Fork, which many consider to be the most beautiful part of the Current River country.

There are a few summer resorts along these streams, and most of them are quiet and homelike places, in keeping with the general nature of the country. There are also a few privately owned cottages and camps, and the number of these is increasing each year.

The rivers are clear, swiftly flowing streams, lying in deep, heavily wooded valleys, and often bordered by high cliffs, which all but overhang them. The streams have been stocked by the State Game and Fish Commission, and each year increasing numbers of fishermen float the river and try their luck. Experienced guides are available both in Eminence and Van Buren, and it is possible to rent the entire outfit or whatever part of it is needed for such a trip at moderate rates. The usual plan is to "put into" Jacks Fork at Eminence or Mountain View, or else into Current River at Round Spring or Cedar Grove and float to Van Buren, camping out each night wherever fancy chooses. It is possible to float from Eminence to Van Buren in two days, or from Round Spring to Van Buren in four, but it is far better to allow more time for these trips. There are many interesting and beautiful places which cannot be seen from the river, but lie close to it, and will well repay the time spent in visiting them. One of these is Prairie Hollow Canyon, at the west end of Coot Mountain; a narrow gorge cut into the porphyry, through which Prairie Hollow Creek tumbles with a drop of nearly 200 feet in less than a quarter of a mile. Though this gorge lies within a few rods of the river it is commonly unnoticed, because of the thick screen of trees at its mouth. Another interesting spot is Jam-Up cave on upper Jacks Fork, a subterranean short-cut by which Jam-Up creek enters Jacks Fork several miles above its former mouth.

Both Current River and its principal tributary, Jacks Fork, derive the greater portion of their average flow from large springs, which are themselves one of the great scenic features of the region. There are probably more large springs along these streams than in any other area of equal size in the Ozarks. Big Spring, about 5 miles south of Van Buren is the largest single spring in the Ozarks, and is thought to be the second largest in the United States. Blue Spring, "The Spring of the Summer Sky," as the Indians called it, is famous for its intense blue color and for its great clearness. When the sun is directly above it, the rocks and sand on the botton are plainly visible through 50 feet of water. Alley Spring and Round Spring, the principal scenic feature of two state parks, attract thousands of visitors every year. There are a number of large springs on the upper portion of Current River. The most noted of these are Montauk, Welch, Pulltight and Cave Spring. The first named is situated in a state park, while the others are privately owned. All of the above mentioned are truly Big Springs, actually the mouths of subterranean rivers. Those which are now included in state parks and some of the others, have been stocked with rainbow trout, and the cold, swiftly flowing spring branches, are fast becoming known as trout streams.

In addition to these big springs, there are dozens of others which would pass as large in almost any other region. Many of them are listed in a subsequent chapter, but one of them, the Ebb and Flow Spring, on Upper Jacks Fork, is deserving of mention because of its peculiar periodic fluctuations.

Magnificent views of the winding river and the enclosing hills, from almost any of the high bluffs will well repay one for the effort spent in climbing them. (Plates, I, II, III.) In the spring the dogwood and redbud make brilliant splashes of color against the bright green of the half-opened leaves and the gray of the rocks.

Indian summer is the most beautiful of the seasons. The streams are at their clearest, the trees bordering them are all shades of green and yellow, while the distant hills are tinted in rich tones of red and brown from the myriads of oak leaves, with here and there a patch of deep green which marks a grove of pines.

The beautiful river, with its alternation of deep quiet pools and turbulent rapids and chutes; the ever-changing vista of the cliffs and the forest covered hills; and the peaceful and primitive character of the country make a trip of this sort an event long to be remembered.

POPULATION AND INDUSTRIES.

The region is sparsely settled. The rural population is estimated at less than 10 persons per square mile. A large proportion of these people live on farms on the flood plains of the rivers and larger creeks.

The plateau surface in the western and southern portions of the region, is a part of a large farming area which extends into the adjoining counties on the south and west, and probably contains the thickest rural population.

A small element of the population has no fixed residence, but builds temporary settlements near the sites of the small portable sawmills, and moves when the mills move.

Most of the inhabitants are the descendants of the pioneers who emigrated to Missouri from Kentucky and Tennessee early in the nineteenth century, and it is not uncommon to find farms that have been in the possession of a single family for several generations. There are very few foreigners in the area and no negroes.

Eminence, the county seat of Shannon County, had a population of 325 people, according to the census of 1920; the figures for 1930 are not available.

Winona, which is the railroad point for Eminence, has a population of 442, and West Eminence, a sawmill town, successively owned and operated by different lumber companies at different times during the course of this work, had a population of 439 in 1920. This town is now practically abandoned and most of its inhabitants have moved elsewhere.

There are no other towns within the area, with the exception of Exchange, a small settlement of about 50 persons on Logan Creek, in the northeastern corner of the region.

Country stores are located at Shawnee and Exchange, and Rural Post Offices at Gang, Owls Bend, Beal and Map, while combined stores and Post Offices are located at Bartlett, Angeline, Venice, Alley, Delaware, Jacks Fork and Deslet.

There are several small towns just outside of the boundaries of the area. Birch Tree, with a population of 434 is about ½ mile south of the southwest corner. It formerly was a sawmill town and at the present time is the shipping point of a fairly prosperous farming district in the plateau country.

Van Buren, the county seat of Carter County, is about ½ mile south of the southeastern corner of the region. It is about the same size as Birch Tree and Winona, and together with Chicopee which lies just across the river is the shipping point for the timber which is rafted down Current River.

Low Wassie and Fremont, are small settlements on the railroad between Winona and Van Buren, and both of them lie about two miles south of the area.

Just north of Fremont and ½ mile south of the Eminence region is Midco, a town built and formerly owned by the Mid-Continental Iron Co. Between 1916 and 1918 it had a population of more than 5,000 persons, but at the present time the iron works are abandoned and dismantled and the population is less than 50.

Ellington, the principal town of Reynolds county is in the valley of Logan Creek, about 1½ miles east of the northeast corner of the area. It has a population of 1,066 persons, and is the center and shipping point of a rather large farming community.

Ink, is a small settlement and Post Office in Spring Valley, about 1 mile north of the northwest corner of the region.

Agriculture and stock raising are the main industries of the Eminence Region. The best farms are along the bottom lands of the rivers and larger creeks, but many of these are subject to floods. The upland farms in the plateau area are apt to suffer severely in dry seasons. Corn and hay are the principal crops. In pioneer times a great deal of wheat was also raised, but at present very little is planted.

The greater portion of the hay and corn crop is not marketed, but is utilized to fatten cattle and hogs for the St. Louis markets.

Hogs are raised throughout the district, but the majority of the cattle are brought in from the south and southwest. Much of the rough land along the rivers is open range, and as the winter climate is mild, the country is an ideal one in which to winter stock.

When the region was first settled it was covered with an excellent stand of pine and hardwood timber, and for many years lumbering was a leading industry. There were large, centralized lumber mills at Birch Tree, Winona, West Eminence, Ellington and Grandin. The companies operating these mills built a network of logging railroads into the more accessible portions of the region and removed the best of the timber. These mills are now shut down and dismantled, the last one to close being the mill at West Eminence in 1927. Small planing mills still exist at Winona and Ellington, but for the most part these handle timber cut on small portable mills. The logging railroads have all been torn up.

Small tracts of good timber still exist in the rougher and more inaccessible places, but their number is decreasing each year. Portable sawmills are set up near these and the rough sawed timber is either hauled to the railroad on motor trucks, or else rafted down the river to Chicopee, and there taken out of the water and transferred to the railroad. The most important lumber products at the present time are ties and bridge timbers. Shingles and oak staves are also produced in small quantities.

Most of the lumbering has been carried on in a most wasteful manner. The cut-over country on the plateau has been in part reclaimed as farm land, but in the rougher portions have been burned over repeatedly and the present second growth is an almost worthless variety of scrub oak. The writer has seen a few good stands of second growth pine, which if properly protected from fire, will be of considerable value in another twenty years.

Much of the country is too steep, or too rocky to be profitably farmed, and should be left in timber. There is no reason why the rougher portions of the Ozarks could not be made an important future reserve if properly planted and cared for.

In some portions of the Ozark region small fruits and berries are an important crop, and there appears to be no reason why they would not be profitable here.

RAILROADS.

The Current River Division of the St. Louis and San Francisco railroad crosses the southern Ozarks, for the most part, just south of this region, passing through Van Buren, Winona and Birch Tree. It enters the Eminence quadrangle about a mile east of Winona and leaves it some six miles farther west at Bartlett. Until recently, the Salem, Winona and Southern Railroad, owned and operated by the lumber company at West Eminence, connected Winona with West Eminence and Angeline, but this line was discontinued when the sawmill at West Eminence closed in 1927 and the rails have been torn up.

The Missouri Southern Railroad, a subsidiary of the St. Louis, Iron Mountain and Southern Railroad, connects Ellington and towns to the north and west, with the main line at Leeper, and serves a large territory lying between the Black and Current Rivers.

ROADS.

The early pioneers settled in the valleys, and the main roads were naturally located there. These roads cross and recross the streams, and in the narrower valleys they were often located in the dry creek beds, in order to save the last few feet of flood plain for cultivation. Such locations are extremely difficult and expensive to maintain, and large sections of the roads are destroyed annually by floods. Until recently there were very few bridges across the smaller creeks and none on the larger rivers. Many of the fords are deep and soft. Only a few of them on the larger rivers are shallow enough to permit the crossing of automobiles, and then only at times of extremely low water. Many of the fords especially those along Current River and on Jacks Fork east of Eminence are quite deep at ordinary river stages and almost every year there are long stretches of these rivers which for months at a time, are "past fording" even for saddle animals. This is almost always the case during the winter and spring months but during the seasons of 1927 and 1928 the river was unfordable at many crossings throughout most of the summer as well.

Thus the river constitutes a natural barrier and divides the region into two parts. It has been a highly important factor in the economic history of the country and this will be discussed later.

The logging operations of the past few decades, have covered the wooded areas, and particularly the ridge tops with a network of old wagon trails, some of which are now used as roads. Others, though long since abandoned may still be easily traced through the woods. On steep slopes these roads gully badly and unless regularly maintained are soon destroyed. On the level ridge-tops the fine residual chert gravels which cover much of the country soon pack down, and if the traffic is not too heavy form a good road which lasts for many years if given a little care. The increased use of motor trucks instead of wagons in the lumbering industry, has resulted in a marked improvement in these roads. Stumps are now cut lower, large boulders are removed and, consequently these narrow ridge trails make it possible to get into most portions of the region with an automobile at all seasons of the year.

At the time that this survey was begun there were few good roads in the entire area; but the situation has been greatly improved within the last five years, largely because of the development of the State Highway system, and partly because of some systematic county road building within this particular region. The most important improvement has been the construction of the bridges on State Highway No. 19 across Current River and Sinkin Creek, at Round Spring, fourteen miles north of Eminence. This north-south highway crosses the Eminence quadrangle, and at the present time is one of the best routes by which to enter the region from the north. U. S. Highway No. 60 crosses the southern portion of the Eminence quadrangle from Birch Tree to a point a few miles east of Winona, where it turns to the south for a short distance and then continues eastward to Van Buren, keeping from one to three miles south of the southern border of the region. At Van Buren it crosses Current River, and turns northeastward, crossing the extreme southeast corner of the Cardareva quadrangle, and continues in a general north-east direction, joining State Highway No. 21 about 8 miles from Van Buren. At this point it again turns southeastward toward Poplar Bluff, but Highway No. 21 continues northward to Ellington, at a distance of from one to five miles east of the eastern boundary. This is a direct route from St. Louis.

State Highway No. 17 does not enter the area, but runs parallel to the western border, from Summersville to Mountain View.

The greater portion of the State Highway system in this part of the state is now completed according to standard specifications, and those portions which are still temporary are well maintained, and may be traveled at all seasons. From these highways many short roads lead off into the region.

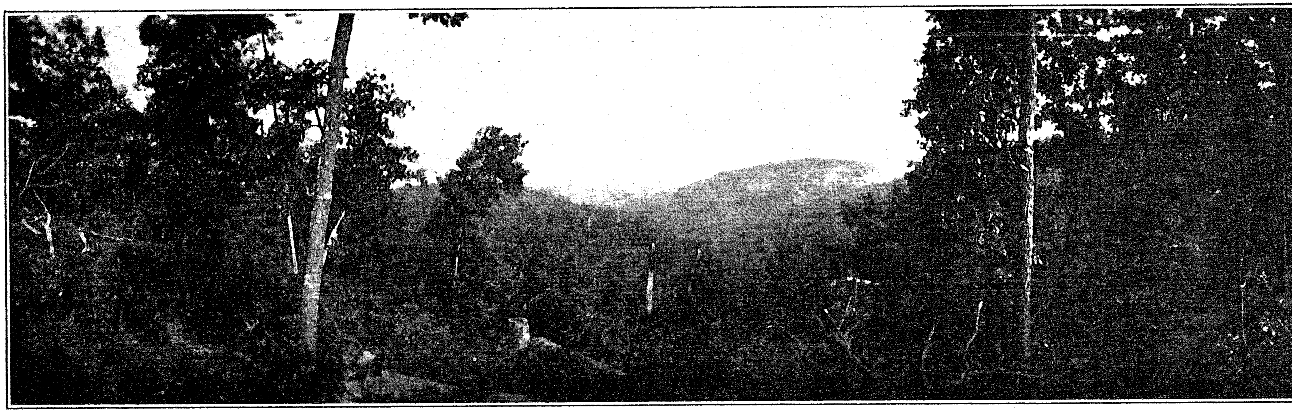
A fair road connects Birch Tree, Eminence and Summersville, passing for a part of the distance over Highway No. 19. Alley Spring State Park may be reached from any of these towns over roads of about the same quality. Another important road, and one on which considerable work has been done connects Eminence and Ellington, crossing Current River at Powder Mill ford. A branch of this road turns south to Winona a few miles west of the river. Owing to the depth of the river at this ford this route has been impractical for automobiles except during low water stages. The road has been greatly improved during the last few years and a ferry was established at Powder Mill Ford in 1927. Ferry service was interrupted in 1927 and again in 1928 by high water, but the distance from Eminence to Ellington is much shorter by this route and the country is doing all that it can to keep the road open. It has recently been included in the farm-to-market system, and is thus assured of continued maintenance in the future.

CLIMATE.

The climate does not differ appreciably from that of the southern Ozarks[1]. The average annual temperature is about 55 degrees. The winter daily average is about 30°, the average maximum daily temperature during the winter is about 40° and the daily minimum is between 25 and 30°. The daily average of the summer temperatures is between 75° and 80°, the average daily maximum is about 85° and the daily average minimum is between 60° and 65°. The temperatures are subject to great variations in extremely short periods of time. During the winter months the temperature may drop to 20° or 30°, below zero, and on the other hand temperatures as high as 75° have been recorded in January. The summer temperatures normally vary between 50° and 100°.

The summers are fairly hot, but as a general rule the winters are mild and open, and snow rarely remains on the ground for more than a few days at a time. The valleys of the larger rivers

[1]For a rather full discussion of the climate of the Ozark Highland, see Sauer, C. O., The Geography of the Ozark Highland of Missouri, Chicago., Geol. Soc. Bull. 7, 1927, Chap. IV.



A. View southeast from the Powder Mill Ford road, in sec. 25, T. 29 N., R. 3 W.

B. Looking east, down the valley of Indian Creek, from the ridge in the NE. ¼ sec. 2, T. 28 N., R. 3 W.

are not subject to as great extremes of temperature as are the uplands.

The prevailing winds are westerly and southwesterly. Windstorms are fairly common at some seasons, and tornadoes occasionally occur.

The annual rainfall is subject to great variation, and averages about 45 inches. Most of this falls in the spring and early summer. During the years of 1925 and '26 the average rainfall was considerably less than this figure, but in 1927 and '28 it greatly exceeded it.

TOPOGRAPHY.

General Statement—The Ozark Highland of Missouri has been divided into eight geographic subprovinces[1] based upon topography, drainage, water supply, and other factors. The Eminence region lies almost entirely within the subdivision which has been termed the Courtois Hills subprovince, although a small area in the western and southwestern portion belongs to the margin of the Central Plateau subprovince. The Courtois Hills subprovince is characterized as follows: "This is the most hilly * * * * * part of the Missouri Ozarks. The hills are steep sided, chert covered ridges, monotonous in their similarity. * * * Because it is the largest and most compact body of intricately and deeply dissected country, this region is the most isolated of the Ozark Highland." The Eminence region lies in one of the most rugged portions of this subdivision.

Relief—Elevations range from 453 feet above sea level at the point where Current River leaves the Cardareva quadrangle at Van Buren, to almost 1,370 feet above sea level on the summit of one of the crests of Stegall Mountain. The total relief is thus about 900 feet, but the average hills rise from 400 to 550 feet above the valleys.

Great contrasts in elevation occur within short distances. Cardareva Mountain rises 550 feet above the flood plain of Current River in less than a quarter of a mile. The summit of Coot Mountain is 700 feet above Current River and is less than a half mile from it, and the crest of Tip-Top (sec. 6, T. 29 N., R. 3 W.) is more than 600 feet above river and is less than a half a mile from it at two different points.

[1]Sauer, Carl O., The Geography of the Ozark Highland of Missouri, Geog. Soc., Chicago, Bull. 7, 1920, pp. 61-70.

The Summit Level—The summits of the hills are remarkably accordant, and the skyline, when viewed from any commanding elevation, is decidedly level. (Plate IV-A.). The summit elevations in the western portion of the region lie between 1,130 and 1,170 feet above sea level. They rise gently toward the center, reaching elevations of 1,220 feet, and then slope off gradually to the southeast. The average summit elevation in the vicinity of Van Buren is between 880 and 920 feet. A few summits rise above this general level, and although none of them exceed it by more than 200 feet, they stand out conspicuously. Coot, Blair Creek, Jerktail, Stegall and Big Thorny Mountains are examples of such peaks, and all of them are composed of porphyry.

These accordant summits are evidently the remnants of a gently domed upland surface which formerly extended over most of the central Ozark Highland. This surface is known as the Salem plateau, and is best preserved in the Central Plateau area a few miles to the west[1].

The Salem Plateau in the Eminence region has been profoundly dissected by river and stream erosion, so that at the present time but little of the upland surface remains, and the topography is mature. This dissection is naturally the most complete in the vicinity of the larger rivers, where only small disconnected patches of the original upland remain.

The largest of these areas is the "Flatwoods" in the northwestern portion of the Eminence sheet. There are similar areas along the slightly dissected divide between the Jacks Fork and Eleven Point drainage in the southwestern portion of the region, and these are regarded as the eastern marginal phase of the Central Plateau, that is, of the undissected portion of the Salem Plateau. In driving through the Flatwoods the first impression obtained is that the country contains broad areas of gently rolling, forested upland, but more careful observation shows that the road follows a long flat-topped, narrow, winding ridge, from either side of which narrow ravines descend abruptly, and soon reach grade at elevations from 200 to 500 feet below the level of the upland. Between these ravines are other long, narrow, winding flat-topped ridges many of which may be followed for several miles without ascending or descending more than 60 to 80 feet, until they terminate abruptly in a river bluff, or else taper off

[1]The Springfield Plateau is an older and still higher surface.

rather steeply into some valley at the junction of the ravines on either side of the ridge or on the slip-off side of a meander.

Thick beds of sandstone underlie most of this upland. These are resistant, and valleys cut in them widen about as fast as they are cut down, and give a gentle rolling character to the upland surface, which is well shown in the Central Plateau area to the west, and to a lesser extent in the vicinity of Birch Tree and Winona. The dolomites underlying these resistant sandstone beds are highly soluble and are readily eroded so that when the streams cut through the sandstone cover, they trench the dolomites with great rapidity. The sandstone acts as a protective cap and retards valley widening, which results in the formation of deep narrow valleys with over-steepened sides.

The undissected portion of the upland is pitted with shallow sinks many of which are large enough to be shown on the topographic map. They are especially well developed in the vicinity of the Woodland School House in sec. 13, T. 27 N., R. 5 W. A few of them contain small ponds, but the great majority are dry except for short periods after heavy rains. In the southern portion of the region the divides are just as narrow and as winding, but the valleys are much shallower, and the entire aspect of the country is less rugged. The early settlers were quick to appreciate the difference, and, while the rougher portions are still forest, and should always remain so; much of the upland surface of the southwestern portion, especially around Birch Tree and Winona was cleared early in the history of the country and is now covered with fairly prosperous farms.

The Intermediate Level—Traces of a second level may be seen along the main streams in the form of a high, much dissected terrace. This is not a conspicuous feature on the topographic map, but it is well shown by the accordant summits of the low hills on the north side of Jacks Fork, about a mile northeast of Eminence. It may also be seen in the low hills opposite the mouth of Rocky Creek; the north side of Current River at Eaton Ford; in the vicinity of Van Buren and at many other places. The summit of this terrace is about 800 feet above sea level in the vicinity of Eminence. It rises slightly to the north and west, and slopes off gently to the southeast, the elevation in the vicinity of Van Buren being about 650 to 680 feet. The average width of this level on the main streams is about twice the width of the present valleys. It is rarely found on both sides of the valley at a given point, but occurs in small patches, first on one side and then on the other, and appears to be the uplifted and dissected remnant of a wide valley and marks a temporary halt in the uplift of the region.

Like the upper level, it is not developed at a given stratigraphic horizon, but cuts across the various formations.

This level is also found on the smaller streams, but is seldom preserved, except along those which cut across one of the porphyry ridges. In such cases it always occurs upstream from the point where the stream crosses the porphyry, and at first sight appears to be a temporary grade level, whose location and elevation is controlled by the differential hardness of the rock. A more careful study shows that the elevation of most of these "shut-in" plains agrees with that of the much dissected terrace along the main streams, and that they owe their preservation to the superior hardness of the rock, and to the small size of the streams draining them.

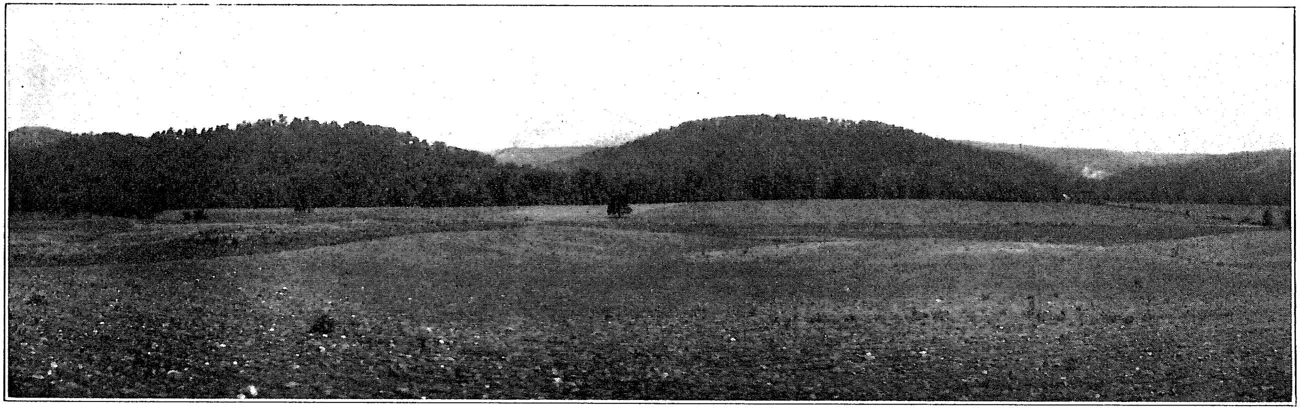
Prairie Hollow in sec. 29, T. 29 N., R. 3 W.; the large, oval valley on the upper course of Little Rocky Creek, in secs. 2, 10 and 11, T. 28 N., R. 3 W., and the valley of Rocky Creek above the Falls are the most conspicuous examples, (Plate IV-B). They are the only portions of this intermediate level which are large enough to be farmed, and most of these areas are under cultivation.

Thin deposits of river worn gravels have been found at this level at a few localities, notably in the N. ½ sec. 22, T. 29 N., R. 4 W., and in secs. 33 and 34, T. 29 N., R. 2 W. Such deposits were doubtless widespread on this level at one time, but most of them have been removed by erosion. Boulders containing Mississippian fossils have been found in these gravels at several places, associated with chert derived from older formations, and are plainly a part of the deposit.

The Flood Plain Level—The present flood plains of the rivers and larger creeks constitute a third level. These flood plains average about a quarter of a mile in width and are for the most part narrow, discontinuous strips. They border the streams first on one side and then on the other throughout most of their length, but are rarely found on both sides at a single locality.

These narrow strips of bottom land contain the most fertile soil in the region, and almost all of them are now cleared and under cultivation. The majority are fairly high and are only covered by the highest floods.

A. View of the Upland Level, looking east from the divide at the head of Indian Creek.



B. View of the Intermediate Level on the upper portion of Little Rocky Creek. The creek flows out through the gap to the right. The porphyry ridge has been instrumental in preserving the level at this point. Upland Level shown by the skyline.

The slopes connecting the bottom lands with the intermediate level are commonly too steep to be cleared, but on the inner sides of some of the larger meanders, the slope is quite gradual and such areas are always cleared and cultivated. In many places the flood plains are bordered by bold cliffs which may be as much as 200 feet in height. There are many such along Current River and Jacks Fork. (Plate V.) Bee Bluff, on Current River, just north of Mill Hollow, in sec, 32, T. 30 N., R. 3 W., and White Bluff on Jacks Fork, in the center of sec. 9, T. 28 N., R. 5 W., are both over 200 feet high and rise so precipitously out of the river that a person standing on the edge of either one can easily throw a stone across the river. The great bluff on the east side of the river at Powder Mill Ford is also over 200 feet high.

None of these cliffs extend above the intermediate level, and the slopes which connect this level with the upper one, while often steep, are never precipitous.

In some instances the summits of these cliffs coincide with a stratigraphic boundary, but in most cases it is independent of them.

DRAINAGE AND WATER SUPPLY.

Drainage Basins—Current River[1] is the master stream of the area, and with its tributary Jacks Fork, drains about 450 square miles of the Eminence region, or about 93.5 per cent. Logan Creek, with its tributary drainage, comprising an area of about 25 square miles in the northeastern corner of the Cardareva quadrangle is a portion of the Black River drainage system, while a small area containing about six square miles in the extreme southwestern portion of the Eminence quadrangle drains south to the Eleven Point River.

During low stages the rivers and streams receive practically all their water from springs, and as a consequence the streams are very clear, and their flow is quite uniform. Current River has a larger average low water discharge than any other stream of equal size in the state[2], and this is largely due to the fact that its most important tributaries are large springs which serve to regulate its flow.

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[1]For description of Current, Black and Eleven Point Rivers, areas of drainage basins, average flow, etc., see Beckman, H. C., Water Resources of Missouri, Mo. Bur. Geol. and Mines, Vol. XX, 2nd ser., 1927, pp. 272-317.

[2]Beckman, H. C., op. cit., p. 278.

Most of the water from ordinary rains is quickly absorbed by the highly porous soils, and excessively high stages occur only after prolonged rains, or when the ground is frozen. The streams rise rapidly after a heavy rain, but subside about as quickly as they rise.

The beds of the streams are floored chiefly with chert gravel or sand.

Character of the Main Valleys—The courses of Current River, Jacks Fork, Spring Valley,[1] Logan Creek and Davis Creek[2] are all more or less meandering. These are not flood plain meanders, but true entrenched meanders which plainly indicate that the courses of these streams have been inherited from a previous cycle. The same may be true of Mahan's Creek, but in this case the evidence is not as clearly marked. From the point where Current River enters the Eminence region to the point where it leaves it is 26.25 miles in a straight line, but the length of the river between these points in 46.5 miles.

Cut-off Meander near Eminence—In some instances entrenched meanders of this type have been abandoned, the river cutting through the narrow neck and taking the shorter course. A good example of this is found on Jacks Fork about a mile northwest of Eminence (in the N. ½ sec. 27, T. 29 N., R. 4 W.) (Plate VI-A.) Originally Jacks Fork flowed up the lower portion of the valley of Storey's Creek, and around the small knob, as shown in Fig. 2.

It occupied this course until comparatively recent times as is shown by the fact that the elevation of the floor of the old channel is but 20 or 30 feet above the present channel.

There are two possible ways in which a cut-off of this type may be effected. In the first method, the river undercuts the neck of the meander on both sides, and gradually narrows and lowers the divide until it breaks across at some high stage and completes the cut-off.

The second, and more probable explanation is that as the neck is being narrowed down by stream erosion, ground water has been dissolving the soluble limestones along joint and bedding planes and opening up subterranean courses, so that some of the water from the river crosses the neck by an underground route.

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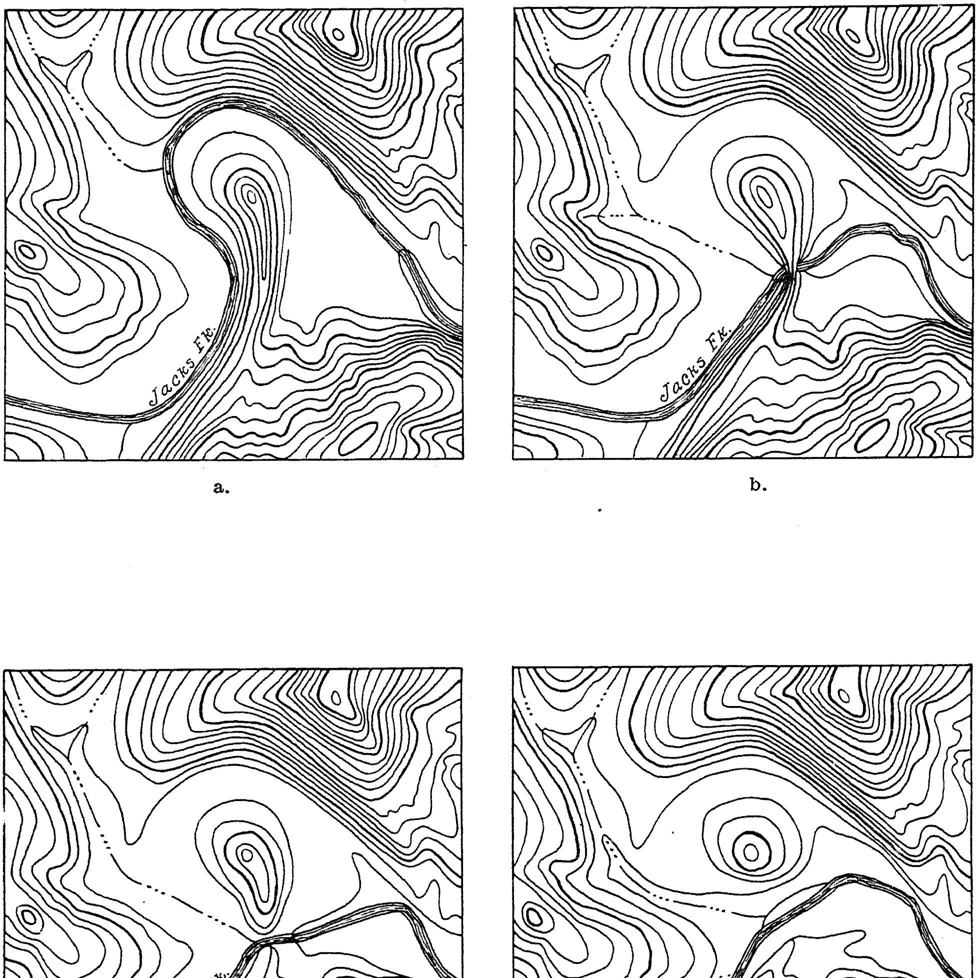
[1]Spring Valley is the large valley which crosses and recrosses the northern margin in the sheet in T. 30 N., R. 5 W.

[2]Davis Creek is formed by the junction of Pike and Sycamore Creeks near Low Wassie, and joins Current River opposite Van Buren. Throughout most of its course it is close to the southern boundary of the Eminence region, and receives considerable drainage from it.



a. b. c. d.

Hypothetical stages in the formation of the cut-off meander near Eminence.

a—Original course of Jacks Fork.
b—Tunnel stage, compare with Fig. 4.
c—Stage immediately after collapse of tunnel.
d—Present course of Jacks Fork.

The shorter distance and consequently steeper gradient on this route favors erosion, and the channels enlarge rapidly, and soon there is an underground passage through the neck. At first this channel takes only a portion of the water, but as the passage enlarges, more and more water travels by the shorter, steeper route until the entire stream is diverted. Eventually the roof of the tunnel collapses and the cut-off is completed. Various stages of this process may be seen on Sinkin Creek and its tributaries in the northern part of Shannon Co. At one place on Barren Fork of Sinkin Creek the creek sinks into the ground on one side of a meander, and reappears about a half a mile away on the opposite side in a large spring. This locality has been described by Nason[1] and others. It is on the old Eminence-Salem road, about 9 miles north of Round Spring.[2] The meander, which carries water only during flood stages is more than a quarter of a mile long, and the divide under which the stream passes is about 50 feet high (Fig. 3). A somewhat later stage is found on Sinkin Creek, a few miles southeast of the case just described (Fig. 4). In this case a meander about three-quarters of a mile long has been abandoned and the creek now flows through a tunnel under the neck of the meander. (Plate VI-B, C.) It is possible to take a boat through this tunnel. The case on Barren Fork is believed to be an early stage in the development of these cut-offs, the one on Sinkin Creek a somewhat later stage, while the one on Jacks Fork represents the completed cut-off. Fig 2 shows the various hypothetical stages in the abandoning of the meander near Eminence.

There are a number of places in this region where subterranean diversions, either of this type, or of the type which involves a tributary stream, may take place at some time in the future. A notable example of this sort is the case of Jam-Up Creek on Jacks Fork about 8 miles northwest of Birch Tree.[3]

Characteristics of the Tributary Drainage—Not all of the larger tributary valleys contain permanent streams. In some instances these latter have their sources in small seepages, and begin as very small streams and gradually grow larger by the addition of other seepages and small springs. In most cases, however, the permanent portions of the tributary streams have

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[1]Nason, F. L., Report on Iron Ores, Mo. Geol. Survey, Vol. II, 1892, pp. 91-92.

[2]Round Spring is on Current River, about two and a half miles north of the point where Jacks Fork Hollow leaves the north edge of the region.

[3]Dake, C. L., and Bridge, J., Subterranean Stream Piracy in the Ozarks, Bull. No. Sch. Mines and Met., Tech. ser., Vol. 7, No. 1, 1923, pp. 4-14.

their sources in fairly large springs, and thus start out creeks of considerable size. There are no permanent springs of any size above the altitude of 900 feet, and the majority of these permanent streams have their sources between the altitudes of 900 and 760 feet, and this indicates the level of the permanent water table in this region.

The majority of the small tributaries are dry valleys. These are floored with a thick mantle of chert fragments and soil and this porous cover quickly absorbs the rainfall so that a surface stream is formed only after heavy and prolonged rains. Many of these smaller valleys are without definite stream channels.

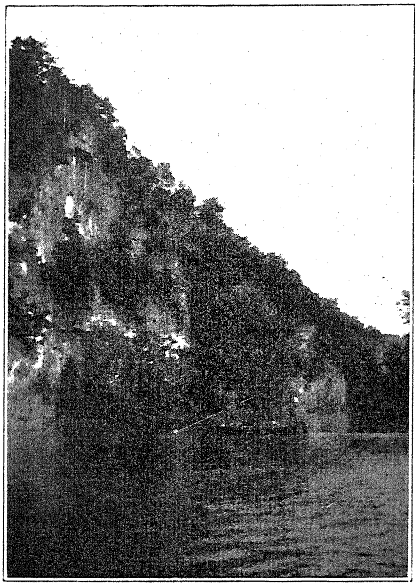
A few of the larger valleys contain only temporary streams. In this region the most conspicuous of these are those of Logan Creek, Spring Valley and Davis Creek. These are as wide, or in some cases even wider than the valleys of Current River, and Jacks Fork. Like them, they are floored with alluvial deposits. After heavy rains these intermittent streams may become raging torrents for a few hours and may do a great amount of damage, but the flood soon subsides and within a few days at the most, the stream beds are again dry. Such conditions point to a well developed system of subterranean drainage.

Instances of this sort are common in the Ozark Region and several of them have been described by Dake and Bridge.[1]

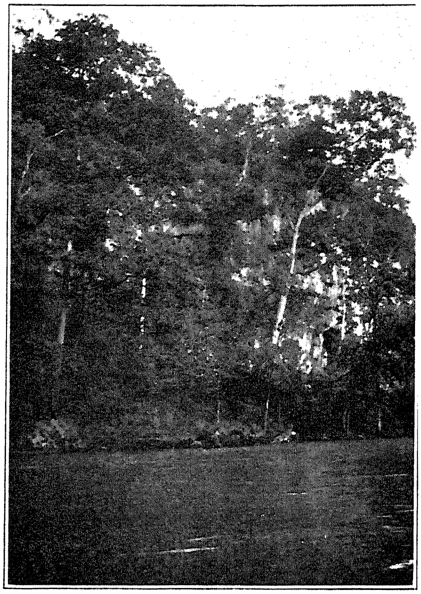
Drainage Pattern—With the exception of the entrenched meandering courses just described, the drainage pattern developed by the rivers and their tributaries is typically dendritic. The majority of the rocks of the region are well stratified and essentially horizontal sediments and they consequently have but little effect in the development of the drainage pattern. In some instances a resistant bed produces a narrowing of the valley and a rapid in the stream. Such cases are fairly common on the smaller creeks, but are quite rare along the larger streams. The best illustration of this is the narrow gorge on Jacks Fork in sec. 28, T. 29 N., R. 4 W., which is formed at a point where a resistant bed of sandstone crosses the river. (See geologic map.)

Adjustment of Streams—The soft sedimentary rocks rest upon an irregular, highly inclined surface of massive, dense porphyry. As soon as the streams erode to this resistant rock their courses are modified, and instead of cutting directly downward, the weaker rock is eroded and the valley shifts laterally

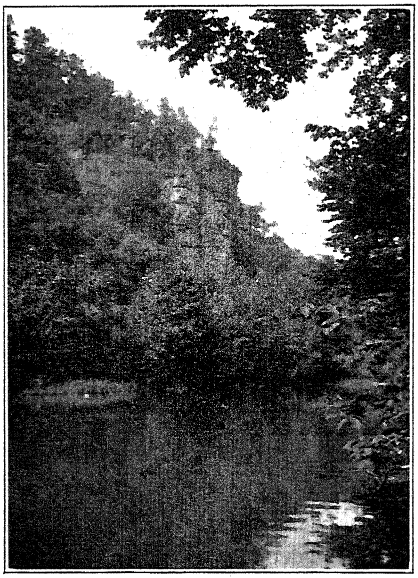
[1]Dake, C. L., and Bridge, J., op. cit.

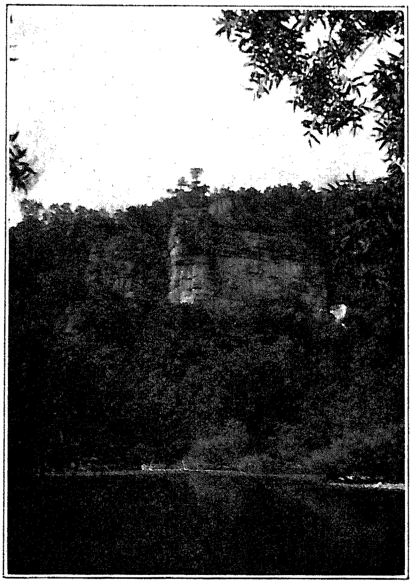


A. Bee Bluff, a 200-foot cliff of Eminence dolomite on Current River.



B. An overhanging cliff of Eminence dolomite, near the mouth of Paint Rock Creek.





C-D. Cliffs of the Gasconade, on Jacks Fork, about 15 miles west of Eminence.

and downward along the contact between the two types of rock. Thus the boundary between the massive rocks and the stratified rocks is commonly outlined by valleys.

Where erosion has freed the porphyry masses from the enclosing limestones, they appear as knobs, separated from the sedimentary rocks by encircling valleys. The profile of these knobs is broadly rounded, and is in marked contrast with the steep conical hills with slightly concave profiles which are formed by the erosion of the sedimentary rocks. Good examples of these bowl-shaped isolated knobs on a small scale may be seen along Highway No. 19 about 4½ miles south of Eminence in sec. 7, T. 28 N., R. 3 W., and sec. 12, T. 28 N., R. 4 W.

Where the sediments have not been completely removed, and the porphyry knob is higher than the surrounding hills, it is common to find the central mass surrounded by a circle of lower hills carved from the sedimentary rocks. These hills are separated from the central mass by deep saddles, and from each other by the radiating drainage lines. This arrangement is well shown on the north slope of Stegall Mountain.

In those cases in which the porphyry knob is lower than the surrounding hills of sedimentary rock, it commonly protrudes from the hills and forms a distinct crest of its own, separated from the main mass by a conspicuous saddle. This is well shown in sec. 18, T. 29 N., R. 2 W., just west of Owls Bend and at several other points.

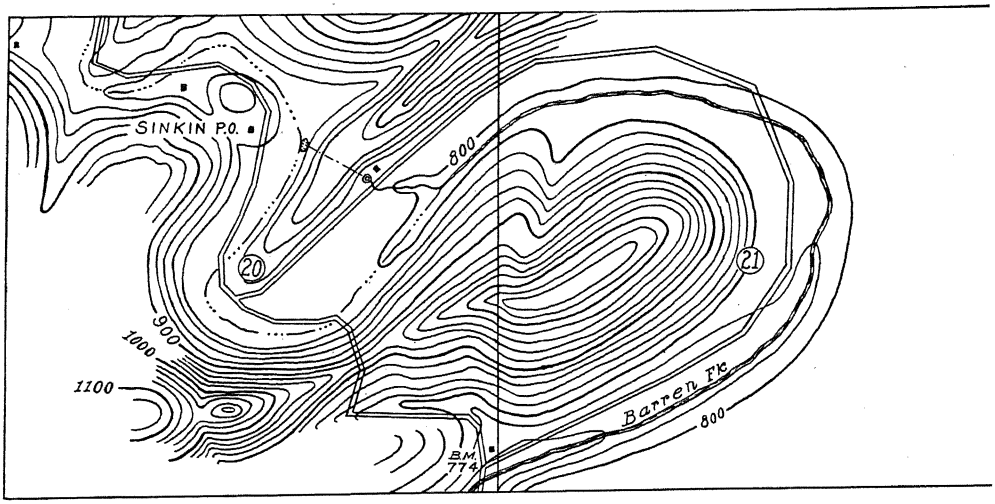
"*Shut-Ins*"—At a few places on the rivers and at several places on the smaller streams deep gorges have been cut into the igneous rocks. These are always narrower than the valleys above or below them and are locally known as "shut-ins". They are best shown in the smaller valleys. One of the best of these is on the head of Little Rocky Creek, in the NE. ¼ sec. 11, T. 28 N., R. 3 W. This gorge has been cut into the hard rocks to a depth of at least 50 feet and is not over 50 feet in width at the base in some places, but the valley above it is nearly two miles wide. The explanation is obvious. The general course of the stream was developed while it was still flowing on the softer rocks which formerly covered this region. When it reached the hard rocks it shifted laterally down the slope until it reached a point where the contact between the hard and soft rocks sloped in the opposite direction. By this time it was deeply entrenched, and could no longer turn aside on the softer rocks and has been forced to cut its course across the harder variety.

There are three of these "shut-ins" on Rocky Creek, one at the Falls in sec. 18, (Plate IX-A) another in the SE. ¼ sec. 6 and the third at the milldam in the NW. ¼ sec. 5, all in T. 28 N., R. 2 W. There is one on Thorny Creek, sec. 2, T. 28 N., R. 2 W., one in Prairie Hollow, sec. 15, T. 29 N., R. 3 W. (Plate IX-B, C) and another in Matthews branch in sec. 10, same township and range. There is one near the mouth of Lick Log Hollow, in sec. 24, T. 29 N., R. 4 W., which although very small, serves to show all of the essential characteristics of this interesting topographic feature.

The gorge of Current River at the north end of Coot Mountain has all the appearance of a "shut-in" formed in this manner, but in this case the river is still cutting on the soft sedimentary beds and is merely re-excavating an old gorge carved in the hard rocks by some ancient stream, which was afterwards filled with marine sediments.

Stream Piracy—At a few places there are deep gorges cut through the porphyry which are not occupied by streams. Good examples are to be seen near Liberty School, sec. 5, T. 28 N., R. 2 W., and the gap in sec. 2, same township and range. At some earlier stage in the topographic development of the region these gorges were probably occupied by streams. A stream flowing through such a gorge is at a disadvantage and cannot cut its channel down as rapidly as the neighboring streams on the softer rocks. These latter because of the steeper gradient lengthen their valleys headward, and often capture the upper portions of the streams flowing across the harder rocks. This appears to have happened in both of the cases listed above, although the evidence is not entirely conclusive.

There are several places where captures of this sort may take place in the future. The headwaters of Little Shawnee Creek are rapidly cutting into the divide and will eventually capture the headwaters of Little Rocky Creek above the gap in sec. 11, T. 28 N., R. 3 W. The upper portion of Prairie Hollow Creek may eventually be captured by tributaries from Little Shawnee Creek, or from Jacks Fork, or it may be diverted into a stream working headward along the eastern side of Coot Mountain. A careful study of the topographic and geologic maps will reveal other cases of this sort.



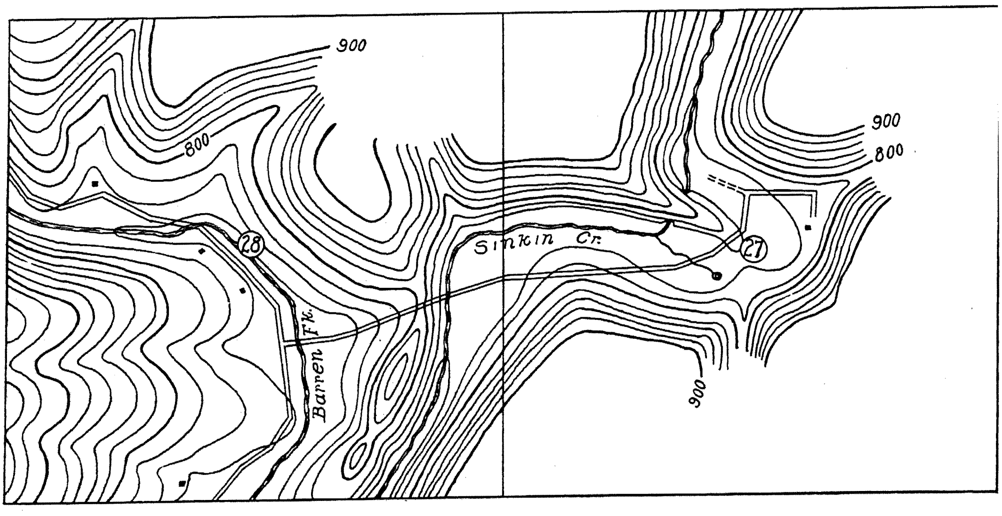


Fig. 3 (Upper)—Sketch map showing subterranean cut-off on Barren Fork of Sinkin Creek, T. 31 N., R. 4 W., Shannon County, Mo.

Fig. 4 (Lower)—Sketch map showing tunnel through Meander Neck on Barren Fork of Sinkin Creek, T. 31 N., R. 4 W., Shannon County, Mo.

Age of Streams—The main streams are not yet at grade, as is shown by the numerous low rapids along their courses. In some instances these are produced by a stratum of hard rock crossing the course of the river, but in other cases they owe their existence to the presence of large gravel bars dumped in by tributary streams.

Temporary grade levels have been developed above some of these riffles, and along Jacks Fork a few incipient flood plain meanders have been formed on some of these temporary levels.

There are no waterfalls on the main streams, the steepest descents averaging about 5 feet in a quarter of a mile. These rapids, or "chutes" alternate with long stretches of quiet water. The average fall of the River from Round Spring to the Junction is about 4.8 feet per mile, and from the Junction to Van Buren it averages about 3.7 feet per mile. The main streams may be classed as being in late youth.

Subterranean Drainage—The large number of springs in the Eminence region implies a well developed system of subterranean drainage. The capacity of this underground system is very great, and it acts as a storage reservoir and serves to equalize stream flow. For this reason flood stages are seldom of long duration and are only produced by exceptionally heavy rains, or when the ground is frozen.

The valleys of many of the tributary creeks are floored with a deep accumulation of highly porous residual and transported material which absorbs all ordinary rainfall, and unless it is thoroughly saturated with water, there is no surface flow. Mill Creek is a good example of this type of stream. There is a small spring in the SW. ¼ sec. 25, T. 28 N., R. 3 W., which runs the year round. Its average flow is probably not more than ¼ second foot, and the entire flow sinks beneath the gravels of the creek bed within a few hundred feet. From here on the creek bed is usually dry until the south line of sec. 31 is reached. At this point it receives the flow of three or four springs and flows as a surface stream for at least a half a mile and again sinks beneath the gravels. Other springs flow into it just below Mill Creek School house and it again becomes a surface stream for a mile or so, and then is a dry channel until it reaches the large spring in sec. 1, T. 28 N., R. 2 W. The flow of this spring is very quickly absorbed, and the channel remains dry for another mile. From the big spring in sec. 6, T. 28 N., R. 1 W., to its junction with Current River it is a permanent stream. Many other valleys show the same phenomenon. The entire flow from Midco Spring sinks beneath the gravel within a half a mile of the spring, and the flow from Pine Hollow Spring, and from many others, is absorbed in this fashion. A portion of this sub-surface flow is along the contact of the residual material and the bed rock, and a shallow hole dug in almost any part of the flood plain will soon fill with water.

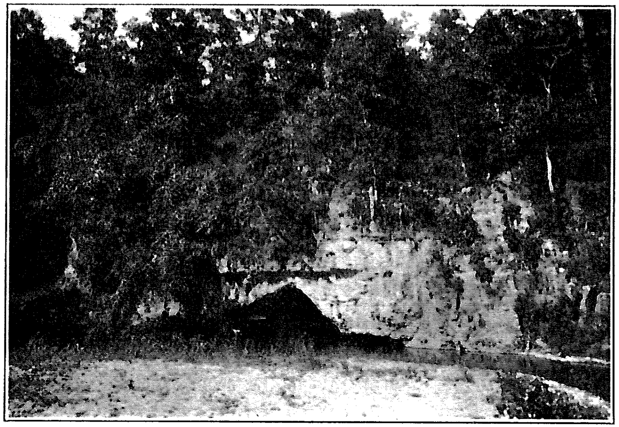
Most of the ground water works down along the joints and bedding planes in the dolomites, dissolving the rock and enlarging the passages and forms a highly complex system of underground drainage, much of which eventually comes to the surface again in the form of springs.

There are a number of sinks in the bed of Davis Creek just south of the town of Midco and it is definitely known that water draining into these comes to the surface again in Big Spring, which is 10 miles away in a straight line. When the plant at Midco was in operation quantities of chemical waste were discharged into the dry bed of Davis Creek at Midco, and this soon contaminated the water at Big Spring.

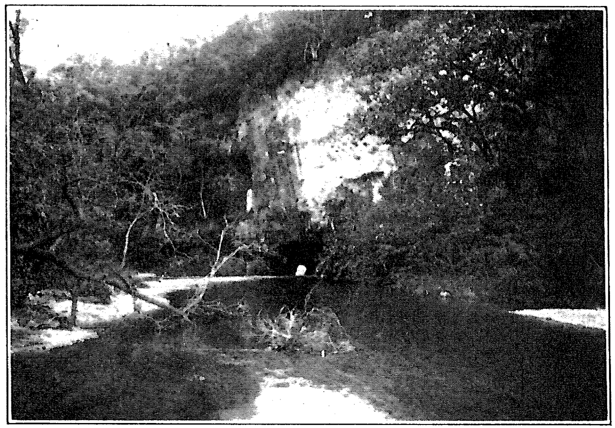
In the NE. ¼ sec. 18, T. 27 N., R. 2 W., there is a sink hole about 70 feet in diameter in the floor of the valley. During wet seasons the water in this hole rises to within a few feet of the rim, but in dry seasons the hole is about 20 feet deep and connects with an underground passage, in which a stream flows to the southeast. This passage has not been explored, but the inhabitants sometimes place a lighted candle on a small plank and set it afloat on the stream and they declare that the light may be seen for a long distance. This stream is probably one of the feeders of Big Spring. The area which drains underground to Big Spring must be very large, and doubtless contains most of the drainage basin of Pike, Sycamore and Davis Creeks, the upper portion of Mill Creek, as well as a large territory south and east of the Eminence region. It may also receive a portion of its water from some of the dry valleys on the north side of Current River.

Blue Spring appears to derive most of its water from the Logan Creek drainage basin, though the upper portion of Car Creek may also be a contributor. Logan Creek, (Plate VII) which is dry except for short stretches most of the year contains a number of sinks into which small streams are continually running, and a number of others which carry the surface water away rapidly in time of high water. It has been observed that

A. Abandoned meander on Jacks Fork, about 1 ½ miles northwest of Eminence. Looking east from the sharp turn in the road in the NW. ¼ sec. 27, T. 29 N., R. 4 W. The section described on p. 34 is measured in the slope in the left background.



B. Mouth of the Natural Tunnel which cuts off a meander on Sinkin Creek.



C. Entrance to the same tunnel. The rock in the bluff is the Eminence dolomite.

Blue Spring always rises after heavy rains on the upper portion of Logan Creek, but that it is not affected by rains on the upper portion of Current River.

In addition to the evidence already presented, the following observations seem to confirm this belief:

1. The general trend of the porphyry ridges is northwest southeast and the eastern boundary of the central porphhry mass is a few miles west of Blue Spring. (See chapter on structure, geologic map and Fig. 9). As this rock is practically impervious not much ground water may be expected to migrate toward Blue Spring from the west or south.

2. The general dip of the stratified rocks is from Logan Creek toward Blue Spring, and the latter lies almost in the trough of a shallow, sharply asymetrical syncline, and therefore the water might easily migrate down the dipping bedding planes; and be forced to the surface when it reached the bottom of the trough.

3. The valley of Logan Creek is about 200 feet higher than the spring.

Alley Spring presents a somewhat similar case and its sources are believed to be in the plateau region to the north and west. An interesting story, which appears to be well authenticated is told about this spring: On a certain day the flow of the spring was observed to be decreasing rapidly and it finally ceased altogether and the water in the spring basin sank to about five feet below its normal level. It remained in this condition for about 12 hours and then suddenly resumed flow. For several days the water was quite muddy, but it gradually cleared up. At about the same time a large sink was suddenly formed in the plateau about 15 miles to the northwest of the spring. It appears quite probable that the material which fell into the underground channel when this sink was formed, blocked them temporarily, and thus checked the flow of the spring.

Much of the water issuing from Round Spring appears to come from the Spring Valley drainage basin. Again there is no direct evidence, but heavy rains on the upper portion of Spring Valley always appear to be followed by a rise at Round Spring. Moreover the location of the spring near the mouth of this dry valley is extremely significant.

When the relationships of the big springs of the Ozarks to the topography is studied it is found that practically every large spring is close to a large valley which is either dry, or else occupied by a stream which appears much too small for the size of the valley which contains it. The subterranean drainage is independent of the surface divides and is controlled by the major structural features of the region. The various systems seem to be fairly well separated from one another, even in some of the smaller cases, as is shown by the manner in which some springs fluctuate while others in the immediate vicinity do not.

Sinks—A portion of the run-off drains into sinks. These are roughly circular depressions, which vary in size from a few feet to a quarter of a mile or more in diameter, and from a foot or so to about 50 feet in depth. They are formed by the gradual settling or the sudden collapse of the surface due to the solution of the underlying rock. In the Eminence region they are most abundant on the upland surface, and are found at all levels, but are quite rare at elevations below 800 feet.

A few sinks open directly into underground channels and are true sink holes, but the majority are floored with a highly porous accumulation of soil and rock fragments. These sinks fill up during heavy rains, but the water quickly drains off underground, and they seldom contain water for more than a few hours at a time.

In some cases the floor of a sink becomes impervious, either from natural or artificial causes, and such sinks contain small, permanent ponds, a number of which may be seen on the map. These ponds serve as a source of water supply for stock on the farms and for those on the free range in the otherwise dry uplands.

As soon as such a depression is formed it diverts more of the run-off to itself and in some cases the larger sinks have several small ravines draining into them. These wash material into the sink, and in the case of sink holes distribute it at lower levels. Unless the subterranean drainage can remove this material as fast as it is carried in, it accumulates in a large mound of fragmental material below the opening, and in time, may completely close it. Many of the present sinks were doubtless originally sink holes which have been filled up in this manner. After the throat is closed in this fashion, sediments accumulate on the floor of the sink, and in some cases form good fields or pastures.

Sinks have played an important part in the formation of the present system of tributary drainage. It is no uncommon thing to find a sink in the upland surface just beyond the head of a tributary valley, and it seems to be fairly well established that in this region valleys often lengthen headward by the capture of sinks.

This capture is effected either by the collapse of the rim due to undermining by ground water, or by the cutting down of the rim by surface waters which sometimes fill the sink to overflowing. Many of the abrupt, cirque-like heads of the tributary valleys may very well be breached sinks.

Although many of these sinks form slowly, there are a number of well authenticated cases in which a sink was formed by the sudden collapse of the roof of some subterranean passage. In the NW. ¼ SE. ¼ NE. ¼ sec. 12, T. 27 N., R. 5 W., about 100 yards east of the Eminence-Birch Tree road, and on the spur of a hill about 40 feet above the road is a small sink which was formed suddenly in 1922. When seen by the writer in 1924 it was about 200 feet in diameter, and perhaps 30 feet deep. On the eastern or uphill side of the rim were several concentric cracks in the soil, which although partially filled with surface wash were still one or two feet in width and three or four feet deep. The walls of the sink were still fresh, and showed many large fragments of rock, but none was seen in place. At the time it was visited by the writer there was no opening in the bottom, through which a person could reach the cave below, and according to information obtained, there never was one.

Men were felling timber within a few hundred feet of the spot when the cave-in occurred. They heard the rumbling noise of the falling rock and reached the spot a few moments after the sink had been formed. Cases of this sort could be cited from all parts of the Ozark region.

In the summer of 1922 a similar event occurred near Bland in Gasconade County. A portion of a wheatfield collapsed suddenly, forming a sink 150 feet in diameter, which was said to be 200 feet deep. This sink filled slowly with water, and at the time of the writer's visit, the water level was about 40 feet from the surface and there were no means at hand for making soundings, so the depth could not be verified.

Caves—There are no large caves in the Eminence region but there are a great number of small and moderate sized ones. Some of them are now well above the level of ground water and are practically dry, but others at lower elevations contain permanent streams. The majority of the caves consist of one or more long, narrow, winding passages, which are developed along the joint system. Large rooms, such as are characteristic of the great caves of southwest Missouri are not common.

There is a small cave on Alley Branch in sec. 26, T. 29 N., R. 5 W., which is one of the principal attractions of Alley Spring State Park.

Cyclops Cave[1] is on the east side of Jacks Fork Hollow just north of the edge of the region in the NW. ¼ sec. 32, T. 30 N., R. 4 W. The entrance to this cave is an opening about 6 feet square and is in the west wall of the cave about 39 feet above the floor of the main room. The cave consists of a single moderate sized chamber and one or two narrow winding passages which cannot be traversed for any considerable distance. It is of local interest because of the stalactites and stalagmites which it contains. In the late afternoon the sun shines directly into the opening and illuminates the single chamber for a considerable distance.

There is a small but interesting cave on the north side of Cave Hollow, in sec. 1, T. 29 N., R. 4 W. The opening is very small, but the passage enlarges rapidly and may be easily explored for a half mile or more.

There are two caves on Blair Creek in sec. 7 T. 29 N., R. 2 W., which are said to be quite large, and another on Little Blair Creek in sec. 6, same township and range.

On the north side of Current River in sec. 36, T. 30 N., R. 4 W., is a cave which consists of a large arched recess beneath an overhanging cliff. At the back of this recess are two narrow passages, one of which is said to extend through the hill and come out on Big Creek. The passages are very low and narrow and were not explored.

Banker Cave on Carr Creek at the mouth of Banker Hollow is a single twisting passage which may be followed for about a quarter of a mile. It is said that this cave has a small upper opening which receives a portion of the surface drainage of Banker Hollow, and sticks, dried leaves and other surface debris were found in the cave at the farthest point reached. This would seem to support the statement. A small permanent stream flows from this cave.

Powder Mill Creek has its permanent source in a stream which issues from a small cave in the NE. ¼ SW. ¼, sec. 9, T. 29 N., R. 2 W.

[1] Preliminary Report, Mo. Geol. Surv., Vol. 13, 1900, p. 102.

A. View downstream from a point just west of the mouth of Pumpkin Hollow, showing the broad valley of Logan Creek, an intermittent stream.

B. View of the dry stream-bed of Logan Creek, at the mouth of Pumpkin Hollow. This is the normal condition of the creek at this point.

Many small caves are used by the inhabitants as spring houses or storage cellars. Some of the larger ones afford shelter for cattle during the winter.

The above list of caves is not complete, and no attempt has been made to list or to examine all of them. Doubtless there are many others in the region.

Natural Tunnels—The Natural Tunnel on Sinkin Creek has been described on page 35, and a possible tunnel has been mentioned in connection with one of the caves just described.

In sec. 1, T. 28 N., R. 3 W., there is a large sink, from the bottom of which a tunnel slopes off to the east and south and finally emerges in the head of a small ravine. The tunnel is about 10 by 12 feet at the upper entrance, and somewhat larger at the lower end. The sink which it drains is developed along the contact of the dolomite and the porphyry and the tunnel itself is an excellent illustration of one stage in the development of the radial drainage pattern around one of the porphyry outcrops.

All of the caves and natural tunnels in this region have been formed by the solvent action of ground water, and they form an important part of the subterranean drainage system. They have also played a large part in the development of the present tributary drainage. The courses of many of the small ravines were doubtless originally determined by subterranean drainage lines, both by the settling of the surface above these passages, and by the collapse of their roofs.[1]

Springs—There are many springs in the Eminence Region. They are practically confined to the valleys, and no permanent springs of any size are known above the elevation of 900 feet. During extremely wet seasons the ground water level rises and many temporary springs, some of them of considerable size make their appearance but these disappear during the drier periods.

The spring water is cold, the average temperature of the larger springs being between 52 and 58 degrees F. The water is very clear, and in deep springs has a decided bluish tinge. In some of the larger springs the water is so clear and quiet that it is possible to see the gravel on the bottom even at depths between 30 and 50 feet.

Many of the springs are quite large, and a few of them rank among the largest in the state.

[1]In this connection see Ball, S. H. and Smith, A. F., Geology of Miller County, Mo. Bur. Geol. and Mines, Vol. I, 2nd ser., 1903, pp. 6-7.

A spring with a flow of one second foot[1] will discharge 27,000 gallons per hour, or 648,000 gallons per day. At a conservative estimate there are at least 20 springs in the Eminence region whose minimum flow is one second foot or better, and there are probably twice that many which have a normal flow of at least ½ second foot. The flow is more or less proportional to the amount of rainfall, and varies greatly from season to season, as is shown by the records of those which have been measured.

In the following list of important springs a few large ones which lie beyond the borders of the area have been included for the sake of completeness, and also because in some cases they derive a large portion of their water from the Eminence region.

Big Spring[2]—This spring is located in sec. 6, T. 26 N., R. 1 E., about 4 miles southeast of Van Buren, and is, therefore, outside of the boundaries of the Eminence region. It is the largest spring in the Ozarks and is believed to be the second largest single spring in the United States, being exceeded in size only by Silver Spring in Florida. It is the principal attraction of Big Spring State Park.

The spring issues from the base of a high cliff of Eminence dolomite[3] and falls about 5 or 6 feet to a large spring branch which flows into Current River a short distance away. Abandoned outlets may be seen in the cliff above the spring. It is completely covered at high stages of the river and no attempt has ever been made to develop power here.

The spring and its surroundings are very beautiful. It may be easily reached from Van Buren. The state maintains a camp ground, and the spring is now visited by thousands of tourists every year. The spring branch has been stocked with rainbow trout.

The maximum flow is given as 840 second feet or 543,000,000 gallons per day, the minimum as 268 second feet or 173,000,000 gallons per day, and the average flow as 375 second feet or 242,000,000 gallons per day.[4]

This spring, like all other large springs of the Ozark region, is actually the outlet of a subterranean river. This stream must

[1]One second foot equals one cubic foot of water per second, equals 7.5 U. S. gallons approximately.

[2]A complete description of this spring together with detailed discharge measurements for several years has been published by Beckman, H. C., Water Resources of Missouri, Mo. Bur. Geol. and Mines, Vol. XX, 2nd ser., pp. 302-306 and p. 343.

[3]For names and descriptions of the rock formations, see Chap. II.

[4]Beckman, H. C., pp. cit., p. 343.

drain a considerable area. Something of the size of its drainage basin is known and this has been discussed on page 40.

Blue Spring—This spring is located almost on the east line of the NE. ¼, sec. 21, T. 29 N., R. 2 W. It is about ¼ mile from and 15 feet above the level of Current River at ordinary stages. The spring issues from the foot of a vertical bluff of Eminence dolomite, about 30 feet high. The water rises from a depth of more than 30 feet, into a circular basin about 75 feet in diameter and flows into a turbulent spring branch which connects it with Current River.

The surface of the pool is perfectly calm, and the water at most seasons of the year is exceptionally clear, so that on bright days it is possible to see the sand and gravel on the bottom, even in the deeper portions of the pool.

The water is deep blue in color, and this tint contrasts sharply with the greener tint of Current River and remains distinct from it for a hundred yards or so below the junction of the spring branch. The temperature of the water on July 7, 1923, was 54° F., while the temperature of the air was 80°. On the same date the temperature of the river above the spring was 72° and the cooling effect of the spring water could be noted for at least 100 yards below the junction of the spring branch and the river.

Accurate records of the flow of this spring have not been kept. Three discharge measurements have been made on widely separated dates, which gave results of 214 (138,000,000 gallons), 133 (86,000,000 gallons), and 83 (54,000,000 gallons), second feet, respectively.[1] It is tentatively ranked as the eighth largest spring of the Ozark region, but it may deserve a somewhat higher rating.

This is one of the most beautiful springs in Missouri. Its water is clearer, and the color more vivid than most of them. The early Indian inhabitants had several legends concerning it, and called it by a name which is best translated "The Spring of the Summer Sky." It is known to the present inhabitants as Blue Spring or as Fancher Spring. In past years it furnished power for a small mill, but it is subject to inundation at high river stages, and no trace of the mill remains.

Blue Spring is about one mile south of Powder Mill Ford on the Eminence-Ellington Road, and about halfway between the

[1] Beckman, H. C., op. cit., p. 344.

two towns. It is difficult of access, and is best reached from Ellington.

Alley Spring—This is the second largest spring in the Eminence region proper, and ranks about tenth among the big springs of the Ozarks. It is located near Alley post office in sec. 25, T. 29 N., R. 5 W., about 5 miles west of Eminence. It issues from the base of a high semi-circular cliff of Gasconade dolomite into a large basin, the size and height of which have been somewhat increased by a dam. The water in the pool is blue, but is not as clear or as deep a tint as is that of Blue Spring. Soundings show the maximum depth of the basin to be about 40 feet. The branch which carries the flow of the spring to Jacks Fork is about a half mile long and is quite picturesque.

The spring has long been used to operate a grist mill, which is still standing and was operated until 1927. In former days its power was also used to run a saw and planing mill, and to generate electric power to light the few houses in the vicinity.

At the present time the spring is owned by the state and is the chief feature of Alley Spring State Park. The spring branch is stocked with rainbow trout. The Park is easily reached from Eminence, Birch Tree, or Summersville, and a camp ground is maintained there by the state.

No regular records of the flow of this spring have been kept, but three discharge measurements made between 1922 and 1925 show that its flow varies between 68 and 89 second feet or from 45 to 58 million gallons per day.

Round Spring—This is one of the smaller of the large springs of the Ozark region. It is on the right bank of Current River, in sec. 20, T. 30 N., R. 4 W., about 2 miles north of the north boundary of the Eminence quadrangle.

This spring occupies a large, circular sink hole about 80 feet in diameter in the Eminence dolomite. (Plate VIII.) The walls of this sink are practically vertical, and are about 30 feet high except on the southeast side, where the wall is broken down and a path leads to the water's edge. Soundings in the basin show a maximum depth of 55 feet. The water in the pool is of a milky blue color, and like Blue and Alley Springs is perfectly calm, there being no visible sign of any current in the basin at ordinary stages. The water escapes from the sink through a subterranean passage about 80 feet long, which starts on the southwestern side of the wall and emerges at the base of a small

ROUND SPRING.

View of the spring from the north wall of the sink. The water escapes through an underground passage at the extreme right of the photograph.

(Photograph, courtesy of Noel Hubbard, Mo. School of Mines.)

cliff on the south side of the spring. The spring branch is about 700 feet long and empties into Current River.

The level of the spring is about 30 feet above Current River and it is not subject to overflow. In former times there was a dam across the branch and the power obtained was used to operate a small mill, but this has long since been abandoned, and few traces of it remain.

The spring is now the principal attraction of Round Spring State Park. As State Highway No. 19 passes directly through the Park, it is readily accessible either from Eminence or from Salem.

The flow is quite variable. Three measurements made between 1923 and 1925 give readings between 156 and 18 second feet. The average flow may be considered to be about 30 second feet[1] or 20,000,000 gallons per day.

Pulltight Spring—This spring is located in sec. 4, T. 30 N., R. 5 W. It is on the right bank of Current River and is about 5 miles due north of Ink.[2] It is a very beautiful spring and is about the same size as Round Spring.

The five springs listed above are the only ones in or near the Eminence region which may be classed as big springs. There are several springs of moderate size which elsewhere would be regarded as large springs and some of the most important of these are listed below.

Powder Mill Spring—This spring forms the permanent source of Powder Mill Creek. It issues from a cave in the SE. corner of the NW. ¼ sec. 9, T. 20 N., R. 2 W. Its average flow is estimated at about 4 second feet or 2,500,000 gallons per day. It has been used as a source of power.

Mill Creek Springs—There are several springs on Mill Creek. The largest one is in the NW. ¼ SE. ¼ sec. 6, T. 27 N., R. 1 W., and furnishes practically all of the permanent flow of the creek. It was formerly used as source of power for a small mill. The average flow is between 4 and 5 second feet.

There is another large spring on Mill Creek in the SE. ¼ NE. ¼ sec. 1, T. 27 N., R. 2 W. which has an estimated average flow of about 1 second foot, and a group of springs in the NE. corner of sec. 5, T. 27 N., R. 2 W., which have a combined flow of between 2 and 3 second feet or approximately 1,500,000 gallons per day.

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[1]Beckman, H. C., Water Resources of Missouri, Mo. Bur. Geol. and Mines, Vol. XX, 2nd ser., 1927, p. 352.

[2]Ink P. O. is about ½-mile north of the NW. corner of the Eminence region.

Clear Spring—There are actually several springs at this locality, which is at the edge of the flood plain of Henpeck Creek, in the SW. ¼ NW. ¼ sec. 36, T. 28 N., R. 1 W. They have a combined flow of 2 or 3 second feet. The largest supplies water for several families.

Dazey Spring—This spring flows from a small cave on Spring Hollow in the NW. ¼ SE. ¼ sec. 22, T. 28 N., R. 1 W. Its flow is estimated as between 2 and 3 second feet. A hydraulic ram has been installed on this spring and the water is piped to the large estate about ½ mile to the south.

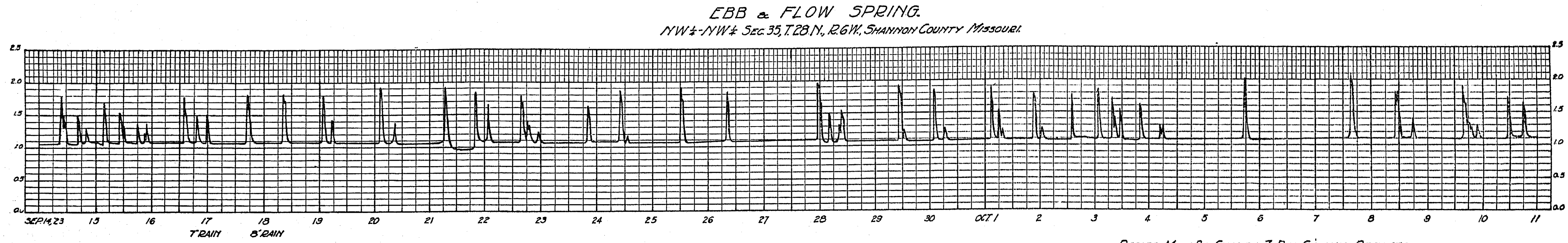
Slater's Springs—A group of springs in the NW. ¼ NE. ¼ sec. 1, T. 28 N., R. 4 W. They have a combined flow of about 3 or 4 second feet and are of historical interest in connection with the early mining industry.

Midco Spring—This spring is in the NW. ¼ sec. 22, T. 27 N., R. 2 W. It comes out from the base of a high bluff of Gasconade dolomite, and was originally a very beautiful spring. For about two years it was used as water supply for the town of Midco, and for the Mid-Continental Iron Company's plant, and the construction and destruction of these have ruined most of its natural beauty. The flow of this spring was measured and found to be a little over 2 second feet in July, 1929, but the discharge at that time was low.

Gang Spring—This is a large spring at Gang post office on Blair Creek, in Lot 8, NW. ¼ sec. 1, T. 29 N., R. 3 W. Its flow is estimated at 2 second feet.

Williams Spring—This is a large spring on the right bank of Current River, in the NW. corner of sec. 17, T. 29 N., R. 2 W. Its flow is estimated at about 1 second foot. The flow is quite strong, and clear water may be dipped up here when the spring is submerged by overflow from Current River.

Gravel Spring—This spring is in the bed of Current River at the east end of Paint Rock Bluff, near the center of sec. 4, T. 28 N., R. 1 E. The spring has a considerable volume, and has thrown up a gravel bar about 30 feet long and half as wide which rises some two or three feet above the level of the river at ordinary stages. While very little flow is ordinarily to be seen, a good flow of cool water may be had by scooping a hole in the gravel at any point on the bar. On July 8, 1923, the temperature of the spring was 55° F. while the temperature of the river was 72°. It is not possible to estimate the flow but it is thought to be fairly large, for on the date mentioned, the cooling effect of



Discharge record of Ebb and Flow Spring on Jacks Fork, Shannon Co., Mo., Sept. 14 to Oct. 11, 1923. Record made with Gurley 7-day water stage recorder.

the spring could be observed at least 20 feet from the bar, measured at right angles to the current. This spring is a favorite fishing spot.

Pine Hollow Spring—This is a very small but well known spring in Pine Hollow, on the Eminence-Birch Tree road in the northern portion of sec. 36, T. 28 N., R. 5 W.

There are many other good springs in the region, but it is not practical to list all of them.

Ebb and Flow Spring—This is a small spring near the mouth of Thompson Creek, in the SW. ¼ sec. 9, T. 29 N., R. 3 W. Its average flow is perhaps one-sixth of a second foot. It is interesting because of its peculiar periodic character, the flow of the spring varying greatly and rhythmically once or twice an hour.

On July 10, 1922, this spring was observed for two hours and the results obtained are shown in the following figure. (Fig 5.) The periodicity of the spring varies with the amount of rainfall and the season of the year.

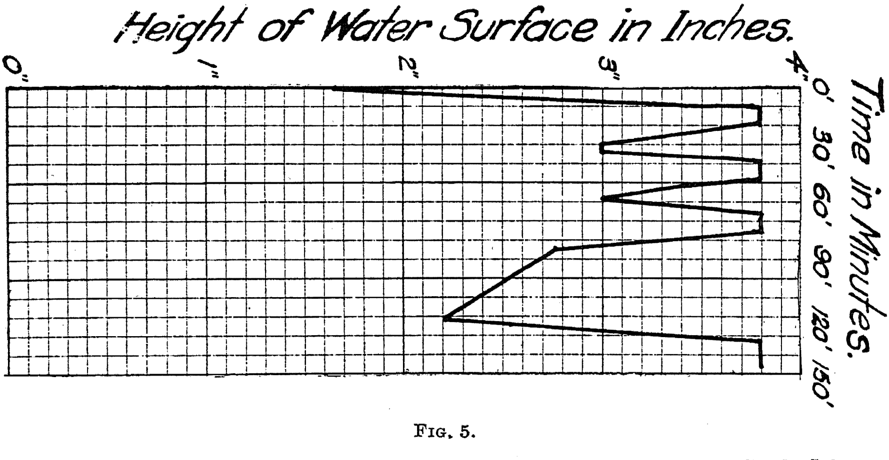


FIG. 5.

Graph showing the fluctuations of the Ebb and Flow Spring on Thompson Creek, July 10, 1922.

Ebb and Flow Spring on Jacks Fork—This is a much larger spring and is located in the NW. ¼ sec. 35, T. 27 N., R. 6 W. It is about 8 miles northwest of Birch Tree, and about 4 miles west of the west border of the region. The minimum flow of the spring is partly measured and partly estimated at 5 second feet, the maximum at 25 second feet. It takes the spring from 15 to 20 minutes to rise to maximum flow and the flow lasts about as long. During the summer months the spring rises about twice a day, but the number of rises in any given time is dependent upon amount of ground water.

An automatic water stage recorder was placed on this spring in the fall of 1923 and a continuous record of the fluctuations of this spring over a period of 28 days was obtained. (See Fig. 6.) Although there is considerable fluctuation in the periodicity of this spring, the average as computed from this record is 2.4 crests per day. The following summer the station was re-established and maintained for three months. There was a great deal of rainfall during the early part of the summer and there were sometimes as many as 5 and 6 crests in a single day. The latter part of the summer was unusually dry and at the time that the station was discontinued there had not been a single rise for nearly two weeks.

There are several springs of this type in the Ozark region. Their erratic behavior is thought to be caused by natural siphons in the rock which discharge subterranean reservoirs as fast as they fill. They have been described in detail in a previous publication.[1]

SOURCES OF DOMESTIC WATER SUPPLY.

Springs are a most important source of domestic water supply throughout the greater portion of the region. A small spring in the NE. ¼ of sec. 2, T. 28 N., R. 4 W., has been piped to a large covered reservoir on the hill above Eminence, and supplies the hotel, bank and several private homes in the town.

On account of the great porosity of the rock, due to the well developed system of underground drainage, the water table is quite deep under the higher portions of the region. Shallow wells in the plateau country commonly go dry in summer, but wells drilled to bedrock commonly obtain a good supply. The Gunter sandstone is an important water bearing horizon in other parts of the Ozark region. It may also carry water in the southwestern portion of this region but as yet it has not been tested.

The inhabitants of the upland rely on cisterns for domestic water supply, and upon cisterns, upland ponds, either natural or artificial, for water for their stock.

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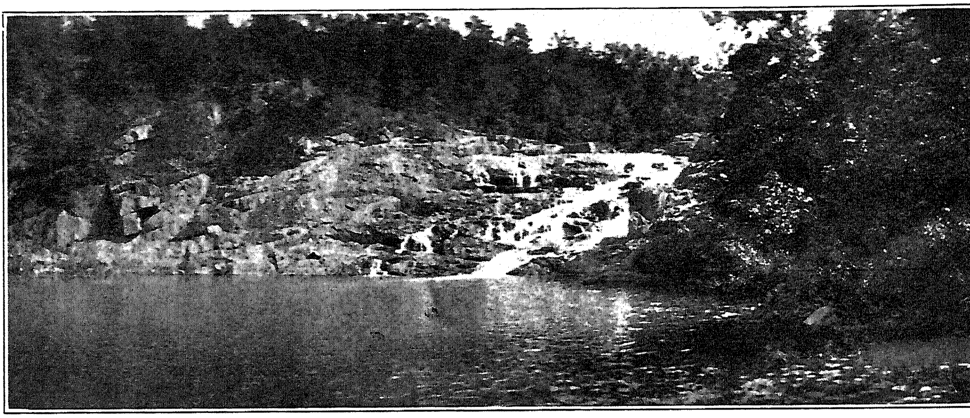
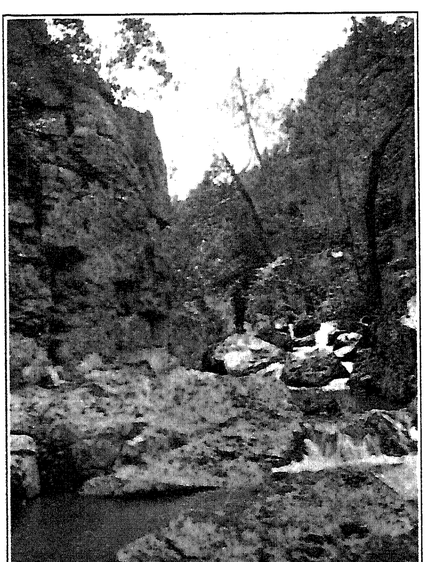
[1]Bridge, J., Ebb and Flow Springs in the Ozarks, Bull. Mo. Sch. Mines and Met., Tech. Ser., Vol. 7, No. 1, 1924.

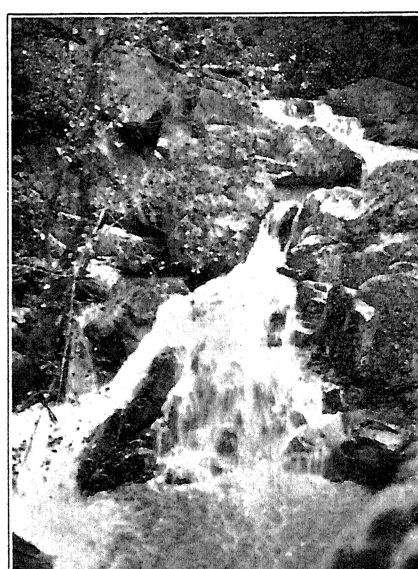


SHUT-INS.

A. The Falls, on Rocky Creek, a place where the creek has become superimposed upon a porphyry ridge.



B.



C.

B-C. Prairie Hollow Canyon, a narrow gorge cut in the porphyry between the Intermediate Level and the present flood plains.

PHYSIOGRAPHIC HISTORY.

The level accordant summits of the highest ridges are the remnants of a broad, gently sloping plain which formerly extended over most of the central Ozark Highland. It was a plain cut by river and stream erosion and at the time of its completion its elevation was much lower than at present. The rivers flowing across its surface were graded, meandering streams, and they had cut the interstream divides about as low as it was possible for them to be cut. This surface was low and gently undulating, and was highest in this portion of the Ozark region and sloped gently to the north, east and southeast, where it merged with the flood plains of the Missouri and Mississippi Rivers. To the south and west it was bounded by escarpments, the summits of which preserved the remnants of older and higher erosion levels.

The surface of this plain cuts across the edges of the gently dipping strata and is therefore to be regarded as a true peneplain rather than a stripped structural plain, although locally it may appear to be the latter. A few low isolated hills stood above this surface as monadnocks. Some of these were composed of sedimentary rocks, and owed their preservation to a favorable position between the headwaters of streams. The majority of them, however, are composed of porphyry and were preserved because of the superior hardness of this rock. The period of erosion necessary to develop this peneplain was a long one as is shown by the wide extent of this level and the great scarcity of monadnocks.

There is little evidence to date the age of this peneplain but from the fact that there are older and higher levels in other parts of the Ozark region and from certain gravel deposits which are found on its surface at a few localities, it is believed that it was completed about Pliocene time.

When the conditions just described had been attained the entire Ozark region was bowed upward. The maximum uplift was in the central portion of the Ozarks and amounted to about 400 feet. In the Eminence region the amount of uplift varies from 300 to nearly 400 feet, the greatest uplift being in the northwestern portion. This uplift rejuvenated the streams and they rapidly trenched their courses through the soft alluvial deposits which covered the plain and then cut their channels into the underlying rocks, thus preserving the meandering courses. In some instances they encountered the harder porphyry and shifted their courses laterally to get around it, at other times the course of the stream was directly across one of these ridges, and the stream was forced to cut a gorge through the hard rocks.

The period of quiet which followed this uplift was of sufficient duration to allow the major streams to again reach grade, and to widen their valleys. It was also long enough to allow the smaller streams which were cutting across the porphyry to cut their channels to grade and to develop extensive flats upon the soft rocks behind them.

It was thought at first that the "shut-ins" were responsible for the development of this second level, but it now appears that they have merely been instrumental in preserving it, and that it represents an extremely well defined period in the history of the Ozarks. It has been recognized far beyond the area influenced by the porphyry knobs, and far beyond the borders of the Eminence region.

The time employed in cutting down to grade and in widening the valleys to form the bench which constitutes the intermediate level, was of short duration when compared with the time necessary to complete the first one, and the streams had done less than one-fourth of the amount of work necessary to destroy the upper level and develop a peneplain at the lower elevation when the region was again uplifted.

From the standpoint of geologic time, this uplift must have been a comparatively recent event, for although the streams have cut about 200 feet below the second level, they are not yet graded, and have not yet begun to widen their valleys to any appreciable amount. The smaller streams which cut across the porphyry have scarcely been able to make any impression upon it, and every porphyry crossing is marked by an abrupt change of grade. Another proof of the recentness of the uplift is to be found in the cliffs which border the main streams. Many of these extend up to the intermediate level, but there are practically no cliffs between the intermediate level and the upper level. Thus the intermediate level is best preserved in these protected side valleys, while along the main streams it has been completely dissected and is no longer a conspicuous feature.

The present time appears to be a period of quiet. The main streams are approaching grade, and are beginning to widen their valleys, especially behind local barriers, which are still to be removed from their channels.

CHAPTER II.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

General Statement—The rocks of the Eminence region consist of nearly horizontal dolomite, sandstone and conglomerate strata of Upper Cambrian and Lower Ordovician age, which rest upon pre-Cambrian rhyolite porphyry and associated igneous rocks.

These pre-Cambrian rocks outcrop as isolated knobs in the central portion of the region, and are features of a buried topography which is now being uncovered by the processes of erosion.

Much of the region is covered with a thick mantle of residual chert derived from the weathering of the Cambrian and Ordovician formations. Small accumulations of Mississippian and Pennsylvanian (?) residual materials, derived from formations which in past ages completely covered this area, are present in a few places. The valleys of the rivers and larger creeks are floored with a mantle of alluvium and chert gravel, which also has been derived from the decay of the older rocks.

The pre-Cambrian igneous rocks of Missouri have been described by Haworth[1] and although he makes little mention of the rocks of this particular region, many of the types which he describes from the St. Francois Mountains also occur here.

The Paleozoic sedimentary rocks of the Ozark section have been described in many previous publications[2]. There is some controversy as to their age, stratigraphic relationships and correlation. Prior to 1908 the entire series was classified as Cambro-Ordovician; from 1908 to 1912 it was all referred to the Cambrian, and since that time, the practice of the Missouri Survey has been to divide the series between the Cambrian and Ordovician periods, using the Gasconade-Roubidoux contact as the boundary. In the present report the Van Buren and Gasconade are included in the Ordovician, and the reasons for this change will be discussed later in this chapter.

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[1]Haworth, E., The Crystalline Rocks of Missouri, Mo. Geol. Surv., Vol. VIII, 1895, pp. 84-222; also Vol. IX, Sheet Report No. 3, 1894, and Sheet Report No. 4, 1895, pp. 24-44.

[2]For the earlier descriptions of many of the rocks described in this report, see in particular Reports of the Mo. Bureau of Geol. and Mines, 2d series, Vol. I, 1903, pp. 23-78; Vol. III, 1905, pp. 21-33; Vol. VII, 1907, pp. 24-46; Vol. IX, Pt. 1, 1908, pp. 14-70; Vol. X, 1912, pp. 36-37 and 40-47; Vol. XII, 1913, pp. 7-40; Vol. XVI, 1922, 28-43 and Vol. XXII, 1928, pp. 38-84; Vol. XXIII, 1930, pp. 26-177.

In 1911, Ulrich[1] proposed two new periods, the Ozarkian and the Canadian, which he believes should be placed in the standard section, between the Cambrian and Ordovician periods. His type section of both periods is compiled largely from various localities in Missouri. One of the most important of these areas is the Eminence region, for it contains the type section of the Eminence formation, one of the most important divisions of the proposed Ozarkian system, and in fact, practically the entire sedimentary section in this area is referred by Ulrich to these two periods. Therefore a study of this and other key areas of the Ozark region is of great importance as an aid to the understanding of Ulrich's views.

The position of the Ozarkian and the Canadian periods, together with the formations referred to them, are shown in the accompanying table.

[1] Ulrich, E. O., Revision of the Paleozoic Systems, Bull. Geol. Soc. America, Vol. XXII, 1911, pp. 627-680.

TABLE I.

GEOLOGIC COLUMN FOR THE EMINENCE REGION.

Era	Period	Epoch	Classification of E. O. Ulrich		Formation and Thickness	Character
Cenozoic	Quaternary	Recent			0–50′.	Residual soil and alluvium
					Unconformity	
Paleozoic	Pennsylvanian	Des Moines			Cherokee (?) 50–75′.	Red, yellow, and white clays with some sandstone
					Unconformity	
Paleozoic	Mississippian	Osage			Burlington-Keokuk 5′.	Residual boulders of white, fossiliferous chert
					Important Unconformity	
Paleozoic	Ordovician	Canadian or Beckmantown	Canadian	Upper	Cotter and Jefferson City 50′.	Residual boulders and nodules of chert. Sparingly fossiliferous
					Unconformity	
Paleozoic	Ordovician	Canadian or Beckmantown	Canadian	Middle	Roubidoux 150–200′.	Sandstone and thin-bedded cherty dolomite
					Unconformity	
Paleozoic	Ordovician	Canadian or Beckmantown	Ozarkian	Upper	Gasconade 200–220′.	Gray, crystalline cherty dolomite contains Cryptozoon reef
					Unconformity (?)	
Paleozoic	Ordovician	Canadian or Beckmantown	Ozarkian	Middle	Van Buren 60′.	Gray crystalline dolomite, with hard white chert thin-bedded at base
					....	....
Paleozoic	Ordovician	Canadian or Beckmantown	Ozarkian	Middle	Gunter ss. mem. 15–20′.	Massive sandstone or sandstone and dolomite
					Important Unconformity	
Paleozoic	Cambrian	Saratogan or St. Croixan	Ozarkian	Lower	Eminence 250–310′.	Massive, gray crystalline, poorly bedded dolomite. Weathers to rusty porous cherts
Paleozoic	Cambrian	Saratogan or St. Croixan	Ozarkian	Lower	Potosi 50′ on outcrop 167 + in wells	Dark gray and brown finely crystalline cherty, drusy dolomite
					Important Unconformity	
Paleozoic	Cambrian	Saratogan or St. Croixan	Cambrian	St. Croixan	Bonneterre 60′.	Light gray, coarsely crystalline dolomite. Noncherty
					Important Unconformity	
Proterozoic	Algonkian (?)					Rhyolite porphyry and associated tuffs and agglomerates

The majority of the formation names appearing in this report have been in use for the last thirty years, and some of them are even older. They have not always been applied in exactly the same sense as now. In addition a great many other formation names which are no longer recognized have been employed by various authors with the result that it is often difficult to tell exactly what beds a particular author was describing.

Neither this statement, nor any other explanation of some other writer's interpretation of formations, appearing elsewhere in this paper, are to be construed as criticism. The stratigraphy of the Ozarks is difficult, and present knowledge of it is the result of many observations by many different individuals. Classifications are continually growing, and therefore changing. Formational boundaries which were difficult to recognize a decade ago, are now easily differentiated; while others which are extremely troublesome at the present time, will doubtless be readily distinguished by future workers.

In the great majority of cases the older workers drew their formational boundaries to fit the facts as they saw them, and used such criteria as they and their predecessors had been able to establish.

In general the growth of the classification has been a process of discrimination and refinement of formational units. In the earliest reports about all that could be done was to separate the sandstones from the dolomites, but as information was gathered and systematized, new criteria were developed, and it has become possible to recognize definite units with certain peculiar and individual characteristics in these sandstones and dolomites, and this process of discrimination is still going on.

Table II (in pocket) has been compiled to show the growth and refinement of the stratigraphic column of the Ozark region. It is based upon a study of the literature and also upon detailed and reconnaissance studies, and shows, in terms of present usage, the limits of the formations described by the older writers. In most cases these correlations are based upon present knowledge of the area for which the older report was prepared, and in some instances the present correlation is radically different from that proposed by the original author. A comparison of the stratigraphic columns published in some of the older reports with Table II will make this clear.

In this connection attention should also be called to the "Tentative Correlation of the Named Geologic Units of Missouri" which has recently been compiled by Miss M. Grace Wilmarth of the United States Geological Survey.

ALGONKIAN (?) IGNEOUS ROCKS.

Distribution. The oldest rocks of the region are a series of rhyolites and associated igneous rocks. They are found only in the central portion of the area, and the outcrops are all contained in a rectangle measuring approximately 9 by 14 miles, the sides of which strike approximately northeast and northwest. Within this area are exposed some 40 or more masses of igneous rock ranging in size from a square yard up to five or six square miles. Some of the larger masses form the highest summits in the region. These masses are portions of a range of hills carved out of the igneous rocks in pre-Cambrian and early Cambrian time; buried beneath early Paleozoic sediments, and now being uncovered by erosion.

The most northerly outcrop is on the right bank of Current River, in Lot 6, NW. ¼ sec. 5, T. 28 N., R. 3 W., the southernmost is the large mass on the north bank of Mill Creek, in sec. 31, T. 28 N., R. 2 W. The most western outcrop is at the McKinney prospect, at the head of a small tributary of Storey's Creek, in the W. ½ sec. 15, T. 29 N., R. 4 W., while the most eastern outcrop known is the so-called "Porphyry Mountain" near Eaton Ford on Current River in the SW. ¼ sec. 11, T. 28 N., R. 2 W. This area contains all of the pre-Cambrian outcrops known in the Current River valley, with the exception of a single outcrop of granite on the left bank of the river, about three miles southeast of Van Buren, in the SW. ¼ sec. 29, T. 27 N., R. 1 E. It lies about four miles southeast of the southeast corner of the Cardareva quadrangle, and since it appears to be definitely related to the igneous rocks of the Eminence region, and since it is different from them, it will be described later. Another outcrop of granite occurs near Garwood in sec. 27, T. 28 N., R. 1 E. about 12 miles northeast of Van Buren, and perhaps 4 miles east of the east boundary of the Cardareva quadrangle. It has not been visited and it is not known whether it is in the Current River valley or whether it is in the valley of Black River.

Thickness. The base upon which these igneous rocks rest is not known, and therefore their total thickness cannot be measured. At Coot Mountain nearly 600 feet of rhyolite porphyry is exposed between river level and the top of the mountain. A similar thickness is found on the slopes of Blair Creek Mountain, just across the river to the northeast. This represents but a fraction of the actual thickness. From other lines of evidence it is believed that the relief on the pre-Cambrian surface was at least 1500 feet, and, since it is carved on these undeformed rhyolites, their thickness must be at least as great.

Lithologic character. Rhyolite porphyry. There are four or five varieties of igneous rocks exposed. Rhyolite porphyry is the most common of these, and may be found at all outcrops within the area. Fresh surfaces of this rock are dark purplish-red in color but this becomes much paler when weathered. The rock is dense, felsitic or sub-vitreous. Flow structure is conspicuous. On freshly broken surfaces it appears as a series of light and dark color bands. On weathered specimens the flow lines often stand out in low relief. Phenocrysts of pink orthoclase are abundant, and most of them are less than a quarter of an inch in diameter. Many are partially kaolinized.

Another phase of this rock shows the same fine-grained texture, almost no flow structure, and much larger phenocrysts, some of which are at least three-quarters of an inch in diameter. These phenocrysts are deeply kaolinized in all specimens observed. This latter variety is found on the dump of the Slater mine, and is believed to have come from the deeper portion of the workings. Specimens have been found which show gradation from the one phase to the other.

The rhyolites are cut by two systems of nearly vertical joints, which are approximately at right angles to each other, and which strike about northeast and northwest. Horizontal joints are also present. These three joint systems divide the rock into large blocks. As weathering has been more active on corners and edges many of the blocks found at the surface are rounded or subangular in form. This same convex profile is characteristic of the summits of the porphyry knobs, and is in sharp contrast to the pointed summits and slightly concave profiles of the hills carved from the sedimentary rocks.

Thin sections of this rock show a fine-grained ground mass of quartz and feldspar, the individual particles measuring .02 mm. or less in diameter. Flow structure is well shown by the banding of different sized grains. The phenocrysts are chiefly orthoclase, and almost all of them are more or less kaolinized. In some instances only a shell of the original mineral remains, in other cases the crystal outlines have been filled with secondary quartz. In size they vary from .5 mm. up to 2 or 3 mm. Plagioclase is rare.

Many of the orthoclase crystals show Carlsbad twinning. The quartz phenocrysts average from .1 to .3 mm., in diameter. Small crystals of zircon .02 to .04 mm. in diameter are sparingly but consistently present, and magnetite occurs in a few instances. Many of the slides show a well developed micro-granitic structure, with a well defined intergrowth of quartz and orthoclase. This is particularly true of the specimens in which flow structure is not well developed, though both structures may occur in the same specimen.

Rhyolite porphyries of the types described constitute over 95 per cent of the igneous rocks in this area.

Pyroclastic Rocks. Volcanic Ash and Tuff. In several localities, but particularly at the Slater Mine, and on the knob in sec. 14, T. 28, N., R. 3 W., very fine grained felsitic rocks, which show neither porphyritic texture nor flow structure are found. They are dull red, and resemble a fine grained pressed brick, in both color and texture. Some appear amorphous to the unaided eye and resemble red chert. They are rather widely distributed, but are nowhere abundant. These rocks are all quite similar in hand specimens, but thin sections show many differences. Specimens from sec. 14, T. 28 N., R. 3 W., exhibit typical bogen structure and appear to be a fine-grained volcanic ash. This is also the case with specimens from Jerktail Mountain in the south part of sec. 5, T. 29 N., R. 3 W.

A thin section of another fine grained, dull red felsitic rock from the Slater Mine shows it to be a crystalithic tuff, composed of angular and rounded fragments of orthoclase, plagioclase and quartz. These vary from .02 up to .3 mm. in diameter the average being about .2 mm. Orthoclase is probably the most abundant, many of the fragments show Carlsbad twinning, and nearly all are more or less kaolinized. Plagioclase is the least abundant, and is also more or less decomposed. It is more common in this specimen than in any other rock examined with the possible exception of the granite. The quartz occurs in rounded and angular fragments. The ground mass is very fine grained, and in ordinary light shows traces of bogen structure. The deep red color of the rock is due to thin films of hematite in the ground mass.

None of the pyroclastic rocks described above have been found in place, but they are known from float at several localities. They are most abundant at the Slater Mine; at the south end of Jerktail Mountain, lot 2, SW. ¼ sec. 5, T. 29 N., R. 3 W., and on the south face of the knob at Flip store, sec. 14, T. 28 N., R. 3 W. None of the areas found are large enough to be indicated on the geologic map.

Another interesting pyroclastic rock occurs at the Slater Mine and has been collected from the outcrop. It is found on the east side of the knob, near the valley at the north end of the old workings; and rests on the typical rhyolite porphyry. It consists of extremely fine-grained, pinkish-red rock, with definite color banding which is interpreted as bedding. In the unweathered rock there is a regular alternation of pinkish-red bands with others of a pale greenish-gray color. In most cases the color bands grade gradually into one another, but in a few instances the change is quite sharp. The bands average from 1 to 5 mm. in width. In weathered specimens the color is more uniformly pink, but the bedding is still distinct. Under the hand lens minute particles about .25 mm. in diameter may be seen arranged along some of the bedding planes. Large rounded pellets of greenish-gray material are fairly common. They vary from 5 to 20 mm. in diameter, and like the small particles are arranged parallel to the bedding. The color lines curve around them, as though they had been dropped into an unconsolidated mass and had partially compressed it.

The unweathered rock breaks with a good conchoidal fracture, but weathered specimens are more apt to break along the color bands and along joints.

Thin sections are difficult to interpret. The rock shows the finest grain of any specimen examined, the average size of the particles being .003 x .006 mm. Small phenocrysts of orthoclase and quartz are fairly common, but they are considerably smaller than those occurring in the typical rhyolites. No traces of the bedding or of the included masses could be detected in the sections.

The rock is interpreted as an extremely fine grained rhyolitic tuff, and it may be a final phase of the other tuff described from this locality. The inclusions are thought to be lapilli of volcanic ash which accompanied the eruption.

Agglomerate. A single boulder of agglomerate was picked up on the northeast slope of Coot Mountain, but the outcrop from which it came was not found. It consists of angular fragments of rhyolite porphyry and of the tuffs already described, in a deep red, fine-grained ground mass. The individual fragments range from very small up to 3 or 4 cm. in diameter. Most of them are greatly weathered.

A thin section shows that the majority of the fragments are the characteristic rhyolite porphyry with the same micro-granitic structure which characterizes the majority of the sections of the porphyry. A few of the inclusions are of the fine grained tuffaceous type already described, and the ground mass is similar in structure.

The Van Buren granite outcrop. The location of this exposure has already been given. It is a hill about 200 feet high which rises abruptly from the left bank of the river and which is surrounded by hills formed of the Eminence dolomite. The rock is a red granite, the color being due to the large pinkish-red crystals of orthoclase. Quartz crystals are abundant, and hornblende is present. No micas were observed. A thin section shows a subordinate amount of plagioclase. The crystals are of medium size, individual grains consistently averaging over 1.5 mm. in diameter. Portions of the slide show well defined micro-granitic structure, similar to that observed in the porphyry, and suggest a relationship to it.

Basic dikes, which are fairly common in the Algonkian rocks of the St. Francois Mountains are not known to occur here. The earlier writers make no mention of any, and none have been reported by any of the inhabitants. In view of the fact that prospecting for minerals has been going on in this area for a long time, this last fact is believed to afford good proof that no basic dikes of any considerable size exist.

Correlation. These igneous rocks are definitely older than the sediments which overlie them. The proof of this is to be found in the total absence of metamorphism along the igneous-sedimentary contact, and in the presence of heavy basal conglomerates, containing rounded and waterworn pebbles of the igneous rocks at the base of the sedimentary series. These conglomerates are often several feet in thickness and will be more fully described later. The oldest sediments, as shown by their contained fossils are of Upper Cambrian age, and since igneous rocks are practically unknown in the lower and middle Cambrian series in other portions of North America, these rocks are classed as pre-Cambrian. There is no direct evidence as to what portion of pre-Cambrian time they belong, but in the past it has been customary to class them as Laurentian.[1] This is partly due to the lithologic character of the rocks, which compares favorably with that of the Laurentian rocks of the type areas, and also partly due to the presence of younger rocks of pre-Cambrian age in the St. Francois Mountain area. These latter have been classed as Huronian, by Haworth,[2] mainly on the basis of lithologic similarity, but this interpretation has been questioned by Ulrich.[3]

Although these rocks are of lithologic types more common to the Archean than to the Algonkian, they lack any traces of regional metamorphism. This was commented on by Haworth[4] and afterwards discussed by Keyes,[4] who concluded, mainly from this line of evidence, that all of the igneous rocks of Southeastern Missouri were Algonkian.

Recently this lack of regional metamorphism has been emphasized by others, and while it in itself is no safe criterion as to the age of these rocks, it is the present practice of this Bureau to refer them to the Algonkian (?). This classification agrees most nearly with other classifications and is adopted for that reason.

PALEOZOIC SEDIMENTARY ROCKS.

BASAL CONGLOMERATE.

In many instances the debris resulting from the breaking up of the pre-Cambrian rocks forms a well defined basal conglomerate at the contact of the pre-Cambrian and the Paleozoic rocks. It is not limited to any one horizon in a single formation, but occurs at all horizons, in all formations from the Bonneterre to the Van Buren inclusive, where they come in contact with the pre-Cambrian. As would naturally be expected, the conglomerate is best developed in the bottoms of the narrow, steep-sided, pre-Cambrian valleys, where the amount of running water was not sufficient to remove the debris formed by weathering and where slumping would favor accumulation. It is often absent or poorly developed on the ancient divides, and on steep slopes, which were exposed headlands at the time of deposition.

The basal layers of the conglomerate consist of angular fragments of porphyry of all sizes, ranging from very small

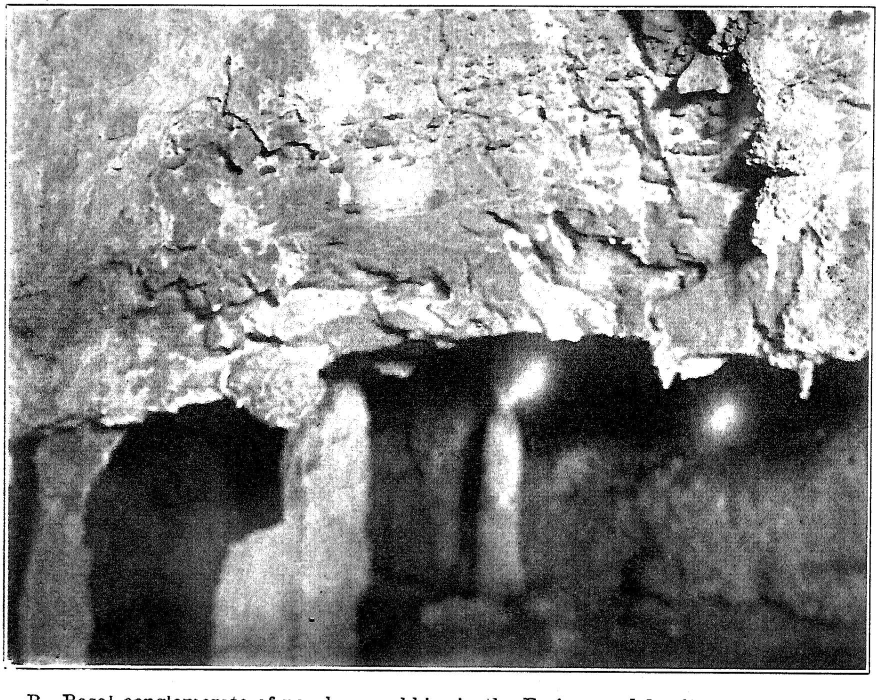
[1]Buckley, E. R., Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Mo. Bur. Geol. and Mines, Vol. IX, Pt. 1, 2nd ser., 1908, p. 16.

[2]Haworth, E., Mo. Geol. Survey, Vol. IX, Sheet Report No. 3, 1894, pp. 15-27.

[3]Ulrich, E. O., and Bain, H. F., The Copper Deposits of Missouri, Bull. U. S. Geol. Surv., No. 267, 1905, p. 21.

[4]Keyes, C. R., Geographic relations of the granites and prophyries in the Eastern Ozarks. Bull. Geol. Soc. Amer., Vol. VII, 1896, p. 375 (also contains the quotations from Haworth noted above).

A. Conglomerate of porphyry pebbles in the Van Buren dolomite from the north face of Stegall Mountain. .5 actual size.



B. Basal conglomerate of porphyry pebbles in the Eminence dolomite as exposed in the roof of the cave on Current River opposite the Cardareva School. See also Plate XVI.

pieces to masses several feet in diameter; packed closely together, with no semblance of bedding. For the most part this represents residual material, and is to be compared with the residual masses now accumulating at the bases of many of the porphyry slopes. This phase may be entirely absent, or it may be as much as ten feet in thickness. Over this is often found a layer of fine angular and sub-angular porphyry fragments, still in contact, but showing traces of stratification, evidently material which was sorted and spread by wave action during the early stages of sedimentation. This in turn is succeeded by smaller porphyry fragments, not in contact with each other, but commonly arranged in layers parallel to the bedding. These are believed to be pebbles which were washed into the sea from higher slopes, while the calcareous muds which form the matrix were yet plastic. Most of the pebbles in this zone are small, less than two inches in diameter, and very much of the same size in any given layer. Large boulders up to a foot in diameter do occur, but these are close to the old land surface. The pebbles become smaller and smaller as the distance from the porphyry increases (both vertically and horizontally) and eventually become so fine that they can only be detected with a lens. Thus the conglomerate is very definitely related to the dolomite in which it occurs, and is to be considered as a basal or marginal phase, rather than a separate formation. Its general appearance, and relation to the other rocks is shown in Plate X, and Fig. 7. Since it is much the same, in all formations in which it occurs, but quite different from the main mass of these formations, it is described here as an interesting lithologic

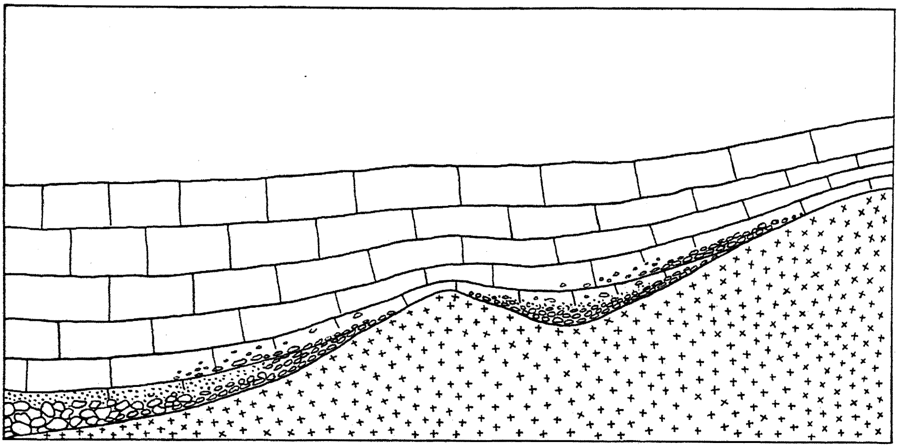


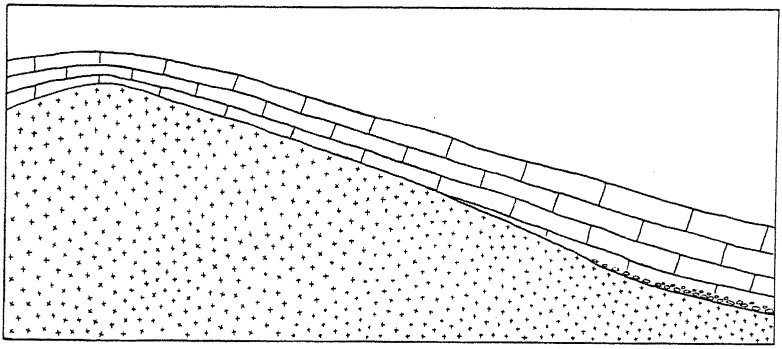
Fig. 7.
Diagram showing the relationship of the conglomerates to the igneous and sedimentary rocks.

type. The thickness of this conglomerate varies from a few inches up to 15 or 20 feet. How far it may extend laterally away from the porphyry at any given horizon has not been determined, but there is some evidence at hand which would seem to indicate that the belt in which these conglomerates formed, might have been as much as ¼ mile in width in some places but it is commonly less than this.

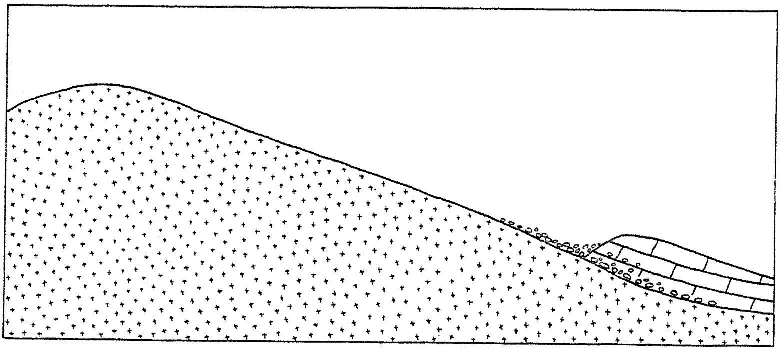
This conglomerate is found at many places. It appears in the Bonneterre in sec. 5, T. 29 N., R. 3 W. and in the Potosi at the mouth of Mathews Branch, in the NW. ¼ sec. 15, T. 29 N., R. 3 W., along the north face of Coot Mountain, and around the small porphyry knob in the center of sec. 34, T. 29 N., R. 2 W., and at many other places where the Potosi rests upon the pre-Cambrian.

There are more good exposures of the conglomerate in the Eminence dolomite than in any other formation, because the Eminence is most often in contact with the porphyry. One of the best of these is in a cave about 150 feet above the river level, on the south end of Russell Mountain, opposite the Cardareva School House (SW. ¼ sec. 2, T. 28 N., R. 2 W.) (Plate XVI.) The floor of this cave is at the dolomite-porphyry contact, and dips about 20 degrees to the south, thus conforming with the slope of the ancient pre-Cambrian hill. In the walls of the upper portion of the cave the conglomerate can be studied in all its phases. See Plate X. It is between 8 and 10 feet thick here. It is also well developed in the cave in the center of the SW. ¼ sec. 1, T. 29 N., R. 3 W. The shaft of the Sutton Mine penetrated about 15 feet of conglomerate resting upon the porphyry, and it also appears in a small ravine about 100 yards northeast of the shaft. Other good localities are: in the shaft of the Jerktail Mine (Lot 3, NE. ¼ sec. 5, T. 29 N., R. 3 W.; and at the mouth of the small creek, on the north side of the porphyry knob, at the junction of Jacks Fork, and Current River (NE. ¼ SW. ¼ sec. 9, T. 29 N., R. 3 W.).

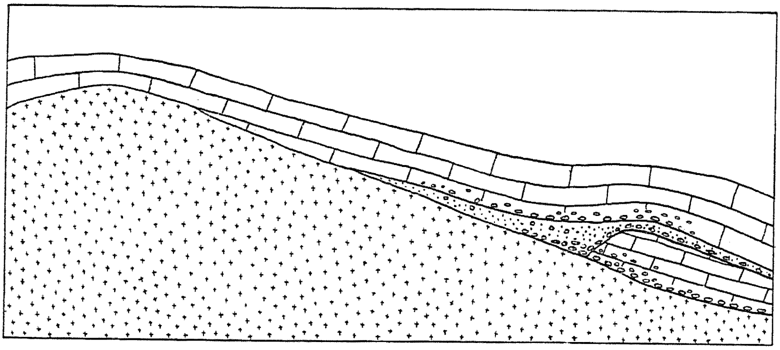
It has been found in the Gunter sandstone and the overlying Van Buren dolomite at one locality. This is in the NE. ¼ sec. 24, T. 28 N., R. 3 W., in the bed of the small east-west ravine, which separates Stegall Mountain from the foothills, and also on the slope of the hill facing the mountain. The conglomerate is much the same as that which has already been described, and will be discussed more fully in connection with the Eminence-Van Buren unconformity.



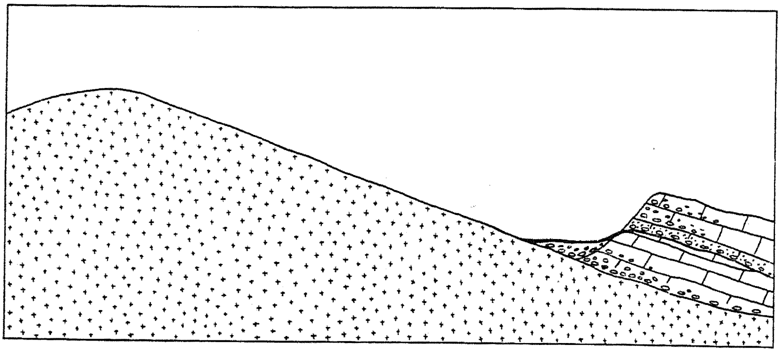
a—After deposition of the Eminence.



b—After Post Eminence erosion.



c—After deposition of the Van Buren.



d—Present time.

Diagrams illustrating the formation of conglomerates in the Van Buren formation on the north side of Stegall Mountain.

CAMBRIAN SYSTEM.

BONNETERRE DOLOMITE.

Description. The Bonneterre dolomite which is the principal lead bearing formation of the state has been well described by Buckley[1] and more recently by Dake.[2] Though it is known to underlie the greater portion of the Ozark uplift, outcrops for the most part are limited to the area around the St. Francois Mountains.

In the Eminence region the formation is known from a single area in Lot 5, NW. ¼ sec. 5, T. 29 N., R. 3 W. On the right bank of Current River is a low porphyry knob about 75 feet high. A small stream cuts across the southern end of this knob making a miniature "shut-in" just before reaching the flood plain of the main river. On the south and west sides of this knob, the overlying formation consists of about 60 feet of light gray, medium to coarsely crystalline, non-cherty dolomite. These beds dip at angles up to 25 degrees to the west and southwest, and soon disappear beneath the flood plain, or beneath younger beds. Immediately west of the "shut-in" the first few feet of the formation contain a well developed basal conglomerate of the type already described, with pebbles up to 5 and 6 inches in diameter. Green glauconitic material is abundant in some beds.

These dolomite layers are exposed along the valley to the west of the "shut-in" for about 100 yards and are probably exposed in the valley on the north side of the porphyry. In the saddle between the two valleys, the outcrop is covered by residual materials from the Potosi formation.

These beds are overlain by about 50 feet of typical, brown drusy Potosi dolomite, but the contact is not well exposed. This, in turn is succeeded by a full section of the Eminence. Although Potosi is normally much thicker than this, it thins markedly in the St. Francois Mountain area, where it overlaps onto the older strata, and in many instances is much thinner than the section at this point. The Davis, Derby and Doerun formations with a total thickness of over 200 feet normally intervene between these two formations, but in the St. Francois mountains they are

[1]Buckley, E. R., Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Mo. Bur. Geol. and Mines, Vol. IX, Pt. 1, 2nd ser., 1908, pp. 26-32.

[2]Dake, C. L., Geology of the Potosi Area, Mo. Bur. Geol. and Mines, Vol. XXIII, 1930, page 51.

completely missing in dozens of similar situations, and the Potosi, much reduced in thickness rests directly upon the Bonneterre.[1]

No other exposures of this dolomite are known in the Eminence region, but deep drilling in the basins among the porphyry knobs and in the areas around them should reveal its presence.

Mr. H. S. McQueen of the Missouri Bureau of Geology and Mines has examined the insoluble residues from samples of these rocks and says that they are quite similar, if not identical with the residues obtained from known samples of the Bonneterre.

Fossils are extremely rare in the Bonneterre formation, at most localities and none have been found in these exposures.

Correlation. These outcrops are correlated with the typical Bonneterre of the lead belt on the basis of lithologic similarity, stratigraphic position and insoluble residues. At a few localities in Missouri notably in Ste. Genevieve Co.[2] the Bonneterre carries the *Crepicephalus texanus* fauna. For this reason Ulrich correlates it, in part at least with the lower portion of the Cap Mountain formation of Texas; with the upper portion of the Eau Claire formation of Wisconsin and with the upper portion of the Maryville and Conasauga formations of the Southern Appalachian region.

POTOSI DOLOMITE.

History. The formation is named from the characteristic exposures in and near Potosi, in Washington County. It was originally proposed by Winslow[3] who used the term in a much broader sense, and included in it by implication, although not actually, all beds between the Bonneterre dolomite and the St. Peter sandstone. Buckley[4] re-described it, and defined its limits more exactly, but included in it at times, a portion of the overlying Eminence dolomite. A full account of the history and usage of the name Potosi, together with a good description of the formation at its type locality has been given by Dake.[5]

Areal distribution. The Potosi is exposed at various points along Current River and the small streams tributary to it, from Conway Bend, in the extreme northwestern portion of sec. 6, T. 29 N., R. 3 W., to Cardareva Mountain in sec. 36, T. 29 N.,

[1]Dake, C. L., op. cit.

[2]Weller, S., and St. Clair, S., The Geology of Ste. Genevieve Co., Mo. Bur. Geol. and Mines, Vol. XXII, 1928, page 45.

[3]Winslow, A., Report on Lead and Zinc, Pt. 1; Mo. Geol. Surv., Vol. VI, 1894, p. 331.

[4]Buckley, E. R., Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Mo. Bur. Geol. and Mines, Vol. IX, Pt. 1, 2nd ser., 1908, pp. 51-58.

[5]Dake, C. L., op. cit.

R. 2 W. It outcrops at various points in the valley of Jacks Fork as far west as the NE. ¼ sec. 28, T. 29 N., R. 4 W. No other exposures are known in the Current River valley, but the formation appears again in the Black River valley at Ellington, about 2 miles east of the northeast corner of the Cardareva sheet.

It is the surface rock over large areas in and around the St. Francois Mountains and underlies the greater portion of the Ozarks.

In the Eminence region the individual outcrops are small in extent, and are confined to bottoms of the larger valleys. All of the exposures lie within the area of porphyry knobs, and in many instances the formation partially or completely encircles a knob at a higher elevation than the exposures in the nearby valleys. There are also many small inliers of the Potosi in valleys tributary to Current River at points where there are no exposures in the main valley. This indicates that the main valley is in a structural trough, in which the dip of the formations off of the porphyry knobs is greater than the gradient of the tributary streams, a point which is fully discussed in the chapter on structure.

Good examples of these inliers are to be found in Barn Hollow, (sec. 6, T. 29 N., R. 3 W.), and the two hollows north of it, also in several valleys in sec. 7, same township and range, in the vicinity of Sutton Creek school. Another exposure occurs on Big Thorny Creek, just east of Coot Mountain (sec. 24, T. 29 N., R. 3 W.). A section about 50 feet thick is exposed in the mouth of Lick Log Hollow, in the bluff just north of the bridge. The formation is also well shown along Sutton Creek from the west side of sec. 12, T. 29 N., R. 4 W., to the river; in Asher Branch, (left side of Current River, in the northern part of sec. 5, T. 29 N., R. 3 W.) and northward along both banks of Current River to the mouth of the creek.

Thickness. In the type area in Washington County the Potosi has an average thickness of 250 to 390 feet. In the Eminence region the contact of the formation with the older sedimentary rocks is exposed at only one place, (the Bonneterre outcrop already described) and here the observed thickness is between 50 and 60 feet. This figure is equalled but not exceeded in Lick Log Hollow, at Powder Mill ford and at Cardareva Mountain. It represents only the upper portion of the formation, where it overlaps onto the higher portions of the pre-Potosi surface. The formation thickens in the basins between the porphyry knobs, as is shown by the log of the drill hole at the Casey Mine (see appendix) which stopped in dolomite 167 feet below the top of the formation. From this it seems probable that the formation may attain its full thickness in these basins. It is also quite thick in the vicinity of Ellington. On State Highway No. 21, just north of the bridge across Logan Creek, over 120 feet of the formation is exposed between creek level and the Eminence contact.

Lithologic character. The Potosi is a massive, finely crystalline, pale to dark chocolate brown, magnesian limestone. The rock breaks with a fairly even fracture. Freshly broken surfaces give off a characteristic fetid odor, which is strongest in the darker colored varieties. This odor which is probably due to decomposed hydrocarbons, is present in many sedimentary rocks, but in the Ozark section it is appreciably present only in the Potosi, and therefore serves as a ready means of identification. Bedding planes are from one to several feet apart, and are not conspicuous. Vertical jointing is well developed and in some instances the joints are so closely spaced that they tend to obscure the bedding and give a false impression of the structure. A good example of this is seen on the southwest side of the small porphyry hill in sec. 34, T. 29 N., R. 2 W. The actual dip at this point is about 15 degrees to the southwest, but the joints which simulate bedding dip about 70 degrees in the same direction, giving the impression of highly tilted strata. Other instances of this sort have been noted both in this formation and the overlying Eminence dolomite.

In the type area in Washington County, and in many other places the Potosi is readily recognized by the abundance of quartz and banded chalcedony druses which it contains. These have been described by Buckley,[1] Dake,[2] and others. In the Eminence region, the druses are commonly not as well developed. This is due to the small size of the exposures, and also to the fact that most of the outcrops are in the form of fairly steep cliffs. Under these conditions of weathering abundant siliceous residues are not produced. Where large areas of the formation are exposed to weathering on gentle slopes, as for example in the vicinity of Bee Bluff school house, the characteristic large quartz druses are well developed. Smaller, but

[1]Buckley, E. R., Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Mo. Bur. Geol. and Mines, Vol. IX, Pt. 1, 2nd ser., 1908, p. 52.

[2]Dake, C. L., Geology of the Potosi Area, Mo. Bur. Geol. and Mines, Vol. XXIII, 2nd ser., 1930, p. 113.

equally characteristic forms are present in the exposures on Sutton Creek, in the bluff on Jacks Fork, in the northern portion of sec. 28, T. 29 N., R. 4 W., and at many other localities. Drill cuttings from this formation are readily identified by their fine grain and color, and by the presence of small fragments of the banded chalcedonic druses. The insoluble residues from these cuttings are likewise identified by the fragments of druse and also by the abundance of dolocastic chert found in them. According to McQueen[1] the Potosi is the oldest formation in Missouri in which dolocasts[2] are found in the chert.

Weathering. Where silicification is sparingly developed, the formation weathers to smooth, or slightly pitted surfaces, which are light gray in color. The color developed by weathering is common to most of the dolomites in the region and is of little use in distinguishing the formation. Weathering is accomplished mainly by solution. This is most active along joint and bedding planes and since the former are commonly more numerous and better developed than the latter, the net result in many instances is the reduction of a given stratum to a series of pinnacles, locally known as "niggerheads." These have smooth rounded tops and are quite characteristic of certain parts of the formation, and especially of the transition zone between the Potosi and the Eminence formations.

Shallow rounded pits are common on weathered surfaces but they are quite distinct from the deep jagged pits which occur in the Eminence. Where druses are typically developed, the formation weathers into rough and craggy pinnacles, which greatly resemble the Eminence pinnacles, but which may be distinguished from them by their chert and druse content. Where the formation outcrops on gentle slopes, weathering produces an abundance of rusty, porous, residual chert which also greatly resembles the cherts derived from the Eminence formation, but which is commonly intimately associated with the characteristic druses, and therefore is easily recognized. Cherts of this type are well developed on the slopes just north of the small porphyry outcrop on the right bank of Current River in sec. 5, T. 29 N., R. 3 W.

The soils produced by the weathering of the formation are deep-red clays, which include numbers of small chert frag-

[1]McQueen, H. S., op. cit., p. 15.

[2]A term proposed by McQueen to designate material containing rhombohedral cavities, formed by the leaching out of dolomite crystals.

ments. Where exposed over large areas, it is literally riddle by subterranean water channels and many fine springs are founc In the Eminence region the areas of outcrop are too small t make these features noticeable. For the same reason, its effec upon the topographic features of the region is also negligibl

Stratigraphic relations. The Potosi rests unconformabl upon the pre-Cambrian, and must also rest unconformably upo the Bonneterre, since there is no trace of the formations whic normally appear between them. Where it rests on porphyr the basal part of the formation often contains a conglomerate c porphyry pebbles, of the type already described. The exac contact with the Bonneterre in the Eminence region is coverec but in other areas the contact is even and there is no conglomerat developed in the basal layers.

It appears to grade conformably into the overlying Emi nence formation, and in the field it is often difficult to draw th line between them, especially in those places where the char acteristic druses are poorly developed. The transition fron from one formation to the other is marked by change of colo and texture, loss of the druses, and by a distinct change in th weathered appearance of the rock. The color changes from dar chocolate brown through light brown to steel gray, and the feti odor of the freshly broken rock of the lower series disappears The rock becomes much more coarsely crystalline. The char acteristic quartz-chalcedony druses of the Potosi are replace by the porous, rusty, non-drusy cherts of the Eminence. Th smooth rounded niggerheads into which the Potosi weather where exposed on gentle slopes, are replaced by rough, cragg pinnacles. These changes do not take place simultaneously, an it is common to find a zone about 40 to 50 feet thick composed o rather coarsely crystalline, chert-free, gray dolomite, whicl resembles the Eminence in color and texture, but which weather like the Potosi. Good exposures of these transition beds ar to be seen on the lower slopes of the hills southeast of Wes Eminence. This transition zone has been consistently mappec with the Eminence formation, both in this area and in the Potos region, and the contact has been drawn at the top of the browı drusy dolomite.

In his original description of the Eminence formation Ulrich[1] states that it probably rests unconformably upon th Potosi, and he is still inclined to adhere to this statement. Th

[1]Ulrich, E. O., see quotation on p. 78.

recent work of McQueen on insoluble residues obtained from drill cuttings tends to support this view. He finds that the residues obtained from the Potosi are strikingly distinct from those of the Eminence, and that there is a sharp line of demarcation between them. There is a sudden rise in the percentage of insoluble materials at this line, a condition which seems to occur along old erosion surfaces. He also finds that the Potosi is missing over large areas in the western portion of the state and that in most cases the Eminence rests directly upon the Bonneterre. Such a relationship may indeed indicate a period of erosion during which the Potosi was removed, but it may just as well indicate a normal overlap of the Eminence against the old highland, which is now known to have been present in western Missouri and eastern Kansas throughout much of early Paleozoic time.

In the present state of our knowledge this break is difficult to detect in surface exposures, and if present, it must have been of short duration.

The few fossils found in the Potosi are closely related to the Eminence forms and no faunas are known to intervene between these formations or their equivalents.

Paleontology. No fossils have been found in the Potosi dolomite of the Eminence region, and the formation has commonly been regarded as unfossiliferous. Two gastropods and a single cranidium of a trilobite have been found by Dake in beds which lie close to, but below the Eminence-Potosi contact, in the Potosi quadrangle. F. L. Sevier, formerly a student at the School of Mines found a few fossils in drusy cherts in the NE. ¼ sec. 6, T. 35, N., R. 1 E. (Potosi quadrangle.)

The writer has found three gastropods in decayed chert in the interior of a large, typical, Potosi druse, picked up in the vicinity of Davisville, in Crawford County. St. Clair collected a single poorly preserved gastropod and fragments of a Cryptozoon from Potosi cherts near Piedmont, Wayne Co., Mo. Five or six gastropods, one trilobite, and two cephalopods represent the total fauna of the Potosi as known at present.

The following forms have been identified:

	Dake.	Sevier.	Bridge.	St. Clair.
(Cryptozoon) sp.	....	....	....	x
Dirhachopea dubia, Ulrich and Bridge	....	....	....	x
Scaevogyra cf *swezeyi*, Whitfield	x	x	x	....
Shelbyoceras sp.	....	x	....	....
Plethometopus modestus, Ulrich	x	....	....	....

The preservation of the gastropods is very poor, but the majority of them appear to belong to the same species. All of these genera occur in the overlying Eminence dolomite, and the *Scaevogyra* and *Plethometopus* appear to be conspecific with Eminence forms. This serves to strengthen the idea of the close relationship of the two formations.

Correlation. The formation is correlated with the Potosi of the type area on the basis of stratigraphic position, general lithologic character and on the character of its insoluble residues.

Owing to the scarcity of identifiable fossils, correlation with areas outside of Missouri is difficult, and the relationships stated here are purely tentative.

Scaevogyra swezeyi was originally described from the Mendota dolomite of Wisconsin, which Ulrich has already correlated with the Potosi on the grounds of stratigraphic position. He also makes it the equivalent of a portion of the Briarfield-Ketona series of Alabama but this evidence is entirely upon similar position in the stratigraphic section and is without any direct paleontologic support. More recently he has correlated the Potosi with the Royer formation of Oklahoma. This latter carries an extensive fauna of Arctic-Pacific origin, which Ulrich believes to be older than the Eminence fauna, but since these two have not yet been obtained from a single area their exact relationships are still conjectural. Buehler[1] reports druses and chert from the lower portion of the Ellenburger limestone of central Texas which closely resemble those from the Potosi dolomite and it seems possible that some portion of these formations may be regarded as homotaxial.

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

In connection with the correlation of the Potosi, see description of *Shelbyoceras*, Chapter VI.

A. Tabular weathering characteristic of the Gasconade and Van Buren dolomites. Basal Gasconade, top of hill just west of Eminence.

B. Pinnacle weathering characteristic of the Eminence and Proctor dolomites. NW. ¼ NW. ¼ sec. 1, T. 28 N., R. 4 W.

EMINENCE DOLOMITE.

History. The formation is named from the numerous exposures in the vicinity of Eminence. Shannon County does not appear to have been visited by Swallow, Pumpelly, or Broadhead, or by any of their assistants, but the earlier reports of the Survey in other counties in which the formation is exposed refer it to the Third Magnesian Limestone, a term which at that time apparently included everything in southeastern Missouri below the top of the Gasconade dolomite,[1] with the exception of some of the sandstones which were referred to various members of the sandstone series.

The first member of the State Geological Survey to visit Shannon County appears to have been Dr. C. P. Williams.[2] He referred all of the Paleozoic strata to the Second Sandstone, and the Third Limestone, thus including in the latter formation all of the sedimentary rocks below the Roubidoux.

The deficiencies of the Magnesian Limestone series soon became apparent; the intervening sandstones were not continuous, neither were they constant in number, and mistakes in correlation were of frequent occurrence. In 1892, Nason[3] in the course of his studies of the iron ores of the Ozark region, made float trips from Cabool to the Missouri River, by way of Big Piney and the Gasconade rivers, and also from Cedar Grove to Doniphan on Current River, thus crossing the Ozark Uplift. On these trips he measured many sections, and outlined the broader stratigraphic relations of the rocks of the uplift. In summing up his observations he called attention to the faults of the existing classification, and proposed the name, Roubidoux sandstone, for the Second Sandstone of Swallow, using the term in practically the same sense that it is used today. For the limestones beneath it, he proposed the term Gasconade limestone, including in this all the limestones exposed below the Roubidoux in this area. In the Gasconade valley, no rocks older than the Gasconade and Van Buren dolomites as now delimited are exposed, but in the Current River valley Nason's Gasconade included, not only the

[1]Swallow, G., First and Second Ann. Repts. of the Geol. Surv. of Mo., 1855, Table between pp. 61-62, also pp. 126-8.
Shumard, B. F., Reports of the Geological Survey of the State of Missouri, 1873, Rept. of Crawford Co., pp. 247-8; Rept. on Ste. Genevieve Co., pp. 299-300.
Gage, J. R., Report of the Geological Surv. of the State of Mo. for 1873-74, 1874, Chap. XXXI, pp. 604-5.
[2]Williams, C. P., Industrial Report on Lead, Zinc and Iron, together with Notes on Shannon County and its Copper Deposits, Geol. Survey of Mo., 1877, p. 163.
[3]Nason, F. L., Report on Iron Ores, Mo. Geol. Surv., Vol. II, 1892, Chap. V.

Gasconade and Van Buren, but the Eminence, Potosi and Bonneterre formations as well. In the vicinity of Van Buren the thick Gunter sandstone was correlated with the Roubidoux, and the Gasconade and Van Buren as now restricted were left entirely out of Nason's section at this point.

In 1894 Winslow[1] published a correlation table for the Ozark region. In his section for southeastern Missouri (i. e., the lead belt) the Eminence formation is included in the Potosi division of the St. Francois limestone, a formation which according to Winslow's table included everything from the top of the Lamotte sandstone to the base of the St. Peter (Crystal City) sandstone. In his table for Central Missouri, he followed Nason in assuming the Roubidoux to be the equivalent of the St. Peter, and included in his Gasconade formation everything below the base of the St. Peter (Roubidoux or Saccharoidal)[2] sandstone. He divides this Gasconade formation into five members, the lowest of which is the Proctor, this being the first usage of the name. From the table and the text it was plainly intended to be the equivalent of the Fourth Magnesian limestone, a formation which had been recognized by Swallow and his assistants along the Niangua and Osage rivers only. The Gasconade and Van Buren formations were termed the Osage limestone, and the Eminence of the southern Ozark region was probably included in it.

During the brief administration of Gallaher[3] Shannon County was again visited by State Survey parties, and the Eminence and Potosi were lumped together as the "Massive Siliceous Cap Rock" which Gallaher considered to be the uppermost division of the Cambrian. He followed Winslow and Keys in regarding the limestones below the Gunter sandstone (Roubidoux[4]) in Morgan and Camden counties, as being much older than their equivalents in southeastern Missouri, and he made the Proctor limestone the equivalent of the "Fourth limestone," the fifth and highest member of his "Lower Cambrian" series and therefore the equivalent of the upper portion of the Bonneterre.

His descriptions of his stratigraphic units were vague and involved, but most of the exposures illustrated in his plates may

[1]Winslow, A., Lead and Zinc Rept., Pt. 1, Mo. Geol. Surv., Vol. VI, 1894, p. 331.

[2]Names in parentheses are the names used in Winslow's table.

[3]Gallaher, H. A., Mo. Geol. Surv., Vol. 13, 1900, pp. 98-105; also Plate XI.

[4]Gallaher consistently used the term Roubidoux for the Gunter sandstone and applied the term St. Thomas to the true Roubidoux. See Table II.

be readily located, and leave little doubt as to the rocks which he was describing.

In 1901 Nason[1] assigned a definite base to the Potosi series in the lead belt. He determined the unconformity at the base of the formation and collected fossils which proved for the first time the undoubted existance of Cambrian in Missouri.

The Potosi, as thus defined, included the Eminence, and practically all of the Davis, Derby and Doe Run formations.

In 1905 Ulrich and Bain[2] published a classification of the Cambrian and Ordovician rocks of the Ozarks. They included everything between the Davis (Elvins) and the Roubidoux in the Gasconade limestone. They definitely make the Proctor the lowermost member of the Gasconade in the northwestern portion of the Ozarks, and mention its occurence along Current River but neither the Eminence nor Potosi formations as now known were recognized in Shannon County. In fact, due to a misunderstanding, they followed Winslow, and included the Gasconade, Roubidoux and Jefferson City formations in the Potosi Group. In the course of this investigation, Ulrich obtained fossils from the various divisions of the "Gasconade" and from these as well as from certain physical evidence became convinced that the "Gasconade" should be still further subdivided. He is directly responsible for the name Eminence, although he was not the first to use the term in a published article.

In 1907, Buckley[3] published a geologic column for Missouri, in which a number of new stratigraphic units are named. Among these are the Davis, Derby and Doerun (Elvins of Ulrich and Bain) and also the Eminence. No descriptions accompany this table. The following year Buckley[4] described the first three formations in detail, and mentioned the Eminence[5] saying that it has been recognized above the Potosi in Shannon County, by Ulrich, but that he personally was not familiar with it.

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[1]Nason, F. L., on the presence of a limestone conglomerate in the lead region of St. Francois County, Mo., Amer. Jour. Sci., 4th ser., Vol. 11, 1901, p. 396. See also,

Nason, F. L., The geological relations and age of the St. Joseph and Potosi Limestones of St. Francois County, Mo., Amer. Jour. Sci., 4th ser., Vol. 12, 1901, pp. 358-61.

[2]Ulrich, E. O., and Bain, H. Foster, The Copper Deposits of Missouri, Bull. U. S. Geol. Survey, No. 267, 1905, p. 12.

[3]Buckley, E. R., The Lead and Zinc Resources of Missouri, Amer. Min. Congress, Proc. 10th Ann. Session, 1907, p. 286.

[4]Buckley, E. R., Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties, Mo., Bur. Geol. and Mines, Vol. IX, Pt. 1, 2nd ser., 1908, pp. 33-49.

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

The first description of the Eminence was given by Ulrich[1] in 1911, and is as follows:

"*Eminence Chert*—This is the proposed name of a very cherty dolomite that rests, apparently unconformably, on the Potosi, or overlaps that formation and then usually comes into contact with the pre-Cambrian formations. Above, it is limited by the base of the Proctor dolomite, the interval between the top and bottom being not less than 200 feet in Shannon County. The Eminence is widely distributed in Missouri, being especially well displayed in the valleys of Carter and Reynolds counties which adjoin Shannon on the east. It comes to the surface also in some of the deep valleys near the Osage, in the northern part of Camden and the southern part of Morgan counties. Though of varying kinds, a large proportion of the chert of this formation is white and dense and much of it is fossiliferous. Many species have been collected and most of them are well marked and characteristic of the formation. They comprise several species of umbilicated Holopea-like gastropods, which, having a deeply notched outer lip, I am referring to the new genus *Sinuopea*.[2] *Holopea sweeti* Whitfield is a congeneric species. Another of the more striking gastropods is a large trochoid shell which also belongs to an undescribed genus. Among the cephalopods are three species reminding of *Piloceras* and one or two of *Cyrtocerina*. Associated with the mollusca are a few trilobites—*Dikellocephalus* and *Illaenurus*, the latter apparently being confined to the Eminence in Missouri.

Characteristic species of the Eminence fauna have been found at a number of localities in Alabama and Tennessee, and near Lexington, Virginia, in the Lower part of the Copper Ridge division of the Knox; also in the lower part of the Oneota dolomite in the upper Mississippi Valley, and at Beauharnois, near Montreal, Canada. Judging from these occurrences, the Ozarkian continental seas attained their maximum continental distribution at this time."

In 1912 Ulrich prepared a set of plates illustrating the most characteristic species of the Eminence and other formations of his proposed Ozarkian and Canadian systems, and distributed a few copies of them among those who were working in this field.

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[1]Ulrich, E. O., Revision of the Paleozoic Systems, Bull. Geol. Soc. Amer., Vol. XXII, 1911, pp. 630-1.

[2]Later divided into *Sinuopea* and *Taeniospira*, the latter the common Eminence form. J. B.

The original description of the formation as published in the Revision, and the plates were based upon preliminary studies, and were never intended to be regarded as final. They both contained certain errors, due largely to the fact that the occurrence of fossils in residual cherts is apt to result in mixed faunas.

These have since been recognized and corrected by Ulrich.

Other Missouri reports make brief mention of the Eminence.[1]

St. Clair[2] studied the section in western Ste. Genevieve County, and concluded that the lower or typical Eminence was not represented in his area, but that the "Upper Eminence" of Ulrich was present in the form of residual boulders. At the time that his field studies were made, (1913-15) little was known of the formation and recently Dake[3] has shown that the typical Eminence formation is well developed in the area studied by St. Clair. Branson[4] described the formation briefly, and concluded that further studies may prove it to be the equivalent of the Proctor. Tarr[5] refers the formation between the Gasconade and Potosi formations in Washington County to the Proctor, from its great resemblance to the typical Proctor of Morgan and Camden counties, but Dake[6] has shown that the formation Tarr described is abundantly fossiliferous, and is to be unquestionably correlated with the Eminence of Shannon County.

Scope of the formation. As defined by Ulrich[7] the Eminence rests upon the Potosi dolomite, and is overlain by either the Proctor or the Van Buren formation. In the Eminence region the Proctor has not been recognized by the writer, and if present has been mapped with the Eminence. Ulrich[8] claims that the Proctor is present locally, though much reduced in thickness. McQueen[9] has recognized a difference between the insoluble residues from the upper and lower portions of the formation in

[1]Dake, C. L., The Sand and Gravel Resources of Missouri, Mo. Bur. Geol. and Mines, Vol. XV, 2nd ser., 1918, pp. 89 and 91; also Wilson, M. E., The Occurrence of Oil and Gas in Missouri, Mo. Bur. Geol. and Mines, Vol. XVI, 2nd ser., 1922, pp. 39-40.

[2]Weller, Stuart, and St. Clair, Stuart, Geology of Ste. Genevieve County, Mo., Bur. Geol. and Mines, Vol. XXII, 2nd ser., 1928, p. 58.

[3]Dake, C. L., op cit., p. 132.

[4]Branson, E. B., Geology of Missouri, Univ. of Mo., Bull., Vol. 19, No. 15, 1918, p. 49.

[5]Tarr, W. A., The Barite Deposits of Missouri and the Geology of the Barite District, The Univ. of Mo. Studies (Sci. ser.), Vol. III, No. 1 (1916).

[6]Dake, C. L., Geol. of the Potosi-Edgehill Area, Mo. Bur. Geol. and Mines, Vol. XXIII, 1930, p. 135.

[7]Ulrich, E. O., op. cit.

[8]All references to Ulrich in which no publication is cited are to be construed as personal communications.

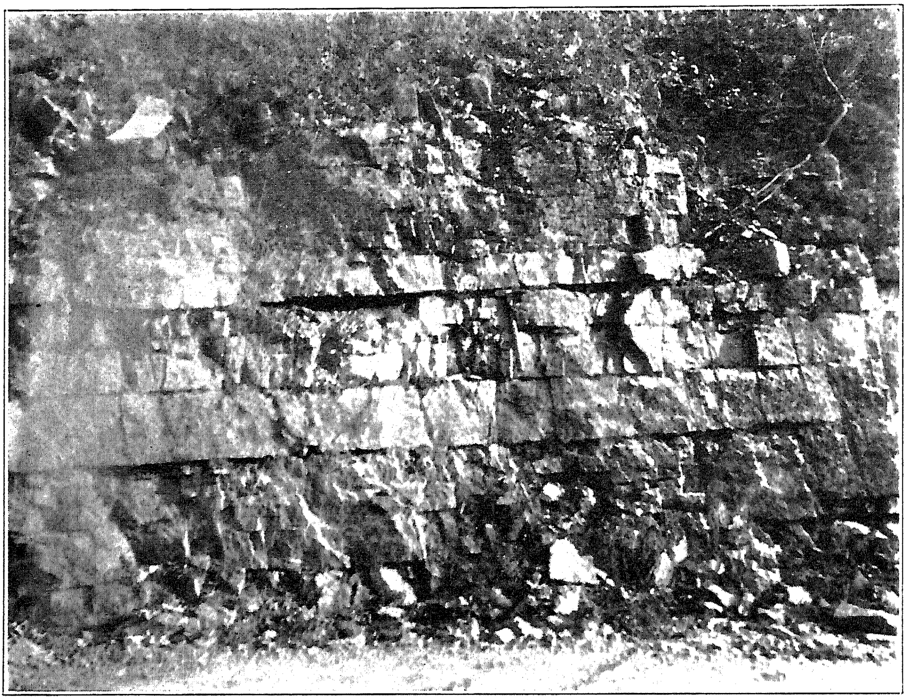
[9]McQueen, H. S., Insoluble Residues as a Guide to Stratigraphic Studies, Mo. Bur. Geol. and Mines, 56th Biennial Rept., Appendix 1, p. 18, 1931, *p* reprint, 1929.

the southern portion of the state, and has suggested that this upper portion, varying from 30 to 100 feet in thickness be correlated with the Proctor. In some cases it is known that these Proctor-like residues occur below the *Plethopeltis* zone and are therefore, in part at least to be classed as Eminence. This similarity serves to strengthen the idea of the close relationship of the two formations.

In this area the overlying formation in all cases is the Gunter sandstone member of the Van Buren.

Areal distribution. The Eminence dolomite is found along Current River and its tributaries from near Akers Post Office in northwestern Shannon County, to a point some 5 or 6 miles south of Chilton in Carter County. It outcrops along Jacks Fork and its tributaries from the junction with Current River to a point a few miles west of Eminence. It also occurs in the valleys of all the drainage systems radiating from the St. Francois Mountains, although it thins and disappears entirely in the central portion of these mountains. The most northerly point in the state at which the formation is found at the surface is in the valley of the Meramec River near Morrelton (Anaconda) in Franklin County. The most southern exposures are those south of Chilton. The easternmost outcrops are in the central portion of Ste. Genevieve County, while the most westerly point from which the characteristic Eminence fauna has been collected is at Wesco, in Crawford County. The formation outcrops over an area measuring approximately 100 miles in a north-south direction, by 70 miles in an east-west direction. It has been encountered in deep wells throughout most of the Ozark area and may come to the surface again in Morgan and Camden Counties. It appears to be missing in the area immediately north of St. Louis, and does not appear to have extended much farther north, as there is no trace of the formation or of its characteristic faunas in the sections in the upper Mississippi Valley. In the Eminence region it is exposed over about ¼ of the total area.

Thickness. The maximum exposed thickness of the Eminence in this area is 250 feet and its average is about 200 feet. Where it overlaps onto the pre-Cambrian it may be much thinner, due to the failure of some of the lower beds to be deposited. The top of the formation is an old erosion surface, and in some localities a considerable portion of the upper strata are missing. It thickens toward the center of the basins



A. Section of Van Buren formation exposed on U. S. Highway 60 (temporary) about two miles east of Fremont, Carter Co., showing the thin band of siliceous oolite (just above the hammer) which has been mapped as the upper boundary of the Van Buren.

B. Section exposed on State highway 19 about 1.5 miles north of Eminence, showing the Gunter sandstone member of the Van Buren. The section page was measured at this exposure and at the one immediately east of it.

between the porphyry knobs as is shown by the log of the drill hole at the Casey Mine which penetrated 310 feet of strata referable to it.[1] (see appendix).

Lithologic character. In its unweathered condition the Eminence formation is composed almost entirely of magnesian limestones, with very small amounts of sandstone and shale. The rock is rather massively bedded, the individual beds ranging from 6 inches to 3 feet or more in thickness, the beds becoming more massive toward the base.

In general, the bedding planes are more numerous and better developed than in the underlying Potosi, but they are not as numerous nor as well developed as those in the overlying Van Buren. Thin-bedded, fine-grained dolomites such as are common in the base of the Van Buren, have not been observed in the Eminence.

Freshly broken surfaces of the unweathered rock are commonly a light, bright gray in color, although certain beds show red, pink and greenish mottlings. Where the rock has been somewhat weathered, freshly broken surfaces often show an irregular yellow mottling due to unequal oxidation, and which appears to indicate certain structural differences not apparent in the unweathered rock.

Exposed surfaces weather to a dull neutral or bluish gray tint, indistinguishable from the color of other weathered dolomites in the area. Where somewhat protected, as for example the under surfaces of overhanging ledges and cliffs, the rocks commonly show cream, buff and reddish tints.

The texture is medium to coarsely crystalline and closely resembles the Bonneterre. It is more coarsely crystalline than the Potosi, Van Buren or Gasconade. Its light color and coarse texture distinguish it from the dark colored, more finely crystalline Potosi. It is more difficult to distinguish from the Van Buren and Gasconade dolomites, but in general it appears to be more coarsely crystalline and not as well bedded as are the rocks of those formations.

Partings of green shale, rarely more than a fraction of an inch in thickness, are fairly common, especially in the upper portion of the formation, but are seldom observed except in fresh exposures and drill cuttings.

Many of the layers of dolomite contain scattered sand grains and at some localities there are thin non-persistent lenses

[1]Correlation by McQueen, Mo. Bur. Geol. and Mines.

of calcareous sandstone. On U. S. Highway No. 60 about 1.7 miles west of Van Buren, two thin beds of sandstone less than a foot in thickness are exposed in the road ditch, on the west slope of the hill. They are about 40 feet below the top of the formation, and appear to be local. In some localities this sandy zone contains an intraformational conglomerate. It has been observed in the unweathered condition in but a single locality, in the bed of a small creek at an elevation of about 730 feet, in the center of the NW. ¼ sec. 6, T. 28 N., R. 2 W., but chert which is thought to have been derived from this horizon is widely distributed throughout the area in which the formation outcrops.

This conglomerate is composed of circular or oval, flattened pebbles of fine-grained argillaceous dolomite in a matrix of dolomitic sandstone. The individual pebbles vary from 3 to 40 millimeters in diameter, and from 1.5 to 15 millimeters in thickness. The edges are commonly rounded, and some of the smaller pebbles are subspherical. Many of them show bedding parallel to the long diameter, and for the most part they lie with this diameter parallel to the bedding of the matrix. In some specimens, however, the pebbles are heaped in an irregular fashion and constitute a true edgewise conglomerate.

Thin beds of siliceous oolite occur at many horizons, but like the sandstones they are local in their development. One such bed was noted in situ in the cut at the south end of the bridge across Jacks Fork, near Eminence, but it does not appear to be continuous. At this locality it is nearly 100 feet below the top of the formation. Small blocks of deeply iron stained, fossiliferous oolite, have been found at many other localities. They seem to be more abundant near the top of the formation. Siliceous oolite is extremely common in the Eminence and overlying formations, but is rare or absent in the Potosi and Bonneterre.

The Eminence is very much a lithologic unit from top to bottom, and there are no distinctive beds in it which can be used as horizon markers. This makes it difficult to determine how much is missing from the top of any particular section, due to erosion or to non-deposition, and also how much has been lost from the base by overlap.

The following section, measured on the south face of Council Hill, in the NE. ¼ NE. ¼, sec. 27, and the SE. ¼ SE. ¼ sec. 22, T. 29 N., R. 4 W., will serve to give a general idea of the formation. The entire section is given in order that the Eminence may be contrasted with the over and underlying strata.

Section measured on the south slope of Council Hill, on a north-south line through the center of the NE. ¼ sec. 27 and the SE. ¼ sec. 22, T. 29 N., R. 4 W., from Jacks Fork to the south summit of the hill.

Measured by J. Bridge and E. T. Campbell.

	Thickness Feet.	Thickness Inches.
Top of Hill		
Gasconade formation. Elevation 1025 ft.		
Residual cherts, dense, china white, in small fragments, no ledges of rock exposed, on top of the hill are a few large blocks of rusty, porous, ropy chert, containing Gasconade fossils, a few fossils found on the slope	60	
Dolomite, medium to coarsely crystalline, light gray on freshly broken surfaces, dull lead gray when weathered. Weathers to rough, step-like ledges, but not into pinnacles. Grades laterally into dense white cherts, similar to the preceding	35	
Total Gasconade	95	
Van Buren Formation.		
Dolomite, fine-grained, very light gray on freshly broken surfaces, weathered surfaces darker, but not as dark as preceding, weathers to smooth surfaces in sharp contrast with the preceding, yields no chert upon weathering, a typical "Cotton Rock"	10	
Siliceous oolite, a narrow band of dense white oolitic chert		6-8
Dolomite, another cotton rock similar in all respects to the rock above the oolite	5	
Covered interval—hillside strewn with chert, similar to that of the overlying beds, fossiliferous toward the base—The Van Buren fauna of Ulrich	38	
Ropy, porous, drusy chert in loose blocks	4	
Total—Dolomite Member	57	6
Gunter Sandstone Member:		
White sandstone, rusty brown when weathered poorly exposed		6
Covered interval	3	
Dolomite, finely crystalline, dark gray, weathers rough	1	
Dolomite, fine-grained, light gray, weathers smooth, similar to the cotton rock ledges	2	
Covered interval	3	
Calcareous sandstone, well rounded and frosted sand grains in a matrix of coarse-grained dolomite, grading downward into hard white sandstone, the basal layers of which contain a fine conglomerate of small rounded chert pebbles	2	6
Base of this sandstone at 860 feet.		
Total—Gunter Member	12	
Total—Van Buren	69	6
Eminence Dolomite:		
Dolomite, medium to coarsely crystalline, light gray on freshly fractured surfaces. Dull lead gray on weathered surfaces. Beds from 1 to 3 feet thick. Vertical joints well developed. Weathering breaks the rock into a mass of rough, jagged pinnacles the height of which is controlled by spacing of the bedding planes. Very small stringers of fine, porous white chert developed on weathered surfaces, section mostly covered by float from the overlying Gunter, Van Buren and Gasconade, very little of the float on the ledges of the cliff indigenous to this formation	30	
Dolomite, similar in all respects to the preceding, when traced laterally along the outcrop to the east, breaks down into rusty, porous, ropy cherts, carrying a large fauna characterized by *Taeniospira eminencensis*, Ulrich and Bridge *Plethopeltis*, and many other forms (Locality 98.15). This type of chert is produced by both the over and underlying beds, but is poorly exposed along the line of the section	2	

	Thickness Feet.	Inches.
Dolomite, similar to the preceding, outcropping in pinnacled ledges, from 3 to 6 feet in height. Chert sparingly developed along the line of the section, but abundant in the fields to the east........	108	
(Road level, the key point in the section, Elev. 720 ft. Section described above starts up the hill on sharp bend in the road, just before main road descends steep hill to west. Beds essentially horizontal. Lower part of section is 200 feet east of this point.)		
Dolomite, moderately crystalline, light gray on freshly fractured surfaces, medium gray on weathered surfaces, weathers into pinnacles which are fairly smooth and rounded. Individual beds from 1 to 2 feet thick. Very little chert developed, small quartz druses resembling Potosi druses rare. Transition beds.........	45	
Total Eminence....................................	185	
Potosi Dolomite:		
Dolomite, fine to medium crystalline, dense, bright light gray in color, becoming pale brown toward the base, weathered surfaces light gray, bedding obsecure, only shown on weathered surfaces, little or no chert developed, shows small banded quartz druses at many horizons. Lower 5 or 6 feet of section covered by talus........	35	
River level elevation 640 feet.		

Apparently the full thickness of the formation is not present at this point. On the west face of Cardareva Mountain, in sec. 36, T. 29 N., R. 2 W., the following generalized section was measured.

Generalized section on the west face of Cardareva Mountain, sec. 36, T. 29 N., R. 2 W.

Measured by J. Bridge and R. Mabrey.

	Thickness feet.
Top of Hill, Elev. 1060.	
Roubidoux formation, represented by residual material.	
Gasconade and Van Buren formations, represented mostly by residual material..	200
Gunter sandstone member:	
Massive white sandstone, in beds from a few inches to 1 ft. thick, weathers rusty, well exposed along the face of the mountain.......	15
Eminence dolomite:	
Massive dolomite, light gray on fresh surfaces, dull gray on weathered surfaces, beds from 2 to 5 ft. thick. Weathers into rough pinnacles.	260
Becomes more massive toward the base and grades downward into	
Potosi Dolomite:	
Finely crystalline, light to dark chocolate-brown, massive bedded dolomite, with small quartz druses................................	50
Alluvium..	10–15
River level Elev. 520 ft.	

Topographic expression. In the bottoms of the larger valleys the formation commonly outcrops in bold mural cliffs, some of which overhang the river or road at their base, and form some of the finest scenic features in this area. Many of these cliffs raise for 100 feet or more sheer above their base, and then break off into a more gentle slope at or near the contact with the overlying Van Buren. One of the most spectacular of these is Bee Bluff (Pl. V-A) just north of Mill Creek, in sec. 32, T. 30 N., R. 3 W., which rises as a sheer cliff for 200 feet above the river.

Another is the great cliff at the mouth of Powder Mill Creek, in which over 200 feet of Eminence is exposed. Others occur at Conway Bend, (NW. portion of sec. 6, T. 29 N., R. 3 W.); at Taylor's Hole, just above the mouth of Cave Hollow, on the southeastern spur of Blair Creek Mountain, (sec. 13, T. 29 N., R. 3 W.); along Jacks Fork between Lick Log Hollow and the Junction; and at various points along Current River throughout its entire course in this region.

The faces of these cliffs are smooth, or but slightly pitted, and bedding planes are not prominent. Certain layers, particularly those in the lower portion of the formation often contain numerous small, narrow, slightly curved slot-like cavities, which are for the most part arranged parallel to the bedding planes. They appear to indicate certain structural differences in the rock, and may be due to the presence of Cryptozoons, which have begun to weather into relief, but which have not developed far enough to show the forms characteristic of these organisms.

As the formation weathers, the bedding and joint planes become prominent and each bed is divided into a series of rough, jagged pinnacles, which rise in tiers one rank above another as the cliff face recedes. A splendid example of this terraced, pinnacled phase is found on the south slope of Council Hill, west of the point where the section was measured. As weathering proceeds and the slopes become more gentle, the terrace effect is largely lost and the entire hillside becomes covered with a mass of pinnacles or "niggerheads." In the lower 40 or 50 feet of the formation, these knobs are smooth and rounded, and resemble those developed in the Potosi dolomite, but throughout the remainder of the section the unequal hardness of the limestone results in selective solution, and the surfaces are roughened and pitted, by rudely spherical hollows, which give them a characteristic jagged appearance not found in any other formation in this area. This phase may be seen at many places, but is especially well developed on the east side of state highway 19 (temporary) about 4 miles southeast of Eminence between the highway and Big Shawnee Creek.

Characteristic exposures occur at many points, and they have been observed in the Eminence dolomite in every area in which it has been found. They are also characteristic of the Proctor dolomite in Morgan and Camden counties. Within the Eminence region some of the best examples are to be found on the south face of Council Hill on the slopes northeast of West

Eminence; along Highway No. 19 at various places between Eminence and the Sutton Mine, but particularly in the vicinity of the porphyry exposures in Big Shawnee Creek; and along the divide between the Shawnee creeks in Sec. 30, T. 29 N., R. 3 W. An exceptionally large and fine development of them is exposed on U. S. Highway No. 60 at the top of the first hill southwest of Van Buren.

Plate XI-B illustrates their general characteristics.

The formation is readily soluble, and solution is naturally most active along joint and bedding planes. As both of these are rather widely spaced, the solution process is strongly localized, and this tends to produce caves and a well developed system of subterranean drainage. Because of its topographic position in the bottoms of the larger valleys, a portion of the formation is below the water table, and much of this subterranean drainage again comes to the surface in the form of springs. All of the large springs of the region, with the single exception of Alley Spring, issue from this formation, and it contains more springs than all of the other formations in the area. Most of the large caves of the region also occur in the Eminence.

Chert. Where conditions of weathering are favorable the formation yields an abundance of chert. Free silica, in particles large enough to be seen with the unaided eye, or even with a hand lens, are extremely rare on fresh exposures, and drill cuttings from the unweathered rock show little or no siliceous matter to the casual observer. However, when samples of the unweathered rock are dissolved in hydrochloric acid, a fine residue of colloidal silica is almost invariably obtained, and this is probably the nucleus about which the cherts are formed. Whether a rock will form chert during the process of weathering or not appears to depend in part upon the original nature of the rock, and in part upon the speed of weathering and the topographic slope. Certain dolomite layers in this region produce no chert whatever under any circumstances, and in some of these at least, the siliceous residues (skeletons) referred to are present. Under certain conditions, practically all of the horizons of the Eminence produce a heavy chert residue upon weathering. In regard to the speed of weathering Ulrich[1] says: "In the erosion of dolomites at a rate rapid enough to form bluffs, the segregation of silica in the form of chert is slight, or fails entirely, whereas the same beds weathering slowly on gentle slopes or flats commonly

[1]Ulrich, E. O., Letter dated June 28, 1922.

produced a large amount of chert, providing of course, that the beds concerned are of the chert producing kind." The truth of this statement has been verified in many instances. Where the Eminence is exposed in vertical bluffs, chert is entirely absent or inconspicuous. As weathering proceeds the chert makes its appearance in the form of small, jagged, irregular segregations. These are white or yellowish white in color and are for the most part soft, mealy and very porous. They adhere tightly to the unweathered rock, but do not penetrate deeply into it, for if a thin chip containing one of these segregations is broken off the freshly fractured surface shows no trace of chert. In rare instances the fossils silicify first and thus stand out sharply from the remainder of the rock. This is particularly true of some of the uppermost layers of the Eminence and is quite common at certain localities in the Proctor.

Shepard[1] has noted the secondary silicification of some of the dolomites of the Ozarks and comments as follows: "This replacement of dolomite by chert seems to have been especially marked above and below the sandstone horizons,—so much so as to make it very difficult to separate the Moreau (Roubidoux Sandstone) from the Gasconade limestone below, and the Gasconade limestone from the Gunter sandstone, by which it is underlain, for the reason that the Gasconade limestone merges, through massive chert beds, into the sandstone horizons above and below." * * * * "It will be noted that this special chert replacement predominates along the main line of water flow on both sides of the sandstone horizons."

He invoked the aid of thermal waters to account for the replacement in this particular instance, but the same process seems to take place in areas where such solutions are not available.

It seems that much of the chert of the Eminence formation is of secondary origin, and this statement applies with equal force to the cherts formed by the weathering of the other formations within the Ozarks.

Cherts are distinctive in their general appearance. Their form and texture are closely related to their internal structure, and this, as McQueen has shown, is closely related to the rock from which they are derived. They therefore constitute an important lithologic criterion, and may be used as an aid in

[1]Shepard, E. M., Springs of the Decaturville Dome, Missouri Geol. Survey, Water Supply Paper 110, 1905, pp. 124-25.

separating formations, after the general types occurring in each have been studied and contrasted. It has been found that in many cases dolomites which are extremely difficult to distinguish from one another by means of samples of unweathered rock, yield cherts which are strikingly different, and constant in their characteristics.

Ulrich has recognized and employed this principle for many years not only in the Ozark region, but also in other areas of Cambro-Ordovician rocks in North America. The geologists of the Missouri Survey have also made extensive use of this principle, and recently McQueen has applied it with great success to the siliceous residues obtained from well cuttings, throughout the state.

Much of the Eminence chert, particularly that occurring in the lower portion of the formation is massive, hard, vitreous, white or translucent, and forms in large masses, a foot or more in diameter. The slightly weathered phases are white, cream or light buff in color, and have a tripolitic texture. The color deepens and the texture becomes coarser as weathering proceeds and the final product is a dark red or reddish-brown, coarse spongy chert, which greatly resembles the cherts derived from the Potosi, In many instances, cavities in the chert are coated with small quartz crystals, but the banded, chalcedonic druses which characterize the Potosi are conspicuously absent.

The absence of these druses is one of the best distinctions between the deeply weathered residual material of the Eminence and Potosi formations, and the dead, rusty, porous appearance of the chert serves to distinguish it from much of that of the succeeding formations. This chert is often highly fossiliferous, and in localities where it is only moderately weathered the fossils are often beautifully preserved, as for example in the cuts along state highway 19, (temporary) about four miles southeast of Eminence in the NE. ¼ SE. ¼ NE ¼ sec. 12, T. 28 N., R. 4 W., (locality 98.4).

In the upper portion of the formation some of the chert has a ropy, anastomosing texture, which at first sight, is much like that occurring in upper portion of the Gasconade.

Closer study shows interesting differences between them. (Plate XIII). Both are plainly the result of selective silicification, but the Eminence form seems to represent the replacement of the matrix surrounding irregularly branching and anastomosing tubes, while in the Gasconade form, the tubes themselves are commonly silicified while the surrounding portion of the rock has been leached away. The Eminence type may be studied in all its phases on the tip of the hill just east of Eminence, and again on Council Hill a mile or so northwest of the town. It is thought that this selective silicification is due, in part at least, to a difference in the structure of the rock, and this point is more fully discussed in the description of the Gasconade cherts. As weathering proceeds, the chert masses increase in size, join together and penetrate the rock more deeply. They also acquire a reddish brown tint on the surface, due to staining by limonite, and in the final stages this staining penetrates the entire mass. When all of the soluble materials have been removed, the hillsides are strewn with blocks of light, porous, reddish and rusty-brown cherts. The masses are commonly less than a foot in diameter, though in some instances they are much larger.

The entire transition from dolomite to chert may be traced out along a hillside in any number of cases. An especially good example may be seen on Council Hill, a mile northwest of Eminence. Here the southwest face of the hill contains practically no chert, while on the southeast face less than a quarter of a mile away there are practically no outcrops of dolomite at the same horizons, but cherts are abundant. Similar examples may be found in almost any locality where the formation is exposed.

Siliceous oolite is fairly common at various horizons within the formation, and blocks of this material often contain small silicified fossils. Near the base of the formation the cherts often contain small smooth flattened ovoid pellets, sometimes in such great numbers as to make it appear conglomeritic.

Black varieties of the type noted by Dake[1] in the Potosi region are rare, but have been observed at a few places.

Much of the dense, white, vitreous chert, mentioned by Ulrich in his original description of the formation is now known to come from the overlying Van Buren.

In many localities a peculiar variety occurs near the top of the formation. It is believed to be the silicified matrix of the intraformational conglomerate described on page 82, from which the soft pebbles have been leached. It consists of a mass of platy chert, perforated by thin slot-like openings from 15 to 40 millimeters long and from 3 to 15 millimeters thick. These openings are about as wide as long, and have rounded edges; in

[1]Dake, C. L., op. cit., p. 125.

size and shape and arrangement in the matrix they greatly resemble the conglomerate. Like the other residual products of the Eminence, it is stained various shades of gray, brown and dull red.

It is abundant in the form of boulders on the hilltop in the SW. corner of sec. 36, T. 29 N., R. 4 W., and along the ridges to the east of it, and they have been observed at many other localities, not only in the Eminence area, but elsewhere throughout the Ozark region. This variety has been figured by Dake.

The residual soils developed on the Eminence formation are commonly deep red in color, very much like those of the Potosi, but in most cases somewhat lighter in color. This affords another rough means of distinguishing the Eminence from the formations which immediately succeed it, for the soils developed on the latter are commonly yellowish and much lighter and this distinction holds good over much of the Ozark region.

Stratigraphic relations. The Eminence-Potosi contact has been described in the section devoted to the older formation. Where it overlaps the Potosi and rests upon the pre-Cambrian, the characteristic basal conglomerates are commonly developed, and the formation thins somewhat. This is due to the failure of the lower beds to be deposited over the tops of the higher porphyry knobs, and also to the thinning and wedging out of individual beds throughout the thickness of the formation. Throughout the Eminence region the formation is overlain unconformably by the Gunter sandstone member of the Van Buren formation. This unconformity is not conspicuous, and is difficult to detect in exposures within the area, and were it not for the thin but nevertheless persistent basal conglomerate, of small rounded and waterworn chert pebbles, in the base of the Gunter its presence would not ordinarily be suspected. Closer study, however, reveals the fact that the thickness of the Eminence varies from place to place, and while part of this variation is due to the overlap against the porphyry, still more of it is due to the absence of some of the upper strata. Whether this is due to non-deposition or to removal of strata, is not clear. This variation is difficult to observe in the Eminence region, because of the great similarity of the formation from top to bottom, and because of the lack of contrasting lithologic horizons which would serve as markers. It is proved however, by the fact that a given fossil horizon appears at different distances below the top of the formation, and in many places the uppermost faunal zones are entirely missing.

The most striking example of the unconformity in the Eminence region is to be found in the exposures on the north face of Stegall Mountain, in the NE. 1/4 sec. 24, T. 28 N., R. 3 W., in the small east west ravine which marks the contact between the pre-Cambrian rocks and the sediments. About 150 yards west of the turn in the creek, a heavy sandstone, containing porphyry pebbles several inches in diameter outcrops in the bed of the creek. It rests on the porphyry, and south bank of the creek is a great porphyry slope. The north bank is much steeper and is composed of sedimentary formations. Directly north of this exposure, and about 10 feet above the bed of the creek are outcrops of sandstone. These may be traced along the hillside to the west for nearly a quarter of a mile, and finally rise and pass over the saddle into the next valley without coming in contact with the pre-Cambrian. Above this is the characteristic drusy layer of the lower Van Buren, and the rocks below it, though not well exposed appear to belong to the Eminence formation. About 200 yards west of this first exposure, the sandstone bed is about 20 feet above the creek, and a fairly complete section of the Van Buren formation up to the oolite bed, occurs above it. This 60 feet contains a great profusion of porphyry pebbles, most of which are not in contact with one another. (See Plate X-A.)

Although the Van Buren formation comes to within 10 or 15 feet of the porphyry in many other cases, this is the only place known in the entire area where it contains materials derived from the pre-Cambrian, and evidence is presented in another chapter to show that the Eminence formation completely covered the porphyries. Furthermore, the elevation of the Gunter in the creek bed at this point is only 840 feet above sea level, and there are dozens of places in the area where the Eminence-Van Buren contact is well above 900 feet and in a few instances it has been found at even higher elevations. It is believed that during the post-Eminence, pre-Van Buren interval, erosion cut down to the porphyry at this one locality, thus allowing the formation of a conglomerate in the Van Buren. Fig. 8 illustrates the stages in the formation of the conglomerate at this point.

This unconformity is much better developed in other sections of the Ozarks. Dake[1] has shown that the Eminence is absent from large areas in the center of the St. Francois Mountains and that in these places the Gasconade or Van Buren formation rests unconformably upon the Potosi and upon all older formations down to the pre-Cambrian. There was faulting in this area during this period of erosion, as is shown by the fact that in the Potosi quadrangle the Eminence is present in full thickness north of the Palmer fault, and completely absent south of it, except where it is preserved in down-faulted blocks. The same situation is also believed to occur along the Scotia fault, south of the point where it crosses the Palmer fault. Within the angle formed to the southeast of these two faults, the Eminence is almost entirely missing, and the Van Buren and Gasconade rest upon the older formations. On the opposite sides of these faults the Van Buren rests upon a thick section of Eminence, and it is quite evident that the central block, which contains the main mass of the St. Francois Mountains was lifted in late Eminence time or in post-Eminence—pre-Van Buren time and profoundly eroded before the Van Buren was deposited.

Summing up the physical evidence it appears that the break between the Eminence-Proctor series and the overlying Van Buren-Gasconade is marked in Missouri by uplift and erosion, accompanied locally by faulting and that it is a break of considerable magnitude.

The paleontological evidence for the break is not as conclusive, and would seem to indicate that the break, though well marked, was of short duration. The Proctor fauna is the youngest fauna known to occur below the break, and the fauna of the Van Buren member of the Gasconade is the first to occur above it. The former is a residual fauna, directly derived from the Eminence faunas; the latter, though related in many ways to the Proctor, carries new elements which denote an invasion of the sea from some new source. As yet, however, no fauna has been found which is known to intervene between these two.

In other parts of North America, however, the physical and paleontologic evidence of the hiatus is as great, or more commonly, much greater than that which is exhibited in Missouri.

Ulrich's recent separation of the Arbuckle limestone into a number of formations shows that this break exists in both the

[1]Dake, C. L., op. cit., page 121.

Arbuckle and Wichita mountain sections of Oklahoma; and that in both areas the time interval of the break is as great or greater than in Missouri.

In southern Wisconsin the Oneota dolomite which is the equivalent of the Gasconade as now restricted, rests upon the Madison sandstone, which Ulrich tentatively correlates with the lower portion of the Eminence. Thus the minimum time interval in this area is equal to most of the Eminence, all of the Proctor and Van Buren and to perhaps a part of the Gasconade, and is therefore, much greater than in Missouri.

In the southern Appalachian region, the Copper Ridge dolomite which is most nearly the equivalent of the Van Buren of Missouri[1] rests upon a number of different formations. At a few localities, these underlying beds may be as young as the Eminence, but in most instances they are older.

In Pennsylvania and New York, beds equivalent to the Van Buren appear to be wanting, and a thin horizon which corresponds to one of the upper zones of the Gasconade rests upon horizons of Eminence and pre-Eminence age at various localities.

In Wisconsin and Minnesota, the physical evidence of the break is conspicuous, and it has long been used as the boundary between the Cambrian and Ordovician periods. In Oklahoma the break comes somewhere in a thick, sparingly fossiliferous limestone, the Arbuckle; while in the southern Appalachians a similar situation was found in the Knox dolomite, and as these were extremely difficult to subdivide they were classed as "Cambro-Ordovician."

In Missouri, the entire pre-St. Peter series has been variously classified. At times it has all been referred to the Cambrian and at other times the greater portion of it has been classed as Cambro-Ordovician. On the recent editions of the State Geological map the separation between the Cambrian and Ordovician has been drawn at the top of the Gasconade dolomite; but in this report the Gasconade and Van Buren have also been included in the Ordovician.

Paleontology. The Eminence formation is abundantly fossiliferous. Fossils are almost invariably preserved in the cherts derived from the weathering of the formation, and are practically never found in the unweathered limestones. In rare instances

[1]According to Ulrich the Copper Ridge probably includes the Proctor of Missouri.

the fossiliferous cherts are practically in place, as for example at locality 98.15 one mile northwest of Eminence, where such a stratum may be traced for about a hundred yards along the hillside. Another locality from which fossils have been obtained in place (98.16) is on the north point of the hill just east of Eminence, and a third locality of this sort (98.14) is on Paint Creek in the Cardareva quadrangle. At this last named point silicification is far from complete and fossils have been collected from cherts which still adhere to the limestone ledges. These occurrences are of the utmost importance, for they furnish definite information as to the stratigraphic position of the fauna; information which can only be inferred from faunas obtained from purely residual materials.

The majority of collections must be made from boulders scattered over the hillsides, and it must always be realized that in making such collections the chances of obtaining mixed faunas are very good. The collector must learn to recognize the type of chert commonly produced by the formation from which he is collecting, and must be constantly on the lookout for cherts which have slumped down from overlying formations.

In his original descriptions of the formations, Ulrich recognized a lower and an Upper Eminence fauna, but the present studies have shown that the Upper Eminence fauna actually occurs in the base of the overlying Van Buren formation. Most of the correlations made in Ulrich's original description, quoted on page 78 were based upon this upper fauna. Ulrich has long since corrected this statement, and his present Eminence fauna includes only that which was originally termed the Lower Eminence and it is much more restricted in its geographic distribution than the original description of the formation would indicate.

The Eminence fauna consists predominantly of trilobites and gastropods. The trilobites are similar and closely related to forms occurring in the older formations and formerly many of them were placed in genera which are now restricted to older formations. The careful discriminating work of Ulrich and his associates have shown that practically all of these forms are generically distinct from the forms in the older strata, though plainly derived from them. Very few gastropods occur in the older strata, and the presence of these forms in abundance in the Eminence faunas serves as a ready means of distinguishing them from the older faunas. They represent a new element, and directly foreshadow Ordovician forms. It is largely because of this conflicting faunal testimony: trilobites with definite Cambrian affinities associated with gastropods with Ordovician relationships. that Ulrich has advocated the establishment of the Ozarkian system.

Brachiopods, chiefly Billingsellidae, Pteropods, and Chitons make up the remainder of the invertebrate fauna, while plants are represented by various forms of the problematical line secreting algae, commonly termed *Cryptozoa*.

At least two well defined faunal zones may be recognized. The main zone apparently occurs about 75 to 100 feet below the top of the formation, but may be nearer to it because of the failure of the upper beds to be present. It is a zone of considerable thickness, and while the fauna is most abundant in the upper layers elements of it are found throughout the lower two-thirds of the formation. With more careful study it may be possible to still further subdivide this zone. It is characterized by the presence of *Calvinella*, *Acheilus*, *Acheilops*, *Euptychaspis*, *Triarthropsis*, *Plethometopus* and other genera of trilobites, and by several genera of gastropods, chiefly, *Scaevogyra*, *Matherella*, *Pelagiella*, and *Dirachopea*. Brachiopods belonging to the genus *Finkelnburgia* are locally abundant, while the Pteropods are represented by *Hyolithes*, *Hemitheca* and the peculiar form *Matthevia*, originally described by Walcott from the Hoyt limestone of New York. This zone is well exposed in road cuts on State Highway 19, (temporary) about four miles southeast of Eminence, in the NE. ¼ SE. ¼ NE. ¼ sec. 12, T. 28 N., R. 4 W. (locality 98.4) and excellent collections have been secured at this point.

About 50 or 60 feet above this is another zone which contains many of the forms already listed, but which is characterized by the trilobites *Plethopeltis*, and *Entomaspis*, and also by large gastropods belonging to the genus *Taeniospira*. This is known as the *Plethopeltis* zone, and in many sections it is not found, either because of the failure of the strata to be deposited, or because of post-Eminence erosion. This horizon is well exposed on the southeast slope of Council Hill about 1 ½ miles northwest of Eminence in the NW. ¼ NE. ¼ sec 27, T. 29 N., R. 4 W., (locality 98.15) and again on the point of the hill just east of Eminence, (locality 98.16). The cherts at the first locality are more deeply weathered and more highly fossiliferous than they are at the second.

At a few places a third faunal zone has been found which appears to lie above the *Plethopeltis*. The best exposures are on Big Paint Rock Creek, in the SE. ¼ NE. ¼ sec. 33, T. 29 N., R. 1 W., on the west side of the road, above the spring and opposite the house, (locality 98.14). The fossiliferous cherts are in place, about 100 feet above the road, and about 40 feet below the Gunter sandstone.

They contain, among other forms, *Plethopeltis* and *Calvinella* and certain gastropods common to the Eminence, and in addition, certain other forms which are characteristic of the Proctor. This zone, or one closely allied to it, occurs along the eastern exposures of the formation in Wayne Co., (locality 100.2), and has also been found in the Potosi region, (localities 74.30 and 74.36). The faunal studies of this interesting zone are not completed, and until more work has been done it is impossible to say what the exact relationships are.

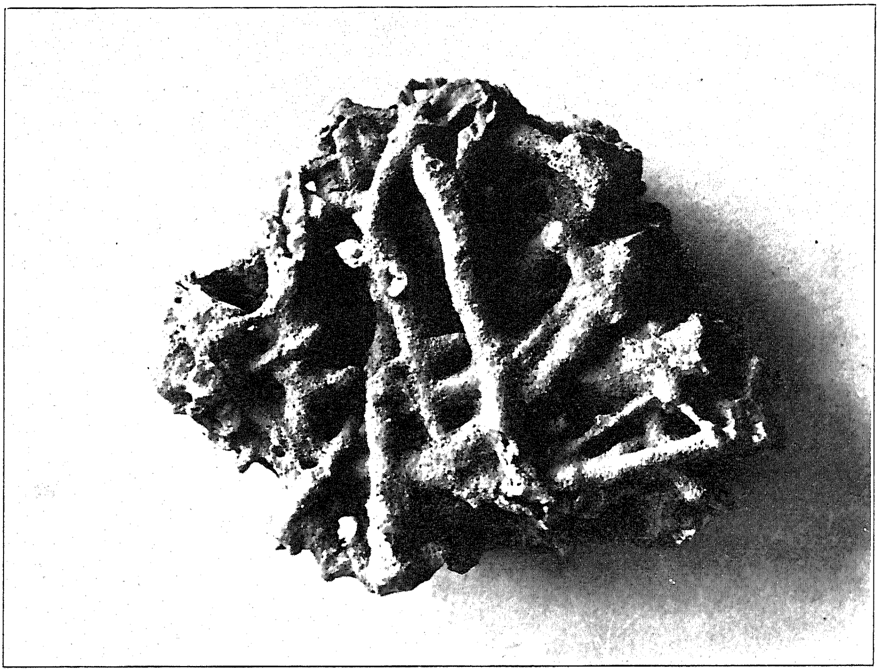
Some of the most characteristic species of the Eminence formation are figured on Plates XVIII & XIX and are described in a subsequent chapter.

Correlation. There seems to be no formation in the Mississippi valley which is the exact equivalent of the Eminence. On the basis of lithologic similarity the Proctor formation of the northwestern portion of the Ozarks has been considered to be equivalent, but the Proctor carries a modified Eminence fauna, and appears to be somewhat younger. McQueen finds that the insoluble residues obtained from the Proctor differ enough from those obtained from the Eminence, to make the identification of the two horizons possible, but as has already been shown, it is by no means certain that the contact between the two formations which he has established on lithologic grounds, is the same as the boundary drawn on a paleontologic basis.

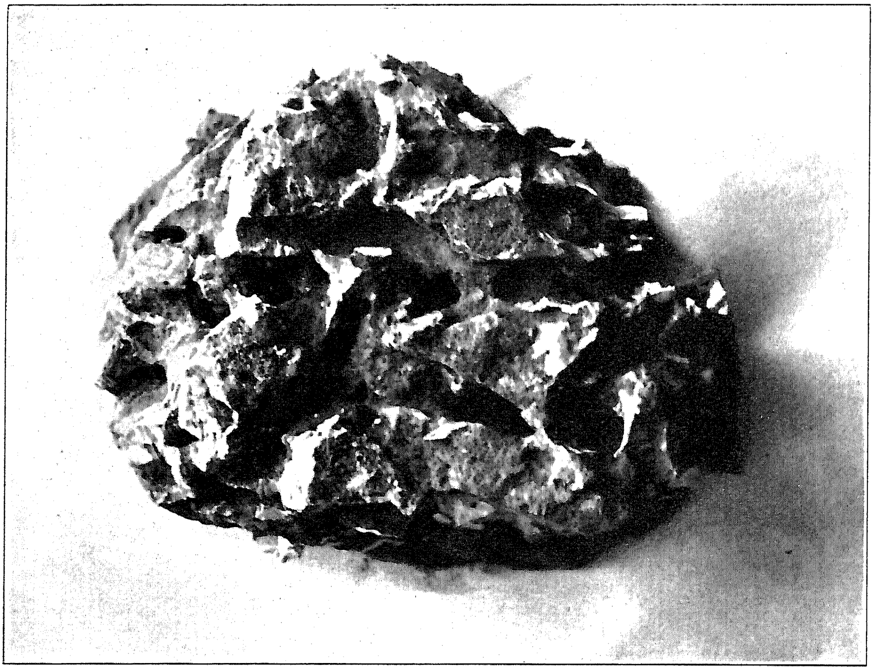
Although Ulrich originally stated that the Eminence was found "in the deeper valleys along the Osage and Niangua rivers," he no longer holds this view.

There is no place in the entire Ozark region where the two formations are definitely known to outcrop in the same section, and therefore the exact nature of the contact between them is not known.

Ulrich has always regarded the Eminence and Proctor as distinct formations. They may be, but the relationship between them is extremely close, and for the present at least, the writer



A. Typical ropy chert from the upper portion of the Gasconade formation.



B. Rusty porous chert, characteristic of the *Plethopeltis* zone of the Eminence formation. Note that this form is practically the reciprocal of that shown above in A.

prefers to regard the Proctor as an upper division of the Eminence, a faunal member, rather than a separate formation.

In the Appalachian region elements of the *Plethopeltis* fauna which characterizes the upper part of the Eminence occur also in the Greenville formation a division of the Knox dolomite, in eastern Tennessee. Another closely allied fauna has been described by Raymond[1] from Highgate Falls, near Milton, Vermont, and the same fauna has been identified from boulders in the conglomerates from Levis, Quebec. Many forms closely related to or identical with Eminence species occur in the Hoyt limestone of New York.

The correlation of a portion of the Ketona and Bibb formations of Alabama with the Eminence is entirely on stratigraphic position. No fossils have been found in these formations as yet.

Another closely allied fauna is the *Plethometopus* fauna which Walcott[2] described from the lower portion of the Mons formation under the name of the *Briscoia* zone (?).

There seems to be no similarity between the Eminence faunas and those obtained from the Ft. Sill, Royer and Signal Mountain formations of Oklahoma, although they appear to be about the same age. They were doubtless separated from the Missouri basin by the Kansas granite ridge, which appears to have been out of water at this time, and may be partly contemporaneous.

No strata carrying the Eminence fauna have been reported from the British Isles or from Scandinavia.

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[1]Raymond, P. E., New Upper Cambrian and Lower Ordovician Trilobites from Vermont, Proc. Bost. Soc. Nat. Hist., Vol. 37, No. 4, 1923-24. In this article Raymond referred this fauna to the Milton formation. It was afterward found that the true Milton was Lower Cambrian, and the Beds carrying the fauna described by Raymond were referred by Keith to the Missisquoi formation. The article was republished with this change under the title of "New Trilobites from Vermont," in the Report of the State Geologist of Vermont, for 1923-24, Vol. 14, 1924, pp. 137-203. Since that time the name of Missisquoi has been found to have been preoccupied, and at the present time no new name has been assigned to this formation.

[2]Walcott, C. D., Cambrian Geology and Paleontology, Geological formations of the Beavefoot-Brisco-Stanford Range, British Columbia, Canada, Smithsonian Misc. Coll., Vol. 75, No. 1, 1924.

ORDOVICIAN SYSTEM.

VAN BUREN FORMATION.

History. In his earlier work in Missouri Ulrich obtained a large and distinctive fauna from boulders of residual chert, in the vicinity of Eminence. The exact horizon of the beds producing this chert was unknown, but he classed the fauna as "Upper Eminence" because many of its fossils closely resembled Eminence species, and used this name for several years in correspondence and in manuscripts. It appears in the stratigraphic column of the geologic map of Ste. Genevieve Co., published by this Bureau in 1922, but its distribution is not shown.

The cherts carrying the "Upper Eminence" fauna were subsequently found in the dolomites just above the Gunter sandstone at several places in the Eminence quadrangle, in strata which were a portion of the Gasconade formation as then recognized. They are separated from the Eminence by a pronounced unconformity and for that reason the name "Upper Eminence" was discarded. The name Van Buren was proposed by Ulrich in the course of a field conference in which Dake and the writer participated. The relations of the Eminence and Van Buren, and the sequence of faunas is well shown along U. S. Highway 60 about 1.7 miles west of Van Buren, Carter Co., Mo., and the formation was named from these exposures. The town of Van Buren is built on an outcrop of Eminence, the Van Buren formation being found on the top of the hills in the immediate vicinity.

For some time it was considered to be a member of the Gasconade formation by the geologists of this Survey, but it has recently been decided to recognize the Van Buren as a distinct formation. This has been done for the following reasons:

1. Ulrich has shown that the geographic distribution of the Van Buren and Gasconade faunas is not the same.

2. McQueen has been able to identify the Van Buren horizon in well cuttings from all parts of the Ozark region, and to use it successfully as a unit in correlation.

3. The Van Buren faunas, while resembling the Eminence and Proctor faunas on one hand, and the Gasconade faunas on the other are distinct from any of them.

Scope of the formation. The Van Buren, as now understood, consists of a basal member, the Gunter sandstone, and a cherty dolomite member which carries the distinctive Van Buren fauna. It is the lower portion of the Gasconade formation, as defined by the Missouri Bureau of Geology and Mines in 1907.[1] In the Eminence region it includes the Gunter sandstone and the overlying dolomites up to the beds containing a thin but well defined stratum of siliceous oolite, which has been arbitrarily selected to mark the top of the formation.

Areal Distribution. The Van Buren is included in the Gasconade formation, as shown on the Geological Map of Missouri, edition of 1926. Its distribution in the state is approximately the same as the Gasconade, but it does not outcrop at all localities where the Gasconade is found. It outcrops in the Current and Black River Valleys; in and around the St. Francois Mountains; in the Potosi area, where it has been described by Dake; in portions of the Meramec Valley and in the valleys of the Osage and Niangua Rivers. It probably occurs in the valleys of Gasconade and Piney rivers, but in these its presence has not been definitely shown.

It has been encountered in deep wells throughout most of the Ozark region in Missouri and Arkansas, and is believed to extend for some distance north of the Missouri river. Strata of equivalent age are known in Oklahoma and in the Southern Appalachian region.

The Van Buren is well exposed in the central and eastern portions of the Eminence region where it forms a narrow band lying between the Eminence and the Gasconade (restricted).

The field mapping of the Eminence region was completed before the Van Buren was definitely accepted as a formation. The Gunter sandstone had been differentiated, and two well marked horizons in the Gasconade had been indicated on the map by colored lines. The lower of these is a bed of siliceous oolite, 4–8 inches thick, which marks a horizon above which no Van Buren fossils have been found and below which no Gasconade fossils have ever been collected, and therefore it has been selected as a tentative boundary. The exact contact of the Van Buren and Gasconade has not been definitely determined but probably lies within 20 or 30 feet of this horizon in most instances.

Thickness. The Van Buren is between 60 and 70 feet thick in the section of Council Hill and from 80 to 85 feet thick in the

[1] Mo. Bur. Geol. and Mines, Vol. VII, 2nd ser.

Grassy Creek section. This is the maximum thickness observed in this region, and is measured from the base of the Gunter sandstone to the oolite bed already mentioned.

The average thickness is about 60 feet in those places where neither the Van Buren nor the overlying formations have been greatly affected by solution. In the eastern portion, particularly in the valleys of Powder Mill and Carr Creeks, the Van Buren, along with the overlying formations is largely residual, and averages about 40 feet in thickness.

Lithologic Character. The Van Buren consists of two members, the basal Gunter sandstone and an upper division, consisting of beds of cherty dolomite.

Gunter Sandstone Member. This member averages about 15 feet in thickness and rarely exceeds 20 feet. It is highly variable in composition from place to place, but it contains the only sandstone beds which have been recognized in the formation. In the eastern portion of the area it consists entirely of sandstone, but when traced westward dolomite lenses appear, and, in the vicinity of Eminence it consists of two or three thin beds of white sandstone with intercalated dolomite beds. The sands are fine to medium grained, and are commonly well rounded and frosted. In some instances samples taken from the outcrop may show a considerable proportion of sharp, angular grains, with well formed crystal faces, and such occurrences are interpreted as examples of secondary enlargement.

The base of the member often contains a thin conglomerate seldom more than a few inches in thickness. The pebbles are of white, yellow and black chert, and are rarely more than an inch in diameter. The shapes vary from angular and subangular to forms which are well rounded, or rounded and flattened, and show evidence of considerable wear. Conglomerates of this type are also found in other sandstone layers of the Gunter. The occurrence of pebbles derived from the pre-Cambrian at a single locality has already been noted and their absence elsewhere is considered as fairly conclusive proof that very little of the pre-Cambrian was exposed at the time of the Van Buren submergence.

All of the sandstones are more or less calcareous, and locally they may grade into arenaceous dolomites, in which the individual sand grains are barely in contact with one another. Freshly broken surfaces of this rock are easily mistaken for dolomites, but a closer inspection reveals the presence of many small rounded sand grains, showing as clear or frosted specks in the gray matrix.

A study of the heavy minerals of the Paleozoic sandstones of the Ozark region made by Cordry[1] fails to show any striking difference between the heavy mineral content of the Gunter and of the other sandstones studied, and seems to indicate a common source of material for all of them.

The following sections, together with those given for the Van Buren and Gasconade and those given for the Eminence formation (pp. 83, 84, 111) will serve to give an idea of the character and variability of this member.

Section of the Gunter Sandstone Member, exposed along the old Eminence-Winona Road, ½ mile S. E. of Eminence, in the NE. ¼ SW. ¼ sec. 35, T. 29 N., R. 4 W.

Measured by J. Bridge.

	Thickness Feet.	Inches.
1. Sandstone, coarse-grained, white on fresh surface, gray or rusty on weathered surfaces, thin conglomerate with chert pebbles up to ¾ inch in diameter at top. Evenly bedded, splits readily along bedding planes	1	
2. Dolomite, coarsely crystalline, bright gray on fresh surfaces, sometimes with a pinkish tinge, darker on weathered faces, many small cavities filled with brown, porous siliceous residues, a 6-inch layer of white, partially decomposed chert near base	2	6
3. Dolomite, coarsely crystalline, much the same color as the preceding, weathers dull gray with rounded faces and slightly pitted surfaces resembling the pitted dolomite of the Jefferson City fm., except for the siliceous druses of the latter. Many cavities filled with brown, porous residues. Forms a strongly projecting ledge	1	6
4. Dolomite, fine-grained, thin and irregularly bedded, dove colored on fresh surfaces, darker on weathered ones, but on the average lighter than the preceding. Many thin irregular partings of white decomposed chert, giving the rock a mottled appearance. Near base several layers of dense white chert, which appear to be fossiliferous, but from which no identifiable specimens could be obtained. (Approx.)	2	6
5. Calcareous sandstone, composed of well-rounded frosted sand grains in a dolomitic matrix, light gray with a pinkish tinge on fresh surfaces, leaches to a rusty porous sandstone and in many instances is recemented to a dense, vitreous, quartzitic rock. Bedding distinct, the individual layers from one to three inches thick, many of them intricately and minutely cross-bedded. Exposed thickness	2	
Total thickness	9	6
Base concealed.		

Another section, somewhat similar to this just east of Eminence, is not as well exposed, but shows both contacts.

Section of the Gunter Sandstone Member, exposed on road on line between secs. 26 and 35, T. 29 N., R. 4 W., about ¼ mile east of the hotel in Eminence.

Measured by J. Bridge.

Top of section, north side of road, Elev. approximately 760 ft.

Top of section, about 55′ above creek level, Elev. 690′. Above this point are ledges of dolomite for 8 or 10′ and above these the hillsides are covered with dense white cherts.

[1]Cordry, C. D., Heavy Minerals in the Roubidoux and Other Sandstones of the Ozark Region., Jour. Pal., Vol. III, No. 1, Mar., 1929.

		Thickness Feet.	Inches.
1.	White sandstone, equivalent to No. 1 of the preceding section.......		6
2.	Practically covered, similar to No. 2 of the preceding section........	2	
3.	A well defined overhanging ledge similar in all respects to No. 3 of the preceding section..	1	6
4.	Similar to No. 4 of the preceding section, but much thicker..........	5	
5.	Similar to No. 5 of the preceding section, fine-grained at the top but toward the base the characteristic rounded sand grains appear, the basal 18 inches being practically pure sandstone....................	4	
6.	Dolomite, coarsely crystalline, greatly resembles No. 3. Weathers to granular, iron-stained mass which greatly resembles a coarse sand, but which is practically free from siliceous material....................	1	
7.	Sandstone, similar to that in the base of No. 5....................	1	
	Total thickness..	15	

From this sandstone to the level of the creek are exposed layer after layer of gray, coarsely crystalline, rough weathering Eminence dolomite.

An excellent section has recently been exposed in cuts made in the construction of State Highway 19 just north of Eminence, and is as follows:

Section of Gunter Sandstone as exposed on Highway 19, 2 miles north of Eminence. SW. ¼ NW. ¼ sec. 23, T. 29 N., R. 4 W.

Measured by J. Bridge.

(Top of section in 3rd cut west of turn.)

		Thickness Feet.	Inches.
1.	Sandstone, well cemented, white, weathering rusty and porous, beds 4 to 6 inches thick...	2	
2.	Dolomite, gray, coarsely crystalline, chert free, weathers dark gray and pitted. A single bed.....................................	1	3
3.	Dolomite, thin-bedded, gray, moderately crystalline, with many thin stringers of tripolitic white chert.............................	2	
4.	Dolomite, massive, coarsely crystalline, gray, weathers pitted, in all respects like second member above.............................	4	
5.	Dolomite, thin-bedded, argillaceous cotton rock, smooth weathering, light gray with buff tints, interbedded with thin layers of sandstone and calcareous sandstone. Exposed thickness, 6 ft. (Bottom of cut—section transferred to next cut east.)		
5.	Dolomite, like the preceding, total thickness......................	10	6
6.	Sandstone, white, crossbedded, well cemented, with conglomerate of small rounded and worn chert pebbles at base.....................	1	6
	Total thickness..	21	3

Eminence dolomite to base of cut.

The three sections given above serve to give a good description of the Gunter sandstone member in the vicinity of Eminence, while the section given on page 111 shows its general character in the eastern portion of the area.

This member is one of the important water bearing horizons of the Ozark region, and wells drilled in the southern and western portions of the Eminence quadrangle should encounter it at depths ranging from 400 to 600 feet.

Dolomite member. The dolomites of the Van Buren are light gray in color and variable in texture. A few of these resemble the strata of the Eminence in these respects, but most of them are finer grained, and present a somewhat different aspect when weathered. The Van Buren is well bedded and in many instances, thin-bedded. This causes the formation to weather into a series of steps, which is in marked contrast with with the craggy, pinnacled Eminence beneath. At the base is a zone two or three feet thick made up of thin-bedded, argillaceous, fine-grained dolomite. The individual strata average a few inches each in thickness, and the bedding is slightly irregular. They are often separated by thin partings of green shale. They weather light gray or buff. In some sections this zone seems to be absent. This is overlain by a stratum of massive, coarsely crystalline, gray dolomite, from 12 to 18 inches thick, which closely resembles some of the more massive beds of the upper portion of the Eminence. This stratum weathers to a rusty, porous, ropy, drusy chert, closely resembling the cherts of the *Plethopeltis* zone of the Eminence, but distinguished from them by the more abundant druse, and the occasional presence of large Cryptozoons. This zone and the portion of the formation immediately overlying it carry the Van Buren fauna. It is well exposed on a small tributary of Rocky Creek in the NE. ¼ SE. ¼ sec. 13, T. 28 N., R. 3 W.

This layer is succeeded by beds of medium coarsely crystalline, well-bedded, light gray, cherty dolomite. The cherts are white, and often fossiliferous. They are well exposed on the ridge just east of Eminence, and many of the best Van Buren fossils have come from this locality.

The uppermost beds of the formation consist of light gray, fine-grained argillaceous dolomite. They range from 8 inches to 2 feet in thickness. Fresh surfaces are light gray, often with buff and reddish tints, while the weathered surface is a dull neutral gray, somewhat lighter in color than the more coarsely crystalline beds. They produce very little chert, but contain a single, persistent stratum of siliceous oolite, which varies from 4 to 8 inches in thickness. It is a dense, white chert in which the oolites are very closely spaced. Small flattened and rounded chert pebbles are found in it at some localities.

This is the stratum which has been arbitrarily selected to mark the top of the formation. The dolomites immediately above and below it appear to be identical and if the oolite is to be included in the Van Buren, they should also be placed there. Such procedure would add from 5 to 10 feet to the thickness already recorded in this area.

Weathering. The weathered sandstones of the Gunter are commonly rusty and porous, but locally recementation has taken place, rendering them quartzitic. Where the Gunter is largely sandstone, as in the eastern portion of the region it often forms a well defined bench, and outcrops are numerous, but in those places where dolomite beds make up the greater portion of the member, is covered and difficult to locate.

In most cases the sandy dolomites of the Gunter weather to a rusty, porous, almost incoherent sandstone but at times recementation by secondary silica takes place almost simultaneously with the leaching of the carbonates and the rock becomes quartzitic.

There is considerable difference in the appearance of the weathered surfaces of the dolomites. The massive crystalline varieties which make up the bulk of the member, weather rough and craggy and greatly resemble the Eminence in their general appearance. The well defined bedding planes cause the layers to weather back in steps rather than into pinnacles, and this serves as a rough means of discrimination.

The fine-grained types, such as are common in the upper part of the formation resist weathering to a remarkable degree and outcrop much more frequently than the beds below them. These exposures commonly show broad, smooth, gently rounded surfaces, which are in marked contrast with the jagged, pitted type of weathering which characterizes much of late Cambrian and early Ordovician dolomites.

Cherts. The coarsely crystalline beds in the center of this member yield an abundance of dense, vitreous, china-white chert, which breaks with a semi-conchoidal or conchoidal fracture. The average diameter of the chert fragments is between 2 and 3 inches but large masses up to a foot or more in diameter are known. These are more common toward the base of the formation. This chert is similar to some of the chert produced by the Gasconade formation, and in the absence of fossils it is not always possible to distinguish them. In many places, not only in the Eminence region but throughout the Ozarks, they form a heavy residual mantle which effectively conceals the outcrops. They are not greatly affected by weathering, and rarely assume the rusty porous appearance of the Eminence and

Potosi cherts. Certain beds when weathered are highly dolocastic, the dolocasts being readily visible with the aid of a hand lens.

Fossils are not common in these cherts, but near the base of the formation they are locally abundant and it is from this zone and the one immediately underlying it that all of the Van Buren fauna has been obtained.

The reef-like bed which lies between the thin-bedded, fine-grained dolomites at the base of the formation and the more massive crystalline beds, weathers to a mass of rusty, brownish or reddish, ropy, anastomosing chert, which is similar to, but much coarser than the cherts of the *Plethopeltis* zone. They are often coated with thin druses, and the bed may conveniently be referred to as the drusy layer. This ropy chert is thought to be the siliceous replacement of an algal reef of uncertain affinities. In some localities it is highly fossiliferous.

The thin-bedded dolomites at the base of the formation yield a small amount of fine, soft, white tripolitic chert. The fine-grained beds at the top of the formation are almost chert-free.

The siliceous oolite, already referred to, weathers into rectangular slabs and blocks of various sizes up to one or two feet in length, and is one of the most easily recognized horizons in the formation. It is well exposed at various points along the hill-top between Eminence and the school house; on the top of the ridge in the center of the E. ½ sec. 18, T. 29 N., R. 3 W., along U. S. Highway No. 60 (temporary) about 2 miles east of Fremont, and at numerous other points. Unlike the other cherts of the formation which form only at the surface, the silicification of this bed persists far underground, doubtless because the original porosity of this layer permitted the ready migration of ground water.

It forms the impervious horizon beneath which the ore accumulated in the lower level of the Casey Mine (see page 176) and has been recognized in drill cuttings in wells in the southern part of the Ozarks, and should prove of value in future deep well correlations.

Stratigraphic relations. In the Eminence region the Van Buren rests unconformably upon the Eminence, and the magnitude and extent of this break has been discussed in the preceding section. The relations of the Van Buren to the Gasconade are as yet obscure. In those areas where the formations outcrop the transition appears to be conformable. However, the thickness of the Van Buren-Gasconade series, which averages less than 300 feet in those areas where the formations are exposed, increases greatly in some of the deep structural basins in the state. This is shown by the logs of some of the deep wells in the Ozark region.[1]

The well at Cabool, in southwestern Texas County, penetrated 455 feet of strata assigned to these formations, and at Lebanon, in Laclede County, the same series had a total thickness of 510 feet. A maximum of 540 was recorded in the well at Seymour in Wright County. Many other wells in this south central region show thickness in excess of 300 feet.

As a result of his studies of the insoluble residues obtained from the cuttings of these and many other wells, McQueen believes that this thickness is due to the intercalation of a series of beds between the typical Van Buren and typical Gasconade. If so this constitutes definite proof of unconformity.

Paleontology. No identifiable fossils have been found in the Gunter sandstone member, although a few imperfect fragments were obtained from one of the dolomite ledges in the section described on page 101. The majority of collections from the Van Buren have been obtained from residual cherts, which occur in the drusy bed and in the dolomites immediately overlying them. At a few localities, notably in the NE. ¼ SE. ¼ sec. 13, T. 28 N., R. 3 W., (98. 43) and in the NW. ¼ SW. ¼ sec. 35, T. 29 N., R. 4 W., (98. 23) fossils have been obtained in place.

At first sight the faunas show marked resemblances to both the Eminence and to certain of the Gasconade faunas, but a little study shows many differences. Brachiopods and trilobites are extremely abundant in the Eminence, but are almost entirely lacking in the Van Buren collections. The gastropods resemble those of the Eminence, and there is a slight overlapping of generic types, but for the most part the forms are distinct. The majority of the coiled gastropods of the Van Buren belong to the genera *Sinuopea* and *Rhachopea.* These forms are characterized by the possession of a single, rounded, median or sub-median peripheral keel, which terminates in a shadow apertural notch. These genera are both present in the Eminence, but reach their maximum development in the Van Buren. They closely resemble certain forms, *Taeniospira* and *Dirhachopea,* which are common in the Eminence. But these forms are distinguished

[1]McQueen, H. S., op. cit., Plates X, XI, XII.

by the possession of a pair of peripheral keels, separated by a narrow impressed zone. The preponderance of gastropods of the one or two keeled type is of great value in the rapid separation of Van Buren and Eminence faunas. A gastropod allied to *Ophileta* is present in many of the Van Buren faunas, and so far, no forms of this general type have been found in the Eminence.

The other conspicuous element of the Van Buren fauna is the cephalopods which are so sparingly represented in the older formations as to be almost negligible, but appear in abundance in this formation, and this fact serves to distinguish the Eminence and Van Buren faunas. They are represented by rather small, straight and slightly curved forms, and belong for the most part to undescribed genera and species.[1]

Many of the gastropods of the Van Buren are congeneric with the forms found in the Gasconade, but practically no species are common to the two formations. In addition the Gasconade faunas contain many other types of gastropods, and an abundance of cephalopods, trilobites and brachiopods, which makes their separation from the Van Buren faunas an easy matter.

Cryptozoa are locally abundant in the drusy layer of the Van Buren, and two distinct types may be recognized. The smaller form greatly resembles *C. undulatum* Bassler, and appears to be identical with forms occurring in the Copper Ridge of Tennessee and Alabama. In this type the columns are closely spaced, and the curved laminae connecting them average less than an inch across. In the larger and rarer type the laminae average from 4 to 6 inches across, although there are notable departures from this measurement. This form has been identified by Ulrich as *C. proliferum;* Hall and many of the specimens closely resemble that species. In some of its phases it also resembles the Gasconade species, here called *C. ozarkensis.* In the field it is not always possible to distinguish between them.

Cryptozoa are extremely common at many horizons in the Ozark section, and if carefully used are valuable aids in correlation. The nature of the organism and its manner of growth make considerable variation possible within a given species, and distinctions cannot be made with the same exactitude that characterizes much of the new work in invertebrate paleontology.

[1]At the present time Ulrich and Foerste have practically completed a monograph upon the Ozarkian and Canadian cephalopods, in which most of these forms are described and figured.

The general aspect of the organism has to be considered, and no single factor or measurement can of itself be regarded as diagnostic.

Correlation. The outcrops of the Van Buren in different portions of the Ozark region have been correlated with one another on the basis of actual continuity, paleontology, stratigraphic position and lithologic similarity. The formation is fossiliferous throughout much of southeast Missouri, but in the northwestern portion of the Ozarks the paleontological evidence is almost entirely lacking. Much of the present knowledge of subsurface distribution is due to McQueen's studies on the deep wells of the Ozark region, and serves to strengthen the belief in the equivalence of the sections in the northwestern and southeastern portions of the Ozarks.

In the original description of the Eminence formation, published in the Revision, Ulrich included the Van Buren fauna with the Eminence, and many of his statements as to the widespread distribution of that formation, actually apply to the Van Buren.

The Van Buren is the partial equivalent, at least of Ulrich's newly proposed Chapman Ranch formation, a division of the Arbuckle limestone of Oklahoma. Several species of Van Buren gastropods have been found in this horizon, and indicate a direct connection between the two areas at that time.

Several of the Van Buren species, and several others which are closely allied have been found in the Copper Ridge dolomite in Alabama,[1] while the Cryptozoa previously mentioned have been found in Missouri, Alabama, and Tennessee.

In Alabama the Copper Ridge submergence extended across the full width of the Appalachian Valley, but farther north in Tennessee and southwestern Virginia it was confined to the western half, and it does not appear to have reached Pennsylvania. There is, however, a suggestion of the Van Buren faunas at Phillipsburg, Quebec, in Division A[2] of Billings section.

No equivalents of the Van Buren are known in Minnesota and Wisconsin, and in general the submergence appears to have been localized over the south-central and southeastern portions of the continent.

[1]See Butts, Geol. of Alabama, Special Rept. 14, 1927, also Birmingham and Bessemer, Vandiver folios.

GASCONADE FORMATION.

History. The origin of the name, and much of the history of this formation has been given in connection with the discussion of the Eminence and Van Buren formation. Nason[1] defined the Gasconade as the great limestone series lying beneath the Roubidoux sandstone. Thus while the upper boundary of the formation was well defined, the base was not established. For several years thereafter the name was used rather loosely and, as has already been shown, included at times (by definition, though not actually) everything below the St. Peter sandstone, and above the Davis formation. (See Table II.) The base of the Gasconade was first defined by Ball and Smith[2] who drew it at the top of the Gunter sandstone, the Third Sandstone of Swallow. A few years later, Marbut[3] included the Gunter sandstone in the Gasconade, making it the basal member of the formation. The formation as thus delimited, has been described in a number of state reports, issued between 1907 and 1928. In Ste. Genevieve Co., the lensing out of the Gunter Sandstone made the contact with the underlying Eminence difficult to locate, and as a result some Eminence was included in the Gasconade.[4] In 1923 Ulrich suggested the separation of the Van Buren formation, and in 1929 the Missouri survey adopted this term, and McQueen[5] described the insoluble residues from the two formations and gave criteria for the recognition of them in well cuttings.

Scope of the Formation. The upper contact of the Gasconade formation is still drawn in accordance with Nason's original definition. In the Eminence region, the base of the formation is placed just above the thin bed of siliceous oolite, described in connection with the Van Buren, while in those areas in which the oolite bed is not developed, it is drawn so as to exclude the beds carrying the characteristic Van Buren fauna.

Areal Distribution. The formation is widely distributed throughout the Ozark region, and its extent may be ascertained from the 1926 edition of the State Geological Map. It is not known to outcrop beyond the borders of the state, but it has been

[1]Nason, F. L., Rept. on Iron Ores, Mo. Geol. Surv., Vol. II, 1892, p. 115.

[2]Ball, S. H., and Smith, A. F., Geol. of Miller Co., Mo. Bur. Geol. and Mines, Vol. 1, 2nd ser., 1903, pp. 30-50.

[3]Marbut, C. F., Geol. of Morgan Co., Mo. Bur. Geol. and Mines, Vol. VII, 2nd ser., 1907, pp. 26-32.

[4]Weller, Stuart, and St. Clair, Stuart. The Geol. of Ste. Genevieve Co., Mo. Bur. Geol. and Mines, Vol. XXII, 2nd ser. (1928), pp. 61-68.

[5]McQueen, H. S., op. cit., pp. 19-21.

encountered in deep wells throughout the Ozark region and in fact throughout nearly all of Missouri and northern Arkansas. Formations which are either completely or partially homotaxial are known from Iowa and Wisconsin and from various areas in the Appalachian Trough, and elsewhere in North America.

In the western and southern portions of the Eminence quadrangle the Gasconade is confined to the valleys, but throughout most of the remainder of the area it forms the upper slopes of the valleys and caps many of the divides. It probably outcrops over a greater area in the Eminence region than any other formation, with the possible exception of the Roubidoux.

Thickness. The average thickness of the formation in this region is between 200 and 220 feet. This thickness is fairly constant over the western portion of the Eminence quadrangle where the formation is protected by a thick cap of the Roubidoux sandstone. In the area of the porphyry knobs and to the east of them the Gasconade is much thinner, although still capped in many places by a few feet of the overlying formation. This thinning has been caused by the removal of the soluble portions of the formation by circulating ground waters, and in some instances as much as two-thirds of the original thickness appears to have been removed in this manner. In such areas dolomite outcrops are practically wanting and the formation appears to be made up of a mass of heterogeneous residual cherts, but a careful examination will commonly show that all horizons are represented.

A full discussion of this solution process and its effects is given in the chapter on structure.

The formation thins toward the St. Francois mountains and in places is less than 150 feet in thickness, but this thinning is largely due to non-deposition of lower horizons from the base of the formation.

In a deep well at Rolla in Phelps County the formation has a thickness of 178 feet, and at California in Moniteau County it is about 225 feet thick. Deep wells at Columbia show 230 feet of Gasconade, while at Hannibal about 200 feet is encountered in deep drilling. In nothern Iowa and Wisconsin where the formation again makes its appearance at the surface, it is known as the Oneota, and has an average thickness of less than 200 feet, and from its faunas is known to be the equivalent of the formation as developed in Missouri.

Lithologic Character. The bulk of the formation is composed of well bedded, light gray, medium to coarsely crystalline, dolomite. In general, the texture is less coarse than the Eminence, but coarser than the Van Buren. Bedding is well developed, much more so than in the Eminence and Potosi, but the individual strata are massive, and the formation rarely shows the thin bedded phases common in portions of the Van Buren. The more coarsely crystalline varieties, like the Eminence and the Van Buren, weather into rough pitted masses, but the pinnacle weathering, so characteristic of the Eminence is not developed. Instead, the formation weathers into a series of steps, the height of which is controlled by the spacing of the bedding planes (Plate XI-A). The individual strata may be as much as 3 or 4 feet thick, but the average is about 2 feet. Jointing is about as well developed as in the older formations, but is not as conspicuous, because of the greater development of the bedding planes. Sheer cliffs of Gasconade show very little bedding or jointing. These features are emphasized by weathering, and are always better developed than in the older formations (Plate V-C, D). Outcrops of the formation are well exposed on the upper part of Jacks Fork, and in the vicinity of Alley Spring.

Although the Gasconade is well exposed at many places, within the area complete sections are difficult to obtain. A composite section measured at various places in the valley of Grassy Creek will serve to give a general idea of the character and sequence of beds in this formation.

Composite section of the Van Buren and Gasconade formations measured along Grassy Creek, in sections 33 and 34, T. 30 N., and sec. 3, T. 29 N., R. 4 W.

Measured by J. Bridge.

Roubidoux Sandstone

Massive tumbled blocks of sandstone, none of which are in place, capping hill, contact drawn at 1030 feet.

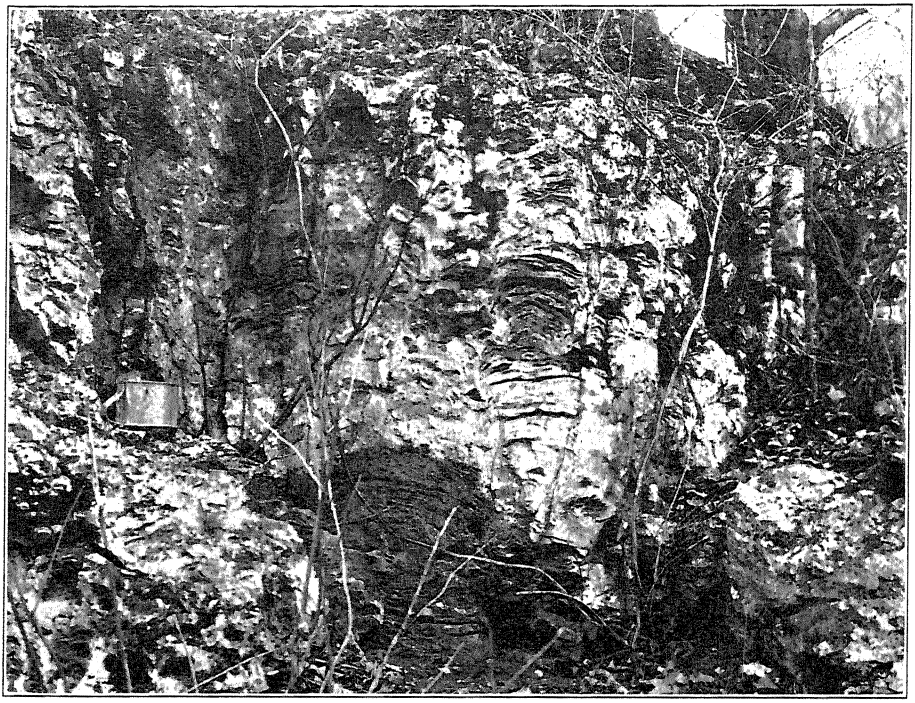
	Thickness Feet.	Inches.
Gasconade Dolomite		
Dolomite, in heavy beds, 2 to 4 feet thick, weathers to rusty, ropy, porous cherts, and a smaller amount of dense china-white chert, the latter more abundant toward the upper part of the member. Dolomite medium to coarsely crystalline, light gray in color, weathering darker. The lower 29 feet of this division carries the characteristic Gasconade fauna with *Ophileta, Ozarkina, Helicotoma, Ozarkotoma, Gasconadia, Cameroceras, Clarkoceras, Chepultepecia*, etc. (Poorly exposed in this section, description supplemented by partial sections measured in Alley Branch)..........	70	

	Thickness Feet.	Inches.
Cryptozoon reef a very persistent bed, the upper marker indicated on the geologic map, and one which has been observed wherever the formation outcrops in the state. Composed entirely of the remains of a large Cryptozoon which is here termed *C. ozarkensis*. In most cases this bed is silicified	3	
Dolomite, similar in general appearance to that of the upper beds, but weathering to dense china-white cherts. In some areas contains druses of large quartz crystals, which somewhat resemble certain of the Potosi types, but which lack the chalcedonic banding of the latter. Sparingly fossiliferous	70	
Dolomite, medium to thin bedded, medium to finely crystalline, non-cherty, or only slightly cherty. Near top of this horizon, or perhaps in the overlying section there locally occurs a thin stratum of porous, mealy chert-carrying *Euomphalopsis*	50	
Total Gasconade	193	
Van Buren Formation		
Dolomite, thick-bedded, fine-grained cotton rock, non-cherty, weathers smooth in sharp contrast to the preceding, commonly makes a conspicuous ledge	5	
Siliceous oolite—a very persistent stratum, always associated with the preceding and following horizons, contact indicated on the geologic map. Consists of hard, dense, white oolitic chert, which breaks out into sharp-edged rectangular blocks		4 to 8
Dolomite, similar in all respects to that lying above the oolite	10	
Dolomite, massive, heavy-bedded in the upper portion, becoming thin bedded toward the base, profusely cherty, cherts, hard, dense and china white, locally fossiliferous. A prominent and persistent bed of rusty, ropy, drusy often fossiliferous chert about two or three feet from the base. The base of this division contains the Van Buren fauna, some of the characteristic genera being, *Sinuopea*, *Rhachopea*, *Burenoceras* and *Dakeoceras*	60	
Gunter sandstone member. Two thin sandstone beds, 6-18 inches thick, separated by from 6-8 feet of thin-bedded, sandy dolomites	10-12	
Total Van Buren	85-87+	
Eminence Formation		
Dolomite, gray, rough weathering, exposed to creek level	10	

The various units remain fairly constant throughout the entire Eminence region, but along the western border the formation thickens, as would naturally be expected in view of the sections reported in drill holes still farther west. Some of it is due to the thickening of the upper members, as is shown by the fact that the uppermost division is approximately 100 feet thick in the bluffs on Jacks Fork in sec. 9, T. 28 N., R. 5 W., on the extreme edge of the area.

Where the formation has suffered greatly from solution, it is much thinner, but sections in which both upper and lower contacts are exposed show characteristic cherts derived from all intervening horizons, and this indicates that the original thickness of the formation over the entire area averaged close to the figures given in the preceding section.

Weathering. Throughout the Eminence region, and for that matter throughout most of the Ozark region the outcrops of the



A. Detail of Gasconade Cryptozoon Reef, *C. ozarkensis*.

B. General view of the reef.
Both views taken on Alley Branch, near the center of the SW. ¼ sec. 22, T. 29 N., R. 5 W.

Gasconade are confined to the larger valleys, and the formation seldom forms the upland surface over any considerable area. On the younger streams, where erosion is active, and where it is the oldest formation exposed, it outcrops in bold, steep bluffs, often more than 100 feet in height, which are such striking features of the Ozark landscapes. (Plate *V-C, D.*) These are well shown on the upper section of Jacks Fork, particularly above the mouth of Alley Branch.

Where down-cutting is not so active, the well bedded character of the formation caused it to weather into a series of step-like ledges, from one to four feet in height, and these are often separated by open grassy slopes. This step-like type of weathering is highly characteristic of the Van Buren, Gasconade and Roubidoux formations, and is in sharp contrast with the pinnacle weathering of the older strata. Good examples of such slopes are to be found in Pine Hollow along the Eminence-Birch Tree road; in the valley of Mill Creek, secs. 34 & 35, T. 28 N., and secs. 1, 2, and 3, T. 27 N., R. 2 W., and at many other points.

In those places where the Gasconade forms extensive areas of ridge top, outcrops of the dolomites are rare or entirely wanting and the surface of the ground is commonly covered with a dense mass of chert fragments. There are local exceptions to this, where ledges of Gasconade form the summit of the hill, but these occurrences are comparatively rare.

Chert. The weathered surfaces of the majority of the individual strata of the formation are rough and pitted.

The Gasconade is profusely cherty, and like the Eminence, chert is most abundant where weathering has taken place on gentle slopes. Steep cliffs are almost free from chert. Some of its chert near the base of the formation is a soft, mealy, creamy-white variety.

Hard, china-white cherts are common from the middle of the formation upward. They resemble the chert of the Van Buren, but are more translucent, and lack the dolocasts which are so characteristic of the older chert.

Cryptozoa of various sorts occur at different levels, and are the forms which are locally known as cabbage, cauliflower or festooned cherts. Several varieties have been recognized, but the most abundant is a large form here termed *C. ozarkensis*, which forms a conspicuous reef 2 to 3 feet thick about 70 feet below the top of the formation. It is almost invariably silicified, and large blocks derived from it are extremely common, wherever the upper portion of the Gasconade is exposed. It consists of a number of parallel vertical columns, from one to one and a half inches in diameter, distant from each other about two to four times their diameter, and connected by thin, parallel laminae which are convex upward. (Plate XIV.) There is an excellent exposure of this chert in place in Alley Branch in the center of the SW. ¼ sec. 22, T. 29 N., R. 5 W., and another in Pine Hollow, along the Eminence-Birch Tree road in the SE. cor. NE. ¼ sec. 25, T. 28 N., R. 5 W. It is also well exposed at several localities in the vicinity of Midco,[1] in the NE. ¼ of sec. 22, T. 27 N., R. 2 W., and it has been recognized wherever the upper portion of the Gasconade formation is exposed in the Ozark region.

Above the Cryptozoon reef there are one or more beds of the ropy, porous, chert which greatly resembles the chert of the drusy layer of the Van Buren, but which lacks the waxy chalcedonic chert associated with it. This chert also greatly resembles some of the cherts of the Eminence, but is commonly coarser in texture and weathers into much larger blocks. A specimen of this variety greatly resembles a mass of twigs which have been heaped together, hit or miss, and then dipped in some substance which has coated and bound them together, and yet preserved their outlines. (Plate XIII-A.) This is due to irregular silicification of the rock, but the reasons for this selective silicification are not entirely clear. A possible clue is furnished by the fact that although the remains of invertebrate life and of Cryptozoons are practically invisible in the unweathered dolomites, their actual form is still preserved and is reproduced with the utmost fidelity in the cherts. It is therefore entirely possible that much of this ropy, anastomosing chert is formed about ancient seaweeds or worm tubes of undescribed types, the form of which is still preserved in the rocks, and which in some way exerts a selective effect in the process of silicification.

In the non-cherty Plattin limestone, weathering produces a series of twisting, branching, anastomosing tubules, while in the unweathered rock there appear to be slight differences between the portions which weather out and those which remain. These tubes have been interpreted as the outlines of ancient seaweeds by

[1]Town about two miles south of the south border of the map in sec. 27, T. 27 N., R. 2 W.

Fenton.[1] There appears to be little proof either for or against this idea in the case of the Eminence and Gasconade cherts, although it is entirely possible.

Both types are often highly fossiliferous and the Gasconade type is common in the zone of the main or true Gasconade fauna.

Stratigraphic Relations. Within the Eminence area the Gasconade rests upon the Van Buren, and the nature of the contact has been discussed in the section devoted to that formation.

In the St. Francois mountains it has been found resting upon all of the intervening formations at some point or other.[2] Throughout the entire Ozark region the Gasconade is overlain, probably unconformably, by the Roubidoux sandstone. There is very little physical evidence of unconformity other than the thin conglomerate which is commonly present in the basal member of the Roubidoux. The case of subaerial erosion cited by Ulrich[3] has been rather carefully investigated, and the true Gasconade fauna has been found at a number of points within the area which he describes. Although his explanation is entirely plausible and possible, it should be borne in mind that in much of this area the contact of the two formations lies approximately at the level of the upland surface, and the Roubidoux where present is represented almost entirely by residual material. The Gasconade has also been greatly weathered by solution, and as described in Chapter IV it is believed that post-Roubidoux solution has been as effective in producing this apparent unconformity as pre-Roubidoux erosion was.

There is a marked faunal break between the Gasconade and the Roubidoux, for no trace of the Tribes Hill-Stonehenge fauna which intervenes between the Gasconade and Roubidoux faunal zones in the Appalachian trough has been found in Missouri.

Paleontology. Many of the Gasconade cherts are abundantly fossiliferous and several distinct faunal zones may be recognized.

Near the base of the formation, in some portions of the state, is a thin zone of soft, mealy, white or light buff-colored chert. This carries the gastropod *Euomphalopsis* in large num-

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[1] Fenton, C. L., The Stratigraphy and Larger Fossils of the Plattin Formation in Ste. Genevieve Co., Mo., Amer. Midland Naturalist, Vol. XI, pp. 88-91; also Plate 1.

[2] See Dake, C. L., Geol. of the Potosi Area, Mo. Bur. Geol. and Mines, Vol. XXIII, 1930, p. 153.

[3] 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, July, 1924, pp. 103-4.

bers and is commonly known as the *Euomphalopsis* zone. This has not been definitely located in the Eminence region, but has been found in Dent, Washington, Phelps and Morgan counties, and appears to be rather widely distributed. On Proctor Creek in Morgan Co., this zone is about 100 feet above the top of the Gunter sandstone; and about 190 feet below the Roubidoux. At Meramec Springs in Phelps Co., it occurs at creek level about 150 feet below the Roubidoux contact.

Above this zone and probably below the Cryptozoon reef is a second faunal zone. This is characterized by a number of small planispiral, bi-concave gastropods, with many slowly expanding volutions, which Ulrich had provisionally grouped into a genus under the manuscript name *Ozarkispira*. This name was subsequently published by Walcott,[1] and unfortunately was applied to a totally different form, and the name *Ozarkispira* is no longer applicable to the group for which it was originally coined. The term *Ozarkina* is here proposed to replace the older term, the zone is termed the *Ozarkina* zone. The genus is described in a subsequent chapter. *The Ozarkina* zone is found on the hills southwest of the Horner School house, in the NE. ¼ SW. ¼ sec. 23, T. 28 N., R. 3 W. (locality 98.34); on the east bank of Current River, NW. ¼ NE. ¼ sec. 33, T. 30 N., R. 4 W., (locality 98.28) and at many other points in the Eminence area. It is sparingly but widely distributed throughout the southeastern portion of the Ozarks, but has not been recorded as yet from the Osage-Niangua basin.

The Cryptozoon reef already mentioned is the most easily recognized and the most useful zone in the formation for purposes of local correlation. In the Eminence region it holds a fairly constant position about 70 feet below the Roubidoux contact, in those areas where little or no erosion or solution has taken place along the contact. It has been found in all portions of the area, in which the upper part of the Gasconade is exposed, and has been found in a similar position throughout the greater portion of the Ozarks.

Above this reef are a number of faunal zones, whose exact limits and relationships are not clear. These upper faunas are characterized, in part at least, by the gastropod *Helicotoma uniangulata* (Hall) and for the present, this upper series is referred to as the *Helicotoma* zone. It is characterized by gas-

[1]Walcott, C. D., Cambrian Geology and Paleontology, V., Smithsonian Miscell. Coll., Vol. 75, No. 1, p. 37, Fig. 6.

tropods belonging to the following genera:—*Ophileta*, *Sinuopea*, *Rhachopea*, *Chepultepecia*, *Ozarkotoma* and *Gasconadia* and by cephalopods referred to *Cameroceras*, *Clarkoceras* and *Oneotoceras*. Trilobites are represented by several species of *Hystricurus* and other forms. *Sinuopea*, *Rhachopea* and possibly *Ophileta* are known in the underlying Van Buren and the first two to a much less extent in the Proctor and Eminence, but the remainder of the genera listed above appear to begin in the Gasconade.

Correlation. The Gasconade of the Eminence region is correlated with that of the type region in the Gasconade valley from its stratigraphic position, lithologic similarity and paleontologic evidence. It is not possible to actually trace the formation on the outcrop from one area to the other, because of the cover of younger formations;—but a number of deep wells have been drilled in the intervening territory and there is no doubt as to the continuity of the formation throughout the Ozark region.

A portion of the Gasconade fauna, particularly that occurring in the *Helicotoma* zone is also found in the Oneota dolomite of Wisconsin. Other elements of the same fauna are found in the Chepultepec dolomite in the southern and western portions of the Appalachian trough. It is particularly well developed in Alabama and Tennessee, but is also known locally as far north as New York. It also appears to be represented in the Cass Fiord formation of northern Greenland, and representatives of the fauna have been reported from northern Scandinavia.

According to Ulrich, the Gasconade is also the partial equivalent of the Mons formation of Alberta. The typical Gasconade faunas of the United States are of southern origin, according to his interpretation; while the *Leiostegium* and *Symphysurina* faunas of the Mons came from the northwest. Some of these northern forms are found associated with the ones of southern origin in the Oneota, and a few of them even reach Missouri, and this association establishes the essential contemporaneity of the two invasions.

A few of the more characteristic Gasconade forms are figured and described in a subsequent chapter.

ROUBIDOUX FORMATION.

History. The name Roubidoux was proposed by Nason[1] in 1892, for the great sandstone beds which cap the divides between many of the Ozark streams, and which form the surface rock of

[1]Nason, F. L., Rept. on Iron Ores, Mo. Geol. Surv., Vol. II, 1892, p. 115.

the Ozark Plateau over much of the central and northwestern portions or the uplift. No type section has ever been specified, but the name was taken from Roubidoux creek in Pulaski county, along which there are excellent exposures of the formation.

The Roubidoux as here defined is essentially the Second sandstone of Swallow and the older Missouri geologists. Nason also included under this term, the First, or St. Peter sandstone, with the idea that the two were the same but the difference between them has long since been recognized. It is probable that in one or two of his sections near Van Buren, he also confused the Gunter with Roubidoux. (See page 76.)

Winslow[1] following Nason, made the Roubidoux the equivalent of the St. Peter sandstone in his correlation table. In his field practice he employed the term correctly in southeastern Missouri, but in the central and northwestern portions of the Ozarks he made the true Roubidoux a member of the Gasconade formation, calling it the Moreau sandstone.

Gallaher[2] uniformly applied the term Roubidoux to the Gunter sandstone, and used the terms St. Thomas and Moreau for the true Roubidoux.

Ball and Smith[3] and Van Horn and Buckley[4] used the name St. Elizabeth for this formation, but this was afterwards discontinued and in all succeeding reports the name Roubidoux has been applied to the great sandstone and dolomite, the term being used in essentially the sense of Nason's original intention.

Areal Distribution. The formation is widely distributed throughout southern Missouri, and exposures are to be found in almost every county in the Ozarks. It is the surface formation over much more extensive areas than is the Gasconade. It forms the plateau surface over much of Miller, Morgan, Camden, Pulaski, Phelps, Crawford, Dent, Shannon, Reynolds, Carter, Ripley and Butler counties, and is extensively exposed in many others. The approximate distribution is shown on the 1926 edition of the State Geological Map.

It is not known to outcrop outside of Missouri or north of the Missouri River, but it has been reached by deep wells in northern Arkansas and northern and western Missouri.

[1] Winslow, A., Lead and Zinc Rept., Pt. I, Mo. Geol. Surv., Vol. VI, 1894, p. 331.
[2] Gallaher, J. A., Preliminary Rept., Mo. Geol. Sur., Vol. 13, 1900, p. 113.
[3] Ball, S. H., and Smith, A. F., Mo. Bur. Geol. and Mines, Vol. I, 2nd ser., 1903, Chap. V.
[4] Van Horn, F. B., and Buckley, E. R., Mo. Bur. Geol. and Mines, Vol. III, 2nd ser., 1905, pp. 21-23.

Beds carrying the typical Roubidoux fauna have a wide distribution in North America and are known in northern Europe.

It is well exposed in the western and southern portions of the Eminence quadrangle, where the plateau surfaces are but slightly dissected. It also caps the divide between Logan Creek and Current River, and forms a rough, broken circle around the area of porphyry knobs. Small remnants of the formation found on some of the higher hills in this central area indicate that the Roubidoux once passed entirely over the region. In the western and southern portions of the Eminence quadrangle and along the divide south of Mill Creek, in the southwestern portion of the Cardareva quadrangle, the formation is largely in place. Throughout the remainder of the area it is very doubtful if there is anything more than a thick mantle of residual material derived from this formation.

Thickness. No accurate determination of the thickness of the formation in this area can be made. The base is well exposed at several localities in the western portion of the region, and good sections of the lower portion of the formation may be readily measured. As a general rule, the Roubidoux is the youngest formation to be exposed in any section and the top is therefore commonly missing. Even in the area where it is covered with residual cherts from the Jefferson City and Cotter formations, the upper part of the Roubidoux has been so deeply affected by solution that the contact is obscure, and accurate measurements are difficult. Sections measured in the southwestern portion of the Eminence quadrangle show that the formation is at least 150-170 feet in thickness and it may be as much as 200 feet.

In Miller County[1] the thickness is said to be between 70 and 120 feet, and in Morgan County[2] the average thickness is given as 100 feet. In the Rolla quadrangle, Lee[3] reports a thickness of 115 to 150 feet, the formation thickening toward the south.

Sections reported from deep wells vary from as little as 50 feet to as much as 300 feet, but are mostly unreliable for the formation is extremely variable in its lithologic composition and may contain a great deal of dolomite which up to the present time has been very difficult to separate from the dolomites of the

[1]Ball, S. H., and Smith, A. F., Geol. of Miller County, Mo. Bur. of Geol. and Mines, Vol. I, 2nd ser., 1903, p. 52.

[2]Marbut, C. F., Geol. of Morgan County, Mo. Bur. Geol. and Mines, Vol. VII, 2nd ser., 1908, Pl. VII, p. 19.

[3]Lee, Wallace, Geol. Rolla Quadrangle, Mo. Bur. Geol. and Mines, Vol. XII, 2nd ser., 1913, p. 21.

under and overlying formations. It is believed that the studies now being carried on by the Missouri Bureau of Geology and Mines will furnish criteria which will permit the separation of the Roubidoux dolomites from others which resemble it, and that in the future much more accurate determinations may be obtained.

From all of the evidence now at hand, the formation appears to thicken in the south-central portion of the state in much the same manner as the Van Buren and Gasconade do.

Lithologic Character. The Roubidoux is composed of interbedded sandstones and dolomites. The latter upon weathering commonly produce large quantities of chert. The formation is highly variable in character and at some places in the Ozark area is composed almost entirely of sandstone beds, while at other places it contains a large proportion of dolomite.

In the Eminence region, the formation, where in place and practically unweathered, contains approximately 50 per cent of dolomites, but over much of the area it consists of tumbled blocks of sandstone and chert in a matrix of red and yellow clay.

Good sections are to be seen in Pine Hollow, Horse Hollow, Alley Branch, and along the upper portion of Jacks Fork, but the best section in the vicinity is one recently exposed by construction work on State Highway No. 17, on the north side of Jacks Fork, about 10 miles west of the west boundary of the Eminence region.

Section of the Roubidoux Formation, on State Highway No. 17 on the north bank of Jacks Fork, in sec. 25, T. 28 N., R. 7 W., Texas County, Missouri.

Measured by J. Bridge.

Top of Hill about 230 feet above Jacks Fork along Highway.

	Thickness Feet.	Inches.
Residual Material, consisting of blocks of chert and sandstone in matrix of reddish clay—partly Cotter	60–70	
Sandstone, thick, reddish, much broken and weathered, forms large blocks, evidently not entirely in place	3	
Covered interval, residual cherts and clay	15	
Dolomite, arenaceous, coarse-grained, weathers sandy	2	
Dolomite, thin-bedded, cherty, cherts white or cream colored	8	
Sandstone, coarse-grained, yellowish, weathers rusty	2	
Dolomite, thin-bedded, gray, cherty, one bed of oolitic chert, 6 inches thick	6	
Sandstone, coarse-grained, rusty (old road crossed new road at this point), section from here down on east side of road	3	6
Dolomite, thin-bedded, gray, contains two or three bands of white chert, 4-6 inches thick	10	
Sandstone, coarse-grained, pale brown, weathers rusty	4	
Dolomite, thin-bedded, nodular, cherty upper surface uneven	6	
Sandstone, quartzitic, capped by thin bed of white chert	3	
Dolomite, similar to that above the sandstone	3	
Sandstone	3	
Dolomite, earthy	2	
Sandstone, similar to the preceding	3	
Covered interval, probably cherty dolomite	4	

	Thickness Feet.	Inches.
Cherty dolomite, and ropy weathered chert, sparingly fossiliferous.......	2	
Sandstone, massive, heavy bedded, and cross-bedded, forms conspicuous ledge at lower end of cut..........	4	
Covered interval, mostly thin-bedded, cherty dolomites..........	6	
Sandstone, thin, porous, weathers rusty brown..........	11	
Dolomite, coarse grained..........	5	
Dolomite, light gray, fine grained cotton rock..........	1	
Dolomite, dark gray, coarse grained..........	4	
Chert, hard, white, porous, sometimes oolitic, fossiliferous, better exposed along the old road to the southeast..........	1	
Sandstone, thin, irregular, base of the formation (about 1-8 mile north of bridge)..........	1	
Total thickness of measured portion..........	102	6
Total thickness of section..........	160-70	

Below the basal sandstone about 58 feet of Gasconade dolomite are exposed to water level of Jacks Fork.

In this particular section there appears to be less dolomite in the base of the formation than in the Eminence region where incomplete sections show from 30 to 45 feet of dolomite below the heavy sandstone beds of the middle portion. This lower portion of the formation is well exposed at a number of localities in Pine Hollow, and there is an excellent section in the vicinity of the school house at Midco (sec. 22, T. 27 N., R. 2 W.).

In the Eminence region the base of the Roubidoux is commonly marked by a thin sandstone, in most cases less than a foot in thickness, which is quite persistent, but is often covered by float from the overlying beds. Immediately above this is a fossiliferous, cherty zone, also about a foot thick followed in turn by a series of dolomite beds, with a few thin streaks of sandstone about 40 feet thick, and this by a series of heavy sandstone beds 2 to 8 feet thick alternating with thicker dolomite members. The upper limit of this series is not well shown anywhere within the Eminence region, for it is this sandstone member which outcrops at the surface over much of the area underlain by the formation.

The dolomites of the Roubidoux greatly resemble those of the underlying Gasconade, and it is not always easy to distinguish between them. As a rule they are more thinly bedded, and the bedding is more apt to be irregular than in the Gasconade. The dolomites vary in texture from coarsely crystalline varieties to fine grained cotton rocks. Many of the beds are distinctly arenaceous, a character not found in Gasconade dolomites.

The sandstone members consist of clean, white fine to coarse sand grains, most of which were originally more or less rounded but many of which are now angular and show well defined crystal faces, due to secondary enlargement.

Silicified Cryptozoa of several kinds are fairly abundant and are of different species from those in the other formations. In one of the most abundant forms the vertical columns are less than two inches apart on the average, and the connecting laminae are crinkly. The occurrence of these forms is always local, and no reefs of any great extent appear to have formed. Oolitic material is found at many horizons, and silicified fragments of it are common in accumulations of residual material.

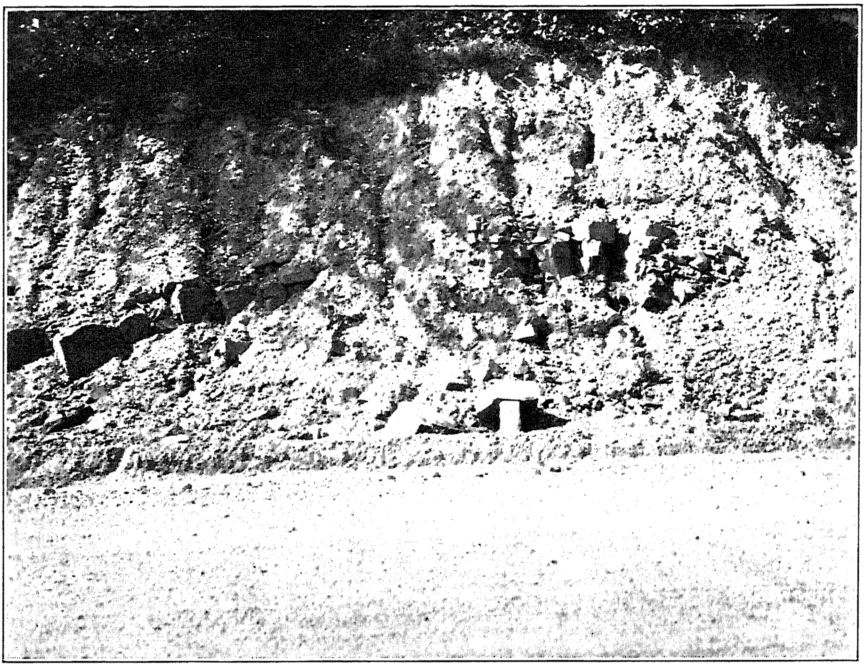
Cherts which have been formed by the weathering of flat pebble intraformational conglomerates, similar to those described from the Eminence formation are common at certain horizons, but the actual conglomerates from which they were derived have not been found.

The sandstones weather according to their topographic situation. In the plateau section, where considerable areas of upland are immediately underlain by the sandstone members, it is common to find a sandy, residual soil, with little or no clayey material and few chert fragments. Where the upland is more dissected the sand grains are washed away, and there remains a mass of sandstone blocks and chert fragments in a clayey matrix. Some of these blocks are soft and crumble readily, but many of them have been recemented by silica carried in the ground water, until they are quartzitic in texture and extremely resistant to further erosion.

On steep slopes and cliff faces the thicker sandstone and dolomite ledges often project out over the weaker strata in a manner which is not commonly seen in the older formations.

The prevailing color of the weathered sandstone is brown to reddish-brown due to staining with limonite. The sandstone layers are well bedded, and often strongly cross-bedded. Ripple marked surfaces are quite common, and many layers show sun cracks. (Plate XV-B.) In the Eminence region no sandstone beds more than 10 feet thick have been noted in the Roubidoux, but in other portions of the Ozarks much thicker beds are known.

Because of its sandstone content and resultant porosity, the Roubidoux is an important water bearing horizon, and many of the shallower wells in the plateau portion of the Eminence region obtain their supply from one or more of the sandstone layers. In the southwestern portion of the Ozark uplift, where the formation is deeply buried its importance as a source of municipal water supply increases, and many towns and small cities obtain their entire supply from wells drilled to this horizon.



A. Characteristic exposure of residual Roubidoux on U. S. Highway 60, about one mile east of Winona. Note the low anticlinal solution structure outlined by the heavy sandstone blocks.

B. Blocks of Roubidoux sandstone showing filled mud cracks. Cut on U. S. Highway 60, about ¼ mile east of Winona.

Weathering. The dolomites of the Roubidoux are extremely cherty, and weathered slopes in the lower portion of the formation are commonly strewn with a mixture of this material and sandstone blocks derived from the higher horizons. Many of these cherts are ropy and porous, and vary in color. They closely resemble those of the underlying Gasconade, and may be distinguished from them only by their faunal content. The hard, dense cherts are commonly cream colored or yellowish and may thus be identified. In addition there is a cellular chert, which resembles a light colored slag, and this variety, so far as is known is confined to the Roubidoux.

Stratigraphic Relations. The Roubidoux rests upon the Gasconade with slight apparent unconformity. As the basal sandstone is often very difficult to locate, it has been found practical to map the base of the formation with reference to the Cryptozoon reef in the Gasconade, which commonly occurs about 70 feet below the Gasconade-Roubidoux contact. This method was used over much of the western and southern portions of the Eminence quadrangle. In the Cardareva quadrangle, where solution has been particularly active, the interval has been greatly reduced over large areas, and in such places it is common to find great blocks of sandstone which could only have come from the upper member of the Roubidoux, only a few feet above, or mixed with the large blocks from the Cryptozoon reef. In such cases the contact has been drawn entirely on the distribution of these residual materials, and it is often difficult to locate it with any degree of exactness.

Every effort has been made in mapping to separate materials which are dominantly Gasconade from those which are dominantly Roubidoux, but such contacts are only approximate and are so indicated.

Inasmuch as the top of the formation is always deeply weathered in this region, and because the overlying formations, where present, are represented only by residual material, not much can be said concerning the nature of the upper contact, but it is probably unconformable.

Paleontology. Just above the basal sandstone there is a thin cherty horizon that is highly fossiliferous. The principal forms found are *Syntrophina campbelli* (Walcott) and a large undescribed trochoid shell which Ulrich designates *Roubidouxia umbilicata.*

The main faunal zone occurs from 60 to 70 feet above the base in a zone of chert immediately overlying one of the sandstone beds. The fossils contained in it consist almost entirely of various species of the genus *Lecanospira*, (Plate XXII) a new genus proposed by Ulrich[1] with *Ophileta compacta* Salter, as the genotype. This zone is widely distributed throughout the state.

Aside from these two horizons, fossils are extremely rare in the Roubidoux.

Correlation. The *Lecanospira* fauna of the Roubidoux is well developed throughout the length of the Appalachian trough, occurring in the Longview limestone of Alabama and in the Nittany limestone of Pennsylvania and Tennessee and in the lower part of Division C of the New York Beekmantown. It continues northeastward and is again found in the northern portion of Scotland and in Scandinavia. It is also known from certain formations in the Rocky mountain trough and from the Arbuckle limestone of Oklahoma, but, according to Ulrich, these western formations contain different species, and represent a separate invasion which was not directly connected with the Missouri embayment.

RESIDUAL CHERTS.

In the southwestern portion of the Cardareva quadrangle there is an area of some 6 or 7 square miles which is heavily mantled with residual cherts of various ages, and in which there are practically no outcrops of the sedimentary rocks.

It lies, for the most part, on the south and east side of Stegall and Big Thorny mountains, on the headwaters of Mill and Rogers Creeks. These long creeks are practically at grade, and have very little water in their upper courses, and are not able to remove the residual material as fast as it accumulates.

The great bulk of these cherts appear to have been derived from the Van Buren and Gasconade formations and the majority of the fossils which have been found here confirm this observation. Associated with this material, however, are cherts and sandstone boulders which are plainly Roubidoux, and in addition to these, sandstone boulders, which are probably Gunter, and cherts, which appear to have come from the Eminence.

[1]See Butts, Chas., Geol. of Ala., Special Rept. 14, 1926, p. 94. Pl. 16 (2 sp. figured and partially described). For *Roubidouxia* see same report, Pl. 17 (not the Missouri form).

This is an area of buried porphyry knobs, and in other parts of the region where outcrops are more abundant, there is in practically every case a thin veneer of Eminence between the porphyry and the Gunter sandstone. From the fragmentary evidence afforded by this area the same type of structure appears to be present here. The evidence for this belief is as follows:

This type of structure is well shown on the north and west sides of Stegall and Thorny mountains, in the valley of Rocky Creek, where erosion is more active.

On the east side of Stegall mountain, there are outcrops of the Van Buren dolomite along the road in the mouth of the ravine in the extreme NE. ¼ sec. 28, T. 28 N., R. 2 W., and there are outcrops of the Gunter sandstone ¼ mile to the southeast along Rogers Creek. These outcrops may be traced up and around Little Thorny mountain, and the small knob to the south of it, and pass completely around there without coming into contact with the porphyry.

In going up the ravine to the northwest, in the center of the SW. ¼ sec. 21, there are outcrops of sandstone in the creek bed. These are at an elevation of 900 feet and are dipping strongly southeast, and are believed to be Gunter. This sandstone extends in boulder form for a considerable distance up the valley and then disappears beneath the residual cherts.

Other valleys on the south flank of Stegall mountain show lines of sandstone boulders along their side which appear to dip away from the mountain and are highly suggestive of the type of structure mapped elsewhere.

In the valley of Mill Creek, in sec. 36, T. 28 N., R. 3 W., there is an abundance of sandstone float just above the road, and very little on the higher slopes. When this line of float is traced up the small east-west tributary valley in the northwest portion of the section, it rises faster than does the floor of the valley, and just across the section line to the west is a small outcrop of porphyry. The 1200 foot hill immediately west of this outcrop is capped with residual cherts, and although this hill is 100 feet higher than the surrounding crests, there is a great scarcity of residual Roubidoux materials on it, whereas they are far more abundant on the surrounding summits at lower elevations. There are other small porphyry outcrops in this vicinity and other rows of sandstone boulders which are highly suggestive of structure on the Gunter sandstone.

There is a great deal of sandstone float scattered along many of the ridge tops in this area. It occurs rather constantly at elevations of about 1100 feet, and is found on practically all of the ridges which join the porphyry knobs, and may come very close to the contact. It is difficult to determine whether this sandstone is Roubidoux or Gunter, but both horizons are believed to be represented. The patches of sandstone which lie close to the porphyry are mingled with cherts which are dominantly from the Van Buren, while those that occur at greater distance are more commonly associated with residual material from the Gasconade and Roubidoux. The Cryptozoon reef is well developed around the borders of the area, but very few fragments of it have been found within the area itself, and these nearly always occur in places where structural basins would be suspected.

Lastly, a few poorly preserved Eminence fossils have been found in cherts lying close to the porphyry contact in the NW. ¼ of sec. 29, T. 28 N., R. 2 W.

From the foregoing, it appears highly probable that the peculiar structure which is so characteristic of the remainder of the central area is also present here, and that it is masked by residual material. On the other hand it is also possible that some of these porphyry peaks were exposed in post-Eminence, pre-Gasconade time, and that the Gunter sandstone actually came into contact with the porphyry at various points.

Owing to the extremely complicated nature of the structure which is believed to exist in this area, and to the lack of reliable criteria, it has been deemed advisable to map this entire area as a mass of residual cherts, and not attempt to draw definite boundaries in it. The inferred position of the Gunter sandstone is indicated by a dashed black line. No attempt has been made to indicate the Van Buren, Gasconade or the Roubidoux boundary; in fact, it is believed that there is very little material from the past named formation present, except in the form of scattered blocks.

JEFFERSON CITY AND COTTER FORMATIONS.

Introduction. Ulrich[1] has divided the Jefferson City formation of older writers into three formations, which, in ascending order are, the Jefferson City (restricted), the Cotter and the

[1] Ulrich, E. O., in Bassler, R. S., Bibliographic Index of American Ordovician and Silurian Fossils, Bull. U. S. Nat. Mus., No. 92, Vol. 2, Pl. 2 (1915).

Powell. Recently he has added two other formations to this series, the Smithville and the Black Rock, but these are not definitely known to occur in Missouri. They have not been described, but their approximate distribution is shown on the newly published Geological Map of Arkansas.

The Jefferson City, Cotter and Powell formations are widely distributed throughout the Ozark uplift, both in Missouri and northern Arkansas. They are grouped together as Jefferson City, on the 1922 and 1926 editions of the Geological Map of Missouri, but are shown separately on the Arkansas Map. The Cotter and Powell have been differentiated in the Eureka Springs-Harrison Folio[1] and in unpublished work on the adjoining Yellville folio. All three formations have been separately mapped in Ste. Genevieve Co., Mo.[2]

In the Rolla quadrangle[3] it is now known that what was mapped as the Jefferson City formation, actually includes a considerable thickness of Cotter, the boundary between the two being drawn at a thin sandstone about 30 to 35 feet above the top of the pitted dolomite member.[4]

The Jefferson City formation is thickest on the north flank of the Ozark region, and appears to completely encircle it. It thins toward the central St. Francois mountain mass and locally may be absent. Whether this is due to non-deposition or to post-Jefferson City erosion is not clear at the present time.

The Cotter is thicker toward the south and thins northward, and is now believed to have covered most of the Ozark region.

The Powell is known along the eastern and southern flanks of the Ozark uplift, but its exact distribution is still to be determined.

Areal Distribution. In the southwestern portion of the Eminence quadrangle is an area of about 10 square miles on the divide between the Jacks Fork and the Eleven Point drainage, which is mantled with large blocks of chert. This area extends from the western edge of the quadrangle to a point a mile or so east of Bartlett, and has an average width of about three miles. It is a portion of a much larger tract lying to the south and southwest, the Central Plateau province of Sauer.

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[1]U. S. Geol. Surv., Folio No. 202.

[2]Weller, Stuart, and St. Clair, Stuart, Geol. of Ste. Genevieve Co., Mo., Bur. Geol. and Mines, Vol. XXII, 2nd ser., 1928.

[3]Lee, Wallace, Geol. of the Rolla Quadrangle, Mo. Bur. Geol. and Mines, Vol. XII, 2nd ser., 1913.

[4]Cullison, J. S., Unpublished Thesis, Library, Mo. School of Mines.

The bulk of the residual cherts capping this divide are characteristic of the Cotter, but here and there a few have been found which indicate the presence of the Jefferson City as well. In other parts of the Ozark region the Cotter is known to yield an abundance of chert, which is highly characteristic, while the Jefferson City furnishes comparatively little, so that its presence is difficult to determine in residual materials unless some of the characteristic fossils are found, as was the case in this instance.

Thickness. Since all of this material is residual, no definite sections can be measured, but the total thickness of these cherts at any one point is probably less than 50 feet.

Lithologic Character. These cherts are quite distinct from those of the underlying Roubidoux. They are fairly large, the average size of the masses ranging from 3 or 4 inches up to a foot or more in diameter. They are dead-white in color, and often are stained various shades of gray, yellow and red. Much of the chert is dense and compact, and breaks into angular blocks. Brecciated, knotted and porous varieties also occur. One of the rarer but most distinctive types consists of round or ovoid nodules from 1 to 8 inches in diameter, which, when broken open show concentric banding of white and bluish layers, a type of chert which is highly characteristic of the Cotter in other localities.

There are no outcrops of the formation from which these cherts have been derived in the Eminence region, or within several miles of it. In following Highway No. 19 southward from Birch Tree, these cherts become more and more abundant, and along this route through Oregon county they cover the hilltops to the exclusion of other forms. In the vicinity of Mammoth Spring, they are definitely associated with outcrops of the Cotter formation.

Paleontology and Correlation. Few fossils have been found in the formation in the Eminence region, and no attempt will be made to discuss the paleontology of the formation at this time.

A single sponge, referred to *Calathium, sp.*, was found in these cherts along the road in the extreme SE. corner sec. 28, T. 27 N., R. 5 W. This sponge is said by Ulrich to be characteristic of the Jefferson City, and has been found in that formation at several places in the Ozark region.

Large silicified fragments of Cryptozoa, apparently *C. minnesotensis* a common Cotter form are occasionally found. Fossils are extremely rare and imperfect, but most of those found appear to be Cotter forms. A list of Jefferson City and Cotter species is published in the report of Ste. Genevieve Co.[1] and some of these forms have been figured by Butts[2] and the formation is correlated in part at least with the Shakopee dolomite of Wisconsin, the Newala limestone of Alabama and with the upper part of Division C of the New York Beekmantown.

MISSISSIPPIAN SYSTEM.

OSAGE SERIES.

Introduction. At a few places in the Eminence region small patches of chert boulders carrying Mississippian fossils have been found. These boulder patches invariably occur on or very close to the plateau surface, and similar occurrences are fairly common in other portions of the Ozark uplift.[3] There are no outcrops from which these materials could have been derived, either in Shannon county, or in the surrounding region, but the topographic position of these cherts indicates plainly that they are residual deposits, and are the remnants of a younger formation which formerly covered most of the area. The largest of them is near Bartlett, where boulders containing Mississippian fossils are found over much of the central portion of the north ½ sec. 17, T. 27 N., R. 4. In this locality they are intimately associated with other residual materials and the entire deposit appears to have accumulated in an ancient sink hole of considerable dimensions. The other Mississippian boulder deposits are much smaller, but they occur in areas where the upland surface is greatly dissected. They, too, may have originated as sink hole deposits, but at the present time they are merely small accumulations of chert boulders on or near the crests of the divides, and the finer materials that were formerly associated with them have been washed away. The location of the smaller patches is given in the list of fossil localities, (see appendix). Localities 98.19, 20, 35, 36, 37, 38 and 90.16, are the ones from which Mississippian fossils have been collected. Doubtless there are other small accumulations of these boulders which have not been found.

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[1]Weller, Stuart, and St. Clair, Stuart, Geol. of Ste. Genevieve County, Mo., Bur. Geol. and Mines, Vol. XXII, 2nd ser., 1928, pp. 80 and 84.

[2]Butts, Chas., Geol. of Ala., Ala. Geol. Sur., Sp. Rept. No. 14, 1926, pl. 17.

[3]Bridge, J., A Study of the Faunas of the Residual Mississippian of Phelps County (Central Ozark Region), Missouri: Jour. Geol., Vol. XXV, No. 6, 1917, pp. 558-75.

Lithologic character. The majority of these cherts are hard, dense, grayish-white in color, and somewhat resemble the white cherts of the Gasconade. Many of them are deeply iron stained. They may be readily distinguished by their fossil content, the most abundant and useful form being the innumerable impressions of the separated disks of crinoid stems. At the Bartlett locality there are a number of almost spherical cherts, from 4 to 6 inches in diameter and these also contain Mississippian fossils.

Paleontology and correlation. As in the case with other deposits of this character which have been examined, several Mississippian horizons appear to be represented, and the faunas of individual boulders must be kept separate.

A single fragment from 98.36 is literally a mass of impressions of crinoid stem joints, among which the oval impressions of the genus *Platycrinus* are extremely abundant. A single brachiopod fragment from the same boulder appears to be referable to *Schizophoria swallowi* (Hall). Material which appears to have come from the same horizon has also been found at 98.35 (Bartlett) and at 98.37 & 38. The lithology of the chert, the abundant crinoid fragments, and the few other fossils found in it make the reference of this particular variety to the Burlington division of the Osage group fairly certain.

Another fragment from 98.35 yields a somewhat younger fauna, characterized by the following forms:

Fenestella sp.

Pustula alternata (N. & P.).

Pustula sp.

Delthyris similis (?) Weller.

Still another fragment from the same locality contains a well preserved specimen of *Hemitrypa perstriata* Ulrich. These forms are characteristic of the Keokuk division of the Osage. Both of these horizons are well represented in residual Mississippian chert accumulations in other portions of the Ozark region, and it seems fairly certain that the Osage seas covered most, if not all of the Ozark uplift.

PENNSYLVANIAN (?) SYSTEM.

CHEROKEE FORMATION.

Introduction. At the Bartlett locality, the Mississippian cherts are associated with a great mass of red, yellow, white and black clays, sandstone boulders, chert fragments etc., which are totally unlike any other deposits noted within the Eminence region. This deposit is a little over a mile in length and half as wide. It is situated on the plateau surface and is almost entirely concealed by a mantle of soil and rock fragments, so that exposures of the clays are extremely poor. A good exposure existed at one time in the railroad cut a half a mile east of Bartlett, in the SE. corner of sec. 16, T. 27 N., R. 4 W., but this has long since been covered by surface wash. About an eighth of a mile northwest of this cut, small exposures of white clay were noted in an outlet ditch draining the small pond shown on the map. Aside from these localities, the only other places at which these clays have been seen is on the dumps of test pits which have been dug by the owners of the property.

Much of this deposit consists of a fine grained deep red clay, which, if pure enough might be used for mineral paint. Associated with this are beds of yellow ochreous clays, some of which appear to be quite pure, and also beds of impure white and black fire clays. The color of the latter is due to small amounts of manganese, but analyses show the manganese content to be less than 2 per cent. The test pits show these clays to be well stratified, but they dip in various directions at high angles.

A few beds of sandstone are interbedded with the clays, and in some portions of the deposit, residual materials, including the Mississippian cherts are abundant. Some of the cherts are thoroughly leached, and have approximately the composition of tripoli, but there does not appear to be enough of this material to warrant mining.

Thickness and character. The total thickness of the deposit is not known, but it is probably less than 100 feet. A combined test pit and auger hole near the center of the north line of the northwest quarter of the section is said to have reached a depth of 55 feet without going out of the red clay. Samples from a test shaft also in the northwest quarter of the section, exact locality unknown, were submited by the owner, and from them the following section has been constructed:

		Thickness Feet.	Inches.
1.	Soil	1	
2.	Yellow ochre, apparently of good quality	5	
3.	Fire clay, impure	4	
4.	Sandstone, dense, quartzitic	2	
5.	Ochre, similar to Bed 2	4	
6.	Clay, reddish, impure, but perhaps suitable for ordinary brick	12	
7.	White clay, impure, of no value		4
8.	Black clay		10
9.	White clay, similar to No. 7		5
10.	Impure residual clays, derived from the weathering of the underlying limestones, exact thickness not given.		
	Total depth of shaft approximately	30	

The entire deposit appears to have accumulated in a shallow swampy basin, which was probably a large sink connected with one of the caves which had been formed in the older limestones. A portion of the roof collapsed or sank slowly, thus dropping these materials into the cave and preserving them from subsequent erosion.

No fossils have been found in any of the clays, but the fossiliferous Mississippian boulders contained in them, indicate that the deposit is younger than the boulders, since they had been reduced to boulder form before they were incorporated in this deposit. Similar deposits in other portions of the Ozark region have commonly been classed as basal Pennsylvanian, from their lithologic similarity to the basal members of the Cherokee formation, and also from the fact that in some of these sink deposits coal is associated with the clays. In one or two instances, Pennsylvanian fossils have been found in beds overlying these sink deposits.

While it is impossible to correlate these clays accurately, there seems to be a strong possibility that they are of the same age as the other clay-filled sinks of the Ozark region, and they are therefore tentatively referred to the Pennsylvanian.

CENOZOIC DEPOSITS.

QUATERNARY SYSTEM.

ALLUVIUM.

The valley bottoms of the larger creeks and of the rivers are floored with a mantle of boulders, gravel, sand and silt, derived from the weathering of the rocks of the region, and transported to their present position by the streams. This deposit varies from a few inches in thickness up to as much as 20 or 30 feet.

The coarser materials are to be found along the smaller creeks. In such places large boulders and coarse gravel make up the bulk of the deposit, and the soils are thin and stony. Along the larger streams the sorting is much more perfect, and the gravels, sands and silts are fairly well stratified.

Limestone boulders and pebbles are found along some of the smaller creeks, but this material is dissolved and ground up before reaching the larger streams, so that practically all the pebbles of the river are composed of angular and slightly rounded fragments of chert and sandstone. Porphyry fragments are abundant in the small creeks heading back into the central area, but pebbles of this material are not common in the river gravels.

Because of the velocity of the larger streams, the gravel beds are commonly very clean, and although more or less mixed with sand, layers of clay and silt are sometimes interbedded with the gravels, and may grade laterally into them. These stream deposits often grade laterally into the residual materials accumulating along the hillsides.

The physical characters and uses of these Ozark stream gravels and sands have been described by Dake.[1] The alluvial soils overlying these sand and gravel beds constitute the best farming land in the region.

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[1]Dake, C. L., The Sand and Gravel Resources of Missouri, Mo. Bur. Geol. and Mines, Vol. XV, 2nd ser., 1918, p. 225.

CHAPTER III.

GEOLOGIC HISTORY.

General Statement. The geologic history of the Eminence Region, when supplemented by that of the St. Francois mountains,[1] is practically the early history of the Ozark uplift. This history has been briefly sketched in various publications, but the present studies have brought many additional facts to light, so that a rather thorough revision and amplification of previously published statements is necessary. The Eminence region is but a small portion of the Ozark uplift, and only a portion of its geologic history can be deciphered from the evidence within its borders. It is therefore necessary to bring in additional data from other parts of the uplift in order to present a more complete outline of the events which have taken place in this region.

Pre-Cambrian. The extrusion of the great mass of rhyolite porphyry, which now forms the basement upon which the sedimentary rocks rest is the first event of which there is actual evidence, either here or anywhere in the Ozarks. Little is known of the floor upon which these rocks were extruded, but the general character of the oldest rocks in other parts of North America, together with the information obtained from a number of deep wells in various parts of the Ozark uplift, leads to the inference that it was probably a complex metamorphic series. This series had a long history of formation, folding, metamorphism, intrusion and erosion, before the extrusion of these rhyolites. Neither the location of the vents through which the rhyolite was extruded, nor the relationship of the rhyolites of the Eminence region to those of the St. Francois mountains is definitely known. Lithologically and petrographically they are much alike, but there is no direct evidence to show that they were ever connected. There is no conclusive evidence as to the relationship of the rhyolite and the granite. Haworth[2] has presented considerable evidence to show that the rhyolite is a fine-grained surficial phase of the granite in the St. Francois mountains. There are, however, several distinct types of granite, and it is

[1]Dake, C. L., Geol. of the Potosi-Edgehill Quadrangles, Mo. Bur. Geol. and Mines, Vol. XXIII, 2nd ser., p. 194.

[2]Haworth, E., The Crystalline Rocks of Missouri, Mo. Geol. Survey, Vol. VIII, 1895, pp. 209-21; also Report on the Mine La Motte Sheet, Vol. X, 1896, pt. 4, p. 20, 24-5 and 36.

quite probable that they belong to different periods of igneous activity. Recently Muilenburg[1] has found an area near Fredericktown, where the granite appears to be intrusive into the porphyry, and therefore distinctly younger. Doubtless both interpretations are correct, for this igneous activity must have lasted over a considerable period of time.

The localization of the pre-Cambrian outcrops in the Eminence region is interesting, but no definite reason may be assigned for it. The outcrops, with the single exception of the granite southeast of Van Buren, are enclosed within a rectangular area, approximately fourteen by eighteen miles in extent. The sides of this block strike approximately northeast and northwest. This is plainly shown on the structure map, Fig. 9. In addition the map shows a prolongation of the northeastern margin of the block to the southeast. This is manifested by a number of low domes in the southeastern portion of the Cardareva quadrangle, just west of Van Buren, and it is an interesting, and perhaps significant fact, that the granite outcrop southeast of Van Buren lies along this general line.

Three interpretations are possible:—

1. That the igneous area in this region and the one forming the St. Francois mountains are erosion remnants of a once larger and perhaps continuous sheet.
2. That there were two sharply localized centers of igneous activity, of which these two areas are now the greatly dissected remnants.
3. That these two areas owe their present relief above the pre-Cambrian surface to faulting, which must have begun in pre-Cambrian time.

The first idea is favored by the close lithologic and petrographic similarity of the rocks, though even this relationship would not necessarily imply that they had ever been connected. If it is the sole interpretation, it implies the removal of an immense amount of material during the latter portion of pre-Cambrian time. Although there was a vast amount of time available in which this erosion could have been accomplished, the idea taken alone appears to be the least probable of the three.

A block of this sort, with fairly regular and steep fronts, might well be produced by the extrusion of lavas from a few vents located along joints or fissures, and in this connection it is in-

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

teresting to note that the joint system observed in the rhyolites is practically parallel with the sides of the block.

The St. Francois mountains owe a large part of their present elevation above the surrounding country to post-Cambrian faulting. It is highly possible that faulting was initiated in pre-Cambrian times close to, or along the present lines of fracture, and that it is responsible for the original greater elevation and consequent dissection of the block. No faults have been observed in the Eminence area. The regular margins of the porphyry area were noted in the course of mapping, and the structure map, Fig. 9, serves to amplify and clarify these observations. The regularity and parallelism of the edges of this central mass are remarkable, and strongly suggest an upthrown block. If faulting has played any part in the formation of the isolated block of pre-Cambrian in the Eminence area, it must at least be pre-Potosi in age, and is more probably pre-Cambrian. The localization of mineralization along the margins, particularly along the southwestern one, and observation first pointed out by Mr. E. T. Campbell, lends some color to the idea of buried marginal faults.

With our present state of knowledge, no definite answer to the problem can be given. The central porphyry mass in this area may be a monadnock, it may be an elevation due to extrusion, it may be a dissected fault block; or, what is much more likely, it may have been caused by a combination of any two, or of all three factors.

Whatever the cause may have been, the fact remains that during the latter part of pre-Cambrian time the central portion of the Eminence region was elevated above the surrounding territory and was thoroughly dissected by stream erosion. The actual relief is not known. The ancient mountain tops are now exposed with a relief of nearly 800 feet, but the deeper valleys, and the surface upon which these mountains stood are still deeply buried, and no drill holes have reached them in this district. From the thickness of the sediments elsewhere, and from the projection of the exposed porphyry slopes downward, it may be assumed with a fair degree of certainty that at least as much of the old topography is buried as is now exposed. In other words, the actual relief of the central area could not have been much less than 1500 feet at the time of the invasion of the Upper Cambrian seas. It is also probable that there were lower hills on either side of the central block, and that it did not rise abruptly from a level plain. This is suggested by a number of low, gentle domes in the eastern portion of the Cardareva quadrangle, which probably indicate the tops of deeply buried hills. No such domes appear on the western side of the area. On this side, erosion has not yet cut to the level of the Gunter sandstone, and the data for the structure contours have been taken from higher contacts, whose elevations have been reduced to that of the Gunter. Because of the filling up of minor inequalities by the intervening sediments, this portion of the structure map is extremely generalized, and the picture which it presents is rather that of the upper surface brought down to the level of the Gunter, than an actual representation of the lower surface. The contrast is quite striking and serves to illustrate the loss of detail of the buried hills, as the thickness of the sediments overlying them increased.

Pre-Bonneterre Erosion. The period of erosion required to produce these hills was an extremely long one, beginning at some undetermined date in the pre-Cambrian, probably late in Algonkian time and lasting until some time early in the Upper Cambrian. The reason for considering these pre-Cambrian rocks as Algonkian has already been discussed, p. 64. When it is remembered that Algonkian time is generally considered to be as long as all succeeding geologic time, and that the Lower Cambrian is now considered to be as long as most geologic periods, and that remainder of the Cambrian is at least as long as the Lower Cambrian, the magnitude of this erosion interval which is here dismissed so briefly due to lack of knowledge, becomes apparent. It is estimated in round numbers that some 550 million years have elapsed since the beginning of Cambrian time.[1] The time of the unrecorded interval between the formation of the rhyolites and the deposition of the Cambrian sediments, is of about the same magnitude. Little is known of what took place in the Mississippi valley during these epochs and there is no evidence in the Eminence region that anything except erosion was going on. In the St. Francois mountains there are basic dikes, which were intruded during this interval. There are also bedded deposits of volcanic ash which are plainly younger than the great bulk of the Algonkian (?) rocks.

During the process of the carving of this topography, terrestrial and fluviatile sediments were undoubtedly laid down

[1]Shimer, H. W., Introduction to Earth History, 1925, p. 178.
Holmes, A., The Age of the Earth, 1927, p. 78.

over parts of the area, and later removed. The sea may have invaded the region once, or several times, and left a record of its presence. Throughout all of this time erosion was the dominant factor, and whatever sedimentary record may have been formed during this long interval, was completely removed before the deposition of the Cambrian series.

First Cambrian Submergence. During the latter portion of the Cambrian period, the Ozark area was gradually submerged. Some portions of it, including a part of the Eminence region, remained above water. The advancing sea worked over the detrital material which had accumulated on the lower slopes, and formed the initial deposits of conglomerates and sands on the lower portions of the old surface. Additional clastic material was brought in from nearby land masses and mixed with these reworked residual products. This deposit, known in Missouri as the Lamotte sandstone, is well exposed in and around the St. Francois mountains, but is not exposed in the Eminence area, where it is doubtlessly present in some of the deeper basins.

There are no records of its having been encountered in deep drill holes. The rhyolites yield practically no sand upon weathering, the granites yield some, but the Lamotte is locally very thick. The areas remaining above the sea in southeastern Missouri were quite small, and do not appear to have been able to furnish much clastic material. Therefore the source of the main mass of this sand is to be looked for outside of this immediate area. Dake has presented reasons for believing that the source of these sands was from the north, particularly from the pre-Cambrian shield in the Lake Superior district. However, Ockerman[1] has found that pink and colorless garnet is an important and in some cases the dominant heavy mineral in most of the Cambrian and early Ordovician sandstones of Wisconsin. Neither Dake, Cordry, Grawe nor Cullison have found this mineral in the sandstones of the Ozark region, and if these have had a common source and origin with those of Wisconsin, this absence is difficult to explain.

It seems more probable that much of Lamotte was derived from less remote sources. Some of it doubtless came from the granite ridges of western Missouri, eastern Oklahoma and Kansas, which were emerged during much of early Paleozoic time, and some of it may have been derived from lower lands lying

[1]Ockerman, J. W., A Petrographic Study of the Madison and Jordon Sandstones of Southern Wisconsin, Jour. Geol., Vol. XXXVIII, 1930, p. 350.

between the Ozarks and the pre-Cambrian shield. As the submergence progressed, the sources of material became more and more remote, and the sandstone was succeeded by thick beds of limestone. This is now known as the Bonneterre limestone or dolomite. It is the oldest sedimentary rock exposed in the Eminence region, and as already noted, the outcrops are limited to one small area. In the base of the formation where it rests against the pre-Cambrian there is a heavy conglomerate, made up of water worn and rounded rhyolite pebbles. In the lower layers of this conglomerate, the pebbles are in contact with each other, as would be expected in an old beach deposit, or submerged talus slope. Farther up in the formation the pebbles are not as abundant, and each pebble is completely isolated in a matrix of limestone. These would seem best interpreted as pebbles washed from the neighboring land surface into the plastic lime mud. The pebbles become smaller and less frequent in successively higher beds and after a few feet none are found. The time during the deposition of this formation, represents a period of maximum submergence, and as far as is known from outcrops and drill records, practically all of the Ozark region, and much of the adjacent territory was under water. A few high peaks projected, forming small groups of rocky islands. Such a group existed in the Eminence region at this time.

This submergence was followed by a retreat of the seas and by the deposition of clastic sediments in the Ozark uplift. There is no record of this event in the Eminence-Cardareva quadrangles, but in the deeper basins of the Ozarks and around the St. Francois mountains, a series of strata known as the Davis, Derby and Doe Run formations having an aggregate thickness of about 260 feet were deposited on top of the Bonneterre. The lower part of this series contains considerable limestone, but it also contains beds of shale, shaly sandstone, thin layers of sandstone, and beds of edgewise conglomerate all of which are indicative of shallow water conditions. Mud cracked surfaces indicate occasional emergences for brief periods. The upper portion of this series contains a larger percentage of limestones and indicates a return to the more normal conditions of sedimentation. Throughout this cycle the lower portions of the Eminence region may have been submerged, but the small islets of Bonneterre period were now higher above sea level, and much of the sediment which had been deposited on them was eroded away and transported to the intermontane basins.

Pre-Potosi Erosion. The cycle of deposition whose history has just been outlined, was followed by a period of uplift which brought the higher portions of the Ozarks above the water, and subjected the newly formed strata to erosion. The time interval involved in this break is long, and is represented in Missouri wherever these formations are exposed. This is shown by the fact, that the Potosi rests on different formations in various localities throughout the state. The stratigraphic hiatus is always greatest in the immediate vicinity of the centers of uplift, and in such places it is not uncommon to find the Potosi resting directly on the pre-Cambrian. This break is widespread, and is found in nearly every late Cambrian section in eastern and central North America. The single exception is in Wisconsin and Minnesota where about 350 feet of strata intervene between the equivalents of the Doe Run and the Potosi.

The Eminence region was subject to erosion, and much of the Derby-Doe Run, Davis and Bonneterre formations were removed from the higher portions.

It cannot be said that they were entirely removed. The probability is that they are still preserved in the deeper basins within the area of pre-Cambrian hills, and in the lower area surrounding them. Their presence or absence can only be proved by deep drilling. These younger formations (Davis, Derby and Doe Run) are almost completely missing in the central St. Francois mountain area, but reappear in full thickness around its margins, and the same conditions probably exist here. A deep well at Pomona, in Howell Co., about 40 miles southwest of Eminence, penetrated 260 feet of strata referred to these formations before reaching the Bonneterre. And a well at Salem, 35 miles to the north encountered 285 feet of the same beds. From this it seems certain that the pre-Cambrian areas in Shannon Co., and in the St. Francois Mountains were ancient centers of uplift, and that they were above sea level more often and for longer periods of time than the surrounding country. Another of these ancient land masses seems to have been located in the extreme western portion of the state, and adjacent portions of Oklahoma and Kansas. This mass is now deeply buried beneath much younger sediments, and all information regarding it must be obtained from studies of well records.[1]

Second Cambrian Submergence (Lower Ozarkian of Ulrich). Following the uplift just recorded, the Ozark region again sub-

[1]McQueen, H. S., op. cit., pls. X, XI, XII.

merged, and a new cycle of deposition started. The initial deposit was for the most part limestone. In many places where this limestone rests against the pre-Cambrian, conglomerates such as are found in the Bonneterre were formed. At other places the old surface was apparently swept clean, and there was no loose material to be incorporated in the younger series. Where this new limestone series, the Potosi, rests upon sediments of the preceding invasion, there is little physical evidence to mark the break between them, and were it not for the fact that three formations are known to intervene between the Bonneterre and Potosi dolomites in closely adjacent regions, there would be little reason for suspecting a break between these two. No basal conglomerates have been observed in the Potosi, where it rests upon an older sedimentary formation. The author agrees with Dake in attributing this to the lack of chert in the underlying sediments.

During the deposition of the Potosi dolomites the tops of the higher peaks in both the Eminence and St. Francois areas were emerged. In the Eminence region, they probably stood from 300 to 400 feet above sea level, to judge from the present relation of the dolomites to these hills.

The deposition inaugurated in Potosi time continues without appreciable break into Eminence time. As previously noted, the two formations are separated by a transition zone about 40 feet thick, the rocks of which partake of some of the characters of both formations. There may have been a slight interruption in the process of sedimentation, but if so, it must have been of short duration. Submergence began again at about this time, or else continued, and by the close of Eminence time the seas were far more widespread. The cuttings from deep wells in the western part of the state show definitely that the Eminence overlaps the Potosi and extends much farther westward. Even the highest peaks in the Eminence region appear to have been submerged and covered with at least a few feet of sediment. The earlier period of sedimentation had done much to bury the older portions of the land surface, and the interval of erosion probably also helped in this process, by transferring material from higher points to lower. The present cycle completed the burial, but not deeply enough to obliterate all traces of the ancient topography. On the contrary there must have been more than 500 feet of relief in the central portion of the Eminence region at this time, and the seas in which these sediments were deposited must have been even deeper. This cycle of sedimentation was closed by a gradual uplift which brought the higher portions of the area above water while the lower portions continued to receive marine sediments, and this fact partly accounts for the thickening of the final series of sediments away from these centers. This final stage is represented in the deeper basins of the Ozark region by the Proctor.

Post-Cambrian Erosion. The emergence at this time was greater in extent and duration than the preceding one. Practically the entire Ozark region was land for a time, and there is abundant evidence to show that this particular emergence was not confined to the Ozarks alone, but that it was rather generally distributed throughout North America, and extended into other continents. There is also considerable evidence to show that this general emergence started in other localities at a much earlier date, and that the central Mississippi valley area was above water only during the closing stages. In the St. Francois mountain region this uplift was accompanied by faulting, and the pegmatite dike at Decaturville is thought to have been intruded at or shortly before this time. Neither faulting nor igneous intrusion is known to occur within the Eminence region, but during the latter portion of this interval practically the entire Ozark region was undergoing erosion, and at one locality the enveloping sediments were removed and the pre-Cambrian rocks were again exposed.

Basal Ordovician Submergence (Upper Middle and Upper Ozarkian of Ulrich). In the Ozarks this second period of erosion was comparatively short as contrasted with other parts of the United States. It was followed by a widespread submergence, which like the preceding one seems to have entered the state from the south or southwest, and spread gradually northward. The basal deposit of this series is a thin sandstone, the Gunter, which marks the initial phase of the new cycle of sedimentation. It rests unconformably upon the underlying formations. This is shown by the basal conglomerate which is present at most localities and by the fact that it rests upon different formations at different places throughout the Ozark region.

It is absent throughout much of the St. Francois Mountains, and particularly in the block south of the east-west Palmer fault and east of the north-south Scotia-Berryman-Goodland fault.[1]

The Gunter appears in full thickness a short distance west of this fault. It is composed almost entirely of sandstone. This condition continues southwestward into the northeastern and northern portions of the Cardareva quadrangle, and beyond this, thin lenses of sandy dolomite interfinger with the sandstone layers. These dolomite beds thicken to the west and southwest and in the vicinity of Eminence they make up the bulk of the member. It would thus appear that much of the Gunter sand of the south central Ozark region was derived from the erosion of the St. Francois Mountain fault block. There is no Gunter in the northwestern portion of this block, and in addition, nearly all of the Eminence and much of the underlying formations were eroded from it at this time.[2]

To the north of the Palmer fault, and east of the Cuba fault there seems to have been a region which suffered some erosion, during this interval, but which received very little clastic sediment. Over most of this area the Eminence is developed in its full thickness, and there are even some indications of the lower beds of the Proctor.

On the other hand, the Gunter is represented by a thin chert pebble conglomerate, rarely more than a few inches in thickness, and by an occasional thin sandstone,[3] and it seems certain that it was never deposited in any considerable thickness in this territory.

Along the eastern side of the Ozark Uplift, the Gunter is well developed, and may be seen at numerous places in Perry and Ste. Genevieve Counties. It has also been found in deep wells to the northeast, north and west of the elevated areas just described and in all of these places it is much thicker.

In the deep basin to the west and northwest of the Eminence region, the Gunter becomes more dolomitic, and in some sections sand is a minor constituent, but as the old land mass in the extreme western portion of the state is approached, the percentage of sand again increases.

The most logical interpretation is to assume the presence of a land mass in the St. Francois Mountain region, which had

[1]This fault is partially shown on the State Geological Map, 1926 edition. Its southern continuation into the Edgehill quadrangle is shown on Dake's map; it has been located at several intervening points and is believed to be continuous between the Scotia and Goodland.

[2]Dake, C. L., op. cit., p. 139.

[3]Dake, C. L., op. cit. p. 139.

been elevated to different heights by faulting, in post-Eminence, pre-Van Buren time. Another land mass lay along the western border of the state, and between the two and completely surrounding them were seaways. The location of these land masses with respect to the distribution of sand and dolomite in the Gunter would seem to indicate that they had been the principal sources of the clastic sediments. Other lands, which were near enough to furnish sediment, may have been in existence at this time, but their location and extent are not known. All of them were probably submerged shortly after the deposition of the Gunter. This is particularly true of the region north of the Palmer fault, for the basal, fossiliferous beds of the dolomite member of the Van Buren are well developed in this area. The higher St. Francois mountain block may have remained out of water for a somewhat longer period.

There was no faulting in the Eminence region during this interval and the entire area seems to have undergone a period of erosion, after which it was submerged and covered by the Van Buren sediments.

The Gunter sandstone is an initial deposit laid down by an advancing sea, and although all of it is of Van Buren age, and while it is always lowest Van Buren in any particular section, the sandstone itself is not of the same age everywhere, but becomes progressively younger and younger as the higher portions of the old lands are approached. In the Eminence region the Gunter sandstone rests upon the Eminence formation in all cases, save one, but in going toward the St. Francois mountains it is found upon the gently beveled edges of all older formations down to and including the pre-Cambrian, while in the deep basin to the west and northwest it rests upon the Proctor. The same phenomenon of overlap is found to a lesser extent along the western margin of this basin, where the Gunter again overlaps some of the intervening formations and in one instance rests upon the pre-Cambrian.

With the exception of this thin sandstone at the base of the series, the Van Buren and Gasconade are remarkably free from clastic materials. The limestones evidently accumulated in warm clear seas, and the shores were either remote or low. At certain times the depth of the water must certainly have been as much as 100 fathoms, to judge from the amount of relief which must have been submerged, and at other times the seas were shallow enough to permit dense growths of bottom dwelling, calcareous algae. There seems to have been a local uplift, in the Eminence and St. Francis mountain region and elsewhere, between the deposition of the Van Buren and Gasconade sediments, for in the deeper basins this sequence is much thicker, and evidence obtained by McQueen, from studies of deep wells, indicates that much of this thickening comes between the Van Buren and Gasconade. From this it is assumed that these old centers were slightly elevated during Van Buren time, while in the adjoining basins deposition was more or less continuous. There was also an uplift to the west of the Ozark area at this time. The Van Buren sea is known to have been continuous with seas in the Arbuckle region, the seaway probably crossing the Spavinaw axis somewhere in northeastern Oklahoma. The barrier raised at this time persisted over a considerable period, for no representatives of the Gasconade fauna have been found to the southwest of this axis. The submergence by the close of this cycle of sedimentation was widespread, as is shown by the great distribution of the upper Gasconade faunas. The sea invading from the south joined with the others coming down from the north, and elements of both the southern and northern faunas are found in the upper Gasconade of Missouri and the Oneota of Wisconsin.

During the deposition of the Van Buren and Gasconade formations many of the local irregularities on the sea bottom in the Eminence region and elsewhere were partially or completely filled in, and at the close of Gasconade time, the effect of the pre-Cambrian topography upon the structure of the sediments was much less marked. If it were possible to draw structure contours on the top of the Gasconade in the Eminence region, they would probably show a gently undulating surface, which would contrast sharply with the extremely irregular surface revealed by the contours drawn on the base of the formation Fig. 9.

Invertebrate life was abundant in the Van Buren and Gasconade seas, and is well preserved at several distinct horizons. It is interesting to note that the most abundant development of life comes during early stages and again during the closing stages of sedimentation; in other words, at exactly the times when the seas would be shallowest, and would receive the most sunlight. Near the close of this stage there also appeared great numbers of the supposed lime secreting algae, Cryptozoon. (Plate XIV.) Cryptozoa of various species are fairly common in Eminence, Van Buren and Gasconade sediments, but in the upper Gasconade they were extraordinarily abundant, and built a great reef which may be found wherever the upper portion of the formation is exposed within this area. Similar reefs occur in the upper portion of the Gasconade throughout the entire Ozark uplift, and were doubtless formed at about the same time. It is not easy to account for the formation of this reef. The region was doubtlessly being slowly uplifted and the seas were becoming shallower at the time of its formation, but it occupies a very definite horizon and has a fairly uniform thickness and then disappears. The peculiar cherts which are so abundant in both the Van Buren and Gasconade are probably in part the replacements of ancient seaweeds which flourished during the opening and closing stages of this cycle, when the seas were comparatively shallow. Some of these cherts may best be interpreted as fillings of worm burrows.

Pre-Roubidoux Emergence. (Ozarkian-Canadian break of Ulrich). The uplift at the close of Gasconade time could not have been very great nor of very long duration for there is little evidence of erosion of the Gasconade surface before the deposition of the Roubidoux. In some localities there is some slight evidence of erosion and resulting unconformity, but much of what has been described as unconformity occurs in areas where both formations have been deeply weathered, and is better interpreted as the result of post-Roubidoux solution. The main evidence of the break is faunal rather than stratigraphic, and this also indicates a break of considerably less magnitude than the ones previously described. Nevertheless, the break is represented by several hundred feet of strata in the Appalachian region, which wedge in between strata carrying the Gasconade and Roubidoux faunas and serve to show something of the magnitude of the unconformity.

Roubidoux Submergence. (Middle Canadian of Ulrich). During the Roubidoux stage, conditions of sedimentation in the Ozark region were markedly different from those of the preceding stages. Limestones, similar in many respects to those of the preceding stages are common, especially in the lower portions of the formation, but they alternate with thick and thin beds of sandstone, which indicates that the seas were shallower and more restricted, and that the Ozark region probably lay somewhat closer to land masses capable of furnishing clastic sediments than it formerly had. Ripple marks and cross bedding in the sandstones also indicate shallow water conditions. Certain layers are notably sun cracked, and this indicates brief periods of emergence[1].

Post-Roubidoux Emergence. Inasmuch as the post-Roubidoux formations in the Eminence region are entirely residual, very little of the subsequent geologic history can be deciphered from a study of this area alone, and the evidence for most of the following paragraphs comes from studies of the entire Ozark region.

There is a slight break between the Roubidoux and the Jefferson City, which indicates a gentle warping of the Ozark region, with the probable emergence of a rather large tract, which included the Eminence region and the St. Francois Mountains. This area was not particularly high, and it is not known whether it was an island, or whether it was connected with the mainland at one or more points.

Jefferson City Submergence. (Upper Canadian of Ulrich). The Jefferson City sea appears to have come in from the north or northeast and to have gradually spread around and finally over most of the Ozark region. It represents a return to more normal marine conditions, for the clastic materials which are so abundant in the Roubidoux are rather rare in the Jefferson City sediments. The total extent of the submergence is not known, but it is thought that the northern portions were submerged first and that they were the last to be re-elevated. There may have been low islands in the St. Francois mountain region at the time of maximum extent of the sea.

Near the close of this cycle the Ozark region was again slowly elevated and gently tilted. A large portion of it was land for a short period of time, and was subject to erosion.

Cotter Submergence. The Cotter stage of sedimentation was somewhat similar to that of the Roubidoux. The seas again invaded the Ozark region from the south or southeast, and covered most, if not all of it. They were doubtlessly shallow, for clastic sediments chiefly sands, were deposited at times, but, as in the case with most of these early formations in the Mississippi Valley, calcareous mud predominated. Some of the sandstone layers are continuous over wide areas, others are mere local lenses in the limestones.

[1]Cox, G. H., and Dake, C. L., Geologic Criteria Determining the Structural Position of Sedimentary Beds., Bull. Mo. Sch. Mines and Met., Tech. Ser., Vol. 2, No. 4, 1916.

The Cotter sea was more widespread than the one preceding it. It crossed the Spavinaw axis in northeastern Oklahoma and covered much of the Arbuckle region, and extended up the Mississippi Valley into Wisconsin and Minnesota.

Post-Cotter History. The history of sedimentation in this region practically closes with the deposition of the Cotter. Not a trace of any of the younger beds of the Beekmantown epoch or any formations referable to the remainder of the Ordovician, the Silurian or Devonian periods have been found here. However, it should not be inferred that the Ozark region, or that this area in particular was land during all of this time. The evidence furnished by adjacent areas indicates that sedimentation probably continued in the Eminence region until near the close of the Beekmantown epoch. It is known that there were marine invasions in other parts of the Ozark region in middle and late Ordovician times, and also in Silurian and Devonian times, and it is possible that some of these invasions may have reached the Eminence region, but there is no direct proof of this.

At the beginning of Mississippian time, the Ozark region was a low, elliptical island, the margin of which was gradually submerged during the Kinderhook epoch. This submergence reached its maximum in the succeeding Osage epoch, at which time the Eminence region again lay in a broad, warm, shallow sea. As was the case in some of the earlier submergences, it was probably remote from land masses, for rocks of this epoch have a wide areal distribution in all directions from this area.

Some time after the close of the Osage epoch, the Ozark region was again warped upward, and the newly formed beds of the Osage series were eroded. By the close of the Mississippian period they have been completely stripped off from the central portion of the uplift, with the exception of scattered patches of silicified residual boulders, such as are found at a few points within the Eminence region.

At the beginning of Pennsylvanian time, the region which at this time was approximately a peneplained surface, was again partially submerged. This submergence was of different character from the preceding ones. The land lay at or near sea level, and only the margins of the Ozarks appear to have been completely submerged. The remainder of the area was subject to minor fluctuations, and was occasionally below sea level, but most of the time stood at or slightly above it. Large areas in the Ozark region appear to have been swamps, in which clays, sands and vegetable matter accumulated, and in the base of many of these deposits much residual material from the weathering of the older formations was included.

After the deposition of the early Pennsylvanian sediments the Ozark dome was again warped upward, and so far as is known, never has been re-submerged. It may be that while this uplift was going on, some of the unconsolidated sediments slumped into caverns and sinks, in the older formations. This may have taken place as the water which formerly filled them was drained off, or some of the sediments may have been originally deposited in such places at an earlier date. The majority of the sink deposits, however, show evidence of having slumped into their present position while still in a fairly plastic state.

There is no record of events within the Ozark region during the remainder of the Pennsylvanian period, nor during the remainder of the Paleozoic era, nor during the entire Mesozoic era. From the history of the surrounding territory it is presumed that it was a portion of a continental mass that was undergoing erosion. It has been thought by some that the region was reduced to base level by the close of the Mesozoic era, and that the old erosion surface which is now manifest in the level skyline of the Ozarks preserves the remnants of the so-called "Cretaceous" peneplain. The more modern view is that this peneplain is much younger, and dates from some time in the late Tertiary. The time of its completion is not certain, but it may have been as late as the Pliocene.

At this time the main river systems of the Ozark region as we know them today had been developed, and were flowing across this nearly level plain in broadly meandering courses, essentially the courses which they hold today. This was followed by a gradual uplift. The rivers, cutting downward through the soft unconsolidated material which covered this old erosion surface, soon encountered bedrock, and, being unable to shift their courses, continued to cut downward, thus entrenching the meanders deeply in the bedrock.

In the Eminence region this uplift amounted to about 400 feet. It was followed by a period of relative stability during which time the main rivers reached grade and began to widen their valleys. The period must have been of considerable duration, for in some instances, small tributary creeks, whose courses were superimposed across a buried porphyry hill, in the vicinity of one of the main streams, were able to cut through the ridge and bring their valleys to the grade of the master stream. Prairie Hollow, and the broad flat at the head of Little Rocky creek are two conspicuous examples of this.

Following this there was another period of uplift, amounting to about 300 feet in this region. This started the streams to trenching the broad valleys which they had carved in the preceding period of quiet, and the remnants of this old level are still to be seen forming the distinct bench, which is so plainly visible at so many points within the area and which has already been described. This last uplift must have occurred in comparatively recent time, for down cutting is still going on along the main streams, and although they have begun to develop narrow flood plains, they have not yet reached grade in the Eminence region, or for that matter anywhere within the central Ozark area.

CHAPTER IV.

STRUCTURE.

Introduction. The Eminence region, in common with much of the Ozark Uplift is a region of essentially horizontal rocks, which have not been greatly disturbed since their deposition.

No faulting of any magnitude has been observed within the limits of the two quadrangles.

Although it has been elevated and depressed a number of times, in each case it has acted more or less as a part of a much larger area, and no sharp folding which can be attributed to crustal deformation is known.

Nevertheless, the region displays several types of structure which are of great interest, and which are splendidly exposed.

STRUCTURES CAUSED BY BURIED TOPOGRAPHY.[1]

The importance of buried topography in the production of local domes or "structural highs" is perhaps nowhere better exemplified than in this region. This is in part due to the excellent exposures and in part to absence of subsequent deformation which would tend to obscure the original structures.

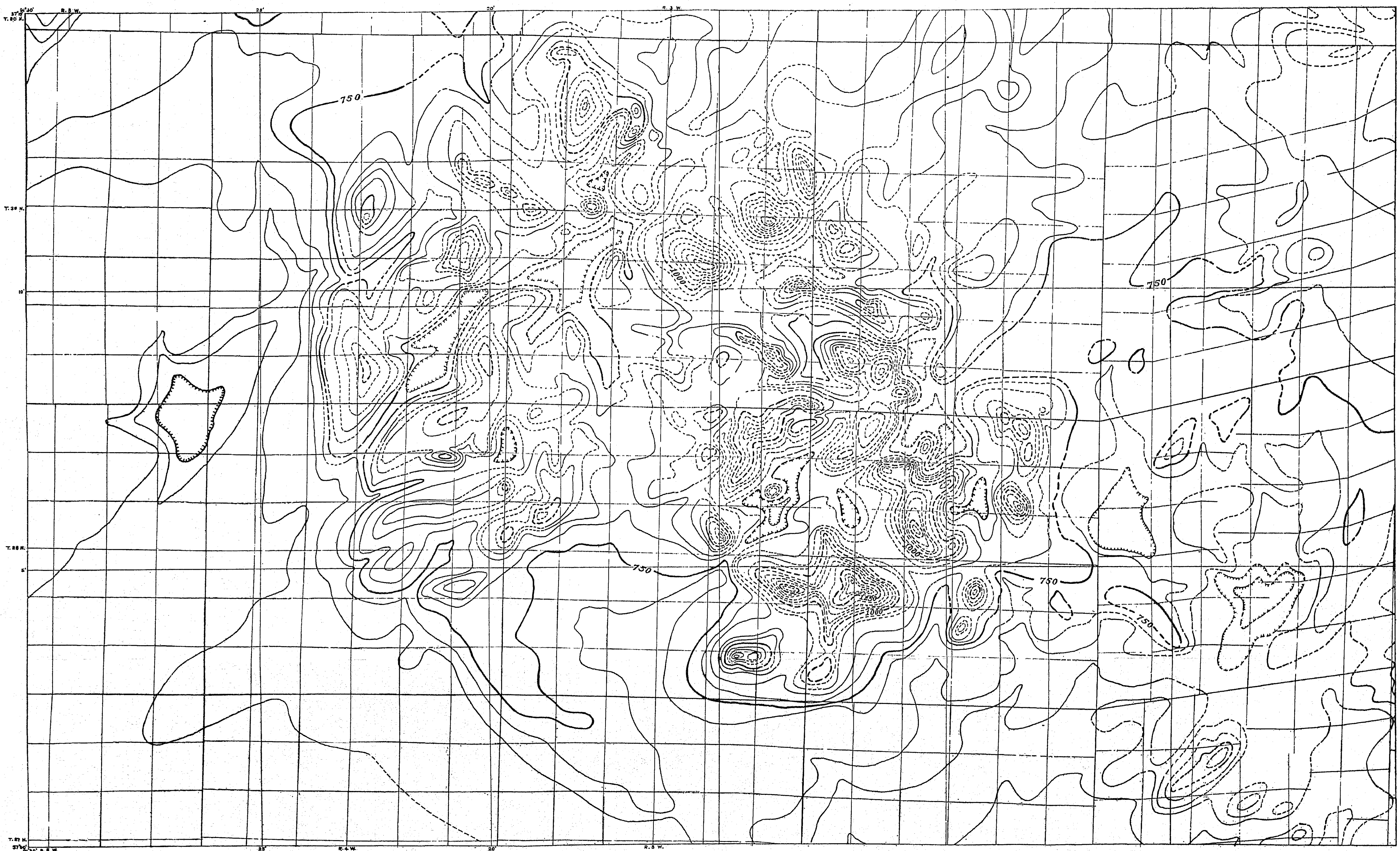
Structurally, the Eminence region may be divided into two parts: the central area in which the porphyry knobs are exposed, and the area surrounding this central portion. In the latter the rocks are essentially horizontal over many square miles and the structure is essentially that of the Ozark Uplift as a whole. The observed dips rarely exceed 5 degrees. In the southeastern portion of the Cardareva quadrangle, in the area between Little Mill Creek and Current River, there are a number of places where the dip of the rocks consistently exceeds this figure, but this small area more properly belongs with the central portion.

In the central portion the most conspicuous structural features are the moderate dips in the sedimentary rocks, which are commonly more than 5 degrees. Dips of from 10 to 20 degrees are quite common and some have been measured as high

[1]The first section of this chapter is essentially an elaboration and re-statement of the paper, "Initial Dips Peripheral to Resurrected Hills," by the present writer and C. L. Dake, published as Appendix I, 55th Biennial Report of the State Geologist of Missouri. In preparing the present chapter a number of sentences and paragraphs of the original paper have been quoted verbatim without credit.

as 30 degrees. Dip slopes are fairly common, and it is often possible to walk up the slope of a single bed, through a vertical distance of as much as 100 feet, and in some instances through a much greater distance, in one instance over 300 feet. In many cases the average inclination of the strata is slightly greater than the average slope of the topography, with the result that the oldest strata are sometimes exposed on the hilltops, while the younger strata floor the valleys, as, for example, in the area in sections 25, 35 and 36, T. 29 N., R. 4 W., immediately south and east of Eminence the direction of dip is not constant, and varies greatly in short distances. When plotted they are found to be arranged radially with respect to the outcrops of the pre-Cambrian rocks. They invariably dip away from such exposures and the amount of dip increases as these ancient rocks are approached, but does not exceed the slope of the old surface. In a few instances, notably at West Eminence and also in the NW. ¼ sec. 2, T. 28 N., R. 4 W., the observed dips radiate outward in all directions. though no pre-Cambrian outcrops are to be found. The intimate association of such dips with the outcrops of the pre-Cambrian in dozens of other instances, and the fact that these localities lie within the area of the pre-Cambrian outcrops, strongly suggests the presence of a pre-Cambrian hill at no great distance beneath the surface. The steep dips in the small area near Van Buren mentioned in an early paragraph of this chapter, are doubtless due to the same cause and, significantly enough, this area lies along the prolongation of the northeast margin of the area of pre-Cambrian outcrops. As already noted this line continues to the southeast and passes through the single pre-Cambrian outcrop southeast of Van Buren.

In order to visualize this peculiar type of structure a structure contour map (Fig. 9) has been drawn on the base of the Gunter sandstone. The data used in its compilation were mainly elevations taken on the Gunter with an aneroid barometer. The Gunter was selected because it is a thin stratum, which is well exposed through the entire area, and which, because of its lithologic character is one which will be easily recognized in any subsequent drilling. These elevations were supplemented in certain areas where the Gunter is buried, by elevations read on the Van Buren-Gasconade contact, on the Gasconade-Roubidoux contact, and upon the Cryptozoon reef in the Gasconade formation. In the areas from which the Gunter sandstone has been eroded, elevations taken on the Eminence-Potosi contact



Structure contour map of the Eminence-Cardareva quadrangles drawn on the top of the Gunter sandstone. Scale, ½ inch = 1 mile. Contour interval, 50 feet.

were employed where possible. In restoring the supposed original surface of the Gunter sandstone it has been assumed that, with one single exception, the sandstone was not in contact with the porphyry. It has also been assumed that all of the porphyry knobs were submerged during the final stages of deposition. The reasons for these assumptions are: first, the failure to find detrital materials derived from the pre-Cambrian rocks in the Gunter or in the overlying Van Buren, even in those places where it closely approaches the porphyry (with the single exception already noted); second, the fact that the Gunter may be traced far up the sides of the highest porphyry knobs without coming in contact with the porphyry; third, the fact that if the observed dip of the sandstone is projected upward it invariably clears the summit of the knob; and lastly, the finding of small patches of residual materials, derived in part from the Eminence formation, on the summits of some of the highest porphyry peaks. The highest of these residual patches is at an elevation of 1180 feet, and there are less than a dozen porphyry summits which rise higher than this. The highest of these exceeds this elevation by 160 feet.

The map, therefore, gives an approximation of the surface of these two quadrangles at the beginning of the Ordovician submergence and is an attempt to show the irregular character of the surface upon which the Van Buren and the succeeding Ordovician formations were deposited. The map shows the course of the pre-Cambrian drainage lines fairly well. Along many of these lines there are now places which are lower than any of the surrounding area. These may be due to one or more of the following causes:

1. Insufficient data at hand for the proper construction of the map.
2. Slight errors in reading elevation of a contact.
3. Failure to allow for thickening of a formation, especially in cases where data have been transferred from an overlying bed to the key bed.
4. Uneven deposition of sediments.
5. Regional tilting.

In regard to the third item listed above there is considerable evidence from deep wells outside of this area. The Van Buren-Gasconade and other formations thicken rapidly away from these old porphyry highlands, and there is some evidence of this thickening along the western edge of the Eminence quadrangle.

In the lack of definite evidence to the contrary, the thickness of the Van Buren and the Gasconade formations was assumed to be 300 feet (that is the amount which could actually be measured), and no allowance was made for thickening. If a uniform increase in thickness of between 5 and 15 feet to the mile to the southwest had been postulated (and this is not improbable), the large depression in the center of the western portion of the sheet would probably disappear or become much shallower.

Various explanations have been offered by different writers to account for these structures. These may be listed as follows:

1. Igneous intrusion.
2. Crustal deformation.
3. Isostatic adjustment.
4. Compacting of the sediments.
5. Increase in dip resulting from removal of soluble beds.
6. Initial dip.

Igneous intrusion. Doming of sedimentary strata by igneous intrusion has long been recognized as a method by which structures resembling these may be formed, the Henry mountains of Utah being the classic example.

It cannot be invoked for these structures, because the relative ages of the igneous and sedimentary rocks are firmly established, the sedimentary series being the younger. This would not even be mentioned, were it not for the fact that in one or two reports, given to various mining companies, statements have been made to the effect that the rhyolites are intrusive into the sediments, and the dips have been cited as proof. These reports have had a fairly wide circulation throughout the Eminence region, and the erroneous idea contained in them has become rather firmly rooted. It should be clearly borne in mind that in this area and in the St. Francois mountains as well, the igneous rocks are distinctly older than the sediments, and consequently could not be intrusive into them.

Crustal deformation. Folds produced by crustal deformation are invariably arranged in more or less regular systems. The dips under discussion are entirely without alignment, and in most cases are peripheral to the adjacent porphyry slopes. They appear to be directly related to the pre-Cambrian topographic surface, and the axes of the structural troughs conform closely to the pre-Cambrian drainage lines. This is quite plainly shown in the gorge of Current River, between Coot Mountain and the porphyry hills on the opposite side of the river; in the gap between Stegall and Thorny mountains, and at many other points. Large portions of the valleys as they exist today are very clearly coincident with the pre-Cambrian drainage lines. At the cable station at Coot Mountain, the river flows in a gorge 200 feet deep between porphyry hills, yet the river is still cutting on Cambrian dolomites, and at this place is re-excavating a pre-Cambrian channel. The gap between Stegall and Thorny mountains is now a low divide, but formerly was a main channel. The smaller tributaries and sub-tributaries extending back into the area of porphyry hills are extensively floored with Cambrian sediments, showing clearly that they are being re-excavated along the lines of the pre-Cambrian drainage. In this connection a comparison of the topographic map and the structural map (Fig. 9) is very interesting. The pre-Cambrian drainage is plainly indicated on the former, and, as would naturally be expected, was radial. The present drainage was developed at a time when this topography was deeply buried, and the master streams now cut directly across it. They were too deeply entrenched when they encountered the buried hills to have been greatly affected by them, but it is surprising to note the large number of pre-Cambrian channels now occupied by streams. The tributary drainage is for the most part adjusted to it. Toward the heads of these old valleys the dolomites grade into the coarse conglomerates already described, as might be expected from their topographic situation. Farther down the valleys and on prominent headlands, where the slopes were swept clean, the dolomite is in direct contact with the porphyry, and fragments of the latter are scarce. This in itself lends strength to the contention that the present structure is controlled by the pre-Cambrian slopes, and not by later deformation. This view is strengthened by the widely observed fact that the dips are always away from the ancient highlands, and toward the main valleys, the tributaries and the sub-tributaries.

It is inconceivable that any system of folding should have coincided with all of these valleys, and, since these dips are all proportional to the slope of the underlying surface, and since no one line shows more prominent dips than any other, there seems to be valid reason for believing that these folds have not been measurably intensified by later deformation. The entire lack of alignment of these structures, which is so highly characteristic of this area, has been pointed out by Blackwelder[1] as a fatal

[1]Blackwelder, Eliot, The Origin of the Central Kansas Oil Domes, Bull., A. A. P. G., Vol. 4, No. 1, 1920, pp. 90-91.

defect in the theory of tangential thrust to account for the Kansas domes, and the argument is just as effective in this case.

When the structure map is studied in detail the utter lack of any system of folding caused by compressive forces at once becomes apparent, and the relation of the structure to the pre-Cambrian exposures is obvious. The fact that successively younger and younger beds overlap onto the porphyry peaks, demonstrates conclusively that the peaks stood as prominences in the seas in which the sediments now enclosing them were deposited, and that they have not been raised to their present position above the Cambrian floor by subsequent sharp local folding.

Isostatic adjustment. Albertson[1] and some others have used this hypothesis in an attempt to account for minor domes, but it seems quite incredible that such adjustments could take place in as rigid materials as these pre-Cambrian rocks, on units of such limited extent. Many of the smaller domes are not over 200 or 300 yards across; and even the most enthusiastic proponents of isostasy would hardly attempt to apply the theory in these cases.

Compacting of the sediments. Mehl,[2] Blackwelder[3] and Powers[4] have considered the compacting of the sediments about the already completely lithified hills of older rock as an important factor. In a recent review Powers[5] states, "The reviewer conceives of regional compaction, due largely to the free underground circulation of waters, together with that due to lithification," as the dominant factor. Disregarding the first clause for a moment, it becomes pertinent to inquire how much compaction is actually due to lithification. The limestones and dolomites involved are extremely fine grained plastic sediments, and were doubtless quite similar to the lime sediments, now accumulating on the Great Bahama Bank. Lithification of these sediments seems to take place only when they are subject to great load. The amount of compaction which a given thickness of this type of sediment suffers during lithification, while not definitely known, appear

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[1]Albertson, M. M., Isostatic Adjustments on a Minor Scale in Their Relation to Oil Domes, Trans. Am. Inst. Mining Engrs., Vol. LXV, 1921, p. 418.

[2]Mehl, M. G., The Influence of Differential Compression on the Attitude of Bedded Rocks, Science, Vol. 51, 1920, p. 520.

[3]Blackwelder, Eliot, loc. cit.

[4]Powers, Sidney, Reflected Buried Hills and Their Importance in Petroleum Geology, Econ. Geol., Vol. XVII, No. 4, 1922, pp. 256-258.

[5]Powers, Sidney, Bull. Amer. Assoc. Petroleum Geologists, Vol. 12, No. 12. 1928, pp. 171-172.

to be slight.[1] Blackwelder[2] has estimated the amount of compaction occurring during the lithification of limestones as about 5%, while that of shales is much higher. The data upon which this estimate is based is not given, and no other figures appear to be obtainable at present. Let it be assumed for the moment that this figure is approximately correct. The approximate thickness of the sediments below the top of the Eminence formation in the basins between the porphyries is now between 600 and 900 feet. The sediments are dominantly limestones, with occasional sandstones, and little or no shale. Disregarding the fact that Blackwelder has given a lower estimate for the compacting of sandstones than he has for limestones, and applying his figure of 5% to the entire thickness, it is found that the amount of compaction in a column of sediments this thick will be between 30 and 45 feet. If the interknob basins were on the average of a mile wide this would produce a dip of about one degree, after compaction. The original thickness of the sediments would have been between 630 and 945 feet. Inasmuch as the total relief of the region was about 1500 feet, and since it was completely covered at the close of this cycle of sedimentation, and since the present relief on the top of the Eminence formation is in excess of 700 feet, it is evident that if the assumption of 5% compacting is correct, some other cause was of much greater consequence in producing these structures. Some part of the 700 feet of relief may be due to post-Eminence-pre-Van Buren erosion, but the greater portion of it is due to the irregular surface upon which the sedimentary formations were deposited. In order to produce this much relief by compaction alone it would be necessary to assume that the loss in thickness due to compaction is much greater, and at present there is no definite evidence that such is the case. Since there are only approximations available, as to the amount of compaction which takes place during the lithification of calcareous sediments, let us assume that the amount of compaction is as great as is commonly observed in shales.

Compaction is directly brought about by the weight of the overlying sediments. Hedberg[3] has shown that the volume of shales varies roughly in inverse proportion to the load above it,

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[1]Field, R. M., The Great Bahama Bank. Studies in Marine Carbonate Sediments, Amer. Jour. Sci., Vol. XVI, 1928, pp. 239-246: also personal communication.

[2]Blackwelder, Eliot, op. cit.

[3]Hedberg, H. D., Effect of Gravitational Compacting on the Structure of Sedimentary Rocks, Bull. Amer. Assoc. Petroleum Geologists, Vol. 10, 1926, pp. 1059-1064. (Hedberg's figures have been questioned by Rubey, see articles by Rubey and Hedburg in Bull. A. A. P. G., Vol. 11, 1927.)

and has computed from a series of laboratory experiments, that approximately 7000 feet of overlying sediments are necessary to compress 500 feet of shale to slightly more than 3/5 of its original volume. He freely admits that this is a rough figure, but assumes that it represents a fair average. Even this would only admit of a compacting of from 240 to 360 feet in the Eminence region, and this much compacting would at the most account for only half of the observed relief. Moreover, as the total paleozoic section above the Cambrian in Missouri is scarcely more than 12,000 feet in thickness, and as the great number of unconformities in the section render it extremely improbable that more than one-fourth of this thickness was ever superimposed above the Eminence formation in this region at any given time, the total amount of compaction is reduced at least one-third. If the ratio of compaction of limestone to shale is anything like the one suggested by Blackwelder,[1] the same amount of overburden would produce only about 1/6 to 1/8 as much compaction in a given amount of limestone as it would produce in an equal thickness of shale.

Overlying the Eminence dolomite is the Gunter sandstone, the key bed upon which the structure contours are drawn. This is the initial deposit upon an old erosion surface. It has a consistent thickness of between 10 and 15 feet, but the actual measured relief is in excess of 600 feet, and if, as is believed, it originally went over the summits of the highest peaks, the relief is in excess of 800 feet.

If there is any truth in the foregoing assumptions it is at once clear from the magnitude of these structures that compaction of sediments has not been the dominant factor in the production, though it may have been of some small assistance.

Solution. The ability of solution to produce folded structures in strata is well known. The general characteristics of such structures have been well summarized by Mather[2] and structures developed in this manner are extremely common in certain parts of the Eminence area. They will be discussed in detail later. Stockdale[3] has done much careful work on the amount of solution which limestones may undergo, and concludes that in many instances formations have been thinned in situ as

[1]Blackwelder, Eliot, loc. cit.

[2]Mather, K. F., Superficial dip of Marine Limestone Strata—A Factor in Petroleum Geology, Econ. Geol., Vol. XIII, No. 3, 1918, pp. 198-206.

[3]Stockdale, P. B., The Stratigraphic Significance of Solution in Rocks, Jour. Geol., Vol. XXXIV, No. 5, 1926, 399-414.

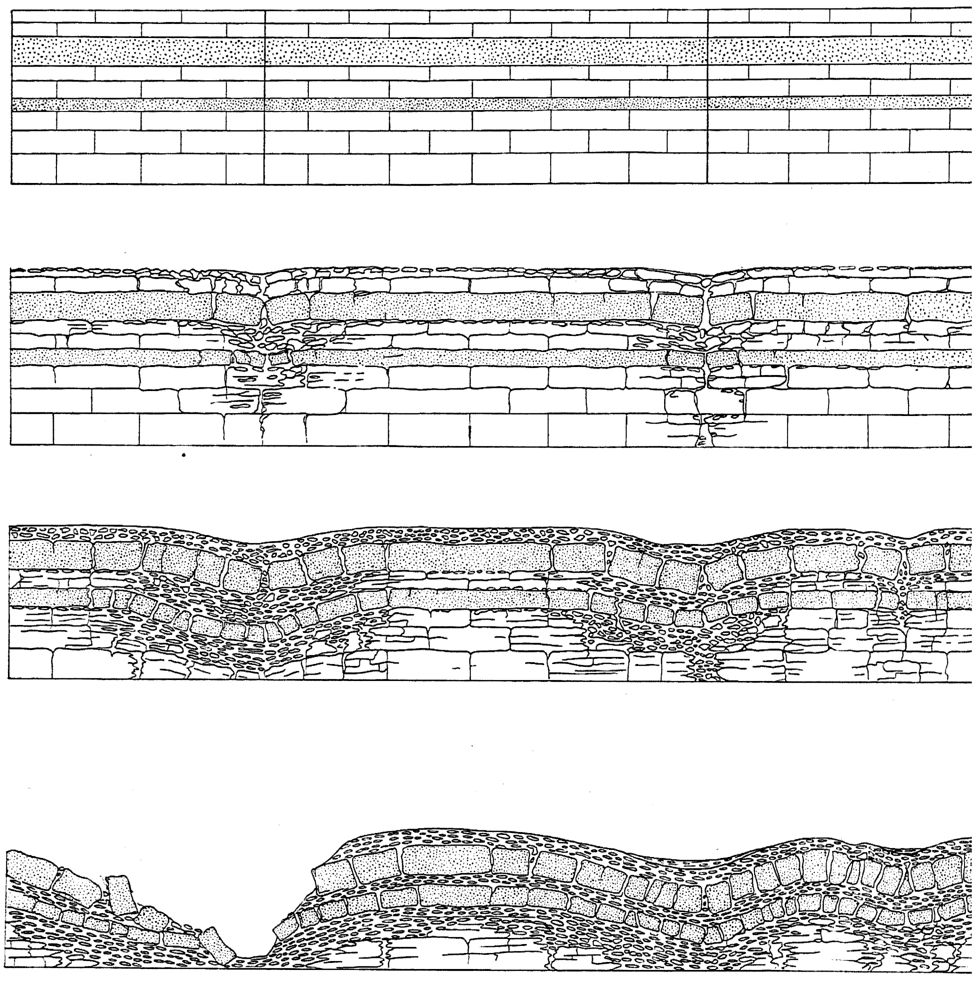


Diagram illustrating the formation of slump structure in residual material.

The upper figure shows a series of limestones and sandstones cut by two master joints; the succeeding figures show differential thinning of soluble beds, and formation of slump structures in residual material.

much as 40 per cent. He presents evidence to show that suture joints, or styloliths, are more or less a measure of the amount of solution. Where they are not developed, as in the case of the rocks under discussion, he feels that the clay partings, which are commonly interpreted as signifying simply a temporary change in conditions of sedimentation from these requisite for limestone making to those necessary for clastic silt accumulation[1] are in many cases actually the residue from the solution of a considerable thickness of rock, and with this interpretation the present writer is in full accord. It becomes necessary to distinguish between these secondary clay seams, which have been introduced since the formation of the rock, and those which actually represent a change of sedimentary conditions. The thickness of the former, when compared with an analysis of the fresh rock should give a fairly accurate estimate of the thinning, and in a relatively pure limestone a thin clay seam formed in this manner would represent a much greater thickness of original rock. Styloliths are practically absent in these strata. Thin clay partings, a fraction of an inch in thickness do occur, and some of these may represent solution residues, though there is no direct evidence for so interpreting them. On the contrary, as pointed out by Buehler,[2] if these dolomites which habitually leave a cherty residue have been greatly thinned in this manner, chert as well as clay should remain along the solution planes, and observations on some of the same formations when exposed under conditions where this weathering may have taken place amply confirm the statement.

The dolomite-porphyry contact is naturally a solution plane, and in the zone of oxidation more water migrates along this contact than along any of the bedding planes. At the Sutton mine the entire conglomerate zone at the contact of the two formations is badly decomposed, and most of its soluble constituents have been taken away. There has been little compaction, however, because the main mass of the conglomerate is of non-soluble material. The same situation obtains in the large cave at the south end of Russel mountain, opposite Cardareva School house, sec. 2, T. 28 N., R. 2 W., and also at the Natural Tunnel at the contact of the dolomite and the porphyry, in the center of the W. ½ sec. 1, T. 28 N., R. 3 W. All of these occurrences have taken place in the zone of oxidation, and are comparatively recent in age. Solution is not particularly active

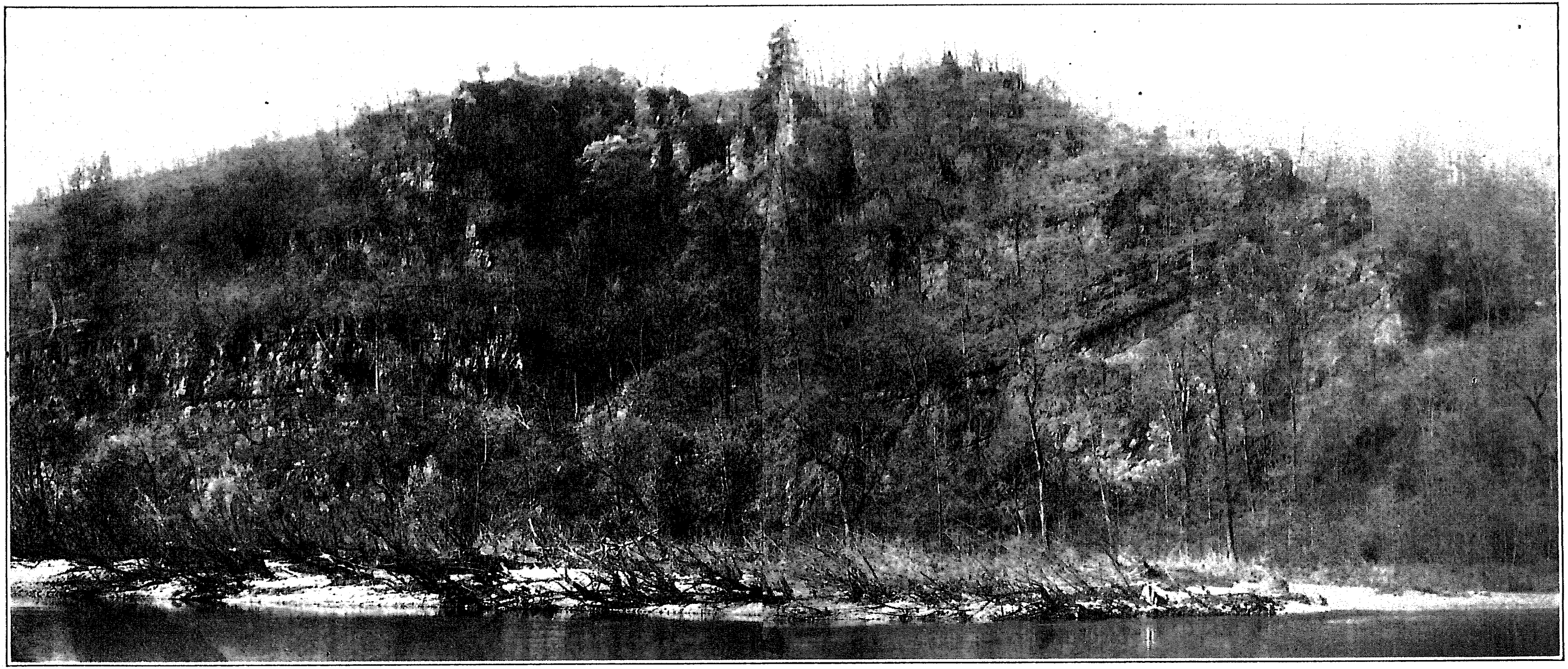
[1]Op. cit., p. 409.
[2]Buehler, H. A., personal communication.

below the water table, and it should be remembered that during the greater part of geologic time the major portions of the basins have been below the level of the water table, and therefore only slightly affected by solution as compared with the much smaller upper portions which have been above it.

The importance of solution in rocks is not underestimated, and in a subsequent portion of this chapter structures will be described in which solution has been the dominant factor. They differ in practically all respects from those now under consideration. For this reason, together with those already presented, solution is considered to be of little importance in the formation of the structures encircling the porphyry knobs.

Initial or Original Dip. Mather[1] has described several interesting cases of inclined bedding in limestones, which he ascribes to original dip, and it is believed that this has been the predominant factor in producing these structures. Sediments naturally tend to arrange themselves in layers parallel to the surface upon which they are deposited, and since the average submarine surface is an approximately horizontal plane, the original bedding of most marine sediments is likewise essentially horizontal. Because of this there has arisen the widespread idea that original dip in marine sediments cannot exceed a few degrees. The dips described by Mather are as high as 7 degrees. Many of the dips observed here approximate this figure, others are much steeper, but none exceed the angle of repose for unconsolidated material. It is a striking fact that the dips in these sediments are proportional to, but slightly less than the slope of the pre-Cambrian surface upon which they rest, as long as these slopes do not exceed 35°. Where they are much steeper than this, there is practically no dip in the sediments which butt against them. In other words, if the slope was too steep to hold the sediments during their accumulation, they slumped, and were deposited in a practically horizontal series at its base. On notably asymetrical knobs a given horizon may rise far up on the gentler slope, and stop short against the base of the steeper slope at a much lower elevation. This is beautifully shown in the irregular contact of the Potosi and Eminence dolomites around many of the porphyry knobs. Within this area the two formations appear to be conformable, but on many of the knobs the Potosi will appear at a certain elevation on one side, and fail to appear at

[1]Mather, K. F., op. cit.



INITIAL DIP.

Bluff of Eminence dolomite on the west side of Current River, showing the steep dips which are found where the dolomites come in contact with the porphyry hills. The cave at the extreme right of the picture marks the contact of the dolomite and the porphyry, and the hillside below it is a portion of a porphyry knob. Note the sudden increase in the amount of dip in the vicinity of the porphyry. This bluff is about 350 feet high. The conglomerate shown in Plate X-B is exposed in the cave.

the same elevation on the opposite side, due to differences of slope on the buried hill.

The steep dips in the coarse conglomerates lying in immediate contact with the pre-Cambrian are certainly largely initial. The dips on the Gunter sandstone, which is the initial deposit on an old erosion surface, which had presumably attained some degree of lithification, are also dominantly initial, and the dips in the limestones lying between these two members and above the Gunter are believed to be due to the same cause. Steeper dips are cited by Cumings and Shrock[1] as being common in lime muds adjacent to coral reefs, and there is abundant testimony that the same thing is occurring today on the outer edges of modern reefs, though it is not always clear how much of the dip is initial. The dips appear to be the steepest where the reef is growing rapidly.

Another interesting modern case which is believed to have much in common with these ancient rocks, is the western margin of the Great Bahama Bank. According to Field,[2] the sediments now accumulating on the bank are extremely fine grained lime oozes (drewites). A coral reef borders the eastern margin but is absent along the western side. This western side is believed to be a submarine fault scarp or cliff, now buried by more recent lime sediments. No dips have been measured upon it, but the chart shows an average dip of from 8 to 9° on the sea floor at the present time. This surface is not exposed to the action of the waves and currents and is apparently stable. When it is remembered that the present surface represents a considerable filling over the original topographic feature, it seems extremely probable that the dips close to the older surface are even steeper. In another paper Field[3] describes the formation of intraformational conglomerates in these sediments. Here the waves quarry out large blocks of recently formed oolitic limestones, which are carried down the steep slope and deposited in the fine grained oozes. The conglomerates already described in which the porphyry pebbles are not in contact with each other, but which are completely surrounded by a matrix of limestone were doubtless formed in the same manner. Field[4] also believes

[1]Cumings, E. R., and Schrock, R. R., Silurian Coral Reefs in Northern Indiana; Proc. Ind. Acad. Sci., Vol. 36, 1926, pp. 71-85; also Niagaran Coral Reefs of Indiana and adjacent states and their stratigraphic relations, Bull. Geol. Soc. America. Vol. 39, 1928, pp. 579-620.

[2]Field R. M., op. cit.

[3]Field, R. M., Suggestions as the Study of Marine Sediments, The Canadian Field Naturalist, Vol. XLII, 1928, pp. 119-122.

[4]Field, R. M., Paleozoic Submarine Landslips Near Quebec City, Journal of Geology, Vol. XXXVI, No. 7, 1928, pp. 577-614.

that the Levis conglomerates were formed in a similar manner although in this case sedimentation along a steep submarine slope was accompanied by faulting.

The conditions favorable for the production of such dips would be the rather rapid submergence of the rugged pre-Cambrian surface, so that the tops of many of the smaller hills were beneath water before the intervening valleys were completely filled with sediment. This condition would permit the simultaneous deposition of lime ooze over the entire hill at elevations corresponding to the slope of the hill. The oozes thus collecting on the slopes would rest at dips up to the maximum angle of repose for such materials, and the winding character of the bays and straits between the higher knobs, in such an archipelago as probably existed, would prevent excessive wave action and would favor the accumulation of sediments on steep slopes. There would be a marked tendency for the material deposited at the higher levels to be transferred by the waves to lower levels, thus filling up the basins and increasing the thickness of the individual beds toward their centers, a condition which has been repeatedly observed. This, if anything, would tend to reduce the amount of dip on successively younger strata, which is actually the case.

The strongly embayed coast of Maine submerged rapidly enough so that deep bays exist in close proximity to exposed rocky knobs. It presents a somewhat close modern analogy to the topographic conditions believed to exist in this area when these dips were being formed. In this latter case, the close proximity of a mainland, capable of furnishing clastic sediments, would materially change the nature of the resulting deposits. Perhaps a closer analogy is to be found in small groups of islands, such as the Azores and Canaries, which rise abruptly from the ocean and are remote from the mainland.

The chief argument against the original origin of these structures appears to be largely inherited prejudice against the possibility of such dips being formed. While it is by no means conclusive, there is now much known evidence to the contrary, both from rocks now being deposited and from older series; and in the light of this evidence, together with the lack of evidence which would assign a prominent part to any of the other causes outlined above, it is believed that these steep dips and the structures produced by them are largely initial. They may have been aided somewhat by both compacting of sediments and by solution, but while it is readily admitted that both of these factors, either alone or in combination, are capable of producing similar structures under certain conditions, and in certain sediments, it is believed that they have been of minor importance in this case.

Summary. Of the six possible causes the first three, igneous intrusion, isostasy and crustal deformation are ruled out as either impossible or as very highly improbable. Compaction, while a possible subordinate factor, does not appear to be capable of producing such large structures, and those produced by solution are of an entirely different type. All evidence at hand points to initial dip caused by deposition on an irregular surface as the principal cause of these structures. The fact that similar dips, produced by a similar cause, have been observed in marine sediments now accumulating is considered as good evidence that the same process has gone on during past geologic periods and that it is not as rare as has been supposed.

Persistence of these structures into overlying strata. The thinning of the strata against the pre-Cambrian hills, and the thickening of the sediments in the intervening basins, eventually tend to obliterate the structure. How far these structures may persist into the overlying strata is still a question which cannot be definitely answered at present, though some ideas of it may be obtained.

At West Eminence there is a well defined dome with nearly 200 feet of closure, and no porphyry exposed. A diamond drill hole put down practically on the crest of the structure, is reported to have passed through a thick series of limestones and to have bottomed in sandstone at a depth of about 500 feet. It has been impossible to obtain a log of this hole, therefore this statement cannot be checked, but all reports practically agree on the statements given. If true, this proves pronounced reflection up about 750 feet, for the sediments in the hills about West Eminence all show strong dips.

In the eastern portion of the Cardareva quadrangle, east of the edge of the exposed porphyry knobs, there are a number of low domes with a closure of between 50 and 100 feet. These are apparently the tops of reflected buried hills. The thickness of the intervening sediments is between 600 and 1000 feet, depending upon whether or not certain beds not exposed in the central mass are present, and whether others are developed to their full thickness. Nothing is known of the relief of the pre-Cambrian floor in this area, but it probably was not as great as was the relief of the central block. On the western side of the Eminence quadrangle, in the area west of the edge of the central block, no domes appear. In this area the datum plane used in making the structure contour map is 300 feet above the one used on the eastern side. It is entirely possible that on this western side there were no low hills to reflect structure, but it is more probable that they were present and that sedimentation during Van Buren and Gasconade time completely obliterated them. Thus it appears that from 900 to 1300 feet of strata are necessary to obliterate structures which are believed to be smaller than those of the central block. It would be interesting to compare the structure map of the central block drawn on the Gunter sandstone with a similar map drawn on the base of the Roubidoux to see how much of the detail is lost in the intervening 300 feet, but the lack of the Gasconade-Roubidoux contact over much of this area makes the construction of this second map impossible. It seems fairly safe to assume that these hills would have to be buried to at least twice their height before these structures would be smoothed out.

Use of the structure map. The structure map (Fig. 9) shows the surface of the Gunter sandstone as it would have appeared if erosion had cut down to this bed, but not through it. The contours are to be read in exactly the same manner as the contours of the topographic map, and show not only the shape of the surface but its elevation above sea level. Where the contours are broken, the Gunter has been removed by erosion; where they are continuous, the formation is buried. By comparing the elevation of the Gunter at a given point on the structure map with the elevation of the surface at the same point on the topographic map and subtracting the first from the second, the approximate depth at which the Gunter may be expected may be found. This will serve as a guide in any future drilling. The map also shows the location and size of most of the pre-Cambrian basins, and may be of use in future prospecting.

Structural effects of solution. The importance of solution in the formation of the present topography has been discussed in an earlier chapter. It has been equally important in producing certain types of structure which are now to be considered.

In essentially horizontal, well-bedded strata which consist of an alternating series of soluble and insoluble beds, or in a well-bedded series of soluble strata which contain a high percentage of insoluble material, the soluble portion may be removed wholly or in part by leaching, allowing the insoluble layers to settle in situ. They may become badly fractured in this process, but their continuity over considerable distance is fairly well preserved, This process may continue until all of the soluble materials have been removed, leaving a mass of fragmental, residual material, which nevertheless retains a distinct stratification, and in which distinct horizons may be recognized.

This is one of the most important methods of rock destruction now going on in the Ozark Uplift, and the failure to recognize it, and assign to it its proper value, may lead to serious errors in the interpretation of structure and of geologic history. Some of these may be briefly considered here.

Apparent thinning of formations. Individual beds which were separated by many feet of strata in the unweathered formation may be brought much closer together, or even into actual contact, provided there is a relatively soluble series of strata between them. Where the Van Buren formation is but little weathered the interval between the Gunter sandstone and the oolite bed is about 70 feet. This interval has been checked by dozens of measurements in various parts of the area. In those places where the formation is badly weathered, as for example along the divide between Carr Creek and Powder Mill Creek; along the Logan Creek-Current River divide, and along the divide extending southwestward from Owl Bend, numerous measurements show that this interval is between 40 and 50 feet. The oolite may still be traced as a distinct band along the hillsides, but it is all float, and actual outcrops of the beds beneath it are rare. Similarly the interval between the oolite bed and the cryptozoon reef in the Gasconade dolomite is normally between 150 and 160 feet, but on the divide between Carr Creek and Powder Mill Creek it is between 100 and 120 feet, and in some portions of the central area the interval between the cryptozoon and the oolite zone is less than 100 feet. If this reduction in thickness occurred in the central area alone it might be interpreted as thinning of strata toward an ancient high mass on the sea bottom, and if this were true good sections showing a large percentage of unweathered rock in place should be found in the areas where the reduced intervals occur. Such, however, is not the case.

The reduction in thickness appears to be tied up with present day erosion, and the Van Buren and Gasconade formations appear to be present in full thickness only in and near those areas which are still covered with a considerable thickness of the overlying Roubidoux. The thinning is not confined to the central area alone, but is quite general over the entire area north and east of Current River as well. In this area, as has already been noted, good exposures of either formation are few and far between, and most of the boundaries have had to be drawn on the distribution of residual materials. It seems certain that originally they were just as thick in this eastern portion of the area as they now are in the western portion, and that the present thinning is due almost entirely to solution.

Apparent unconformity produced by solution. If the contact between two formations happens to lie in the midst of a soluble series such as has just been described, the strata immediately above and below this contact may be leached out, and an insoluble bed above the base of the younger formation may settle into contact with an insoluble bed below the top of the older formation, thus producing an apparent unconformity. Excellent examples of this are to be found along the Gasconade-Roubidoux contact in the area just described. In the western portion of the Eminence quadrangle, along Jacks Fork in Pine Hollow, (Eminence quadrangle) and elsewhere numerous sections show the cryptozoon reef of the Gasconade formation to be some 70 feet below the Roubidoux contact. The contact itself is marked by a thin sandstone, commonly less than a foot in thickness. About 70 feet above the base of the Roubidoux there are a number of heavy sandstone beds averaging between one and three feet in thickness. They are indistinguishable, except for their thickness, from the stratum at the base. The 130 to 140 feet of beds which intervene between the Cryptozoon reef and the second sandstone layer of the Roubidoux are made up largely of soluble dolomites which yield a considerable amount of chert. Over the entire northeastern area this interval is greatly reduced, and it is quite common to find large boulders which could only have come from upper sandstone layers of the Roubidoux at the same elevation as the large blocks of chert which result from the silicification of the Cryptozoon reef. This has led to the assumption that a large unconformity exists between the two formations, but, where the formations have not suffered severely from solution, the contact shows but few traces of unconformity, and it is believed that observations made in areas which have been greatly affected by this solution process have given rise to erroneous conclusions regarding the nature of this contact.

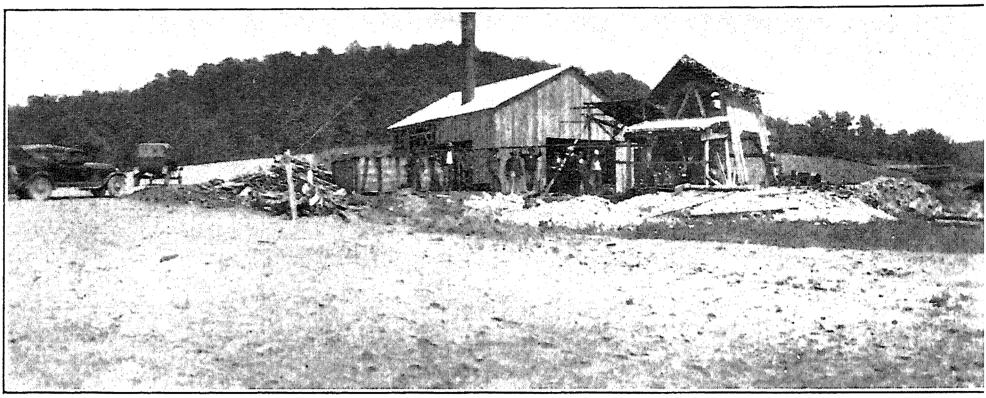
Another way in which this mixing of horizons may occur is by the collapse of the roofs of caverns, or by the washing of material into sink holes. Doubtless both of these methods have been effective here. However, they are merely phases of solution, and while some of the material undoubtedly was mixed in this manner, there is abundant evidence in the form of the rude stratification of the residual material to show that the bulk of it was lowered slowly.

Amount of thinning produced by solution. The amount of thinning which a formation may undergo by this process is directly proportional to the amount of soluble material which it contains. Within this area there are places, particularly along the divide between Carr Creek and Powder Mill Creek, where the Gasconade formation has lost approximately two-thirds of its original thickness of 230 feet. The Roubidoux formation has also been greatly thinned by this process. In the area north and east of Current River many of the hills are capped by patches of this formation, and it covers fairly extensive areas but none of it appears to be in place. The same is true of the upland area about Winona and Birch Tree.

The older formations, Eminence and Potosi dolomites, have not been greatly affected by this particular form of solution. This is partly because of their more uniform character and more massive bedding, and partly because they have not been as high above the water table for as long a time as the younger formations.

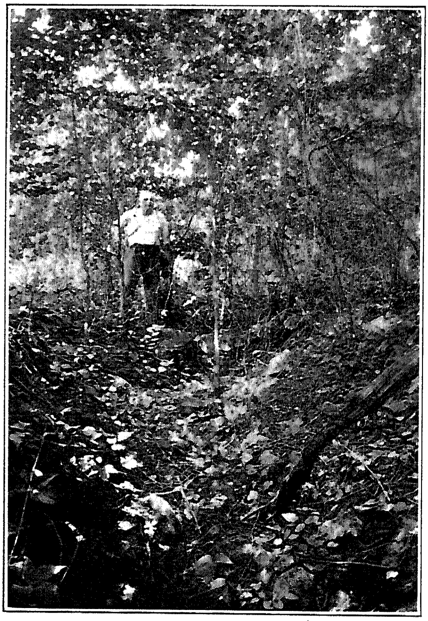
The amount of material which has been dissolved in this fashion is enormous. In Madison County diamond drill holes have penetrated more than 300 feet of residual material formed in this manner from the weathering of the Roubidoux, Gasconade, Van Buren, and perhaps other formations. The Jefferson City and Cotter formations, as exposed in this area, have lost all of their soluble constitutents and exist only as a veneer of residual, cherts, sandstone blocks and admixed clays on the hilltops in the vicinity of Birch Tree. Near Winona, drilled wells starting in the Roubidoux formation commonly penetrate from 60 to 100 feet of residual materials before reaching bed rock. The area south of Stegall Mountain is covered with residual materials from at least three, and probably four, formations, and the slumping is so complete that the formation boundaries cannot be determined with certainty.

Structures produced by this solution process. The amount and speed of solution varies greatly. All factors tend to make it most active along vertical joints in the zone above the water table, and therefore slumping tends to be greatest along these lines, forming depressions and valleys on the surface, as outlined in Chapter I. This in turn serves to increase the amount of water delivered to these areas, and hence the amount of solution. Solution with its resultant slumping of insoluble residues, decreases progressively away from these drainage lines; and this tends to produce dome and basin-shaped structures in the residual materials, which approximately parallel the topographic surface. The stages in the formation of these structures is illustrated in Fig. 10. They rarely show upon the surface and are difficult to detect in ordinary exposures, for the dip of the structure closely parallels the slope of the hillside, and, since the material is all fragmentary, it is commonly taken for float. These are best shown in natural and artificial excavations, such as undercut creek banks and highway and railroad cuts. The former are rare, for in an area which is greatly affected by solution most of the creeks are intermittent and contain running water only after heavy rains. They are well exposed in the recently made highway cuts in many parts of the Ozarks. In the Eminence region the best exposures are to be found along Highway 60, just east of Winona (Pl. XV-A). This is a part of the high upland underlain by the Roubidoux sandstone, and which as yet has no permanent surface drainage. Solution has been almost complete to a considerable depth over a very large area, and the chert and sandstone residues are very thick and have settled irregularly, producing slump structures of the type just described. Similar structures are to be found in some of the road cuts on Highway 19, about 2½ miles north of Eminence, and again on the same highway north of the mouth of Sinkin Creek.



A. General view of the Sutton Prospect as it appeared in 1924.

B. Entrance to the adit at the Casey.



C. Old exploring trench at the Slater.

CHAPTER V.

ECONOMIC GEOLOGY.

The Eminence region contains small deposits of Copper, Iron, Lead, Manganese and Clay, and rather large deposits of river sands and gravel. None of these have been extensively developed, and there is little or no production at the present time.

In past times Copper and Iron have been produced, and in 1912 Shannon County ranked ninth among the counties of Missouri in the production of Iron ore.

There is a great deal of interest in prospecting and much work has been done in attempting to develop the mineral deposits. Some believe that there are extensive deposits of copper minerals somewhere in the district, but the geological evidence thus far obtained does not support this view. All of the known deposits are small, and there is little reason to believe that any great ore bodies exist.

COPPER.

Introduction. The Copper deposits of the Eminence region are confined to the area in which the porphyry is exposed. Traces of copper minerals have been found in almost all portions of this area, but they are most abundant along the western side. The minerals usually occur in the conglomerates at the contact of the Paleozoic sediments and the Algonkian rhyolites, but in a few cases deposits have been found higher in the sediments.

The principal minerals are chalcocite, chalcopyrite, malachite and cuprite. The deposits are believed to have been formed by the concentration of material which was originally disseminated throughout the rocks of the region, concentrated by cold solutions and precipitated by organic or other agencies. There is no evidence of igneous intrusion, or of the action of hot solutions.

History of Mining. Prospecting and development have gone on intermittently for almost a century. Very few documents are available, and there is very little authentic evidence regarding the discovery and early development of the region. The following paragraphs have been compiled from such evidence as is available.

Copper was found in Shannon County, in the early part of the nineteenth century by hunters and trappers. The news of the discovery reached the French settlements along the Mississippi River about 1837, and a group of colonists at Ste. Genevieve, among whom were the Valles and Henry Janis, sent a Cornish miner, named Joseph Slater, to investigate and develop the deposits. The region was a wilderness, and the land had not been surveyed.

Slater arrived in the Current River country in 1837 or '38 and purchased the right to mine copper from a hunter named George Smith, who claimed the deposits by right of discovery. He erected a cabin on Shawnee Creek, in what is now the SW. ¼ sec. 6, T. 28, N., R. 3 W., and built a boarding house, store, and blacksmith shop on a small tributary of Shawnee Creek, in sec. 1, T. 28 N., R. 4 W. This location was determined by a large spring which is still known as Slater's Spring. Slater obtained the most of his ore from the W. ½ of the NE. ¼ sec. 36, T. 29 N., R. 4 W., about a mile north of his settlement, and these diggings are still known as the Slater Mine. He also obtained some ore from the "New Diggings" now known as the Jerktail Mine in lot 2 NE. ¼ sec. 5, T. 29 N., R. 3 W., and some from the vicinity of the porphyry outcrops in Lick Log Hollow.

Slater does not appear to have done any deep mining, but obtained all of his ore from shallow test pits sunk in the dolomite or conglomerate just east of the porphyry contact. Hodge[1] who visited the mine in 1841, shortly after work had been abandoned, described the mine as follows: "The diggings extend to the depth of about ten feet average, the deepest hole being eighteen feet; but concerning this I could get no satisfactory information, no work being now done there."

There was no reason to dig deeper; most of the ore occurred at the contact of the limestone and the porphyry, and, as the miners were paid according to the amount of ore raised, they spent very little time in exploratory work. According to Hodge, some of them purchased the right to work certain particularly rich tracts. Hodge[2] gives the following account of a small smelter erected by Slater on Shawnee Creek, where he manufactured several tons of crude blister copper. "The furnace is about three feet high inside and a foot square. It can run only

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[1]Hodge, J. T., On the Wisconsin and Missouri Lead Region, Silliman's Journal (Amer. Jour. Sci.), Vol. 43, No. 4, 1842, pp. 66-7.

[2]Hodge, J. T., op, cit., p. 68.

about a week at a time before the whole inside must be pulled out and built up anew, there being no good stone for lining a furnace in the country. * * * It is built of quartz rock, and lined with the same, and was originally much larger and gradually diminished to its present internal capacity. A common overshot wheel, twelve feet in diameter, moves a large blacksmith's bellows, and this is all the machinery about the furnace." The ruins of the furnace, the old slag heaps and the ditch which brought water to the wheel, may still be seen.

Hodge also describes the smelting process, saying that the ore was broken by hand, washed two or three times to free it from mud and clay, and smelted. Old slag was used as a flux and charcoal for fuel.

The amount of copper produced by Slater is not known. Hodge gives no production figures, but states that workmen received $27.00 per thousand for cleaned ore and that the wages of common laborers were from $12 to $25 per month and "found," while miners received from $20 to $30 per month.

Williams[1] states that 1,500 tons of ore were produced by Slater, and that part of it was smelted on the location, and the remainder shipped to Swansea.

Phillips[2] states that prior to 1874 about 160 tons of pig copper had been made at the Shawnee furnace and shipped by flatboat to New Orleans, but it is not clear whether this was all mined by Slater, or whether it included the work of later companies. Other mine reports give 75 tons as the figure. The value of the copper produced at this time is variously given as $50,000 to $100,000.

In 1840 the land was surveyed by the Federal government, and the original plats show the locations of Slater's Mine and buildings.

On April 8, 1841, the United States Land Office at Jackson, Missouri, issued certificate No. 8133 covering the NE. ¼ sec. 36, T. 29 N., R. 4 W., to one James Thompson, who on the same day transferred it to John Epps Cowan. The following year Cowan secured title to the NW. ¼ of the section as well.

In the meantime Slater took his case to court, and after much litigation, in the course of which the case went to the Supreme Court, it was decided against him.

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[1]Williams, C. P., Geological Survey of Missouri, Industrial Report, 1875-76 (1877), p. 164.

[2]Phillips, J. V. C., Mine report submitted, Dec., 1874.

Slater left the country, and Cowan disposed of portions of his interest in the property to Alexander Fergueson over a period extending from 1843 to 1847 and realized something over $3,200 from his various transactions. The property came into the possession of the Aberdeen Mining Co. (Scotland) who operated the mine for a short time, and then closed it down[2]. It is probable that a portion of the 160 tons of copper mentioned by Phillips was produced by this company, and that the ore shipped to Swansea represents their production.

In May, 1848, Fergueson, who was evidently one of the officers of the Aberdeen Mining Company, deeded "the N. ½ sec. 36, T. 29 N., R. 4 W., together with all buildings and other improvements made on the said land to Thomas Primrose of South Carolina who was probably connected with the Current River Mining Company, but this is not definitely known. Little is known of the history of the mines between 1848 and 1872, but the owners evidently had an examination of the property made, and the report of this examination has been preserved. It mentions the existence of a shaft 100 feet deep which evidently had been put down by Fergueson and his associates.

In 1872 the property was sold to the Consolidated Land Company of Missouri. Shortly after this the mine was visited by Williams for the Missouri Survey. His report is conservative, but contains much reliable information about the condition of the prospects at that time. Some development work was done by this company and in 1876 the mine was acquired by Chas. T. Biser of St. Louis. He mined and shipped a few carloads of ore, and then sold the property to a Michigan Corporation known as the Current River Land and Cattle Company.

No mining was done for several years and in 1892, F. M. Rogers and others secured a 99-year lease on the property, but a few years later action was brought against them by the owners for non-fulfillment of the terms of the lease. Shortly afterwards this lease passed into the hands of the Slater Copper Company of Winona, although the litigation was not settled until 1917.

At the time of Bain and Ulrich's visit in 1905, considerable prospecting had been done in the region and several other properties had been opened, but very little was accomplished.

There was very little activity until about 1918 when the advancing price of metals revived interest in this district. The

[1]Williams, C. P., Missouri Geological Survey, Industrial Rept., 1875-76 (1877), p. 164.
[2]Bain, H. F., and Ulrich, E. O., The Copper Deposits of Missouri, U. S. Geol. Surv. Bull. 267, p. 42.

Slater Copper Co. was re-organized, and the Casey Company resumed operations, and in 1920 all of the deposits were being worked.

In 1922 when the present investigation was started all of the prospects were idle. A little work has been done at the Slater and the Jerktail by various individuals at different times. The chief activity during the past few years has been the operations of the Shawnee Copper Company at the Sutton property. (Sec. 18, T. 28 N., R. 3 W.). At the present time all of the properties are shut down.

Description of the Prospects, Slater Mine. The Slater Mine is about 2 miles east of Eminence, in the NW. ¼ NE. ¼ sec. 36, T. 29 N., R. 4 W. This is the oldest prospect in the region and the one about which the most activity has centered. The manner of occurrence of the ore at this locality is typical of the majority of the deposits. The workings are situated in a broad saddle which marks the contact between a porphyry knob to the west and a dolomite hill to the east. The contact between the two rocks is, as usual, not well exposed. The dolomite belongs to the Eminence formation and the characteristic pinnacled ledges are well developed, The porphyry shows the characteristic jointing which is perhaps better developed at this locality than at other exposures. The tuffs and silicified ash previously described occur on the east side of the porphyry knob.

Overlying the porphyry is a thick deposit of conglomerate, composed of porphyry pebbles in a calcareous matrix, which grades up into the dolomites.

The copper, in the form of chalcopyrite, chalcocite, cuprite and malachite occurs chiefly in the conglomerate, where it replaces the calcareous matrix. The bulk of the mineralization occurs in this conglomerate zone and in solution channels in the dolomites. The ore is commonly associated with calcite in large masses, or with rhombohedral crystals of dolomite, or is contained in a greenish clay. It penetrates the limestone to a certain extent and also fills joint planes in the underlying porphyry. Some of the joint planes in the porphyry contain minute amounts of chalcopyrite in calcite. None of these fissures are more than an inch or so in width, and the majority of them are smaller than that. The amount of copper which they carry is negligible. A number of shafts, some of them quite deep have been sunk into the porphyry, on the assumption that these mineralized joints were true fissure veins, and that larger deposits might be expected at depth. One of these, the "Big Shaft" is 200 feet deep.

The ground in the Slater has been worked and reworked by so many companies and individuals that it is difficult to assign dates to any portion of the work. Slater apparently mined all of his ore from the conglomerate zone, and his workings consisted of shallow pits and crosscuts, which according to Hodge, covered about three-quarters of an acre. The next owners apparently started the "Big Shaft" and the history of the others is not clear. Williams[1] published a map with his report which shows the conditions of the property in 1875, but it is not possible to locate all of the features shown in it at the present time.

The Big Shaft is said to be 200 feet deep. The first hundred feet were driven at an angle of 80°, to the north, the remaining hundred feet were sunk vertically. From the 190 foot level drifts have been driven for short distances to the northeast and southwest, following the strike of the joints. The northeast drift was crosscut 35 feet from the shaft and drifts were run for 9 feet to the northwest and for 57 feet to the southeast. The shaft has been full of water ever since this investigation was started and these details have been obtained from men who were familiar with the mine. Most of the other shafts have been sunk in the conglomerate or in the limestone. Some of them penetrated the porphyry, but none of them are believed to be over 30 feet in depth.

At some time in the early history of the property an exploring trench was dug along the dolomite porphyry contact, and through the residual material overlying the porphyry. It is shown on Williams' map, and traces of it are still visible. Some believe it to be a portion of Slater's workings, but it is probably of later date. Plate XVII-C.

In 1922 the mine was equipped with a headframe, hoist, boilers, blacksmith shop and the necessary tools, but at the present time the machinery has been removed and the buildings have been demolished.

In 1926 and '27 a large concrete tank was erected on a hill just south of the property, by a person who intended to attempt a chemical treatment of the ores, but up to the present time nothing further has been done.

[1]Williams, C. P., Geological Survey of Missouri, Industrial Report, 1875-76 (1877), p. 164.

The Jerktail Prospect. This is also one of the oldest prospects in the region, but not as much work has been done at it as had been done at the Slater. It is located in about the NW. corner of Lot 2, NE. ¼ sec. 5, T. 29 N., R. 3 W., on the head of a small tributary of Thompson Creek. It is six miles due northeast of Eminence, and is difficult of access. Like the Slater, it is located at the contact of the Eminence dolomite and the porphyry, and most of the ore obtained came from the conglomerate.

The workings consist of a shaft about 16 feet deep. This was unwatered in 1925, at which time the following section was obtained:

Soil	1 ft.
Dolomite	10 ft.
Conglomerate	4 ft.
Porphyry	1 ft.

The thickness of the conglomerate is variable and it was observed to thin to 2 feet in 5 feet along the strike.

At the bottom of the shaft there are two short drifts, neither of them more than ten feet long, one driven east, the other northeast. The dolomite dips about 5° east. It is well exposed in the bottom of the shaft and contains many large angular blocks of porphyry up to 1 or 2 feet in diameter. There are many other test pits in the vicinity but all of them have caved. They are all connected with the main shaft, presumably by a series of fissures, and as the main shaft was emptied, the water level in all the pits was lowered.

The ores are the same as those found at the Slater, and occur in the same situations.

This mine was worked in the early forties, at which time it was known as the "New Diggings" and is said to have been worked again about 1870. There has been some desultory prospecting during the past decade, but no real work has been done. There is no machinery or other equipment about the place at the present time.

The Casey Mine. This prospect is located in the SE. ¼ SW. ¼ sec. 14, T. 29 N., R. 4 W., about two miles due north of Eminence. The main shaft is within a few feet of the newly constructed State Highway 19, so that at the present time the property is easily reached.

The Casey is the exception among the Shannon County copper prospects in that the ore occurs in the dolomites and not at the dolomite porphyry contact.

The location is in a shallow saddle between two dolomite hills. The ridge, of which these hills are a part, trends about N. 25° E. About ½ mile east of the mine is the large porphyry mass exposed in Lick Log Hollow, and about 1½ miles northwest is another porphyry hill. Thus the location is in a basin between two porphyry ridges.

The rock exposed at the surface is the lower portion of the Gasconade dolomite. The ore occurs in this formation, and in the underlying Van Buren. The dip is from 5 to 7 degrees west. The depth to the porphyry at the mine is unknown. A drill hole, put down in 1919 reached a depth of 580 feet and was bottomed in the Potosi dolomite. No cuttings were saved from the first 100 feet of this hole, as they duplicate the section exposed in the main shaft a few feet away. A set of cuttings from 100 to 577 feet was secured by the writer in 1922, and is now on file at the office of the Bureau of Geology and Mines. These cuttings have been examined by Mr. H. S. McQueen, who has compiled the following log:

	From	To	Thickness.
Gasconade and Van Buren formations, including basal Gunter sandstone	0	100	100
Eminence formation	100	410	310
Potosi formation	410	577	167 +

The complete log is given in the appendix to this report. This is the only deep drill hole in the region, of which a fairly complete record has been preserved, and it is greatly to be regretted that it was not drilled to the porphyry, for it would have furnished much valuable information as to the conditions existing in the deeper basins.

The principal ore mineral is malachite, which is associated with small amounts of chalcocite. The deposits occur along bedding planes and always beneath an impervious stratum. The principal horizon is beneath the bed of siliceous oolite in the upper part of the Van Buren formation. This zone has a maximum thickness of about 8 inches but eventually thins out and disappears. It has been mined for a distance of about 50 feet in all directions from the main shaft. This horizon is known as the 60-foot level. On the 26-foot level there has been some concentration of the ore minerals beneath a thin bed of shale in the Gasconade. There are a few vertical, mineralized fissures leading downward from these horizontal sheets, and these are believed to be the fissures along which the mineralizing solutions ascended. Similar vertical, mineralized fissures have been exposed in the recently made highway cuts about ½ mile south of the mine.

There is no evidence of thermal action here. The location of the mine is in a structural basin, and the cold solutions appear to have risen under artesian conditions.

Little is known of the early history of this mine. It is not mentioned by Williams, but is briefly described by Bain and Ulrich. The main shaft is about 100 feet deep, and appears to be bottomed either in the Gunter sandstone, or else in the Eminence. The lower 50 or 60 feet are full of water, and have never been accessible to the writer. The main or 60 foot level is connected with the surface by an adit. The floor of this tunnel slopes toward the entrance so that the mine is practically self-draining.

In 1922 the mine was fully equipped with the necessary machinery and buildings, but these have since been removed, and at the present time the property is abandoned.

No shipments appear to have been made from this mine, although at one time several tons of cleaned and sorted ore were in storage there.

Sutton Mine. This is the most recent development in the Eminence region, and all of the important work at it has been done during the past 5 or 6 years. It is located in the SW. ¼ NE. ¼ sec. 18, T. 28 N., R. 3 W. The location is similar to those of the Slater and Jerktail mines, being a shallow basin, floored with Eminence dolomite between porphyry knobs. Fragments of copper have been turned up by the plow at this location for many years and some small amount of prospecting had been done prior to 1924.

The basal conglomerate is well exposed in the small ravine which marks the dolomite-porphyry contact just north of the main workings. The pebbles of this conglomerate are badly weathered, and the matrix is deeply stained with green ferrous silicate and some malachite.

In 1924 the property was acquired by the Shawnee Copper Co. of Eminence and practically all of the development work to date has been conducted by them or by persons who have leased the property from them.

A main shaft was sunk to a depth of 36.5 feet in 1924, on the site of a former test pit. It passed through about 20 feet of dolomite, and 15 feet of conglomerate and bottomed on the porphyry. The dip of the dolomite-porphyry contact at this point is to the east. A quantity of ore was gotten out of the conglomerate during the sinking of this shaft. The majority of it came from solution channels at the contact of the dolomite and the conglomerate, and from the interstices of the latter. Practically none was found in the porphyry. The ore consisted of large chunks of chalcocite, and cuprite, coated with malachite. Some of the masses weighed as much as 100 pounds. Chalcopyrite was not common, but a little azurite was found. At the bottom of the shaft two drifts were started, following a solution channel. In 1925 one of these drifts had been extended to the north for about 100 feet, and two short cross cuts had been made. The other drift extended to the south for about 50 feet. About two carloads of ore were taken out. One of these was boulder ore, the other was the fines which had been partially concentrated on hand jigs.

In 1926 the company did some systematic prospecting with a churn drill, and determined the depth to the porphyry over a large portion of the tract.

In July 1925, the company shipped a carload of boulder ore weighing 44,390 pounds, to a smelter in New Jersey. This carload assayed 27.29 per cent metallic copper and produced 11,537 pounds net. Copper at that time was selling for 13.77 cents per pound, and the net return to the company after deducting freight, smelter and assay charges was $935.40.

A second shipment was made in October, 1926. This carload consisted of 77,074 pounds of ore, and represented the fine material which had been thrown on the dump and partially cleaned by Joplin jigs. It assayed 8.365 per cent metallic copper, and produced 5,368 pounds of metal, net. Although the price of copper was about a cent higher than it had been the preceding year the shipment resulted in a loss of $66.73 to the company. These two shipments represent the total output of the mine to date.

Tests have shown that the fine material can be partially concentrated on tables, and machinery for this purpose was acquired by the company, but has never been set up.

In 1927 the property was leased and the lessees abandoned systematic prospecting and commenced sinking a new shaft. This shaft is about 50 feet above that of the main shaft. At the present time it has reached a depth of about 90 feet and is still in the dolomite. The conglomerate carrying the copper has not been encountered.

Several other prospects are listed by Bain and Ulrich.[1] These have all been visited with the exception of the Tyrell prospect which lies several miles north of the Eminence region. No work of any consequence has been done at any of these prospects during the course of this investigation.

Origin of the Deposits. From the foregoing descriptions it will be seen that the deposits are essentially bedded deposits, which have replaced the cementing material in the conglomerate and have to some extent invaded the joint systems of the dolomites and the porphyries.

Bain and Ulrich[2] believe that these deposits have been derived from material originally disseminated in the surrounding rocks, and at the present time this seems to be the most acceptable theory.

All of the observations which have been made in the course of this investigation appear to support these ideas. Winslow and Robertson[3] have shown that both the igneous and sedimentary rocks of the Ozarks contain lead, copper, zinc and other metals in very small amounts, and have concluded that these amounts are sufficient to account for all of the deposits.

Bain and Ulrich also call attention to the fact that the majority of the copper deposits occur in formations which have been deposited under shallow water, near-shore conditions, and they believe that there was a greater concentration of the disseminated copper in such places than in deposits which were accumulating farther off shore.

Phillips[4] has shown that copper is a small but constant constituent of marine organisms. He has also shown the presence of finely disseminated copper in marine muds from Tortugas. There is no source nearby from which this could be obtained and as the copper is present in larger quantities in the muds than in organisms it seems certain that it is being concentrated there at the present time. Copper has also been reported as a constituent of oceanic muds at other places. In regard to the copper in the muds, Phillips says: "The calcareous mud of the Marquesas (Florida) is limestone in the making and when the conditions under which it accumulates are considered there

[1]Bain, H. F., and Ulrich, E. O., The Copper Deposits of Missouri, Bull. U. S. Geol. Surv. 267, pp. 46-47; also Fig. 2.

[2]Op. cit., Bain, H. Foster, and Ulrich, E. O., p. 50.

[3]Winslow, A., and Robertson, J. D., Lead and Zinc Deposits, Mo. Geol. Surv., Vol. VI, 1893, pp. 479-80.

[4]Phillips, A. H., Analytical Search for Metals in Tortugas Marine Organisms, Carnegie Inst., Wash. Pub. 251, 1917, pp. 98-93, ibid, Pub. 312, 1919, pp. 95-99.

can be little doubt that the copper and zinc content is derived from organisms which have concentrated these metals from the sea water, and at death the metal content of their decaying tissues becomes fixed as sulphides and becomes a part of the limestone or sedimentary rock thus formed.

Even though the percentage (0.016 per cent for copper and 0.009 per cent for zinc) is seemingly small, the actual weight of the metal present when calculated for large areas of limestone is considerable, as each cubic meter of rock would contain 432 grams of copper and 243 grams of zinc—an amount quite sufficient to produce metallic deposits of commercial value after secondary concentration by natural agents."

This process would account for the concentration of the disseminated sulphides in shallow water deposits as postulated by Bain and Ulrich, for marine organisms of the types studied by Phillips are most abundant in shallow waters.

Thus, an igneous source for the copper in the immediate neighborhood is unnecessary.

This finely disseminated ore is believed to be chalcopyrite, and the most of the ore found in the conglomerates was probably precipitated in this form. This secondary enrichment and concentration is believed to have taken place by the action of ground water during the periods when the region was out of water and undergoing erosion.

The precipitation of the minerals may have been brought about by the decomposition of the soda-lime feldspars, of the porphyries, or by the action of organic material in the dolomites. Doubtless both have been effective. Polished surfaces of specimens of the ores show alteration of chalcopyrite to chalcocite and to cuprite, and there has evidently been a certain amount of secondary enrichment.

It cannot be too emphatically stated that true fissure veins which should become richer with depth are not present in this area. There is no evidence of igneous intrusion, there are no dikes cutting the sedimentary rocks, and there is no contact metamorphism of the limestones and dolomites. In addition there is a complete absence of the minerals which are commonly associated with deposits formed by igneous activities.

It has been shown in a preceding chapter, that the igneous rocks of this district are much older than the dolomites and sandstones which overlie them, and that a long period of time has elapsed between the formation of the two series, during which time the igneous rocks were carved into an extremely rugged topography.

The fissures which have been followed into the porphyry at the Slater Mine so persistently are merely joint planes which have been slightly mineralized by descending ground waters and experience has shown that they pinch out with depth instead of becoming richer.

Economic Considerations. All mineral deposits are not necessarily ore bodies. Briefly, an ore is a mineral deposit which can be worked at a profit under existing conditions. When it ceases to show a profit, it ceases to be an ore, no matter how rich the deposit may be. It may fail to show a profit for any one or more or several reasons, some of which are:

Unfavorable location of deposit with respect to transportation and smelting facilities, etc.

Discovery of more easily accessible deposits.

Presence of objectionable minerals which make the process of recovery difficult or in some cases impossible.

Demand for the metal by manufacturers.

Current price of the finished metal.

Current price of labor.

Nearly all of these factors have exerted their influence upon the Shannon County Copper deposits at one time or another.

In 1840 when the prospects were first being worked, the Michigan deposits were not producing, those of Montana were unknown, while those of Utah and Arizona were not only unknown, but were not even a part of the United States. Copper was scarce, the price of the metal was relatively high, ranging from 20 to 34.6c a pound, while labor was comparatively cheap. Most of the known deposits in the United States were small, and mining methods were much the same in all of them. Under such conditions the deposits in Shannon Co., could be and were worked at a profit.

The first important production from the Michigan deposits was in 1845. Production figures for that year, the first available, credit the United States with the total production of 100 long tons, the greater portion of which came from the Michigan Mines. Five years later the total production for the United States was 650 long tons, of which Michigan produced 88%. The metal was more easily obtained in other localities, the price was the lowest that it had been in years and as a result the deposits in Shannon Co. were not a commercial success.

During the Civil war and for some years thereafter the price of copper was high, and during this time which lasted until about 1875, attempts were again made to develop these properties. From that time on the price of the metal steadily declined, reaching a minimum of 9.5c in 1894. The great western deposits began to produce and the small deposits of Missouri ceased to be of importance. In the early part of the present century the price varied between 12 and 15c but rose sharply during the war to a maximum of 29c in 1917, the highest price that the metal has reached since 1873. At this time attempts were again made to operate these properties, but since the war the price has steadily declined, and for the last few years has been about at its pre-war level.

The great size of the Michigan and western deposits, permit the use of modern mining machinery and methods which cut down the cost of production, while the small size of the Missouri deposits necessitates the use of hand labor which is decidedly expensive.

The small size of the deposits, the remoteness of this region from smelters which can treat the ores, the difficulty of recovering some of the minerals, and the present low price of the metal are the chief obstacles to the development of the region.

IRON.

Small deposits of secondary limonite are widely distributed throughout the Eminence region. They are more abundant, however, in the less dissected areas which lie to the west and south of the Eminence region proper. The ores are commonly found in the residual materials derived from the weathering of the Cotter, Roubidoux, and Gasconade formations. In 1912, Shannon Co. ranked ninth in the production of iron ore and had shipped a total of 40,363 tons.[1] None of the deposits have been worked during recent years, and there is no production at the present time. The geology and origin of the deposits have been discussed by Nason[2] and later by Crane.[3]

About 1915 or 1916 the Mid-Continental Iron Company erected a modern blast furnace, and other works at Midco (sec. 22, T. 27 N., R. 2 W.). They planned to make charcoal

[1]Crane, G. W., The Iron Ores of Missouri, Mo. Bur. Geol. and Mines, Vol. X, 2nd ser., 1912, pp. 323-333; also pp. 186-202 and p. 306.

[2]Nason, F. F., Report on Iron Ores, Mo. Geol. Surv., Vol. II, 1892, pp. 158-162, 241-2, 254 and 261-63.

[3]Crane, G. W., op. cit., chapter V.

from the second-growth black oak timber, by a process of destructive distillation in which all of the by-products, including wood alcohol and pyroligneous acid were recovered, and to use the charcoal thus obtained for smelting the local ore. The plant operated for about 18 months and then shut down. It has since been abandoned and completely dismantled.

MANGANESE.

Small amounts of manganese, chiefly the oxide, have been found in small veins in the porphyry and also as the cementing material of chert breccias at a few localities. The most important of these is in sec. 31, T. 28 N., R. 2 W.[1] Attempts have been made to mine the mineral but no production has ever been reported.

LEAD.

Small amounts of coarsely crystalline galena are occasionally found in cavities in the dolomites, or as boulders in the residual cherts. In pioneer days such finds were an important source of local supply. The mineral could be easily smelted in a crude furnace which was often nothing more than a hollow stump.

Occurrences of this sort are fairly common throughout most of the Ozark region. They do not indicate the presence of extensive ore bodies. There are no important lead prospects in the region.

SAND AND GRAVEL.

River Sands and Gravels. The valleys of the rivers and larger creeks contain moderately large deposits of sand and gravel, which constitute an important, but as yet slightly developed resource. On the smaller creeks the deposits are commonly contaminated with soil, but along the larger rivers both products are remarkably clean. Both are used to supply local demands, but as yet there have been no shipments from the region, and there probably will be none for some time to come on account of distance from the market and lack of proper transportation facilities. A sand and gravel plant could be established along Current River at some favorable point near Van Buren, where the proximity of the river and the railroad would make the shipping of the product relatively easy.

[1]Nason, F. L., op. cit., p. 95.

The river gravels, when properly screened and sized have been used to a large extent in the construction of the state highways in the region.

Hilltop gravel. The deposits of residual chert, particularly those derived from the decomposition of the Van Buren and Gasconade formations have had a limited use in the construction of roads. These cherts weather into small particles, the majority of them less than an inch in diameter and these are mixed with a clayey loam which constitutes an excellent natural binder. The only treatment necessary is the removal of the larger boulders. The common practice is to spread the material on the road just as it is taken from the bank and then rake off the larger fragments. Many of the county roads are surfaced with this material.

CLAY.

The clay deposits in the vicinity of Bartlett have been described in the section devoted to the Pennsylvanian. Some of them appear to be pure enough to be used for pigment if a sufficent quantity could be obtained. They are close to the railroad, but somewhat distant from available markets.

BUILDING STONE.

In 1894 a quarry was opened in the granite outcrop southeast of Van Buren, and for some years thereafter produced crushed granite and paving blocks. It was abandoned some time prior to 1902.[1]

The porphyries are difficult to work, because of their dense texture, conchoidal fracture and numerous joint planes, and no effort has been made to quarry them. The rough blocks, such as can be obtained at almost any outcrop, have had a limited use in the construction of rustic masonry and are well adapted to this purpose.

In the past the sandstone beds of the Roubidoux and Gunter were in great demand as "fire stones" for the construction of chimneys and hearths, but the increasing use of concrete and brick for these structures, and the changing styles of architecture have greatly diminished the use of this material.

[1]Buehler, H. A., The Quarrying Industry of Missouri, Mo. Bur. Geol. and Mines, Vol. II, 2nd ser., 1904, p. 84.

WATER POWER.

The rivers, streams and big springs of the Ozark region constitute an important source of power, which as yet has been little utilized. In pioneer days the power obtained from springs and the smaller creeks was utilized to some extent, the first case of this sort being Slater's development of power for his blast furnace on Big Shawnee Creek. At the present time there is a grist mill at Alley Spring (now closed), and one on Big Shawnee Creek, and another on Rocky Creek which are still operated. In past times there were mills at Round and Blue Springs and at several other places, but all traces of these have long since disappeared.

Current River has excellent possibilities as a source of hydro-electric power. There are a number of good dam-sites between the junction of Current River and Jacks Fork and the Arkansas line. Various companies have made plans at one time or another for the development of this power, but no actual construction work has been started.

In 1927 the Missouri Hydro-Electric Company of Kansas City had a preliminary permit from the Federal Power Commission for the construction of two or more projects between Doniphan in Ripley Co., and the mouth of Jacks Fork. Their tentative plans provided for an installation of about 100,000 horse power.[1]

This permit has lapsed, and at the present time there are three or four other applications before the Commission.

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[1]Beckman, H. C., Water Resources of Missouri, Mo. Bur. Geol. and Mines, Vol. XX, 2nd ser., 1927, p. 278.

CHAPTER VI.

SYSTEMATIC PALEONTOLOGY.

E. O. Ulrich, Aug. F. Foerste and J. Bridge.

During the past 30 years, Doctor E. O. Ulrich has devoted much time to the study of the fossils from the late Cambrian and early Ordovician (Ozarkian and Canadian) formations, and has recognized several hundred species, the great majority of which are undescribed. The task of describing and figuring these forms is an enormous one, and while much has been accomplished, a great deal more remains to be done. At the present time, Ulrich and Foerste have nearly completed a monograph on the Cephalopods of the proposed Ozarkian and Canadian systems. Preliminary descriptions of many of the gastropods have been prepared by the writer, under Ulrich's direction, while Ulrich himself has made numerous preliminary studies of the trilobites and other groups.

Since the publication of these papers cannot be expected for some time, it has been deemed advisable to describe and figure a few of the most common forms found in each formation from the Potosi to the Roubidoux inclusive.

DESCRIPTION OF SPECIES.

GASTROPODA

E. O. Ulrich and Josiah Bridge

Gastropods are by far the most obvious and abundant fossils found in the rocks of the Eminence region, and many of them have proved to be excellent index fossils. The descriptions and figures on the following pages have been abstracted from a report upon the Gastropods of Ulrich's proposed Ozarkian and Canadian systems, now in the course of preparation. They show a few of the great host of forms, mostly undescribed, which have been collected from these formations.

Patellacea,* Ulrich and Schofield

Hypseloconus, Berkey

1898—Hypseloconus, Berkey, Amer. Geol., Vol. XXI, pp. 282-3.

Genotype: *Hypseloconus (Metoptoma), recurvus* (Whitfield).

Original Description—"Shell conical, high; apex smooth and more or less recurved toward or even beyond the broader margin of the oval aperture; aperture entire and

[1]Published by permission of the Director of the U. S. Geological Survey.

*The assignment of genera to families is provisional.

more or less acuminate anteriorly; surface smooth or striated; muscle scars in six pairs forming a circle parallel to the aperture and about one-third of the distance from the base to the apex."—Berkey, 1898.

Stratigraphic and Geographic Distribution—*Hypseloconus* was originally described by Berkey from the Franconia sandstone (Upper Cambrian) of Wisconsin, and it has subsequently been found at a similar horizon in the Davis formation of Missouri. While not widely distributed within the formations named, it is abundant where found. Berkey describes five species and one variety from the Franconia of Wisconsin and Minnesota, to which should be added Whitfield's *H. recurvus*, making a total of 7 forms from the Cambrian of that locality. Most of these forms, and in addition, a few others not yet described, occur in the Davis of Missouri.

The genus is represented by a single species in the Potosi, another in the Eminence, and by two forms in the Van Buren, one of which or a closely allied form, continues into the Gasconade. It has not been found above this latter horizon.

Hypseloconus ozarkensis, Ulrich and Bridge, new species.

Plate XX, figures 23, 24, 25, 26.

Description—Shell conical, height commonly slightly greater than length. Apex pointed, slightly anterior to the center and only very slightly recurved; aperture ovoid and narrowest anteriorly, sides sloping uniformly, no longitudinal keels or furrows developed. On most specimens there is a distinct impressed band from 1 to 3 mm. in width according to the size of shell, completely encircling it, at about ⅓ of the height from the apex to the margin. The dimensions of the cotypes are length 29 and 18.5 mm., width 18 and 13 mm., height 20.5 and 16.5 mm.

Occurrence—Cotypes, U. S. N. M. No. 83533-a-b-c, from chert of the Van Buren formation, at locality 102-c, one mile east of Eminence, Shannon County, Mo.

Remarks—This species strongly resembles *H. stabilis*, Berkey, but is narrower and more compressed anteriorly.

Hypseloconus compressus, Ulrich and Bridge, new species.

Plate XX, figures 20, 21, 22.

Description—Shell conical, compressed anteriorly, expanding posteriorly. Apex pointed, directed posteriorly, anterior profile convex, posterior profile concave, the sides sloping uniformly, flaring outward as they approach the posterior margin. Aperture ovoid, almost pointed anteriorly. Impression of muscle band distinct, about ¼ height of shell above margin. Surface marked with fine concentric lines. Dimensions of the holotype are length 15.5 mm., width 14.5 mm., height 14 mm.

Occurrence—Holotype, U. S. N. M. No. 83532 from chert of the Van Buren formation at locality 102-e, 1 mile southeast of Eminence, Shannon County, Mo., on the old Van Buren road.

Remarks—This form resembles a diminutive *H. recurvus* (Whitf.), but in that species, the apex is always anterior to the center of the shell, and the proportionate height of the shell is somewhat greater. A form indistinguishable from *H. compressus* except for its larger size and slightly more strongly compressed anterior portion, occurs in the Gasconade of Missouri at a few localities.

"Pleurotomariidae", d'Orbigny

Dirhachopea, Ulrich and Bridge, new genus.

Description—Shell small to medium in size; consisting of five or more slowly expanding volutions; spire low in the more typical forms, moderately high in others. Whorl quadrangular or rounded quadrangular in cross-section; suture strongly depressed, the final whorl becoming detached in some forms. Peripheral keel double, enclosing a distinct band; aperture with a deep peripheral notch, the apex of which corresponds with the end of the band. Surface markings consist of fine concentric striae, and occasionally broad undulations, both of which are parallel to the outline of the aperture.—Genotype *D. normalis*, new species.

This genus is to be distinguished from *Rhachopea* by the presence of the peripheral band with its two keels; by its more slowly expanding whorls and by its greater number of whorls. The tendency of the last whorl to separate from the spire is well marked in many species of *Dirhachopea*, and so far has not been observed in any species of *Rhachopea.*

Stratigraphic and Geographic Distribution—This genus appears to be confined to the Potosi, Eminence and Proctor dolomites, and so far has not been found outside the Ozark region. It is highly characteristic of cherts derived from the Eminence dolomite, no less than 8 species occurring here. It is also well represented in cherts derived from the Proctor dolomite, but has not been reported from younger strata. A single specimen referable to this genus has been obtained from chert derived from the Potosi dolomite and doubtless more would be found, if this chert were better adapted to the preservation of fossils.

Dirhachopea normalis, Ulrich and Bridge, new species.

Plate XVIII, figures 14, 15, 16.

Description—Shell of medium size, consisting of five whorls. Spire low, apical angle 160-165°. Whorl gradually expanding; subquadrangular in cross-section, the diameter of the final whorl about twice the diameter of the preceding one; the last half of the final whorl often not in contact with the remainder of the spire and variously deflected. In most instances it rises slightly so that the upper portion of the aperture is as high or higher than the spire. Peripheral band narrow, about .5 mm. high; median. Apertural notch deep, the edges diverging at an angle of 30°. Umbilical keel sharp, median; dorsal and ventral keels prominent, rounded, slightly nearer the umbilical keel. Umbilicus about ⅔ the diameter of the shell at the point where the final whorl diverges; deep, exposing all the whorls.

Surface ornamented by fine concentric lines of growth which parallel the aperture, bending slightly backward from the umbilical keel, the curvature increasing gradually until they reach the peripheral band at an angle of about 30°.

The dimensions of a well preserved specimen, the holotype are: Greatest diameter 23 mm., diameter at point where last whorl becomes free 17.5 mm., diameter of umbilicus at same point 11.5 mm., height 6.6 mm., length of aperture 11 mm., height of aperture 6.8 mm.

Occurrence—Holotype, U. S. N. M. No. 83518 from chert of Eminence dolomite, locality 438-r, on hill ½ mile west of Eminence, Shannon County, Mo.

Remarks—This species is characteristic of the Eminence and is widely distributed. It is one of the largest species of the genus and is readily recognized by its partially detached and slightly elevated body whorl.

Dirhachopea intermedia, Ulrich and Bridge, new species.

Plate XVIII, figures 17, 18, 19.

Description—Shell of medium size, consisting of five whorls. Spire low, apical angle, 155°. Whorl gradually expanding, the final whorl three times the width of the one preceding it, well rounded; subquadrangular, final whorl not separated from remainder of spire; suture strongly depressed. Peripheral band median, about .5 mm. wide in mature forms. Apertural notch deep. Umbilicus open, exposing all of the whorls; deep, diameter about half that of the shell. Surface markings as in *D. normalis*. The dimensions of an average specimen, one of the cotypes, are: Greatest diameter 13.8 mm., height 7.8 mm., diameter of umbilicus 8 mm.

Occurrence—Cotypes, U. S. N. M. No. 83519-a-b, from chert of Eminence dolomite, locality 399-c, 6 or 7 miles south of St. Clair, Franklin County, Mo.

Paratypes, U. S. N. M. No. 83520, locality 452-q-1, near the Munsell school house, 4 miles south of Eminence, Shannon County, Mo., on State highway 19 (temporary).

Remarks—This species appears to be intermediate in form between *D. normalis* and *D. nitida*. It differs from the former in its relatively higher spire and more rounded whorls, and in the fact that the body whorl is not separated from the spire.

Dirhachopea subrotunda, Ulrich and Bridge, new species.

Plate XVIII, figures 21, 22.

Description—Shell below medium size, consisting of five volutions, spire flat or very slightly elevated above or depressed below the outer whorls. Whorl gradually expanding, the diameter of the final whorl about twice that of the preceding one; earlier whorls rounded, final whorl sub-angular. Peripheral band distinct, about .5 mm. wide in a specimen 11 mm. in diameter. Suture depressed, final whorl so far as observed in contact with the remainder of the spire, but dropping slightly below the plane of the other coils. Umbilicus, wide, shallow, exposing all the whorls. Surface markings as in other members of the genus. The dimensions of the cotypes are: Diameter 11 and 9 mm., height 3.5 and 3 mm.

Occurrence—Cotypes, U. S. N. M. No. 83522-a-b, from chert from the Eminence dolomite, locality 100-i, 5 miles southwest of Eminence, Shannon County, Mo.

Common and widely distributed.

Remarks—This is one of the smaller species of the genus and may be readily distinguished from other forms by its flat spire and rounded whorls. *D. intermedia* which also has rounded whorls is larger and has an elevated spire, while *D. appressa* which approaches *D. subrotunda* in size has a low spire and a sharply compressed whorl.

Dirhachopea appressa, Ulrich and Bridge, new species.

Plate XVIII, figures 8, 9, 10.

Description—Shell small, consisting of about four and one-half volutions, spire slightly depressed, umbilicus, open, broad, more than half as wide as the shell. Whorl rather rapidly expanding, the final whorl being 3.5 to 4 times the width of the preceding one at the aperture, although this ratio does not hold throughout. Strongly compressed dorso-ventrally. Sharply keeled on the periphery. Aperture with a deep notch. Peripheral band median, about .5 mm. wide on adult shells. Dorsal and ventral keels well defined, rounded, about 2/3 the width of the whorl from the peripheral edge. Suture depressed. Umbilicus open, about half the diameter of the shell. Surface markings consist of fine growth lines.

Average specimens have a diameter of 9 or 10 mm. and a height of 3 mm. but these dimensions are sometimes exceeded.

Occurrence—Cotypes, U. S. N. M. No. 83514, chert from Eminence dolomite, locality 373-l, (M. S. M. 98.15) hill on north side of Jacks Fork, 1½ mile northwest of Eminence, Shannon County, Mo.

Paratype, U. S. N. M. No. 83515, locality, 188-y, near Elvins, St. Francois County, Mo.

Paratype, U. S. N. M. No. 83516, from same formation, locality 452-q-1, on Current River just below the mouth of Sinkin Creek, Shannon County, Mo.

Remarks—This is one of the smaller species of *Dirhachopea*, and is quite distinct. It is close to *D. subrotunda* in size, and is similar to it in its depressed spire, but differs in its sharply-angled whorl and flat shoulders.

Varieties of this species differing in the more sharply angulated and less rapidly expanding whorls are found in the Proctor dolomite in Camden County, Missouri.

Dirhachopea corrugata, Ulrich and Bridge, new species.

Plate XVIII, figure 20.

Description—Shell of medium size, composed of five volutions. Spire low, apical angle 155-160°. Whorl slowly expanding, the final whorl less than twice the diameter of the preceding one, compressed laterally, height greater than width, subquadrangular in cross-section; suture strongly depressed. Dorsal and ventral keels submedian, prominent, especially on the final whorl; rounded. Umbilicus broad, its width about three-fourths the diameter of the shell. Peripheral band prominent, about 1 mm. wide. Surface markings consist of fine concentric growth lines, and broad gentle undulations which parallel the outline of the aperture. These undulations are spaced about a millimeter apart and are most conspicuous on the body whorl.

Dimensions of the holotype are: Diameter 18 mm., height 5 mm.

Occurrence—Holotype, U. S. N. M. No. 83521 from residual chert from the Eminence dolomite at locality 373-l (M. S. M. 98.15) on hill north of Jacks Fork, 1½ mile northwest of Eminence, Shannon County, Mo. Rather common at this locality, rare elsewhere.

Remarks—This is one of the rarer forms of the genus. It is close to *D. intermedia* in size, but may be distinguished by its surface markings, lower spire, narrower whorl and wider umbilicus. It is larger than *D. subrotunda* and *D. appressa* and differs from them in its narrower whorls, higher spire, and surface ornamentations.

Dirhachopea abrupta, Ulrich and Bridge, new species.

Plate XVIII, figures 11, 12, 13.

Description—Similar in size and general appearance to *D. normalis*, but differing in the position of the ventral keel, which is so placed that the umbilical wall is practically vertical. This gives the mould of the umbilical area a step-like appearance instead of the rather smooth conical mould which characterizes *D. normalis*.

Occurrence—Holotype, U. S. N. M. No. 83517, from chert of Eminence dolomite at locality 100-c, 1 mile south of the Casey Mine, near Eminence, Shannon County, Mo.

Dirhachopea dubia, Ulrich and Bridge, new species.

Plate XVIII, figures 5, 6.

Description—This species is founded upon a single badly corroded and encrusted specimen, which is of interest because it is one of the few fossils which have been obtained from the Potosi dolomite. The specimen is about the size of an average example of *D. normalis* and consists of a closely coiled portion with a low spire, and a detached, descending body whorl. The number of coils is not clearly visible. The final half volution is quadrangular in cross-section and bears faint traces of a band along the peripheral angle. The specimen is evidently a *Dirhachopea* and is very close to *D. normalis*, but differs from it in that the detached portion of the whorl is turned downward.

Occurrence—The holotype and only known specimen, U. S. N. M. No. 83513, was collected by Mr. Stuart St. Clair in chert of the Potosi dolomite 1/3 of a mile west of Piedmont, Wayne County, Mo.

Rhachopea, Ulrich and Bridge, new genus.

Description—Shell consisting of about four volutions, the spire low, only slightly to moderately raised above the top of the final whorl. Apical angle varying in the different species, from 80° in *R. elevata* to about 160°-165° in *R. washburnensis* and 185° in *R. depressa*. Whorl gradually expanding, increasing from two to four times its diameter in a single volution, subquadrangular in cross-section, the peripheral keel most prominent, slightly below the median plane of the whorl, sharply angled; the angle averaging about 110°. There is a distinct angled keel on the umbilical side of the whorl where it makes contact with the preceding whorl, the slope above this keel being concave or sigmoid while the remaining slopes are convex. The dorsal and ventral carinae are obscure and broadly rounded and are situated slightly on the umbilical side of the center of the whorl, making the umbilical slopes somewhat steeper than the peripheral slopes. Suture depressed.

Umbilicus about 1/3 the diameter of the shell; open, exposing all of the whorls.

Aperture with a deep notch on the outer side of the whorl which marks the terminus of the peripheral keel. Surface markings consist of fine growth lines, parallel to the aperture. These lines are gently convex anteriorly and swing backward from the umbilical keel, crossing the dorsal and ventral keels without any sharp change of direction but making an angle of about 75° where they cross the peripheral keel, this angle corresponding to the apertural notch.

Genotype—*R. typica*, n. sp.

Stratigraphic and Geographic Distribution—According to present knowledge, the genus is confined to the formations included in Ulrich's proposed Ozarkian system, and is most abundant in the higher formations of the series. It is represented in the Eminence and Proctor dolomites of the Ozark region, but becomes extremely abundant in the Van Buren, and continues up into the Gasconade. It is also known from the southern portion of the Appalachian Valley, where it occurs sparingly in the Copper Ridge dolomite, and more abundantly in the Chepultepec dolomite.

Schizopea washburnensis, Ulrich, figured by Butts in the Geology of Alabama, Pl. 14, figs. 23-24, is now referred to *Rhachopea.*

Rhachopea typica, Ulrich and Bridge, new species.

Plate XX, figures 1, 2, 3, 4, 5.

Description—Shell of medium size, consisting of four whorls, spire low, scarcely elevated above the top of the final whorl. Apical angle about 150°. Suture strongly depressed. Whorl gradually expanding, the final whorl from 2½ to 3 times the width of the preceding; peripheral keel on adult specimens which preserve the exterior, is a smooth rounded band from 1-1.5 mm. wide, slightly raised. On internal moulds, it appears as a single sharp line.

Aperture subquadrangular, with a deep peripheral notch, the edges of which make an angle of 70°. Surface marked by finely spaced concentric growth lines which follow the general outline of the aperture and become obsolete as they cross the peripheral keel.

A large specimen, one of the cotypes, U. S. N. M. No. 83525-b, has the following dimensions: Diameter, 39 mm., height, 22 mm. (allowing for apex which is missing), diameter of aperture 20.7 mm., height of aperture 19.4 mm., width of umbilicus at base 24 mm., depth of umbilicus 18 mm. An average specimen, another cotype, U. S. N. M. No. 83525-a, has a diameter of 28.4 mm., and a height of 16.5 mm.

Occurrence—Cotypes, U. S. N. M. No. 83525-a-b, from chert from the Van Buren formation at locality 102-e, about one mile southeast of Eminence, Shannon County, Mo., on the old Van Buren road. (Center NW ¼, SE ¼, sec. 35, T. 29 N., R. 4 W.)

In addition to the two specimens here mentioned, there are 8 more cotypes, all from the same locality.

Paratype, U. S. N. M. No. 83526, from the same horizon at locality 261-o, 3 miles southeast of Eminence at top of hill on Highway 19, SE ¼, NE ¼, sec. 1, T. 28 N., R. 4 W.

Abundant at many other localities, both in the Eminence and Potosi regions.

Remarks—This species is one of the most abundant and characteristic fossils of the Van Buren formation and is widely distributed throughout southeastern Missouri, occurring in almost every locality where Van Buren fossils have been found.

Rhachopea transitans, Ulrich and Bridge, new species.

Plate XX, figures 6, 7.

Description—Shell of medium size, consisting of four whorls, spire low, but distinctly higher than *R. typica*. Apical angle 120°-125°. Whorl gradually expanding, the final whorl twice the diameter of the preceding one, subquadrangular in cross-section, peripheral keel sharp, about 1/3 the height of the whorl above the base, making the upper portion or the whorl somewhat steeper, and the bottom somewhat flatter than in *R. typica*. Umbilical keel sharp; dorsal and ventral keels rounded but sharper, and much closer to the suture than in *R. typica*. Suture depressed, narrow. Surface markings as in *R. typica*. Apertural notch shallow, the edges meeting at an angle of 85°.

The slope from the dorsal keel to the peripheral keel is distinctly flattened near the top of the whorl and in many forms is even slightly concave, giving this section of the whorl a somewhat sigmoid profile, which is one of the most striking characteristics of the species.

The dimensions of the holotype are: Diameter 28.2 mm., height 19 mm., diameter of the umbilicus 15 mm., width of aperture 17 mm., approximate height of aperture 14.5 mm.

Occurrence—Holotype, U. S. N. M. No. 83527 from lower portion of chert from the Van Buren formation at locality 438-r, near hilltop about ½ mile west of Eminence, Shannon County, Mo. (center SW ¼, sec. 27, T. 29 N., R. 4 W.).

Remarks—This species is apparently intermediate between *R. typica* and *R. elevata*. From the former it differs, in its higher spire, its narrower and less depressed suture and the position of the peripheral keel. It differs from *R. elevata* in its larger size, lower spire, and more deeply impressed suture.

Rhachopea elevata, Ulrich and Bridge, new species.

Plate XVIII, figures 23, 24.

Description—Shell below medium size, consisting of four whorls; spire moderately high, apical angle 80°. Whorls gradually expanding, the diameter of the final whorl twice that of the preceding one, subquadrangular in cross-section. Peripheral keel sharp, similar in position to that of *R. transitans*, suture only slightly depressed, narrow. Whorl subpentagonal in cross-section, umbilicus narrow.

The dimensions of an incomplete specimen, a cotype are: Maximum diameter 19 mm., height (allowing for top whorl which is missing) 17 mm., diameter of body whorl near aperture 9.4 mm., height of aperture 8.6 mm.

Occurrence—Cotypes, U. S. N. M. No. 83523-a-b-c, from the *Plethopeltis* zone of the Eminence dolomite, locality 102-h, 4 miles west of Eminence, Shannon County, Mo.

Widely distributed in the upper part of the Eminence dolomite throughout the Ozark region.

Remarks—This species is common in the *Plethopeltis* zone of the Eminence, and is apparently the only species of this genus which occurs in this formation. It may be readily distinguished from congeneric forms by its much greater height and narrower apical angle. A cross-section of the whorl of this species shows the dorsal keel to be rounded and nearly median in position. The outline of the whorl is gently concave from dorsal to the umbilical keel and gently convex from the dorsal to the peripheral keel. The diameters of the whorl are approximately equal.

Rhachopea grandis, Ulrich and Bridge, new species.

Plate XXI, figures 15, 16.

Description—Shell large, spire low, apical angle 140°-145°. Whorls, four, gradually expanding, the final whorl three times the diameter of the preceding one; subquadrate, the umbilical and peripheral keels sharp; the dorsal and ventral keels, median, obsolete.

The dimensions of a medium sized specimen, one of the cotypes, are: Greatest diameter 58.5 mm., height (allowing for first whorl which is missing) 35 mm., diameter of umbilicus 30 mm., diameter of aperture 35 mm., height of aperture 28 mm. A somewhat larger specimen, a paratype, gives the following measurements: Greatest diameter (allowing for a broken portion of whorl) 73 mm., height (allowing for first whorl) 42 mm., diameter of umbilicus 40 mm.

Occurrence—Cotypes, U. S. N. M. No. 83545-a-b, from the upper portion of the Gasconade dolomite at locality, 238 on Huzzah Creek, Crawford County, Mo., about one mile west of the mouth of Dry Creek, and 10 miles east of Steelville on the Potosi road (now State Highway No. 8).

Paratype, U. S. N. M. No. 83546, also from the upper portion of the Gasconade, from some locality in Missouri, exact place unknown.

Widely distributed throughout the upper portion of the Gasconade dolomite in Missouri. Also found in the cherts from the Chepultepec dolomite of eastern Tennessee.

Remarks—*R. grandis* closely resembles *R. typica* in its general form and proportions, but is much larger, and occurs at a higher horizon. *R. washburnensis*, from the Copper Ridge dolomite of Alabama is of about the same size, but differs from *R. grandis* in the lower position of the peripheral keel, and in its more depressed spire. *R. depressa* commonly attains the size of *R. grandis* and is associated with it, but is readily distinguished by its more rapidly expanding whorls and depressed spire.

Sinuopea, Ulrich

1911—*Sinuopea* Ulrich, Revision of the Paleozoic Systems, Bull. Geol. Soc. Amer., Vol. 22, p. 630. (Defines the genus and refers *Holopea sweeti* Whitf. to it.)

Description—Shell consisting of about four whorls, spire moderately high, height and diameter subequal. Whorls moderately inflated, round in cross-section, except sutural slope; no peripheral keels. Aperture with U-shaped rounded notch, the apex of which lies along the periphery of the whorl. Suture distinct, but not strongly depressed. Surface marked by fine concentric growth lines parallel to the aperture similar to the markings on *Rhachopea*. Umbilicus small, open, exposing all the whorls. Genotype, *Sinuopea vera*, n. sp.

Stratigraphic and Geographic Distribution—*Sinuopea* is one of the most common and one of the most widely distributed genera of early Paleozoic gastropods. It appears to be limited to the Cambrian and the proposed Ozarkian system of Ulrich. The oldest species *S. sweeti* (Whitf.) occurs in the so-called Potsdam of Wisconsin, at Osceola Mills, in strata which are now included in the Norwalk sandstone, (Upper Cambrian). This genus is also represented in the Oneota of that state.

In the Ozark region the genus doubtfully recorded from the Eminence dolomite, is represented by several species in the Proctor and attains its maximum development in the Van Buren and Gasconade formations. It has not been reported from any younger horizon in this state.

In the Arbuckle region several species, some of them identical with Missouri forms, have been found in Ulrich's proposed Chapman Ranch formation, a subdivision of the Arbuckle limestone of Oklahoma, which is considered to be the partial equivalent of the Van Buren.

The genus is also well developed in the Copper Ridge and Chepultepec dolomites of the southern Appalachian region, and may possibly be represented in the overlying Nittany dolomite.

Holopea obesa, Whitfield from the Oneota of Wisconsin, belongs in this genus and has also been found in the Gasconade of Missouri. Whitfield's figures do not show the notch, but he states that his figure is "somewhat restored" and it is possible that his specimens did not show the surface markings.

Besides the forms mentioned above and those described on the following pages, there are a large number of undescribed species.

Remarks—The general shape of these shells is much like *Holopea*, to which genus many species of *Sinuopea* were formerly referred, but they differ in the possession of an apertural notch. *Taeniospira* differs from *Sinuopea* in having a much deeper apertural notch, which terminates in a distinct band, bounded by well defined peripheral keels.

Sinuopea vera, Ulrich and Bridge, new species.

Plate XX, figures 12, 13.

Description—Shell of medium size, height and diameter subequal, apical angle 95°-100°. Whorls five, moderately expanding, inflated, the final whorl twice the diameter of the preceding one, suture distinct but not depressed. Whorls evenly rounded on the outer slopes, without keels; sutural slope slightly concave. Aperture round, with a rounded peripheral notch, the edges of which make an angle of 75°. Surface markings consist of low, broad, growth lines, which parallel the outline of the aperture. Umbilicus open, exposing all the whorls, about half the diameter of the shell, rapidly diminishing to about ½ of this width, the umbilical slope grading into the basal slope without any marked break.

Dimensions of the holotype are: Height 23 mm., diameter 23 mm., diameter of umbilicus 13 mm., diameter of final whorl near aperture 9.5 mm.

Occurrence—Holotype, U. S. N. M. No. 83529, from chert of the Van Buren formation 102-e, about 1 mile southeast of Eminence, Shannon County, Mo., where it is common and associated with *R. typica*, *R. transitans*, and many other forms.

Remarks—This species is an extremely abundant and well characterized form, and for that reason is selected as the type of the genus. It is the form which Ulrich has for several years referred to in unpublished manuscripts and personal communications as *S. typicalis*. In 1926, Butts figured a specimen from the Copper Ridge dolomite of Alabama as *S. typicalis*, and thereby established the species. Unfortunately, Butts' specimens were not the *S. typicalis* of Ulrich's mss., so that it becomes necessary to propose the present name, *S. vera* for the form which Ulrich had previously called *S. typicalis*.

Sinuopea cingulata, Ulrich and Bridge, new species.

Plate XX, figures 8, 9, 10, 11.

Description—Shell about the size and general proportions of *S. vera* but differing from it in the possession of an impressed median peripheral band from 1 to 1.5 mm., wide, which at first sight resembles the band of *Taeniospira*. In that genus, however, the band shows as a ridge upon internal moulds, and the surface markings change direction abruptly at the bordering keels, while in *S. cingulata* the band appears as a shallow groove, and is crossed by the surface markings without appreciable change of direction. The whorl is somewhat flattened along the periphery, particularly in large specimens and this gives it a sub-squarish appearance. Apertural notch rounded at the apex, the sides making an angle of approximately 55°.

The dimensions of an average specimen, one of the cotypes, are: Height 23 mm., diameter 21.5 mm., diameter of umbilicus 9.5 mm., height of last whorl 12.5 mm., diameter of last whorl 12.5 mm., apical angle 90-95°. Specimens are known which are at least 1/3 larger than this.

Occurrence—Cotypes, U. S. N. M. No. 83528-a-b, from cherts of the Van Buren formation at locality 102-e, about 1 mile southeast of Eminence, Shannon County, Mo., associated with *S. vera*, *R. typica* and *R. transitans*.

A variety, distinguished by its lower spire, occurs with the typical form at several localities.

Remarks—This species is fairly abundant, and is widely distributed in Missouri. It may be readily recognized by the impressed peripheral band, which in most cases is quite distinct. Sometimes the band becomes obsolete, and in such cases the species is best distinguished from *S. vera*, by the sub-squarish whorl of *S. cingulata*.

Sinuopea umbilicata, Ulrich and Bridge, new species.

Plate XX, figures 14, 15, 16, 17.

Description—Shell of medium size, occasionally larger. Spire low, apical angle 105°. Whorls five, moderately expanding, the final whorl twice the diameter of the preceding one; compressed dorso-ventrally, smoothly rounded, slightly embracing; a faint peripheral keel about 1/3 the height of the whorl above the base. Suture moderately depressed. Shoulder distinct, rounded, close to suture. Umbilicus open, exposing all the whorls, less than ½ the diameter of the shell. Aperture not preserved on any of the specimens at hand. Surface apparently smooth. The cotypes both of which are incomplete are: 24 and 26.5 mm., in height, and the restored diameter of the first specimen would be approximately 30 mm.

Occurrence—Cotypes, U. S. N. M. No. 83530-a-b, from cherts of the Van Buren formation at locality 102-e, about 1 mile southeast of Eminence, Shannon County, Mo. Rather common in Missouri.

Also from Ulrich's proposed Chapman Ranch formation, a subdivision of the Arbuckle limestone, locality 459-z at Chapman's Ranch north of Springer, Oklahoma, on the road to Davis.

Remarks—This species is fairly common in the Van Buren formation and may be distinguished by its large size, low spire and its rounded and flattened whorls.

Sinuopea basiplanata, Ulrich and Bridge, new species.

Plate XX, figures 18, 19.

Description—Shell of medium size of the same general type as *S. vera*, but differing from it in its flattened base, and subangular whorl. The dimensions of the holotype which is incomplete, showing only the last three whorls, are: Diameter 24.7 mm., height 24.5 mm., apical angle 75°. Whorls rather slowly expanding the ratio of the final whorl to the one preceding it being as 5:3. Suture distinct, not depressed, shoulder rounded, close to suture, the surface of the whorl sloping abruptly to a faintly defined, obtuse, submedian peripheral notch, the edges of which meet at an angle of about 80-85°. Surface marked with rather broad, low concentric growth lines, paralleling the aperture.

Occurrence—Holotype, U. S. N. M. No. 83531, from chert from the Van Buren formation at locality 102-e, about 1 mile southeast of Eminence, Shannon County, Mo.

A large variety, intermediate between this form and *S. subangulata*, occurs in Ulrich's proposed Chapman Ranch formation at locality 459-z, Chapman's Ranch, Okla.

Sinuopea regalis, Ulrich.

Plate XXI, figure 3.

1926—*Sinuopea regalis*, Ulrich. Butts, Geol. of Ala., Special Report No. 14, Pl. 15' Fig. 12.

Description—Shell large. Whorls five evenly rounded moderately expanding. Final whorl not quite twice the diameter of the preceding one; apical angle 95-100°. Peripheral keel submedian, faint. Aperture with a shallow rounded peripheral notch, the edges of which make an angle of about 75°. Umbilicus about one-half of the diameter of the shell, rapidly contracting to about 1/3 of this figure. Surface markings as in *S. vera*.

Dimensions of the larger cotype are: Diameter 50 mm., height 61 mm., diameter of aperture 27 mm., height of aperture 30 mm., diameter of umbilicus 28 mm.

Occurrence—Cotypes, U. S. N. M. No. 71436, from chert of the Gasconade dolomite, locality 238, on Huzzah Creek, about 1 mile west of the mouth of Dry Creek and 10 miles east of Steelville, Crawford County, Mo., on the Potosi road (now State Highway 8) associated with *Rhachopea grandis, Clarkoceras subcrassum, Cameroceras huzzahense*, etc. Rather common.

Remarks—*S. regalis* is the largest species of the genus. The specimen figured by Butts and re-figured here, was said to have come from the Chepultepec dolomite of Alabama, but this is an error, for it is from the highly fossiliferous Gasconade locality on Huzzah Creek, Crawford County, Mo. The Chepultepec forms agree very well in shape and general proportions, but fail to attain the size of the Missouri forms.

Taeniospira, Ulrich and Bridge, new genus.

Description—Shells composed of four to five whorls coiled in a moderately high spire; height and diameter subequal. Whorls moderately inflated, round in cross-section (except on the sutural slope which is concave) with a pair of faint, but distinct, median or submedian peripheral keels bounding a narrow peripheral band. Aperture with shallow >-shaped notch, the apex of which is truncated and terminates in the peripheral band. Umbilicus open, exposing all of the whorls, narrow, but without any callous.

Surface ornamented with growth lines parallel to the aperture. These are nearly vertical on the inside of the whorl, but after crossing the top and bottom of it they sweep backward in a curve convex anteriorly to the peripheral keels. In crossing the band the growth lines are shallowly concave anteriorly.

Genotype—*T. eminencensis*, n. sp.

Stratigraphic and Geographic Distribution—The genus is most abundantly developed in the Eminence dolomite of the Ozark region, but is sparingly represented in the overlying Van Buren.

Taeniospira eminencensis, Ulrich and Bridge, new species.

Plate XVIII, figures 25, 26, 27.

Description—Shell large, composed of 5 (?) volutions, spire moderately high; apical angle 80-95°. Whorl inflated, moderately expanding, the diameter of the final whorl being about twice that of the preceding one. Peripheral keels, submedian, distinct, 2-2.5 mm. apart on adult shells. Suture distinct, moderately depressed, sutural slope raising steeply to the shoulder which is moderately well defined, rounded, the surface sloping steeply to the periphery. Peripheral angle about 105°. Base sloping almost as steeply to the obtusely angled, rounded, ventral keel. Umbilicus narrow, about half the diameter of the shell, steep sided, deep, exposing all the whorls.

Aperture with a slightly flaring lip, which is particularly well shown on internal moulds and with a deep almost slit-like notch which terminates in the peripheral band, the edges making an angle of about 30°. Surface marked by concentric growth lines, which parallel the outline of the aperture.

The dimensions of a typical large, but incomplete specimen are: Greatest diameter 37 mm., height 33 mm. (to which should be added about 5 mm. for the missing spire), width of the aperture from the inner lip to the apex of the notch, 26.5 mm., height of aperture 24 mm., diameter of umbilicus 18 mm.

Occurrence—Holotype, U. S. N. M. No. 83524 from the *Plethopeltis* zone of the Eminence dolomite, locality 373-1 (M. S. M. 98.15), on the high hill north of Jacks Fork, 1½ miles west of Eminence, Shannon County, Mo., 40 feet below the Gunter sandstone. The species is abundant at this locality. It is fairly common in the upper portion of the Eminence at many localities.

Remarks—This is the largest, most abundant and best characterized species of the genus. It closely resembles *T. st. clairi*, from the Van Buren formation, but differs in the position of the band, the width of the shoulder and in its larger size.

Gasconadia, Ulrich and Bridge, new genus.

Small, turreted shells, whorls six to eight closely coiled, angular or rounded. Aperture with an expanded lip. The outer margin of this lip is interrupted by a deep >-shaped notch, the apex of which lies on the peripheral keel or on the broadest portion of the whorl. Umbilicus very small, but extending the length of the spire.

Specimens which preserve the body whorl show a deep indentation on the lower side just to the left of the lip. This cavity has rounded edges and was interpreted by Sardeson as having been made by some predatory organism, which, in some unexplained manner bent the shell without crushing it.

The indentation occupies a definite position upon the whorl in all specimens which preserve it, and is visible not only upon internal moulds but also upon specimens in which the shell is silicified. It appears to represent an infolding of the shell wall to form a toothlike projection on the floor of the whorl, the exact purpose of which is not known. Whatever its function may have been, it is highly characteristic of this group of shells, and is a feature which at once sets them off from other Pleurotomaroids.

Genotype—*Gasconadia (Murchisonia) putilla* (Sardeson).

Stratigraphic and Geographic Distribution—Gasconadia appears to be confined to the Gasconade and its equivalents. The genotype was originally described from the Oneota dolomite of Wisconsin and Minnesota and appears to be widely distributed in these two states. It also occurs in the Oneota of Iowa. In Missouri it is one of the most characteristic forms found in the Gasconade. It is also fairly common in the Chepultepec dolomite of the southern Appalachian region and has been found in strata of equivalent age in Pennsylvania. Several well-defined species may be recognized.

Gasconadia putilla (Sardeson)

Plate XXI, figures 11, 12, 13.

1892—*Murchisonia* sp. Calvin, S., Amer. Geologist, Vol. 10, p. 147.
1892—*Murchisonia* sp. Calvin, S., Bull. Lab. Nat. Hist., State Univ. Iowa, 2, p. 192.
1896—*Murchisonia putilla* Sardeson, F. W., Bull. Minn. Acad. Nat. Sci., Vol. IV, No. 1, p. 98, Pl. V, figs 5, 6.

Description—Shell small, spire moderately high, apical angle 45° to 50°, whorls 6, strongly angular. There is a strong peripheral keel—slightly below the mid height of the whorl, from which the outer slopes diverge at an angle of about 115°. There are also strong dorsal and ventral carinae, which are in contact along the suture. Aperture with a broad, reflexed, trumpet-shaped lip, the outer margin of which is drawn back into a deep >-shaped notch. Just to left of the lip of the aperture is a narrow depression which indicates the presence of a ridge-like tooth on the inside of the upper end of the body whorl. Umbilicus small, open.

The dimensions of a small, nearly perfect specimen which lacks the two uppermost whorls are: Total height 13.5 mm., height of spire 6.5 mm., height of aperture (including the reflexed lip) 8 mm., width of aperture 7 mm., depth of apertural notch 3.5 mm. Specimens commonly attain a somewhat larger size.

Occurrence—Sardeson's specimens came from the Oneota dolomite near Dresbach and at Stillwater, Minnesota, and from Blanchardville, Wisconsin. He also reports it from the so-called Jordan sandstone near Rapidan, Minnesota, but according to Ulrich, the terms Jordan and St. Lawrence were applied by earlier authors to several different formations, among them the New Richmond and the Oneota. As no gastropods of this type have been reported from the true Jordan at other localities it seems probable that the specimen from Rapidan came from the top of the Oneota or the base of the New Richmond sandstone. Calvin's specimens came from Clayton and Allamakee Counties, Iowa. The Missouri specimen here figured is from the upper part of the Gasconade formation, at locality 238-d at Meramec Springs, Phelps County, Mo. It has also been found in the Gasconade formation at many other localities, at several localities in Wisconsin, Minnesota and Iowa, and from the Chepuletpec dolomite in southeastern Tennessee.

Plesiotypes, U. S. N. M. No. 83593, loc. 238-d, Meramec Springs, Mo.

Ophileta, Vanuxem.

1842—*Ophileta*, Vanuxem, L., Natural History of New York, Pt. III, Geology of the 3d Dist., pp. 35, 36.

1847—*Ophileta*, Hall, James, Natural History of New York, Pt. VI, Paleontology, Vol. I, pp. 11, 12, Pl. III, Figures 4, 5, 6.

Description—Shell composed of from five to eight rather slowly expanding volutions coiled into a broad, low cone—more rarely planispiral. Whorls sub-rhomboidal in cross-section, with a strong, rounded peripheral keel. The keel is bordered above by a well-defined groove, giving the peripheral slope a distinct sigmoid profile which is one of the most characteristic features of the genus. Under surface of the whorls evenly rounded; umbilicus open, exposing all of the whorls. Suture distinct, narrow, not strongly depressed.

Genotype—*Ophileta levata* Vanuxem.

Stratigraphic and Geographic Distribution—Ophileta is an extremely abundant form in the early Ordovician (middle and upper Ozarkian and Canadian of Ulrich) faunas of North America. In the Mississippi Valley the earliest forms are found in the Van Buren of Missouri and the genus reaches its greatest development in the succeeding Gasconade dolomite. Many of the forms found here are conspecific with those found in equivalent formations, both in the Upper Mississippi Valley and in the Appalachian region. It is also common in the younger formations of Beekmantown age. In general these younger forms have somewhat broader whorls than the older ones, and as a result, the width of the umbilicus is proportionately narrower, a fact which is of some value in making a rough separation of horizons.

Remarks—The true nature of this important genus has long been misunderstood. Many species which should have been referred to it have been described under other genera such as *Pleurotomaria*, *Raphistoma*, *Straparollus* and *Euomphalus* while, on the other hand, most of the published forms which have been referred to *Ophileta* belong to an entirely different genus, *Lecanospira*.

O. levata and *O. complanata*, the first species described, came from the Tribes Hill limestone of the Beekmantown group of New York. The original brief description and figures of *Ophileta* are very poor, and might apply to almost any discoidal shell. Fortunately however, the types figured by Hall have been preserved, and since they came from the same localities as Vanuxem's forms, and since nothing else occurs in these strata with which they might easily be confused, it is safe to assume that they are identical with the forms described by Vanuxem.

In 1859 Salter described and figured a new species, *Ophileta compacta*, from supposedly equivalent strata at Beauharnois, near Montreal. He evidently had not seen specimens of Vanuxem's species, and his reference of this new form to *Ophileta* must have been based entirely upon the figures and descriptions of Vanuxem, Hall and Emmons. His generic diagnosis, accompanied by excellent figures, was based entirely upon his own specimens, and, as a result nearly all of the subsequent references to *Ophileta* have been based upon Salter's description and figures rather than upon those of Vanuxem and Hall. The two forms are quite distinct, and many years ago, Ulrich, after studying Hall's types and additional collections from the type localities along the Mohawk River, restricted the term *Ophileta* to its original meaning and proposed the name *Lecanospira* for forms of the type described by Salter.

Although these distinctions were not published, species belonging to each genus were figured by Butts in 1926.*

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*Butts, Chas., Geol. of Alabama. Ala. Geol. Surv. Special Rept. No. 14, 1926, p. 94, Pl. 16. (The spelling Ophiletta is a typographical error.)

At the present time the following appear to be valid species of *Ophileta:*

O. lavata Vanuxem, Tribes Hill limestone of New York.

O. complanata Vanuxem, Tribes Hill limestone of New York.

O. minnesotense (Owen), Oneota dolomite of Wisconsin.

O. oweni (Sardeson) Oneota dolomite of Wisconsin.

O. solida Ulrich, Longview and Newala limestone of Alabama.

O. grandis Ulrich, Oneota dolomite of Wisconsin.

O. canadensis (Billings) "Calciferous" of Canada.

O. pepinensis (Meek) from the Oneota dolomite of Wisconsin may be a distinct species, or may be a synonym of *O. minnesotense. Raphistoma acuta* Hall and Whitfield from the Garden City limestone of Utah may eventually prove to be a member of this genus. The same may also be true of *R. praevium* Whitfield, from the Beekmantown at Fort Cassin, Vermont. In addition to the foregoing there are a great number of undescribed forms.

Ophileta grandis, Ulrich.

Plate XXI, figures 6, 7.

1926—*Ophiletta grandis* Ulrich, in Butts, Geol. of Alabama, Ala., Geol. Survey, Special Rept. No. 14, p. 94, Pl. 16, Fig. 14, (figured but not described).

Description—Shell large—the incomplete holotype having a diameter of 55 mm. Whorls 7, slowly expanding, the diameter of the final whorl near the aperture being about 1½ times that of the preceding one. Peripheral keel strong above the median line of the whorl. Shoulder of whorl low, rounded, the profile from suture to periphery being distinctly sigmoid. Under surface of whorls evenly rounded. Spire low, the apical angle being approximately 115°. Umbilicus open—shallow. Aperture, rounded trapezoidal, with a deep >-shaped notch, the apex of which lies on the peripheral keel. Surface marked by concentric growth lines which curve strongly backward from the suture, making an angle of about 110° with the radius of the shell, and which meet in a sharp angle along the peripheral keel. Some of the better preserved shells show indications of faint revolving striae as well, but these are not often preserved.

Occurrence—Holotype, U. S. N. M. No. 71446 from the Oneota dolomite, locality 351-c, 1½ miles southeast of Wilson, Wis.

Paratype, U. S. N. M. No. 65095 from cherts of the Gasconade dolomite, locality 238-a, near Boyler's Mill, Miller County, Mo.

Also recorded from the same formation at numerous other localities in Missouri and from the Chepultepec dolomite of eastern Tennessee.

Ophileta supraplana, Ulrich and Bridge, n. sp.

Plate XXI, figures 9, 10.

Description—Shell consisting of 7 whorls, spire flat, apical angle 180°, whorls very slowly expanding, the diameter of the final whorl being about 1¼ times that of the preceding one. Cross-section of the whorl rounded subtriangular. (See Plate XXI, figure 10.) Aperture with a deep >-shaped notch, the angle of which lies along the peripheral keel, the plane of this aperture approximately tangent to the whorl. The suture is distinct and slightly depressed, the dorsal keel is rounded and prominent, while the peripheral keel is sharp and angular and is directed upward and outward. The undersurface of the whorl is rounded with a well defined, rounded angulation on the umbilical side of the center. Umbilicus broad, about three-fourths the diameter of the shell, open, exposing all the whorls. Surface marked with fine growth lines which are parallel to the aperture. The dimensions of the cotypes are: Diameter 32.5 and 25 mm., width of body whorl near the aperture, 6 mm. and ? mm., diameter of umbilicus ? and 18.5 mm. Another specimen, a paratype, is 24.5 mm. in diameter; the body whorl is 4.5 mm. wide and 4 mm. high near the aperture and the umbilicus is approximately 18 mm. in diameter.

Occurrence—Cotypes, U. S. N. M. No. 83557 from cherts of the Gasconade dolomite at locality 238-g near top of hill north of Highway 8, one mile east of Berryman, Washington County, Mo.

Paratype, U. S. N. M. No. 83542 from the same horizon, exact locality unknown, probably somewhere in Missouri.

Also from the Gasconade formation at the following localities: 261-l and 401-t, Shannon County, Mo., and 238-a Morgan County, Mo.

Also from chert of the Chepultepec dolomite at locality 255-t, Jasper, Tenn.

Remarks—This is a well characterized species which may be easily identified by its flat spire and narrow whorls. The form figured by Butts as *Ophileta cf. supraplana* has an elevated spire and is more properly referred to another species.

O. alturensis of Sardeson from the upper part of the Oneota dolomite resembles *O. supraplana* in its flat spire. We have had no opportunity of examining the types of this species, but the collections from the Oneota in the National Museum contain a number of specimens which appear to belong to this species. The cross-section of the whorl of this form is entirely different from that of *O. supraplana,* and other forms of *Ophileta.* It strongly resembles a *Lecanospira* and has been referred to that genus.

Euomphalidae, de Koninck

Ozarkina, Ulrich and Bridge, new genus.

Description—Thin, discoidal, planispiral shells composed of from 8 to 10 narrow, slowly expanding, slightly overlapping volutions, all of which are visible from both sides. Spire flat or slightly depressed, umbilicus open, shallow. Cross-sections of the shell are plano-concave, or subequally biconcave.

Whorls reniform in cross-section, always slightly higher than wide, dorsal and ventral sides smoothly rounded, the latter commonly the sharper. Peripheral surface evenly rounded with no trace of a peripheral keel. Surface smooth, or with faint concentric growth lines. Aperture not well shown on any specimens at hand, but believed to be entire or else with a shallow dorsal notch.

Genotype—*O. typica*, new species.

Remarks—*Ozarkina* is abundant in the lower part of the Gasconade dolomite of Missouri (as here restricted) where it is represented by at least four species. It is not known to occur in any older or younger strata in the Missouri section, but is known from beds which are the equivalent of the Gasconade, in other parts of North America.

The genus is easily recognized by its planispiral habit, its plano-concave or biconcave cross-section and its many, narrow, slowly expanding whorls. It differs from *Ophileta* with which it is sometimes associated, in the shape of the cross-section of the whorls, and in its flat or depressed spire. The flat dorsal side of some of the species might be mistaken for a small *Lecanospira*, but in that genus, the flat side is nearly always the umbilical side, so that the direction of coiling is opposite to that of *Ozarkina.* The cross-sections of the whorls of the two genera are strikingly different, those of *Lecanospira* being triangular or trapezoidal, while those of *Ozarkina* are reniform. The specific distinctions are based upon size, shape of the cross-section of the whorl, and upon the relative concavity of the dorsal and ventral sides.

These are the forms which Ulrich has grouped under the name *Ozarkispira* in correspondence and manuscripts for many years, but since the latter name was preoccupied by Walcott,* for a totally different genus of gastropods the name *Ozarkina* is here proposed in its stead.

Ozarkina typica, Ulrich and Bridge, new species.

Plate XXI, figure 8.

Description—Shell below medium size, most specimens averaging from 10 to 12 mm. in diameter. Dorsal side plane or very slightly depressed, umbilical side moderately concave. Whorls eight or nine, very narrow, very slowly expanding, slightly embracing, with a smooth rounded dorsal keel and a slightly sharper ventral keel. Surface smooth or with very faint, concentric growth lines.

Dimensions of the holotype are: Diameter 14.5 mm., height of the body whorl (and also of the shell) 3 mm., diameter of body whorl 2.5 mm., depth of umbilicus 2 mm. (est.).

Occurrence—Holotype, U. S. N. M. No. 83541 from the Gasconade dolomite at locality 104-j, one-half a mile northwest of the pegmatite dike near Decaturville, Camden County, Mo. Found at many localities throughout the Ozark region.

Remarks—This is probably the most abundant species of *Ozarkina* in the collections. It is a small flat form, which differs from *O. complanata* in its smaller size and narrower and fewer whorls. It differs from *O. valida* and *O. elevata* in its narrower whorls, smaller average size and shallower umbilicus.

Ozarkina complanata, Ulrich and Bridge, new species.

Plate XXI, figures 4, 5.

Description—Shell large for the genus, the incomplete holotype measuring 28 mm. in diameter. Spire flat. Whorls 10, higher than broad, the diameters of the final whorl being 5.5 and 3 mm. Whorls sharply angulated where in contact with preceding whorl, slightly angled on the ventral surface, otherwise evenly rounded. Surface markings not preserved. Aperture unknown. Umbilicus broad and shallow, that of the holotype being about 3 mm. deep.

Occurrence—Holotype, U. S. N. M. No. 83540 from the Gasconade dolomite at locality 101-t, near the head of Mill Creek (T. 28 N., R. 3 W.), Shannon County, Mo. Also from the same formation at locality 435-k in the same county. An imperfect specimen clearly belonging to this species was collected by Mr. Stuart St. Clair, of the Missouri Bureau of Geology and Mines, in the NW. ¼, sec. 22, T. 37 N., R. 7 E., Ste. Genevieve County, Mo.

Remarks—This species is distinguished by its large size, strongly rounded whorls and flat cross-section. It is not a common form, but appears to be rather widely distributed throughout the Gasconade of Missouri.

Euomphalopsis, Ulrich and Bridge, new genus.

Planispiral shells consisting of about four moderately expending volutions. Spire depressed, never rising above the top of the final whorl. Whorls round in cross-section, without keels, only slightly impressed where in contact, the body whorl often slightly separated from the spire. Aperture round, with a broad, shallow >-shaped notch, similar to those possessed by *Rhachopea* and *Sinuopea* but situated on the top of the whorl. Surface marked with fine concentric growth lines which parallel the outline of the aperture.

Genotype—Euomphalopsis involuta, n. sp.

Stratigraphic and Geographic Distribution—The genus is abundant in the Gasconade and appears to be restricted to a definite horizon which is rather low in the formation. The two species which are here described are the dominant forms in this zone, but associated with them are occasional specimens of *Hyolithes*, *Gasconadia*, small patelloid gastropods, and fragments of small slender cephalopods.

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*Walcott, C. D., Smith, Miscell. Coll., Vol. 75, No. 1, 1924, p. 37, fig. 6.

This horizon outcrops in the bottom of the valley at Meramec Spring, where it is more than 100 feet below the contact with the Roubidoux formation. It also outcrops near the top of the hill east of the mouth of Procter Creek in Morgan County. At this locality, it is about 100 feet above the top of the Gunter sandstone, or about 40 to 50 feet above the base of the Gasconade as now restricted. It has also been found at several localities in both the Potosi and Eminence regions.

The genus is also found in the Oneota dolomite in the Upper Mississippi Valley and in the Chepultepec dolomite of the southern Appalachian region.

Euomphalopsis involuta, Ulrich and Bridge, new species.

Plate XXI, figures 17, 19, 20.

Description—The general characters of this form have been given in the discussion of the genus. Average specimens have a diameter of 12 to 15 mm., and a height of five to six mm. The whorls are round, in some cases slightly compressed laterally, and the body whorl is often slightly detached in the last quarter turn. The final whorl is about twice the diameter of the one preceding it. The position of the spire in this form is somewhat variable. In most of the specimens studied, it is slightly depressed below the top of the body whorl, but in others it lies in this plane. In a few specimens it is so strongly depressed that the umbilicus is almost flat.

The figured specimen, one of the cotypes, has a diameter of 15 mm. at the point where the final whorl begins to detach itself from the spire. The whorl at this point has a diameter of 6 mm.

Occurrence—Cotypes, U. S. N. M. No. 83547, a-b are from the Gasconade dolomite at locality 238-d, Meramec Spring, Phelps County, Mo. It is abundant here and also at locality 346-j=M. S. M. 56.1, on the top of the hill east of the mouth of Procter Creek, Morgan County, Mo. Widely distributed and locally abundant.

Also from the Oneota dolomite, Clayton County, Iowa, and from the Chepultepec dolomite at Jasper, Tenn.

Remarks—*Straparollus intralobatus*, Sardeson, from the Oneota at Altura, Minnesota, is very similar in size and general proportions and may be a member of this genus. His description is very brief and his figure is inadequate, and we have not had the opportunity of comparing his specimens with ours. He notes that the growth lines "run a little backwards near the dorsal side" and this might indicate that his specimen was a *Euomphalopsis*. He also emphasizes the fact that the whorl is compressed dorsoventrally and in this respect his species appears to differ from ours. The species also resembles *Straparollus pristiniformus* described by Calvin from the Oneota of Iowa. Calvin's descriptions were unaccompanied by figures, but at the request of friends he prepared a photograph of most of his specimens and distributed copies of it to those who were interested. Recently his types have been made available for study through the courtesy of the Department of Geology of the University of Iowa. They contain four specimens marked *Straparollus pristiniformus*, three of which are figured in his photograph. Two of these carry a distinct keel on the dorsal surface and belong to the genus *Helicotoma*. The other figured form is not so well preserved but probably also belongs here. The unfigured specimen, Catalogue No. 7002, University of Iowa, appears to be a specimen of *Euomphalopsis involuta*.

Euomphalopsis robusta, Ulrich and Bridge, new species.

Plate XXI, figure 18.

Larger than the preceding, and with more rapidly expanding whorls, the ratio of the diameter of the final whorl to the one preceding it being 3:1. The holotype is 22 mm. in diameter, and the final whorl is 9 mm. in diameter near the aperture.

Occurrence—Holotype, U. S. N. M. No. 83548 from cherts of the Gasconade dolomite, locality 238-d, Meramec Spring, Mo. Associated with *E. involuta*. *E. robusta* is a much rarer form, but has been found at several widely separated localities in Missouri and also in the Chepultepec dolomite in eastern Tennessee.

Lecanospira, Ulrich.

1859—*Ophileta*, Salter, Canadian Organic Remains, Decade I, p. 10, Pl. 3.
1859—*Ophileta*, Salter, Quart. Jour. Geol. Soc., London, Vol. 15, pp. 378-9, Pl. XIII, fig. 12.
1861—*Ophileta*, Hitchcock, Geology of Vermont, Vol. 1, p. 271.
1862—*Ophileta*, Chapman, A popular exposition of the minerals and geology of Canada. Canadian Journal, n. s. 7, p. 121, fig. 121.
1863—*Ophileta*, Chapman, A popular exposition of the minerals and geology of Canada. Canadian Journal, n. s. 8, p. 190, fig. 158.
1864—*Ophileta*, Chapman, A popular exposition of the minerals and geology of Canada, p. 124, fig. 121, and p. 162, fig. 158.
1865—*Ophileta*, Billings, Paleozoic Fossils, I, pp. 245-6, fig. 232.
1889—*Ophileta*, Lesley, Dictionary of Fossils, Penn. Geol. Survey, Rept. P-4, Vol. 2, p. 499.
1889—*Ophileta*, Whitfield, Bull. American Mus. Nat. Hist., No. 2, p. 48, Pl. 7, figs. 18 to 25.
1889—*Ophileta*, Miller, North American Geol. and Pal., p. 413.
1889—*Ophileta*, Koken, Ueber die Entwicklung der Gastropoden vom Cambrium bis Trias. Neus Jharb. Geol. Min. Pal. 6, Beilage Band, pp. 305 to 484.
1897—*Ophileta*, Ulrich and Schofield, Palentology of Minnesota, Geol. Surv. Minn., Final Rept., Vol. III, Pt. 2, p. 1025.
1898—*Ophileta*, Koken, Ueber untersilurischen Gastropoden, Neues Jharb. Min. Geol., Pal. I, p. 23.
1909—*Ophileta*, Grabau and Shimer, North American Index Fossils, Vol. 1, p. 656, fig. 904 (not 905).
1909—*Ophileta*, Bassler, Va. Geol. Survey, Bull. II-A, p. 50, Pl. III, figs. 1 and 2.
1915—*Ophileta*, Bassler, Bibliographic Index of North American Ordovician and Silurian Fossils, Bull. U. S. Nat. Mus. 92, Pt. II, pp. 878-80.
1919—*Ophileta*, Bassler, Md. Geol. Survey, Cambrian and Ordovician, p. 304, Pl. XXXIII, figs 1 to 3; Pl. XXXIV, fig. 2.
1926—*Lecanospira*, Ulrich, in Butts' Geology of Alabama, Ala. Geol. Survey, Special Rept. 14, p. 93, Pl. 16, figs 1 to 10.

This genus has long been confused with *Ophileta*, Vanuxem, and much of its early history has been given in the discussion of that form. Nearly all of the previously published references to *Ophileta* are based upon Salter's description of the genus and refer wholly or in part to *Lecanospira*. Salter considered *Ophileta* as a sub-genus of *Scalites*. His original description is as follows: "Subgenus *Ophileta*, Vanuxem. Discoidal; spire sunk above; umbilicus below perfectly open, exposing all the whorls on one plane; whorls numerous, truncate and binagular exteriorly; mouth trigonal. Forms with deeply concave spires."

It is to be especially noted that the features stressed by Salter are the depressed concave spire, and the flat open umbilicus. Neither of these characters is possessed by either of Vanuxem's species, and the reference of forms characterized by these features to *Ophileta* is obviously wrong. This inconsistency was recognized many years ago by the senior author, and the name *Lecanospira* was proposed by him for forms of the type described by Salter. It has appeared in faunal lists in a few publications and Butts figured two species under this name and accompanied these with a brief statement of the difference between the two genera.

Description—Shell planispiral, spire depressed below the top of the final whorl, umbilical side flat or slightly concave. Whorls five to eight, moderately expanding, triangular to subquadrangular in cross-section. On the dorsal side of each whorl there is a strong, raised and rounded keel, the position of which, together with the resulting cross-section of the whorl, is an important specific character. Outer wall of each whorl vertical or steeply inclined, depending upon the position of the dorsal keel; the area on the inner face of each whorl where it is in contact with the preceding one commonly bounded by a pair of small keels.

Aperture, triangular to subquadrangular with a deep >-shaped notch, the apex of which lies on the dorsal keel.

Surface marked with strong growth lines which originate near the ventral margin, curve forward along the outer wall for about one-third of its height, and then are directed sharply backward to the dorsal keel. After crossing this they again bend forward to the suture line. They are commonly faint where they cross the keel, and are faint or entirely wanting upon the umbilical surface.

Genotype—*Lecanospira* (*Ophileta*) *compacta* (Salter).

The synonomy given above is admittedly incomplete, but contains the most important references to the genus. As might be expected, some of them refer to both genera, but in nearly all of them, the author's conception of the genus was based primarily upon Salter's description and figures.

At the present time the following described or figured forms seem to be valid species of *Lecanospira:*

Lecanospira compacta (Salter) Beekmantown group of New York and Canada, Nittany dolomite and Longview limestone of the Appalachian Valley. Roubidoux formation of Missouri.
Synonym—*Ophileta complanata* of Whitfield, Miller, Lesley, Grabau and Shimer, and Bassler.

Note—The name *Ophileta complanata* has doubtless been applied to almost every species of *Lecanospira* occurring in these horizons. In most cases it is impossible to tell what particular species the author had under consideration without a study of the original specimens.

Lecanospira nerine (Billings) Quebec group, Div. F., St. John, Newfoundland.
Lecanospira conferta, Ulrich, same distribution as *L. compacta*
Synonyms—See note under *L. compacta*.
Lecanospira alturensis (Sardeson) Oneota dolomite of Minnesota, Wisconsin, and Iowa; Gasconade dolomite of Missouri.
Synonym—*Ophileta alturensis*.

Besides these species and the forms described in this report there are a considerable number of undescribed species.

Stratigraphic and Geologic Distribution—Species of *Lecanospira* of the general type of *L. compacta*, are widely distributed in the early Ordovician (middle Canadian of Ulrich) formations. They are the most important index fossils of the Roubidoux formation of Missouri; of the Longview and Nittany formations of the Appalachian region, and of the lower portion of the Beekmantown of the Champlain Valley. The same species are also found in eastern Canada and Newfoundland and in the northern portion of Scotland. Closely allied forms are found in strata of approximately the same age in the western part of North America.

For a long time this was the lowest horizon in which this genus was known to occur, but it has recently been found in the Oneota and Gasconade formations. The species however are quite distinct. The genus is also found in the younger Lower Ordovician formations, but again the species are readily distinguishable, and they are seldom as abundant as they are in the Roubidoux and its equivalents.

Lecanospira compacta (Salter).

Plate XXII, figure 1.

1859—*Ophileta compacta*, Salter, Can. Org. Remains, Dec. 1, Geol. Surv. Canada, May, 1859, pp. 10, 16 to 18, Plate 3.

1859—*Ophileta compacta*, Billings, Can. Nat. Geol., Vol. 4, No. 5, Art. XXVII, Oct., 1859, p. 356, mentions species from Salter's type locality, no description or figures.

1863—*Ophileta compacta*, Billings, E., Geol. Surv. of Canada, 1863, p. 102, fig. 9a-b, p. 115, fig. 23, a-b.

1865—*Ophileta compacta*, Billings, E., Geol. Surv. Can., Pal. Foss., Vol. 1, 1865, p. 246.

1889—*Ophileta compacta*, Lesley, J. P., Dict. of Foss.; Penn. Geol. Surv., Rept. P-4, p. 499, fig. 23.

1889—*Ophileta compacta*, Miller, S. A., N. A. Geol. & Pal., p. 413 (regarded as synonym of O. complanata).

1894—*Ophileta compacta*, Keyes, C. R., Geol. Surv. of Mo., Vol. 5, Paleontology, p. 162.

1926—*Lecanospira (Ophileta) compacta*, Butts, Chas., Geol. of Ala. Geol. Surv., Ala., Special Rep. No. 14, Pl. 16, figs. 2 and (?) 7 (not 1, 6, 8 or 9).

The foregoing are known to refer definitely to Salter's species. In addition there are many other references which probably apply to it among others.

Original Description—"O. magna, sesquiuncalis, anfractibus 5-6 utraque perangulatus, supra profunde excavatus, infra planissiums: ore trapezoidale fere trigono, facieī interna angustissima externa biangulata,—verticali." Salter, 1859.

Description—Shell large, composed of five or six volutions; spire deeply depressed, the last two volutions rising steeply above the inner ones. Whorls rapidly expanding for this genus, the diameter of the final whorl, being slightly more than twice that of the preceding one. Final whorl often slightly detached. Keel prominent, elevated, situated about one-third the width of the whorl from the outer margin. Outer wall of whorl gently convex, almost vertical, inner wall concave. Base of shell flat. Because of the peculiar cross-section of the whorl they appear to be narrower on the base than on the upper side.

Surface marked with parallel lines of growth which arise from the outer margin, curve slightly forward and then backward, passing over the keel at a distance behind the point of origin which is nearly equal to height of the whorl at that point, and then curve forward intersecting the suture line about opposite the point of origin. Base smooth in most specimens or with obscure growth lines. Aperture trapezoidal, the inner side very short.

Diameter of an average specimen 50 mm., thickness at center of spire 3 mm., height of outer whorl 15 mm., concavity of dorsal surface 12 mm. Width of outer whorl near lip 9 mm., distance of primary keel from outer margin 3 mm.

Occurrence—Plesiotypes, U. S. N. M. No. 14692 and No. 83549 from the "Calciferous" at locality 434-u, along the St. Lawrence River, three miles east of Beauharnois, Quebec. Plesiotype, U. S. N. M. No. 71437 from the Longview limestone 10 miles southwest of Montevallo, Ala. Chas. Butts, collector. Plesiotype, U. S. N. M. No. 83550, from the Roubidoux formation, locality 101-l, 0.25 miles west of New Offenburg, Ste. Genevieve County, Mo. Plesiotype, M. S. M., Dept. of Geology No. 3074-1, from the Roubidoux formation, locality M. S. M. 90.10, Reynolds County, Mo. J. Bridge, collector.

Also from many other localities in Missouri and in the Appalachian Valley.

Remarks—One of the largest species of the genus. The diagnostic characters are the size, the extreme concavity of the spire, the rapid expansion of the whorls, especially the final one as compared with other species, and the almost triangular cross-section of the whorls, due to their slight attachment to each other. The other specimens figured by Butts as *L. compacta*, belong to other species, some of which are as yet undescribed.

Lecanospira sigmoidea, Ulrich and Bridge, new species.

Plate XXII, figure 2.

1926—*Lecanospira (Ophiletta) compacta*, Butts, Geol. of Ala., Ala. Geol. Survey, Special Rept. 14, Pl. 16, fig. 9.

Shell large, composed of six to seven moderately expanding volutions; spire moderately depressed. The ratio of the width of the final whorl to the one preceding it is about 5:3. Keel, prominent, elevated, situated about two-thirds the width of the whorl from the outer margin. Outer wall of whorl convex outward near base, becoming slightly concave near keel, forming in cross-section a gentle sigmoidal curve, the convex portion of which is larger and more prominent than the concave portion. Inner wall steep and gently concave. Base of shell smooth, flat on outer whorls, becoming gently concave on the inner ones. Surface markings as in *O. compacta*. Aperture rounded trapezoidal.

Occurrence—Cotypes, U. S. N. M. No. 83551 from cherts of the Nittany dolomite, locality 256-n, Washburn, Tenn.

Plesiotype, U. S. N. M. No. 83552, from the "Calciferous," locality 434-u, three miles east of Beauharnois, Quebec.

Plesiotype, M. S. M., Dept. of Geology No. 3074-2 from cherts of the Roubidoux formation, locality M. S. M. 90.10, Reynolds County, Mo. J. Bridge, collector. This form has been observed at several other localities in the Ozark region.

Remarks—This is also a large form having about the same diameter as *L. compacta*, but the whorls are narrower, there being about one more in this form than in a specimen of *L. compacta* of the same size. The position of the primary keel and the steeply concave inner slope of the whorl also serve to distinguish it.

Lecanospira salteri, Ulrich and Bridge, new species.

Plate XXI, figure 3.

Description—Shell of medium size, composed of about six moderately expanding volutions. The diameter of the final volution is about twice that of the preceding one. The whorls increase rapidly in height, and overlap to such an extent that the dorsal keel on the inner whorls is only slightly elevated above the suture. Dorsal keel median, outer wall of whorl steep, slightly convex, basal angle rounded. Inner wall concave. External moulds of the spire are rounded conical in form, with only a very slight offset at the junction of the whorls, except between the body whorl and one preceding it. Average specimens are about 35 mm. in diameter. In a form of this size the dorsal concavity is 8 to 10 mm. deep.

Occurrence—Cotypes, U. S. N. M. No. 83553 from cherts of the Nittany dolomite, locality 256-d, one mile southwest of Jefferson City, Tenn. Also from the Roubidoux formation, locality M. S. M. 90.10, Reynolds County, Mo. M. S. M. Dept. of Geol. No. 3074-3. It also occurs at Beauharnois, Quebec.

Remarks—This species is often associated with *L. sigmoidea*, from which it differs in the position of the dorsal keel, the outer profile of the whorls and the much more deeply depressed spire.

Lecanospira biconcava, Ulrich and Bridge, new species.

Plate XXII, figure 4.

Description—Shell of medium size, composed of six to seven rather slowly expanding volutions, which are in contact for about one-half of their height. The ratio of the diameter of the final whorl to the one preceding it is about as 5:3. Dorsal keel median, outer slope uniformly convex, inner slope concave to the suture, which is strongly depressed. Lower margins of the whorl smoothly rounded. Umbilicus slightly concave, its depth about one-third to one-fourth the depth of the spire.

Occurrence—Holotype, U. S. N. M. No. 83554, from the Roubidoux formation, about three miles north of New Offenburg, Ste. Genevieve County, Mo. Stuart St. Clair, collector.

Paratype, U. S. N. M. No. 83555, from the same horizon, locality 346-t, on Highway 60 between Birch Tree and Winona, Mo. It is also recorded from several other localities both in Missouri and in the Appalachian region.

The specimens here figured, M. S. M. Dept. of Geology No. 3074-4, are tentatively referred to this species.

Remarks—This species somewhat resembles *L. conferta*, but is distinguished by its concave base and by its proportionately broader whorls, there being about one more whorl in a specimen of *L. conferta* of the same diameter.

Family Undetermined.

Scaevogyra, Whitfield.

Scaevogyra cf. swezeyi Whitfield.

Plate XVIII, figures 3, 4.

The form figured here is the most common fossil of the Potosi dolomite. Its sinistral spire and inflated whorls show it to be an undoubted *Scaevogyra*, and it most nearly approaches *S. swezeyi* Whitfield in size and general proportions. The spire in the Missouri specimens is somewhat higher than is common in the Wisconsin forms, but this feature is rather variable. Some of the forms from the type locality at Baraboo, Wis., show spires as high as those of specimens here figured. These may eventually be separated as a distinct species but until further studies can be made on this interesting group it seems best to refer it tentatively to Whitfield's species.

Occurrence—The figured specimens, U. S. N. M. No. 83512 and M. S. M. Dept. of Geol. No. 7250, were collected by Mr. F. L. Sevier from residual cherts of the Potosi dolomite in the NE. ¼ NE. ¼ sec. 6, T. 35 N., R. 1 E., near Palmer, Washington County, Mo. (M. S. M. loc. 74.51). Other localities from which this species has been obtained are given in the table on page 74.

CEPHALOPODA

E. O. Ulrich and A. F. Foerste

The following descriptions have been abstracted from a monograph on the cephalopods of the proposed Ozarkian and Canadian systems by Ulrich and Foerste. The greater portion of this monograph is completed and it is hoped that it will soon be ready for publication.—J.B.

Shelbyoceras, Ulrich and Foerste, new genus.

Plate XVIII, figures 1, 2.

The name *Shelbyoceras* is about to be proposed by Ulrich and Foerste for a group of very primitive cephalopods, found in formations assigned by them to the proposed lower and middle Ozarkian series. These are small, laterally compressed cyrtocones, strongly curved on the ventral side, angulate dorsally with the body chamber much larger and longer than the phragmacone.

Butts figured three forms, now referred to this genus under the names of "Levisoceras" and "Quebecoceras."*

*Butts, Chas., Geol. of Ala., Ala. Geol. Survey, Special Rept. 14, 1926, Pl. 14, figs. 1, 2, 3, 6, 7, 8, 9.

Butts' specimens came from chert which was provisionally mapped as Copper Ridge, but which is apparently much older. A similar form has been found in the Eminence dolomite, and is the only cephalopod known from that formation.

The two specimens here figured were collected several years ago, but their true nature was not suspected until they were examined by Dr. Ulrich, who, on the basis of a preliminary examination, referred them to this genus. Detailed descriptions of these forms will be published in the forthcoming monograph by Ulrich and Foerste.

It is interesting to note that the Potosi specimens are associated with *Scaevogyra cf. swezeyi*, and that the same species or a form closely resembling it occurs with the Alabama species.—J. B.

Burenoceras, Ulrich and Foerste, new genus.

Conch small, relatively very short, rapidly expanding, more or less strongly curved, moderately compressed laterally, the phragmacone usually somewhat shorter and much smaller than the living chamber, which, as a rule, continues to expand on all sides to the aperture, flaring especially on the ventral side. Camerae shallow, septa flat to only very moderately concave, the septal sutures nearly straight and direct or very slightly oblique, the usual dorsal saddles inconspicuous. Siphuncle near or in contact with the ventral wall, its diameter relatively large in the older (Van Buren) species but always much smaller in their descendants; lower part of siphuncle with one or more flat, transverse diaphragms that correspond to the endocones of other Holochoanites.

Genotype—*Burenoceras pumilum*, n. sp.

Stratigraphic and Geographic Distribution—Rather widely distributed in the Van Buren and Gasconade formations of Missouri. Also from the Oneota dolomite of the Upper Mississippi Valley and the Chepultepec dolomite of the Southern Appalachians. About 16 species are known.

Burenoceras pumilum, Ulrich and Foerste, new species.

Plate XX, figures 32, 33.

The cross-section of the conch of this species is oval rather than triangularly oval. This is due to the absence of distinct flattening of the dorsoventral sides and to the absence of any tendency toward angulation at the maximum lateral diameter of the conch. On the contrary, the lateral sides of the cross-section increase gently in convexity from the dorsal toward the ventral side without any intermediate angulation. In a specimen with a dorsoventral diameter of 10 mm. and a lateral one of 7 mm. at the base of the living chamber this maximum lateral diameter is located 4 mm. from the ventral wall of the conch. The diameter of the siphuncle here is 3.2 mm. On the dorsal side the height of the living chamber is 7.5 mm., on its lateral surface 8.5 mm., and at the middle of the ventral side only 5 mm. The rate of enlargement of the living chamber and its curvature are similar to that of *B. angulare* n. sp. (not described here) but the curvature of the lower part of the conch, as indicated by the siphuncle, is sharper.

Faint wrinkles of growth slope diagonally downward from the ventral toward the dorsal side of the conch across the lower part of the living chamber, but the slope decreases toward the upper part of the chamber, where the wrinkles are more nearly horizontal.

Occurrence—Van Buren formation; the holotype, U. S. N. M. No. 83537, was found north of Potosi, Washington County, Mo., in sec. 13, T. 36 N., R. 3 E. Two other specimens were collected on Highway 21, between 4.5 and 5 miles south of Potosi. Five precisely similar specimens were found at the same horizon in Shannon County, 1 mile east of Eminence, and two others 8 miles southeast of Eminence. At each of these places the species occur in association with other highly characteristic fossils of the Van Buren formation.

Burenoceras expandum, Ulrich and Foerste, new species.

Plate XX, figures 30, 31.

The holotype and perhaps only known specimen of this small species consists of a silicified cast of the interior of the living chamber, 8.5 millimeters in height, elliptical in cross-section, with a dorsoventral diameter of 9.8 millimeters and a lateral diameter of 7.6 millimeters at its base. From this it enlarges dorsoventrally to 12 millimeters at mid-height and to 17 millimeters at the aperture. The aperture flares ventrally and ventrolaterally like the mouth of a trumpet, the most extended part projecting fully 4 millimeters beyond the ventral outline at mid-length of the chamber. Dorsally, however, the upper part of the vertical outline of the chamber curves slightly inward. The diameter of the siphuncle at the base of the chamber is 3 millimeters. The surface of the shell is ornamented by wrinkles of growth which are strongly oblique, curving downward dorsally at an increasing rate along the lower part of the living chamber but becoming more nearly horizontal at the top of the chamber, indicating that the hyponomic sinus was conspicuous at earlier stages of growth of the conch but became shallow under gerontic conditions.

Another much smaller cast of the living chamber of a supposedly younger shell of this species was found with the holotype. Aside from the matter of size it differs from the latter only in the expected lesser flare of the ventral side of the aperture.

Occurrence—Van Buren formation, 1 mile east of Eminence, Shannon County, Missouri.

Holotype—U. S. N. M. No. 83536.

Remarks—Though most probably a close ally of the associated but less rare *Burenoceras pumilum* the present species, particularly in its mature condition, is readily distinguished by the strikingly abrupt and greater flare of the ventral side of the apertural part of the living chamber. They differ also in their respective cross-sections, the curvature of the dorsal and ventral sides of the outline being nearly alike in *B. expandum* whereas in *B. pumilum* the dorsal side of the section is distinctly narrower than the ventral. Both of these species are also very similar in general expression to such other Van Buren species as *B. compressum* and to such Gasconade species as *B. ungulatum* and *B. curvatum*, but in every case comparison of reasonably complete and undistorted living chambers discloses constant features by which they may be distinguished from each other.

Dakeoceras, Ulrich and Foerste, new genus.

Conchs endogastric, moderately breviconic, more or less compressed laterally, curved but mainly in its lower half, usually intermediate in curvature between *Levisoceras* and *Eremoceras*, the rate of enlargement varying from moderate to rapid. Phragmacone usually considerably longer than the living chamber. Camerae shallow, numerous, the sutures, beginning at the ventral outline, curved downward on the lateral surfaces, the upturn in the dorsal third or half more gentle and failing to rise as high as on the ventral side. Siphuncle usually large, situated close to or in contact with the ventral wall, its circumference often flattened on the ventral side, with flat diaphragms stretched across the truncated lower ends of short endocones in its lower half or two-thirds.

Genotype—*Dakeoceras retrorsum*, n. sp.

Stratigraphic and Geographic Distribution—A number of species and varieties are referred to this genus. The great majority of these forms are found in the Van Buren formation of Missouri, but two species are known from the Oneota dolomite of the Upper Mississippi Valley.

Remarks—In general aspect the group of species here assigned to *Dakeoceras* reminds of *Levisoceras* on the one hand and of *Eremoceras* and *Ectenoceras* on the other. Most of them being older than the typical forms of those genera it seems quite possible that they represent the stock from which both of the mentioned generic groups were derived. In *Levisoceras* the conch is relatively shorter and more strongly curved; in *Eremoceras* the conch is more erect and longer, particularly in the part made by the phragmacone. However, the most striking feature in which *Dakeoceras* differs from both those groups and which is best displayed by the contour of the base of the living chamber is the decided downward slant of the camerae and septa so that the sutures lie lower on the dorsal side of the conch than on the ventral side. In *Eremoceras* the course of the sutures is nearly direct across the lateral surfaces of the conch or slants slightly upward in dorsad direction whereas in *Levisoceras* the dorsal upward slant is always a pronounced feature.

Dakeoceras normale, Ulrich and Foerste, new species.

Plate XX, figure 29.

Species based on five specimens, one fairly complete, the others consisting mainly of living chambers with varying lengths of the matrix-filled siphuncle. The holotype is 27 millimeters long, laterally compressed, and curved lengthwise. The radius of curvature of its convex dorsal outline is about 30 millimeters along the phragmacone, increasing to 40 millimeters along the living chamber. The latter is about 10 millimeters long. The lateral diameter of the conch enlarges from 4.5 millimeters at its base to 9.8 millimeters at the base of the living chamber and to 12 millimeters at the top of this chamber. The dorsoventral diameter at the base of the specimen is estimated at 6.2 millimeters, increasing to about 12 millimeters at the base of the living chamber. The cross-section of the conch is ovate, but the dorsal part of its outline is much more sharply rounded than the ventral. The dorsum, in fact, particularly beneath the living chamber, is obtusely angular. Thirteen camerae, counting downward on the dorsum from the point at which the dorsoventral diameter is 10 millimeters, occur in a distance of 10 millimeters. The sutures of the septa curve downward laterally for an amount equaling 1½ to 2 camerae, producing broad lateral lobes and narrower dorsal and ventral saddles. Beginning at the ventral outline the downward curve of the sutures extends two-thirds across the lateral side before the shorter upturned part of their course begins. The siphuncle is large, strongly depressed on the ventral side, the transverse diameter about 4.5 millimeters, the dorsoventral 2.5 millimeters, where the corresponding diameters of the conch are 9.5 millimeters and 11 millimeters.

The specimen figured here, a paratype, from the same place as the preceding, consists mainly of a living chamber that seems to be nearly complete on the dorsal side where its wall retains a height of about 10 millimeters. Beneath this are two camerae and a 6-millimeter length of the siphuncle. The specimen agrees in all essential respects with the others except that the siphuncle is not so strongly compressed in dorsoventral direction, its diameters at the base of the living chamber being 2.2 millimeters and 3.5 millimeters. It is notable chiefly for two reasons, the first being that the surface of the living chamber is faintly wrinkled in transverse direction. The wrinkles slope slightly downward in a dorsad direction near the base of the chamber but become directly transverse at its midheight and finally rise slightly in dorsad direction at the top of the chamber. The second and more important reason is that the lower end of the siphuncle is flatly truncated at probably the last of the diaphragms. The outline of the diaphragm is rounder than is the section of the siphuncle nearer its top and thus indicates that on at least its ventral side the lower part of the siphuncle exposes the wall of an endocone.

Occurrence—Holotype, U. S. N. M. No. 83534 and paratypes, U. S. N. M. No. 83556, from cherts of the Van Buren formation at locality 102-e about 1 mile southeast of Eminence. Also from other localities both in the Eminence and Potosi regions.

Dakeoceras subcurvatum, Ulrich and Foerste, new species.

Plate XX, figures 27, 28.

Holotype 39 millimeters long, embedded in chert so as to expose only its dorsal half to two-thirds, consisting of a living chamber apparently complete and 18 millimeters in length and a part of the phragmacone, with 22 camerae, 23 millimeters in length, when measured along the dorsal outline of the specimen. The outline of the exposed dorsal part is moderately curved in a lengthwise direction, the radius of the curve varying from 30 millimeters along the phragmacone to 40 millimeters along the living chamber. The concealed ventral outline is assumed to be moderately concave. The lateral diameter enlarges from 5 millimeters at a point 5 millimeters above the smaller end of the specimen to 12 millimeters at the base of the living chamber and about 16 millimeters at the top of the chamber. At the point where the lateral diameter is 9 millimeters the dorsoventral diameter of the conch is approximately 11 millimeters, and at the top of the living chamber, where the lateral diameter is 15 millimeters, the dorsoventral one is estimated at 19 or 20 millimeters. Accordingly the cross-section is ovate, but the dorsal side of the outline is more narrowly curved than the ventral. About 14 camerae occur on the dorsum in a length equal to the estimated dorsoventral diameter of 15 millimeters at the top of the phragmacone. On the remaining basal part of the specimen the camerae average about 1 millimeter each. The sutures of the septa curve downward laterally for a distance of at least two camerae, producing broad lateral lobes and narrower dorsal and probably still narrower ventral saddles. Projecting the curve of the septa from their visible parts to the ventral wall, the sutures should attain somewhat higher levels on the ventral side than on the dorsum, in which respect, then, the species would conform with normal *Dakeoceras*. The siphuncle is very poorly indicated in two artificially made cross-fractures. It lies close to the ventral wall and seems to have a diameter of about 3 millimeters where the transverse diameter of the phragmacone is 11 millimeters. The aperture of the living chamber appears to be directly transverse to the curving vertical axis of the conch. Numerous but rather faintly impressed lines of growth seem to be more clearly indicated on the dorsum than on the lateral surfaces.

A smaller specimen found in the same formation about 4.5 miles south of Potosi, Washington County, Mo., seems to agree in every essential respect with the holotype.

Occurrence—Holotype, U. S. N. M. No. 83535 from the Van Buren formation, locality 102-e, 1 mile southeast of Eminence, NW. ¼, SE. ¼, sec. 35, T. 29 N., R. 4 W. Also from the same formation at other localities in both the Eminence and Potosi regions.

Cameroceras, Conrad.

Cameroceras huzzahense, Ulrich and Foerste, new species.

Plate XXI, figure 14.

One of the larger specimens is 145 millimeters long, enlarging from a dorsoventral diameter of 13 millimeters a short distance above the base of the specimen to 27 millimeters at the base of the living chamber, 90 millimeters farther up. The figured specimen represents an individual of approximately the same dimensions, but lacking more of the apical portion. The length of this chamber is 38 millimeters. The number of camerae in a length equal to the diameter of the conch at the top of the series counted, equals 6.5 camerae where the diameter of the conch is 13 millimeters, 9 camerae where this diameter is 20 millimeters, and 13.5 camerae where the diameter is 27 millimeters. The sutures of the septa are directly transverse even where crossing the siphuncle. The specimen is a cast of the interior of the conch, and in this cast the camerae fail to cross the median part of the ventral side of the siphuncle along a vertical area which is 4 millimeters in width at the top of the phragmacone. Here the lateral diameter of the siphuncle, judging from numerous other specimens, is estimated at 11.5 millimeters.

This species is abundant along Huzzah Creek in Crawford County, Mo., and shows numerous variations in dimensions. The rate of enlargement of the conch varies from an apical angle of 4 to one of 8 degrees. The ventral side of the conch frequently is more or less flattened. The living chambers usually are from 24 to 30 millimeters in diameter at their bases, their length varying from slightly greater than their diameter to fully

1.5 times the length of the latter. In some specimens the number of camerae in a length equal to the diameter of the conch equals 16 to 20 at the top of the phragmacone. While in most specimens the sutures of the septa are directly transverse to the length of the conch along the entire circumference of the latter there are a few in which these sutures curve slightly upward or downward in crossing the siphuncle. The ratio of the diameter of the siphuncle to that of the conch varies from 0.43 to 0.52 in most specimens.

In one specimen including a phragmacone 26 millimeters in length, with a lateral diameter of 18 millimeters at its base, the siphuncle projects above it for a length of 21 millimeters, and an endocone extends beneath it for a length of 16 millimeters. The ventral side of this endocone is flattened along its median part, but laterally and dorsally it is very obliquely annulated in directions parallel to adjacent parts of the septa.

Occurrence—Cotypes, U. S. N. M. No. 83544, from the Gasconade dolomite, locality 238 on Highway 8, 1 mile west of the junction of Huzzah and Dry Creeks, and 10 miles east of Steelville, Crawford County, Mo. Rather common in the upper portion of the formation, particularly in the central part of the Ozarks.

TRILOBITA

E. O. Ulrich

A great many species of trilobites, most of them new and many of them belonging to undescribed genera, have been collected from the various formations outcropping in the Eminence region. These are being made the subject of a monographic study by Doctor Ulrich, and the following descriptions of some of the species, which have proved to be most useful in the identification of the various formations, have been abstracted from his notes and manuscripts.—J. B.

Order Hypoparia

Entomaspidae, Ulrich, new family

This family is proposed for a small group of trilobites which resemble the Harpidae in most characters but in which the genal spine is borne entirely upon the epistomal plate as in the Trinucleidae.

Entomaspis, Ulrich, new genus.

The genotype of the new genus, for which I propose the name *Entomaspis radiata*, n. sp., is represented by numerous dorsal shields of the cephalon, a few cranidia, three ventral (epistomal) plates, a hypostoma, and a dozen or more pgygidia. The cephalon, as far back as the occipital ring, reminds of *Harpes*, especially in such parts as the glabella, the eyes, convex cheeks, the peculiar depressed, semilunate areas which, though separated from them by a shallow groove, suggest lateral extensions of the posterior glabellar lobes, the structure of the ventral plate in front of the genal angles, and the course of the posterior half of the facial suture. The flat or gently concave rim, however, is not so sharply separated from the cheeks, nor is it pitted, as in *Harpes*, being covered with rugose or simple radiating lines instead. A more important difference is the fact that the dorsal shield does not take an equal part with the ventral plate in making the genal extensions, these being also narrower and more spinelike than in *Harpes* and wholly borne by the ventral plate as in the Trinucleidae. All these cephalic characters of *E. radiatus* are found also in the heads of the other species referred to the genus. So far then as the cephalon is concerned *Entomaspis* occupies an intermediate position between the Harpidae and the Trinucleidae.

In the chert derived from the Eminence dolomite of Missouri I have found five similar but distinguishable kinds of pygidia that can belong only to heads of this generic type. Though evidently representing closely related species the peculiarities by which these pygidia are distinguished from each other are readily notable. The assignment of three of the five to particular kinds of the heads is as usual largely a matter of opinion and subject to correction if entire specimens retaining both the terminal shields in place are ever discovered. So long as we are reasonably confident of the generic relations of the associated parts, especially when two or more kinds of each are found in the same bed and place, little harm will have been done when subsequent discoveries prove that the tail of one had been erroneously assigned to the head of a second or third species. In the present instance two of the Missouri species of *Entomaspis* are founded primarily on cephalia and three others mainly or solely on pygidia that are recognizably different from those provisionally assigned to the first two species.

Regarding these pygidia the accompanying illustrations show that they are more like those of *Cryptolithus* and Ampyxidae, both in structural characters and relative size, than those of *Harpes* in which the pygidium is very small as compared to the cephalon. The heads and tails of *Entomaspis* being much less unequal in size than in *Harpes* and the difference in size between the two shields relatively intermediate as compared with Trinucleidae on the one hand and Raphiophoridae on the other, I am inclined to believe that the number of thoracic segments was much smaller than in *Harpes* and probably less than eight or ten.

Entomaspis radiatus, Ulrich, new species.

Plate XIX, figures 14, 15, 16.

Description—Head small, 5 to 7 millimeters wide, semiovate, the greatest width somewhat less than twice the length, the posterior edge straight in the middle half, the outer fourths strongly recurved and passing across the dorsal sides of the basal parts of long genal spines which are inseparably attached to the ventral plate. Glabella small, moderately convex, suboblong, tapering slightly forward, with two, rarely three, rather obscure pairs of short glabellar furrows, surrounded on the sides and front by a wide, minutely granostriated convex area sloping outwardly to the level of a more gently convex border that is edged with an elevated smooth rim. Inside of the rim the border is crossed by somewhat unequal, often alternating fine rugose striae, most of them continuations of the radial lines on the convex inner area. Space between front of glabella and the edge of cephalon about equally divided between brim and border. Middle of anterior slope of brim with a low prolongation into the depressed band of the border. Eyes small, sharply elevated and irregularly lobate, about two-thirds the width of the glabella from the dorsal furrows, connected with the latter by clearly elevated oblique eye lines. The anterior half of the facial suture is generally completely obliterated in the fusion of the cheeks, but a thin ridge that I regard as representing their fused edges behind each eye is commonly clearly notable. It runs with gently sigmoid curvature from the eye to a point opposite the inner half of the wide base of the genal spine (Pl. XIX, fig 14). Post-lateral lobelike depressed areas barely discernible and mainly confined to the dorsal furrows. Occipital ring well defined, wide and carrying a small nuchal spine in the middle, narrow at the dorsal furrows. Extremities of thickened posterior edge of fixed cheeks strongly recurved to inner side of base of genal spine.

Pygidium about 4 millimeters wide, semi-elliptical, short, nearly three times as wide as long, with prominent conical axis carrying six narrow rings. Each of the latter carries a pair of rather widely separated nodes between which the grooves between the segments are shallower than on the flanks of the axis. Pleural lobes flat, divided by five oblique grooved ribs, the anterior half of each with a small tubercle midway out from the axis. Outer margin of pygidium with 13 larger and more prominent regularly spaced knobs, each at the outer terminus of the groove between the segments.

Horizon and localities—Though never very common and, on account of its small size, easily overlooked, dorsal shields of the head and pygidia of this species have been observed at a number of places in Missouri where the partly rotted and therefore rather soft chert debris of the upper half of the Eminence dolomite is at the surface. Some of the most favorable localities for collecting fossils of this zone occur in a belt passing 3 miles to the east and 4.5 miles south of Potosi, Mo. Here it lies at the top of the Eminence and directly under the Van Buren formation. Other good and in part even better exposures of this zone occur in the vicinity of Eminence, the most accessible being the road cut 3 miles south of the town. Another good collection was taken from the brow of a large hill 1 mile north of Eminence. In the latter region the *Entomaspis* zone is succeeded by the *Plethopeltis* zone, which also contains a prolific but strikingly different fauna that has not been found in the region about Potosi.

Entomaspis trigonalis, Ulrich, new species.

Plate XIX, figures 12, 13, 17.

This species is founded mainly on a pygidium. Its appearance in general is much the same as the pygidium referred to *Entomaspis radiatus* but differs in its relatively great length, more triangular outline, and proportionally smaller though equally numerous marginal knobs. The pleural segments also are more deeply grooved and comprise an extra short posterior pair. Its length is 1.8 millimeters, width 3.6 millimeters.

A head found associated with this pygidium also differs slightly from the head of *Entomaspis radiatus*. Its outline is more sharply curved in front, making it just appreciably triangular, the border slightly narrower, the rim somewhat thicker, and the radial markings on the depressed inner band of the border strong and more regular. On the strongly convex cheeks and brim, however, the radial striae are barely notable and, at that, apparently only near the base of the steep convex slopes.

Horizon and locality—The two type specimens were found near the top of the Eminence dolomite, 1 mile east of Berryman, Mo.

Order Opisthoparia

Triarthridae, new family

Provisionally proposed for a group comprising *Triarthrus, Parabolinella, Peltura, Protopeltura, Acerocare,* and *Cyclognathus* and more doubtfully *Triarthropsis*, n. gen., *Stenochilina*, n. gen., and two other allied but as yet undescribed genera. At present this group of genera is generally referred to the Olenidae, but that family, as usually recognized, seems to comprise a very heterogeneous assemblage of forms. Doubtless when these divergent contents are subjected to the closer study and more comprehensive and detailed comparisons they require and deserve, the family Olenidae will be split into several. Anticipating this move for a more natural classification of the Olenidae I shall provisionally use the term Triarthridae for the group of genera listed above.

Triarthropsis, Ulrich, new genus.

Triarthropsis nitida, Ulrich, new species.

Plate XIX, figures 3, 4.

This genus and species were proposed by me about 15 years ago in an as yet unpublished paper read before the Paleontological Society of America for a small form occurring in the Eminence dolomite of Missouri. In general appearance the cranidium of this form is much like that of *Triarthrus* but differs in the possession of narrow brim separating the glabella from the rim. This brim is lacking in all of the Ordovician species referred to *Triarthrus*.

The glabella has subparallel sides and is evenly rounded anteriorly, and the circum-glabellar furrow is strongly defined. There are three pairs of glabellar furrows, all of which are directed posteriorly and some of which unite across the glabella. Occipital ring well defined, shorter than the width of the glabella, narrow at the ends, thicker in the middle and set off from the glabella by a strongly impressed, curved occipital furrow. No occipital spine. Palpebral lobes well defined, narrow, slightly bowed outward indicating a long narrow eye, the center of which is opposite the next to last glabellar lobe. Posterior limbs triangular, the extremities somewhat recurved posteriorly. Surface smooth.

Horizon and locality—The species is fairly common in the Eminence dolomite of Missouri but is likely to be overlooked because of its small size. The holotype, U. S. N. M. No. 83491, is from locality 102-h, 4 miles west of Eminence. A paratype, U. S. N. M. No. 83492, is from locality 100-i, 5 miles northwest of Eminence.

Remarks—This genus is also very closely allied to *Bienvillia* Clark, as that genus is now understood. Good specimens of *Triarthropsis* are to be distinguished by the slightly more posterior position of the eyes, the shorter and more recurved posterior limbs, and in the complete absence of the narrow upturned rim that is barely noticeable in specimens of *Bienvillia* from Levis, but which is more strongly developed in some of the specimens from the Eureka district, Nevada.

Stenochilina, Ulrich, new genus.

Stenochilina spinifera, Ulrich, new species.

Plate XIX, figures 1, 2.

Cranidium moderately convex, consisting mainly of the glabella, the free cheeks being narrow and continued as a very narrow band around the front of the glabella. The latter has parallel sides, is regularly rounded in front, about 3.2 millimeters wide and 4 millimeters long to the occipital furrow, moderately convex, with two pairs of widely separated oblique slit-like furrows, the posterior pair suggesting confluence across the middle and branching so as to draw a faint longitudinal boundary between the inner sides of the posterior lobes and the remaining squarish median third. Occipital ring very narrow at the ends, wider in the middle and posteriorly extended into a long slender spine. Palpebral lobes sharply defined, depressed, moderately bowed, indicating an eye of rather large size located opposite the second glabellar lobe. Posterior limbs triangular, the posterior edge made by a thin elevated straight rim not recurved at the extremities. Surface of glabella, free cheeks, and anterior band thickly covered with minute tubercles.

Horizon and locality—A rather rare fossil in the *Entomaspis* or *Calvinella ozarkensis* zone of the Eminence dolomite, 1 mile east of Eminence, Mo.

Holotype—U. S. N. M. No. 83490.

The above description includes the generic characters of the new genus *Stenochilina* of which the species is the genotype. It reminds of some of the associated species of *Triarthropsis* but is distinguished by its wider glabellar lobes and but two instead of three pairs of furrows, larger eyes, pustulated surface, long occipital spine, and straighter posterior edges of limbs. So far as known to me, this particular combination of characters does not occur in any previously established genus. Two or three other somewhat similar species are found with the genotypes of both *Triarthropsis* and *Stenochilina* in the Eminence of Missouri. These have not been studied sufficiently to determine their relations to either of the mentioned genera, but as they have smooth surfaces and three pairs of nearly transverse glabellar furrows the probabilities seem at present to favor *Triarthropsis* rather than *Stenochilina* as their final resting place.

Solenopleuridae, Angelin

Hystricurus, Raymond.

A large proportion of the trilobites occurring in the Gasconade dolomite belong in this genus. There are a great many different forms, and the separation into species is not easy. One of the largest and most characteristic of these is described below, but descriptions of other species must await more detailed studies.—J. B.

Hystricurus missouriensis, Ulrich, new species.

Plate XXI, Figures 1, 2.

Description—Glabella high, rounded, semi-elliptical. Circumglabellar and occipital furrows strong, deeply impressed, the latter almost straight. No glabellar furrows. Occipital ring strong, rounded, with no trace of an occipital spine. Facial suture cutting the anterior margin almost directly in front of the eyes and continuing backward in a straight line until past the eye, when it turns abruptly outward to cut posterior margin just inside the genal angle. Posterior marginal furrow strong.

Brim sloping abruptly downward to the marginal furrow and then sharply turned upward into a strong, rounded rim, which, when viewed from the front, is strongly arched. The surface of all the convex portions of the cephalon is strongly pustulose, the pustules being of two sizes. The larger ones are commonly surrounded by a circle of five or six smaller ones, which are spaced about twice their diameter apart.

Free cheeks and thoracic segments unknown. There are two or three types of pygidia associated with these heads, but the exact relationships have not been determined.

Dimensions of the holotype are: Length of cranidium, 11.5 millimeters; length of glabella 9 millimeters; width of cranidium at rim 9 millimeters; width at eyes, 12 millimeters; width at the posterior margin 15 millimeters; width of glabella, 7 millimeters; height of cranidium, 5 millimeters.

Occurrence—Holotype U. S. N. M. No. 83538 from cherts of the Gasconade dolomite at locality 101-v, 1.25 miles north of Decaturville, Mo.

Also from the same formation at numerous other localities in the Ozark region.

A similar if not identical form is found in the Manitou limestone of Colorado.

Remarks—This species strongly suggests *Hystricurus conicus* (Billings) but differs in the shape of the glabella and in the proportionately wider brim. In *H. conicus* there is not more than one row of pustules between the anterior end of the glabella and the marginal furrow, while in this form there are two or three rows. It also reminds of *H. tuberculatus* (Walcott) from the Eureka district, but that species has a short occipital spine, and the sides of the glabella are more nearly parallel. It somewhat resembles *H. ravni* Poulsen, but in that species the glabella is proportionately narrower and the anterior edge of the cephalon is more strongly rounded.

Dikelocephalidae, Miller

Calvinella, Walcott.

Calvinella ozarkensis. Walcott.

Plate XIX, figures 8, 9, (?) 11.

1914.—*Calvinella ozarkensis* Walcott, Smithsonian Misc. Coll., vol. 57, No. 13, p. 389, pl. 70, figs. 1, 1a, 2, 2a, 3, 4, 4a, (?) 5, 5a (not fig. 6).

This is the largest as well as one of the most distinctive trilobites found in the Eminence dolomite. No complete or even approximately complete specimen is known, but cranidia, free cheeks, and large pygidia, all more or less fragmentary, are relatively abundant at many localities. The large nearly complete cranidium, the holotype, is here refigured actual size, and in this connection it should be noted that Walcott's figure was enlarged 1.5 times and not twice as stated in the description of his plate. The free cheeks are large, broad, and moderately convex; the lateral and posterior margins thickened into a broad rim which is oval in cross-section. The genal angle is terminated by a long stout spine. The surface of the free cheek inside of the rim is covered by fine raised irregularly branching and anastomosing lines which roughly parallel the outer margin. At the junction of these lines there is often a small raised tubercle. A complete cephalon of a specimen about the size of the holotype would be about 35 millimeters long and 80 to 90 millimeters broad.

The pygidia figured by Walcott belonged to much smaller individuals. A large but incomplete specimen shows that its length and width must have been approximately 35 and 70 millimeters. A great many of the specimens referred to this species are much smaller, but their proportions are identical.

Horizon and localities—The holotype, U. S. N. M. No. 58674, is from chert of Eminence dolomite, locality 102-h, about 4 miles west of Eminence, Mo.

Paratypes, U. S. N. M. Nos. 58675 and (?) 58677, from the same formation at locality 100-b, near the Slater Mine, 1.5 miles east of Eminence.

Paratype, U. S. N. M. No. 60055, from the same formation at locality 102-f, about 1.5 miles east of Eminence.

Paratype, U. S. N. M. No. 60056, from the same formation, locality 102-j, 1.5 miles southwest of Eminence, Mo.

It is also abundant at locality 373-l,=M. S. M. 98.15, about 1.5 miles northwest of Eminence, and at locality 452-u=M. S. M. locality 98.4, about 3 miles south of Eminence on Highway 19.

Calvinella minor, Ulrich, new species.

Plate XIX, figure 10.

1914.—*Calvinella ozarkensis*, Walcott, Smithsonian Misc. Coll., vol. 57, No. 13, pl. 70, fig. 6, (?) 5, 5a.

Smaller than average examples of *Calvinella ozarkensis* and distinguished from it by its relatively longer, narrower, and anteriorly more prominently convex glabella. In *C. ozarkensis* the ratio of the length of the glabella to the width is 3:2, while in *C. minor* it is 2:1. That it is not a young form of *C. ozarkensis* is indicated by the fact that small cranidia with exactly the proportions of that species are commonly associated with it. The small cranidium figured by Walcott and refigured here clearly belongs to this species. The pygidium shown on Plate XIX, Figure 11, has a somewhat higher, narrower, and more sharply defined axis than is found in most specimens and may belong to this species.

The incomplete cranidium here figured is 5 millimeters long, but specimens two or three times this size are fairly common.

Horizon and localities—The cotypes, U. S. N. M. No. 83494, a. b. (not figured) are from the Eminence dolomite, locality 452-u=M. S. M. 98.4, 3 miles south of Eminence, on Highway 19.

Paratype, U. S. N. M. No. 58676, from residual cherts of the Eminence dolomite at locality 188-y, on hilltop near Flat River, Mo. The species appears to be more abundant in the lower part of the formation.

Euptychaspis, Ulrich, new genus.

This genus is founded on a small new species from the Eminence dolomite in Missouri that seems an unquestionable derivative from the typical genus of the subfamily. However, in the meantime its generic characters were so strongly modified that it can no longer be assigned to *Ptychaspis* proper. It differs in the following respects: First, the cranidium is wider, the excess being added to the fixed cheeks, which are as wide as the glabella and smooth. Next, in the widening of the cranidium and the lateral extension of the ends of the convexly bowed and abruptly deflected anterior border, the small eyes, though located in front of the midlength of the facial sutures, are further back, being opposite the middle lobe of the glabella. Third, the occipital ring carries a strong spine extending backward about as far as the length of the glabella. The glabella is prominent and crossed by two deep furrows as in the genotype (*P. striata* Whitfield) and other typical species of *Ptychaspis;* and the deflected brim, which might be called a thick vertically faced edge, also is marked with coarse striations as in those species. Eye lines, extending obliquely backward from the front of the glabella, are usually notable, especially in moulds of the exterior.

Genotype—*Euptychaspis typicalis*, n. sp.

So far as known the genotype is confined to the Eminence dolomite of Missouri. As the same bed contains species of *Calvinella*, whose closest relatives occur in the Conococheague limestone of Pennsylvania and New Jersey, and species of *Acheilus*, *Acheilops*, *Leicoryphe*, *Stenopilus*, and *Plethometopus* that when not identical are at least exceedingly close to species found in northern Vermont and in the boulders at Levis, Quebec, it seems reasonably probable that *Euptychaspis typicalis* was developed in the Arctic or Pacific realm and invaded the Mississippi Valley from the north. This belief finds additional support in the fact that a species of that genus occurs in the Lodi shale member of the Upper Cambrian St. Lawrence formation (Trempealeau of Ulrich) in Wisconsin. *Ptychaspis* itself doubtless originated earlier in the northern Pacific realm from whence it invaded the continental basins of North America at least as far as central Wisconsin. Except the doubtful *P.? affinis* Raymond typical *Ptychaspis* apparently failed entirely to reach the Appalachian troughs on the east side of the continent.

Euptychaspis typicalis, Ulrich, new species.

Plate XIX, figures 5, 6, 7.

The specific characters are sufficiently indicated in the foregoing discussion of the genus, and unmentioned details are shown in accompanying figures. It remains here only to add that the average dimension of the cranidium in 14 specimens is about 3.1 millimeters for the length, excluding the occipital spine, and 4.5 millimeters for the greatest width, which is nearly the same at the eyes and at the posterior edge.

Horizon and localities—Cranidia of this species have been found in the partly rotted cherts of the upper half of the Eminence dolomite at most localities in the vicinity of Eminence, Mo., where any considerable effort was made to collect the fauna of this formation. More than half the number collected were found on the weathered edge of a bluff 1 mile north of the town.

Cotypes—U. S. N. M. No. 83493, a-b.

Corynexochidae, Angelin

Acheilops, Ulrich, new genus.

The cranidium in the five or six species to be referred to this genus may be compared in general features with those of *Corynexochus*, *Dolichometopus*, *Zacanthoides*, and the new genus *Glossopleura* about to be proposed by Poulsen, all of which are Cambrian genera and so far not positively recognized above the Middle Cambrian. However, in none of these Cambrian genera are the fixed cheeks wholly wanting in front of the eyes as in the proposed genus *Acheilops*. In the latter the front of the cranidium is rounded and made by the anterior side of the glabella, in the older types the front edge is always straighter with more or less of a border or at least short and commonly well developed anterior limbs. Compared then with these genera the outstanding peculiarity of *Acheilops* is the fact that the facial suture in front of the eyes lies in the dorsal furrow; consequently the cranidium lacks both anterior limbs and rim. As usual in typical Cornexochidae, to which family *Acheilops* seems properly referable, the eyes are large, situated far back and, especially at their anterior extremities, close to the dorsal furrow. Glabellar furrows may be fairly well indicated, two, three, or four pairs, or quite obsolete; and the well-defined occipital ring may or may not have a nuchal spine. Palpebral lobes simple, apparently always without furrow.

Genotype—*Acheilops dilatus*, n. sp., Plate XIX, Figures 20, 21, 22. Eminence dolomite, Shannon and Washington Counties, Mo.

Stratigraphic and geographic range—Eight closely allied species of this genus have been distinguished. Six of these occur in the Eminence dolomite in Missouri, one of the six in the Madison sandstone in Wisconsin, another, together with a seventh species, in the Milton dolomite of Vermont. The Milton species were described by Raymond as *Acheilus macrops* and *A. spicatus*. All the others are new. The unexpected discovery of an evidently congeneric cranidium in the St. Lawrence formation (Trempeleau of Ulrich) in Monroe County, Wis., shows that the type was already in existence in late Upper Cambrian time. The St. Lawrence (Trempeleau of Ulrich) species is most like *A. dilatus* but differs from it and all the younger species of *Acheilops* in the greater longitudinal convexity of the anterior half of the glabella.

Although Raymond referred his two species to *Acheilus* it seems to me quite improbable that they are closely allied to the genotype of that genus. As determined by *Acheilus marcoui* Raymond, a common fossil in the boulders of the *Hungaia* zone at Levis, Quebec, and a very similar species or variety from the Eminence of Missouri the glabella in *Acheilus* expands in anterior direction very slightly, or not at all, the eyes are of moderate size, situated farther forward, and their anterior extremities do not quite reach the dorsal furrows. Moreover, the suture does not lie in the dorsal furrow and thus bound the anterior half of the glabella but leaves a narrow band-like fixed cheek. But the most striking difference lies in the posterior limbs. These are uncommonly long and narrow in *Acheilops* and are directed much more strongly backward than in *Acheilus*.

Acheilops dilatus, Ulrich, new species.

Plate XIX, figures 20, 21, 22.

The figures show an outline drawing and photographs of the genotype found in the Eminence dolomite of Missouri.

Description—Glabella expanding rather rapidly, the anterior end evenly rounded. Occipital furrow strong. Two pairs of glabellar furrows, the posterior pair directed slightly backward, the anterior ones essentially parallel to the occipital furrow. Palpebral lobes broad, eyes large—half as long as the cranidium. Posterior lobe of the fixed cheeks consisting of a long narrow spine directed slightly backwards. Posterior marginal furrow strong, occupying about half of lobe. No occipital spine.

The dimensions of the holotype are: Length of cranidium, 5.5 millimeters; width of cranidium at posterior end, 9 millimeters; width across the palpebral lobes, 6 millimeters; width of glabella at posterior end, 3.25 millimeters; greatest width of glabella, 4.25 millimeters; width of posterior lobe near glabella, 1 millimeter; length of posterior lobe, 2.8 millimeters; height of cranidium, 1.5 millimeters.

Horizon and localities—Common in the Eminence dolomite, particularly in the lower or main faunal zone. The holotype, U. S. N. M. No. 83499, is from locality 102-j, 1.5 miles southwest of Eminence, but the species is widely distributed, occurring in almost every area in which the Eminence dolomite outcrops.

Family Undetermined

Plethopeltis, Raymond, emend Ulrich.

1913.—*Plethopeltis* Raymond, Victoria Mem. Mus. Bull. 1, p. 64. Describes the genus, makes *Agraulos saratogensis* Walcott the genotype, and refers *Bathyurus armatus* Billings to it.

1915—*Plethopeltis* Field, Ottawa Naturalist, June-July, pp. 37-44. Discusses the two forms of *P. saratogensis* found at the type locality and compares with other species.

1924—*Plethopeltis* Raymond, Boston Soc. Nat. Hist. Proc., vol. 37, pp. 412-419.

In the last paper cited above Raymond states that he had originally intended to restrict this genus to forms similar to *Bathyurus armatus* Billings. However, he selected *Agraulos saratogensis* Walcott as the genotype. The two forms differ in many important particulars, and it is thought advisable to restrict *Plethopeltis* to those forms which are closely related to *Plethopeltis saratogensis*.

Thus restricted the genus may be characterized as follows: Cranidium strongly convex. Glabella oblong, sometimes slightly tapering anteriorly, circum-glabellar furrow strongly developed, entire. Two pairs of glabellar furrows, may or may not be present. Occipital furrow strong, occipital ring well developed, widest at the center, tapering toward the ends, the transverse dimension less than the width of the glabella. No occipital spine.

Palpebral lobes small, bowed upward, situated slightly in front of the middle of the cranidium. Brim rather sharply deflected in most species with no trace of an upturned rim. Posterior limbs short, triangular, slightly recurved. Posterior marginal furrow well defined, broad. Free cheeks smoothly rounded, with short genal spine. Pygidium small, convex, with no border, usually wider than long, axis with about five segments which are well defined, lateral slopes showing four or five pleurae.

Plethopeltis buehleri, Ulrich, new species.

Plate XIX, figures 18, 19, 25, 26.

Cranidium of moderate size, length and width subequal, the length from the brim to the base of the occipital ring being slightly less than the distance between the tips of the posterior limbs. Glabella well defined, strongly convex, widest at the rear, tapering very gradually anteriorly. In average specimens this narrowing amounts to about 1.25 millimeters in a length of 10 millimeters. Occipital furrow and ring well defined. Brim abruptly deflected, making an angle of 125°-130° with the top of the glabella. Palpebral lobes small, somewhat elevated, situated just anterior to the middle of the cranidium and about two-thirds of the distance from the base to the front of the glabella. Posterior limbs short, their tips slightly reflexed, posterior marginal furrow well defined.

The cotypes consist of two cranidia which show the following measurements: Length, 17.5 and 17 millimeters; length of glabella, 11.25 and 11 millimeters; width across posterior limbs 19.5 and 19 millimeters; width at palpebral lobes, 16 and 15 millimeters; width at anterior margin 13 and 12.5 millimeters; width of glabella at base, 10.25 and 10 millimeters; width at front, 8.5 and 8.25 millimeters; height of cranidium 7 and 7 millimeters. An imperfect cranidium, a paratype, is about 20 per cent larger.

Horizon and localities—The species is abundant in the upper portion of the Eminence dolomite. The cotypes, U. S. N. M. No. 83502, a-b, are from locality 100-b near the old Slater Mine about 1.5 miles east of Eminence, and the species has been found at almost every locality where the upper beds of the formation are preserved. It is so abundant and widespread and so characteristic that it is customary to refer to this part of the formation as the *Plethopeltis* zone. The specific name is given in honor of Dr. H. A. Buehler, State Geologist of Missouri.

Plethopeltis platymarginatus, Ulrich, new species.

Plate XIX, figures 23, 24.

Similar to *Plethopeltis buehleri* but with a broader, flatter, and less rapidly tapering glabella. The brim is wider in front, and is not as abruptly deflected, making an angle of 145°-150° with the top of the glabella.

Horizon and localities—The holotype and paratype, U. S. N. M. Nos. 83500 and 83501, came from the Eminence dolomite at locality 102-h, about 4 miles west of Eminence, Mo. It occurs with *Plethopeltis buehleri* at almost every locality where the *Plethopeltis* zone has been found.

Plethometopus, Ulrich, new genus.

Cranidium strongly convex, in general form and proportions similar to *Plethopeltis*. The circum-glabellar furrow is much less clearly defined in *Plethometopus* and in most species is faint or entirely wanting opposite and in front of the eyes, so that the anterior end of the glabella merges into the brim without definite boundary. In some species, e. g. *Plethometopus convexus* (Whitfield), only the posterior third of this furrow is indicated, while in other forms, as for example *Plethometopus armatus* (Billings), the entire glabella is faintly outlined. No glabellar furrows. Occipital furrow more or less distinct in all species. Occipital ring broadly triangular, its posterior extremity sometimes produced into a blunt, thick spine. Palpebral lobes small, bowed outward, slightly elevated, situated just anterior to the middle of the cranidium. Fixed cheeks moderately wide; posterior limbs short, triangular, the extremities often slightly reflexed. The posterior marginal furrows are always distinctly impressed, and this serves to distinguish the smoother forms of *Plethometopus* from *Stenopilus*.

Free cheeks similar to those of *Plethopeltis*. A small, almost complete specimen of an undescribed species from the Eminence dolomite shows that the thorax consists of 10 segments. The pygidium of this specimen is very small, and the axis is not completely outlined. There is no trace of segmentation on either the axis or the lateral slopes of the pygidium, with the exception of a single furrow near the anterior margin. In this respect it differs from the pygidium of *Plethopeltis*, which is distinctly segmented.

Genotype—*Plethometopus* (*Bathyurus*) *armatus* (Billings).

The genus as here proposed includes *Plethometopus armatus* (Billings), *P.* (*Illaenurus*) *convexus* (Whitfield), and five species described by Raymond and referred to *Plethopeltis*, namely, *P. arenicola*, *P. convergens*, *P. laevis*, *P. angusta*, and *P. latus*. It also includes *Plethometopus modestus*, n. sp., from the Eminence of Missouri and a number of other new and as yet undescribed forms from the same formation.

In its general aspect the cranidium in this genus appears to be intermediate between *Plethopeltis* and *Stenopilus*. The glabella and occipital ring as a rule are less clearly defined than in the former and more so than in the latter; and the cranidium differs from both in the possession of the occipital spine. It is by no means certain, however, that this is its true systematic position.

Plethometopus convexus (Whitfield).

Plate XIX, figures 29, 30, 31.

1877—*Illaenurus convexus* Whitfield, Wisconsin Geol. Survey Ann. Rept., p. 66.
1882—*Illaenurus convexus* Whitfield, Geology of Wisconsin, vol. 4, p. 203, Pl. 4, figs. 3, 4 (not fig. 5).

There is little to add to the original description except to note that *Plethometopus convexus* is quite rare at the type locality, Eikey's quarry near Baraboo, Wis., and that the smooth globose cranidia which are so abundant there belong to *Stenopilus*. It was long ago suspected that Whitfield actually had the two forms under consideration, and this has recently been confirmed by a study of the types, which have been made available through the courtesy of the Department of Geology of the University of California. In the lot marked *Illaenurus convexus* there are ten cranidia, nine of which belong to *Stenopilus*. The remaining specimen is the one figured and is entirely different from the others and is a true *Plethometopus*.

The species is fairly common in the lower portion of the Eminence dolomite. The larger specimen, Figure 29, is almost exactly the same size as the holotype.

None of the specimens available at present preserves the occipital spine, and this portion of the cranidium is also missing upon the holotype and was restored in Whitfield's illustration. This restoration was based upon the associated *Stenopilus* cranidia and shows the gently convex posterior margin characteristic of that genus. A study of the material at hand, however, shows that the species possessed a thick blunt spine as indicated in Figures 30-31.

Horizon and localities—Holotype, California Univ. Mus. No. 1216, from the Mendota limestone at Eikey's quarry, Baraboo, Wis. Plesiotypes, U. S. N. M. No. 83504 and 83505, from the Eminence dolomite at locality 103-t, 3 miles south of Fredericktown, Mo., and 238-n, 0.5 mile west of the St. Francois River on the Piedmont-Marble Hill road (Highway 34).

Plethometopus modestus, Ulrich, new species.

Plate XVIII, figure 7; Plate XIX, figures 34, 35, 36, 37.

Average specimens are smaller than *Plethometopus convexus*. The cranidium is flatter, the convexity being less than that of the preceding form. It also differs in its strongly impressed occipital furrow, slender spine, and narrower posterior limbs.

Horizon and localities—Cotypes, U. S. N. M. No. 83506 a, b, from the Eminence dolomite at locality 103-t, 3 miles southeast of Fredericktown, Mo., on the road to Marquand.

Paratype, U. S. N. M. No. 83507, from the north bank of Current River at the old Chicopee Ferry, about 1 mile east of Van Buren, Mo.

Paratype, U. S. N. M. No. 83508, from locality 100-i, 5 miles northwest of Eminence, Mo. It is rather common in the main faunal zone of the Eminence at many localities.

A single specimen presumably belonging to this species was found in a finely crystalline, light dolomite, thought to belong to the Potosi dolomite, at M. S. M. locality 74.28, near Palmer, Washington County, Mo. M. S. M. Dept. of Geol. No. 7251.

Stenopilus, Raymond.

Stenopilus latus, Ulrich, new species.

Plate XIX, figures 32, 33, (?) 27, 28.

Cranidium large, broad, smooth, strongly convex, the greatest convexity being in the posterior third. No trace of any furrows. On the posterior margin at the junction of the glabella and the fixed cheek there is a small deep pit, which appears to be a generic character. It is particularly noticeable upon internal moulds. Occipital portion of the glabella convex posteriorly. Eyes probably small, situated about midway between the posterior and anterior margins and well out toward the sides. Posterior portion of the fixed cheeks small, directed downward, the extremities rounded. Free cheeks, thoracic segments and pygidium unknown.

This is one of the largest species of the genus. The dimensions of the holotype are: Length, 22 millimeters; width, 23 millimeters; height, 9 millimeters. Average specimens are from one-half to two-thirds this size.

Horizon and localities—Common in the Eminence dolomite throughout the Ozark region. Holotype, U. S. N. M. No. 83509, from locality 102-g, 2.5 miles northwest of Van Buren, Mo., on south bank of Current River. Paratypes, U. S. N. M. No. 83510, from locality 438-r on the south slope of the hill about 0.5 mile west of Eminence.

Figures 27-28 are of a much smaller specimen, which is slightly more convex and somewhat narrower anteriorly than the type. It may be a young form of *Stenopilus latus*, or it may represent a distinct species. The specimen figured came from the Eminence at locality 100-b, near the Slater Mine 1.5 miles east of Eminence, and has been noted at many other localities.

Plesiotype, U. S. N. M. No. 83511.

APPENDIX

ANALYSES[1] OF DOLOMITE, EMINENCE-CARDAREVA QUADRANGLES

Constituent	S.753	S.754	S.755	S.756	S.757
Silica (SiO_2)	0.70	0.48	0.13	6.58	4.78
Ferric Oxide (Fe_2O_3)	0.33	0.26	0.23	0.23	0.30
Alumina (Al_2O_3)	0.62	0.54	0.22	2.94	1.66
Alkalies $(NaK)_2O$	0.22	0.12	0.10	0.32	0.29
Loss on Ign[2]	46.50	46.90	47.17	43.37	43.90
Lime (CaO)	29.54	29.54	29.42	26.68	28.18
Magnesia (MgO)	21.82	21.87	22.40	20.10	20.76
Total	99.73	99.71	99.67	100.22	99.87
Calcium Carb. ($CaCO_3$)[3]	52.73	52.73	52.51	47.62	50.29
Mag. Carb. ($MgCO_3$)[3]	45.62	45.73	46.85	42.04	43.42
Insoluble	1.08	0.78	0.14	9.09	6.17

[1] Analyst, H. W. Mundt.
[2] Loss on ignition includes CO^2, organic matter, and other volatile constituents at 900° C.
[3] Calculated from CaO and MgO.

S.753. Eminence dolomite, NW. corner SW. ¼ sec. 26, T. 29 N., R. 4 W., Shannon County.
S.754. Eminence dolomite; SE. corner NW. ¼ sec. 18, T. 28 N., R. 3 W., Shannon County.
S.755. Eminence dolomite; sec. 20, T. 30 N., R. 4 W., Shannon County.
S.756. Van Buren dolomite; center South line sec. 14, T. 29 N., R. 4 W., Shannon County.
S.757. Gasconade dolomite; NW. corner sec. 16, T. 30 N., R. 4 W., Shannon County.

RECORD OF THE CASEY MINE DRILL HOLE

An almost complete set of samples was collected by the writer from the hole drilled at the Casey Mine in the S. ½ SW. ¼ sec. 14, T. 29 N., R. 4 W. The record given below was prepared from a detailed study of the original samples as well as the insoluble residues prepared therefrom by H. S. McQueen. The surface elevation is 925 feet.

	Thickness, in feet.	Depth, in feet.
No samples, duplicated by section in shaft	103	103
Dolomite, white, buff, light gray, finely crystalline. Insoluble residues contain: chert, dense, to crypto-crystalline, quartzose, veined and incrusted with crystalline quartz; sand fine, subangular to rounded, frosted grains; pyrite; limonite, porous, soft	25	128
Dolomite, white, light gray and buff, finely crystalline. Insoluble residue contains: shale, light green, waxy, slightly sandy; chert and sand as above; some limonite	67	195
Dolomite, white and gray, coarsely crystalline. Insoluable residue contains: sand, fine to medium, subangular to rounded, frosted grains; chert, white, light bluish-gray, dense, quartzose, and crypto-crystalline; shale, light and dark green, showing occasional casts of dolomite crystals; limonite	2	197
Dolomite, white to light brown, finely crystalline. Insoluble residues contain: chert, white, and light bluish gray, quartzose and crypto-crystalline, slightly oolitic, sometimes marked by veinlets of crystalline quartz and bands of quartz and calchedony; limonite, psuedomorphic after pyrite; small amount of sand	48	245

	Thick, ness, in feet.	Depth, in feet.
Dolomite, light to pinkish, coarsely crystalline. Insoluble residue contains: chert white, hard, dense, to porous, oolitic; incrusted and veined with quartz; many free siliceous oolites; some sand...	5	250
Dolomite, white, pink, light brown, bluish gray, less crystalline than above. Insoluble residues contain; chert, as above in small amounts; few flakes of green shale; few grains of sand........	30	280
Dolomite, white, pink and grayish-blue medium to coarsely crystalline. Insoluble residues contain: chert, white, and light gray, dense to slightly porous, quartzose, slightly colitic, occasionally banded, incrusted and faintly veined with crystalline quartz; limonite, siliceous, dense and spongy; shale, light green; some sand..........	105	385
Dolomite, white to light gray; coarsly crystalline. Insoluble residues contain: limonite, dense, porous, soft and earthy; chert, white, dense oolitic..........	10	395
Dolomite, similar to above. Insoluble residues contain: chert, white live, dense, quartzose, sometimes marked by quartz-chalcedony bands, with incrustations of the former; also chert, white and dark chocolate brown, hard but slightly porous, marked by occasional dolocasts, limonite, dark to light brown, earthy and dense; shale, pale green, hard and brittle; sand, like above....	15	410
Dolomite, light gray, more finely crystalline. Insoluble residue large contains: chert, white to light bluish gray, dense, quartzose, in part stained green by ferrous iron, marked by dolocasts; many fragments of druse the inner surfaces of which show dolocasts; broken quartz crystals..........	5	415
Dolomite, white to buff, crystalline. Insoluble residue large and similar to 415, except druse is more distinctly banded; chert is darker and less quartzose..........	5	420
Dolomite, white to light gray, medium to coarsely crystalline. Insoluble residue contains chert, white, light gray and chocolate brown, stained green by ferrous iron, marked by dolocasts; fragments of druse, slightly banded, inner surfaces show dolocasts; limonite, spongy, siliceous..........	5	425
Dolomite, white, buff, gray and brown, fine to coarsely crystalline. Insoluble residues considerably smaller than from 410 to 425 feet, contain: chert, as above; limonite, porous, spongy and psuedomorphic after pyrite, also occasionally marked by dolocasts; few druse fragments; and crystals of quartz; few pieces of shale; some brown, granular, silica..........	105	530
Dolomite, white, light and dark brown. Insoluble residues contain: limonite, similar to that above; chert, white, dense, quartzose, locally leached, marked by dolocasts, somewhat drusy, oolitic 575 to 577, which is suggestive of material caved from above; fragments of crystalline quartz, and druse fragments; small amount of shale; small amount of sand..........	47	577

CORRELATION

Cambrian System—(Ozarkian of Ulrich).			
Eminence formation..........	103	410	307
Potosi formation (base not reached)..........	410	577	167

RECORD OF OZARK LAND AND LUMBER COMPANY DRILL HOLE

The following record of the hole drilled by the Ozark Land and Lumber Company, in the SE. ¼ SF. ¼ sec. 13, T. 27 N., R. 4 W., near Winona, has been prepared from an examination of an incomplete set of thirteen samples. The correlations given are based upon the characteristics of the insoluble residues. The surface elevation of the hole is approximately 920 feet.

	Thickness, in feet.	Depth, in feet.
Chert, white, light gray and dark blue, dense, characteristically marked by included grains of fine quartz sand	130	130
Dolomite, light buff to gray, finely crystalline, larger fragments slightly pitted and iron stained. Insoluble residue contains: chert, blue, very quartzose and like above; small amount of quartz sand	30	160
Dolomite, similar to last sample. Insoluble residue larger, but similar to above, except sand grains are absent	20	180
Chert, gray and bluish gray, dense, marked by quartz-lined vugs, the margins of which are composed of banded chalcedony; numerous quartz filled veinlets	51	231
Dolomite, light gray, slightly iron stained, finely crystalline, slightly porous. Insoluble residue contains: chert, light gray, blue, dense, slightly oolitic, with quartz filled veinlets; also, white quartzose, and porous	69	300
Dolomite, light gray, finely crystalline. Insoluble residue contains: chert, white, dense, and white leached; also many quartz-incrusted fragments showing alternating bands of crystalline quartz and chalcedony	75	375
Chert, light bluish gray, slightly oolitic, with smooth and rough pitted surfaces, marked by veinlets of crystalline quartz. Original sample coated with red clay, suggestive of solution channel	11	386
Dolomite, light brown, with slightly pinkish cast, more finely crystalline than samples above. Insoluble residue contains: chert, white to buff, dense and chalk-like	114	500
Dolomite, gray to light brown, finely but more crystalline than sample above. Insoluble residue contains chert, light bluish gray, subcrystalline, very quartzose, with few rounded siliceous oolites	60	560
Dolomite, light gray, somewhat iron-stained, finely crystalline. Insoluble residues very small and contain: oolites, siliceous, cemented into aggregates by crystalline quartz; chert, as in 560; few grains of sand	100	660
Dolomite, light gray, finely crystalline. Insoluble residue contains: chert light bluish-gray, crypto-crystalline, quartzose	50	710

CORRELATION

Ordovician System (Canadian of Ulrich).		
Roubidoux formation	130	130
Ordovician System (Ozarkian of Ulrich).		
Gasconade formation	256	386
Van Buren formation	114	500
Cambrian System (Ozarkian of Ulrich).		
Eminence formation	210	710

List of Fossil Localities.

The localities listed below are those from which fossils were collected by the writer and his assistants during the course of this investigation. The majority of those listed in Chapter VI are the ones from which Ulrich has collected at various times during the last 25 years. Where it is definitely known that one of his localities is the same as one of the Missouri ones, the fact is indicated in the text.

REYNOLDS COUNTY.

Mo. 90.1—On line between secs. 3 and 4, T. 29 N., R. 1 W., south side of Logan creek on section line, at creek level. Large boulder. Horizon-Eminence.

Mo. 90.2—Center SE. ¼ sec. 1, T. 30 N., R. 1 W., just south of upper Dry Valley School, on the old Ellington-Centerville road, west side road Eminence outcrops, fossils from float boulders. Horizon-Eminence.

Mo. 90.10—SW. cor. sec. 5, T. 29 N., R. 1 W., on divide between Pumpkin Hollow and Carr creek, west side of divide, elev. 960-970. Horizon-Roubidoux-*Lecanospira* zone.

Mo. 90.11—In the NE. ¼ SW. ¼ sec. 35, T. 29 N., R. 1 W., on the north side of Little Paint Rock creek, about 20 feet above road. Horizon-Eminence.

Mo. 90.12 a. b.—NE. cor. quad. in the NE. ¼ sec. 1, T. 29 N., R. 1 W., east side of Coleman Hollow on northwest slope of hill. Horizon-12.a-Eminence-12.b. Van Buren.

Mo. 90.16—Near center, SW. ¼ NW. ¼ sec. 1, T. 28 N., R. 1 W., in low saddle between main ridge and large spur running north, elev. 880 feet. Horizon-Osage Group.

SHANNON COUNTY.

Mo. 98.1—Near center sec. 31, T. 29 N., R. 4 W. on road, at elev. 910. Ledge of chert in place and float boulders. Horizon-Base of Roubidoux.

Mo. 98.2—On line between secs. 35 and 36, T. 28, N., R. 5 W., in Dry Camp Hollow. Float boulders. Horizon-Roubidoux.

Mo. 98.3—In the NE. ¼ sec. 4, T. 29, N., R. 4 W., about the center of Lot 7, on hillside west side of Grassy creek. Elev. 860-930. Horizon-Upper Gasconade.

Mo. 98.4—About the center of the east side of the NE. ¼ sec. 12, T. 28, N., R. 4 W. on State highway No. 19 road cut, west side of road on turn at top of low hill. Elev. 670 feet. Horizon-Eminence.

Mo. 98.5—About the center of the SE. ¼ sec. 30, T. 27, N., R. 3 W. on the Eminence-Winona road State highway No. 19 (temporary) along road ditch on steep grade known as Saddler Hill. Horizon-5. Gasconade,-5. a Roubidoux.

Mo. 98.6—In the NW. ¼ SE. ¼ sec. 25, T. 27 N., R. 5 W., on Bluff above Alley Spring. Elev. 850-900 feet. Horizon-Gasconade.

Mo. 98.7—On spur a little south of center SW. ¼ sec. 25, T. 29 N., R. 5 W., near edge of cliff. Elev. 850 feet and up. Horizons-Roubidoux-Gasconade.

Mo. 98.8—SW. cor. NW. ¼ sec. 33, T. 29 N., R. 4 W., on nose of hill. Elev. 915. Horizon-Basal Roubidoux.

Mo. 98.9—In the NW. ¼ SE. ¼ sec. 5, T. 27 N., R. 3 W., about 40 feet above valley floor, northwest of creek forks on point of hill. Horizon-Roubidoux.

Mo. 98.10—in the NW. ¼ sec. 1, T. 29 N., R. 5 W., in Lot 8 on the Eminence-Ink road, on steep hill going down to Reinharts ranch. Horizon-Roubidoux-Gasconade.

Mo. 98.11—NE. cor. sec. 27, T. 28 N., R. 4 W., on point of hill north of road. Elev. about 1000 feet. Horizon-Gasconade.

Mo. 98.12—SE. ¼ NW. ¼ sec. 5, T. 28 N., R. 3 W., on new road crossing the divide between Hay Hollow and Little Shawnee creeks, top of first bench. Elev. about 880. Horizon-Eminence.

Mo. 98.13—NE. ¼ sec. 25 T. 28 N., R. 5 W., at point where Birch Tree road turns onto section line. Northwesterly up the hill from this point. Horizons-Roubidoux-*Syntrophina* zone-Gasconade-Cryptozoon ledge at road.

Mo. 98.14—SE. ¼ NE. ¼ sec. 33, T. 29 N., R. 1 W., on west side of Big Paint Rock Creek, on bluff opposite house and above spring. There are some well marked pinnacles about 100 feet above the road, and these fossils were collected in place at the south end of these pinnacles, and about 40 feet below the Gunter ss. Horizon-Eminence.

Mo. 98.15—Near center of east half of south line of sec. 22, T. 29 N., R. 4 W., on hillside north of road and north of old field. Ledges of chert, in place or very nearly so. Elev. 840 feet, 30 feet below Gunter ss. Horizon-Eminence.

Mo. 98.16—SE. ¼ SW. ¼ sec. 26, T. 29 N. R. 4 W., on nose of hill south and a little east of picnic ground at Eminence. About two-thirds of the way up the hill. Horizon-Eminence.

Mo. 98.17—SW. ¼ sec. 4, T. 28 N., R. 3 W., on hillside west of house. Elev. 820 feet. Horizon-Eminence.

Mo. 98.18—NW. ¼ SW. ¼ sec. 26, T. 29 N. R. 4 W., just northwest of the town of Eminence on the south side of the most northerly spur of the hill. Horizon-Eminence.

Mo. 98.19—On top of long ridge in SW. ¼ sec. 26, T. 28 N., R. 4 W. Horizon-Burlington.

Mo. 98.20—In the NE. ¼ NW. ¼ sec. 29, T. 28 N., R. 3 W., on tip of spur facing NW. Elev. 1000 feet. Horizon-Burlington.

Mo. 98.21—Near the line separating the E. ½ of secs. 12 and 13, T. 29, N., R. 4 W., on hill northeast of the Munsell school below the Gunter sandstone near hilltop. Horizon-Eminence.

Mo. 98.22—NW. ¼ NW. ¼ sec. 18, T. 29 N., R. 3 W., on west side of the 970-foot saddle north of the 1020-foot knob. Horizon-Eminence.

Mo. 98.23—On spur in NW. cor. SW. ¼ SW. ¼ sec. 35 T. 29 N., R. 4 W., about a mile south of Eminence and just east of the Eminence-Birch Tree road at the point where it makes a sharp turn west. Horizon-Van Buren.

Mo. 98.24—In the NE. ¼ SE. ¼ sec. 7, T. 27 N., R. 3 W., along the road to Flip, south side of shallow valley. Elev. 1000 feet. Horizon-Roubidoux-*Lecanospira* zone.

Mo. 98.25—In the SW. ¼ SE. ¼ sec. 22, T. 29 N., R. 4 W., on the bluff of the old meander scarp. Elev. 850 feet, float boulders. Horizon-Van Buren.

Mo. 98.26—SW. ¼ SW. ¼ sec. 9, T. 28 N., R. 3 W., in Hay Hollow on hillside across road and northeast of house, up hill behind barn. Horizon-Gasconade.

Mo. 98.27—On the top of the 1000-foot knob, at the common corner of secs. 35 and 36, T. 29 N., and secs. 1 and 2, T. 28 N., R. 4 W., about 1 mile due SE. of Eminence. Horizon-Eminence.

Mo. 98.28—Just off of the north edge of the quadrangle, on the north bank of Current River, probably near the line between the SE. ¼ sec. 21, and the SW. ¼ sec. 22, T. 30 N., R. 4 W., on ridge top. Elev. about 980 feet and above the Cryptozoon bed. Horizon-Gasconade.

Mo. 98.29—East side of hill above house, center SW. ¼ sec. 4, T. 28 N., R. 3 W., at about 900 feet. Horizon- Van Buren.

Mo. 98.30—NW. ¼ NW. ¼ sec. 10, T. 28 N., R. 3 W. Horizon-Eminence.

Mo. 98.31—Just south of road fork in center of SW. ¼ sec. 32, T. 29 N., R. 3 W. Horizon-Eminence.

Mo. 98.32—On NE. point of hill NE. ¼ sec. 34, T. 29 N., R. 3 W. Horizon-undetermined.

Mo. 98.33—In the SW. ¼ SW. ¼ sec. 32, T. 29 N., 2 W., in saddle. Elev. about 870 feet. Horizon-Eminence.

Mo. 98.34—In the NW. ¼, SW. ¼ sec. 23, T. 28 N., R. 3 W., on ridge behind Horner school. Elev. 900 feet. Horizon-Gasconade.

Mo. 98.35—In the center of the N. ½ sec. 17, T. 27 N., R. 4 W., about ½ mile northeast of Bartlett in orchard belonging to J. L. Webb. Chert float scattered over several acres. Horizons-Keokuk-Burlington.

Mo. 98.36—SE. ¼ SE. ¼ sec. 20, T. 28 N., R. 3 W., two small knobs of residual chert, one about the center of the 10 acres, the other to the southeast, both on divide. Horizon-Osage Group.

Mo. 98.37—NE. ¼ SE. ¼ sec. 1, T. 28 N., R. 4 W., on extreme east tip of small east-west spur. There is a conical mound on the tip of this spur about 30 feet high which is not shown on the contour map. Residual cherts. Horizon-Osage group.

Mo. 98.38—Center, SE. ¼ SE. ¼ sec. 21, T. 29 N., R. 3 W., on ridge top, along secondary road. Elevation, 980 feet a single boulder of chert. Horizon-Osage Group-Burlington.

Mo. 98.39—On the north line of the SW. ¼ sec. 16, T. 28 N., R. 3 W., near the sink. Horizon-Basal Roubidoux-*Syntrophina* zone.

Mo. 98.40—NW. ¼ NE. ¼ sec. 34, T. 29 N., R. 3 W., on spur south side of valley. Elev. about 800 feet. Horizon-Van Buren.

Mo. 98.41—NW. ¼ NE. ¼ sec. 21, T. 29 N., R. 4 W., on hillside northwest of Storey's school.

Mo. 98.42—In creek on section line between NE. ¼ sec. 34 and NW. ¼ sec. 25, T. 29 N., R. 3 W. Elev. about 920 feet. Horizons: Eminence, *Plethopeltis* zone, 98.42.a; Van Buren, 98.42 b; Gasconade, *Gasconadia* zone, 98.42 c.

Mo. 98.43—NE. ¼ SE. ¼ sec. 13, T. 28 N., R. 3 W., on west side of small tributary of Rocky Creek. Chert ledges in place. Elev. 820. Horizon-Van Buren.

CARTER COUNTY.

Mo. 99.1—In the NW. ¼ sec. 26, T. 27 N., R. 2 W., on top of hill overlooking Midco. Horizon-Basal Roubidoux.

Mo. 99.2—On the first hill west of Current River on U. S. Highway No. 60. Horizon-Basal Gasconade.

Mo. 99.3—Top of second prominent divide west of Current River, on U. S. Highway No. 60, 1½ to 2 miles west of Van Buren. Loc. approximate. Horizon-Gasconade.

PLATE XVIII

PLATE XVIII

Shelbyoceras sp.

1-2. Views of two fragmentary specimens tentatively referred to this genus. Residual cherts of the Potosi dolomite, M. S. M., locality 74.51, near Palmer, Mo. F. L. Sevier, collector.

Scaevogyra cf. swezeyi Whitfield

3. Lateral view of an average specimen. U. S. N. M. No. 83512.
4. Dorsal view of another specimen. M. S. M. Dept. of Geology, No. 7250. Both from residual cherts of the Potosi dolomite. M. S. M., locality 74.51, near Palmer, Mo. F. L. Sevier, collector.

Dirhachopea dubia Ulrich and Bridge, n. sp.

5-6. Lateral and dorsal views of the holotype. Residual chert of the Potosi dolomite. One-third of a mile west of Piedmont, Mo. Stuart St. Clair, collector. U. S. N. M. No. 83513.

Plethometopus modestus Ulrich, n. sp.

7. Dorsal view of a cranidium found in limestone, believed to be of Potosi age. M. S. M., locality 74.28, near Palmer, Mo. C. L. Dake, collector. M. S. M. Dept. of Geology No. 7251.

Dirhachopea appressa Ulrich and Bridge, n. sp.

8. Dorsal view of one of the cotypes. Eminence dolomite, locality 373-l, 1.5 miles northwest of Eminence, Mo. U. S. N. M. No. 83514-a.
9. Lateral view of another specimen. Eminence dolomite, locality 188-y, Flat River, Mo. Paratype. U. S. N. M. No. 83515.
10. Ventral view of another specimen. Eminence dolomite, locality 438-v-1, Bluff on Current River, just below mouth of Sinkin Creek, Shannon, County, Missouri. Paratype, U. S. N. M. No. 83516.

Dirhachopea abrupta Ulrich and Bridge, n. sp.

11-12-13. Dorsal, lateral, and ventral views of the holotype. Eminence dolomite, locality 100-c. 1 mile south of the Casey Mine, near Eminence, Mo. U. S. N. M. No. 83517.

Dirhachopea normalis Ulrich and Bridge, n. sp.

14-15-16. Dorsal, lateral, and ventral views of the holotype. Eminence dolomite, locality 438-r, about .5 mile west of Eminence, Mo. U. S. N. M. No. 83518.

Dirhachopea intermedia Ulrich and Bridge, n. sp.

17-18. Dorsal and lateral views of one of the cotypes. Eminence dolomite, locality 399-c, 2.5 miles above mouth of Little Indian Creek, Franklin County, Missouri. U. S. N. M. No. 83519-a.

19. Ventral view of another specimen. Eminence dolomite, locality 452-q-1. on hillside just north of the Munsell School, four miles south of Eminence, Mo. Paratype U. S. N. M. No. 83520.

Dirhachopea corrugata Ulrich and Bridge, n. sp.

20. Dorsal view of the holotype. U. S. N. M. No. 83521. Eminence dolomite, locality 373-l = M. S. M. 98.15, 1.5 miles northwest of Eminence, Mo.

Dirhachopea subrotunda Ulrich and Bridge, n. sp.

21. Dorsal and lateral views of the cotypes x 2. U. S. N. M. No. 83522-a.
22. Oblique view of a wax squeeze, made from the external mould of the specimen shown on the left in Fig. 21, x 3. U. S. N. M. No. 83522-b. Eminence dolomite, locality 100-i, 5 miles northwest of Eminence.

Rhachopea elevata Ulrich and Bridge, n. sp.

23. Dorsal view of an incomplete specimen. Cotype. U. S. N. M. No. 83523-b.
24. Lateral view of another specimen. Cotype. U. S. N. M. No. 83523-a. Both from the Eminence dolomite, locality 102-h, 4 miles west of Eminence, Mo.

Taeniospira eminencensis Ulrich and Bridge, n. sp.

25-26-27. Dorsal, lateral, and ventral views of the holotype. U. S. N. M. No. 83524. Eminence dolomite, locality 373-l = M. S. M. 98.15, 1.5 miles northwest of Eminence, Mo.

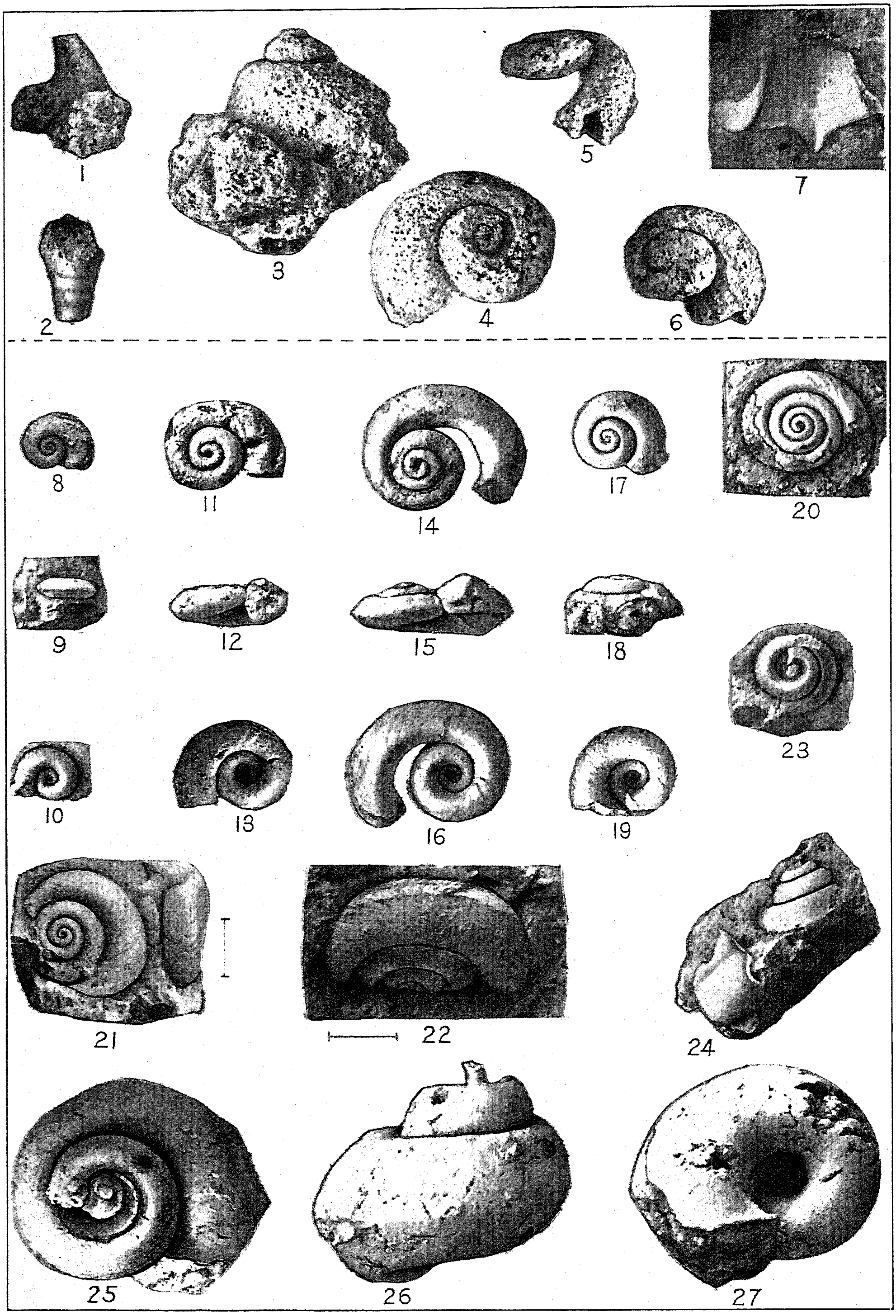
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PLATE XIX

PLATE XIX

Stenochilina spinifera Ulrich, n. sp.

1. Outline drawing of the cranidium x 3.
2. Dorsal view of a cranidium x 2. Eminence dolomite, locality 100-b, near the old Slater Mine, 1.5 miles east of Eminence, Mo. Holotype, U. S. N. M. No. 83490.

Triarthropsis nitida Ulrich, n. sp.

3. Dorsal view of a cranidium x 2. Eminence dolomite, locality 102-h, 4 miles west of Eminence, Mo. Holotype, U. S. N. M. No. 83491.
4. Outline drawing of the cranidium x 3.

Euptychaspis typicalis Ulrich, n. sp.

5-6. Outline drawings showing dorsal and lateral aspects of the cranidium x 5.

7. Dorsal view of an incomplete cranidium x 4. Eminence dolomite, locality 100-i, 5 miles northwest of Eminence, Mo. Cotype, U. S. N. M. No. 83493-a.

Calvinella ozarkensis Walcott

8-9. Lateral and dorsal views of an incomplete cranidium x 1. Eminence dolomite, locality 102-h, 4 miles west of Eminence, Mo. Holotype, U. S. N. M. No. 58674.

11. A small pygidium x 2 figured and referred to this species by Walcott. May belong to *C. minor*. Eminence dolomite, locality 100-b at old Slater Mine, 1.5 miles east of Eminence, Mo. Paratype. U. S. N. M. No. 58677.

Calvinella minor Ulrich, n. sp.

10. Dorsal view of cranidium of an average specimen x 2. Eminence dolomite, locality 188-y, near Flat River, Mo. Paratype, U. S. N. M. 58676.

Entomaspis trigonalis Ulrich, n. sp.

12. Outline drawing of a cranidium referred to this species x 3.
13. Cranidium, natural size, from which Fig. 12 was drawn. Paratype, U. S. N. M. No. 83496.
17. Pygidium x 4. Holotype, U. S. N. M. No. 83495. Both specimens from the Eminence dolomite, locality 238-h on State Highway 8, 1 mile east of Berryman, Mo.

Entomaspis radiatus Ulrich, n. sp.

14. Outline drawing of cranidium x 5 showing the generic characters.
16. Cranidium upon which Fig. 14 is based x 5. Eminence dolomite, locality 453-l, 3 miles east of Potosi, Mo. Cotype, U. S. N. M. No. 83497
15. Outline drawing of a pygidium referred to this species x 5. Drawn from a specimen from the Eminence dolomite, locality 455-v, 4.5 miles south of Potosi, Mo., on the old Caledonia road. Cotype, U. S. N. M. No. 83498-a.

Acheilops dilatus Ulrich, n. sp.

20. Outline drawing of a cranidium x 3 to show the generic characters. Drawn from the holotype.
21. Cranidium x 1. Eminence dolomite, locality 102-j, 15 miles southwest of Eminence, Mo. Holotype, U. S. N. M. No. 83499.
22. Same as Fig. 21 x 2.

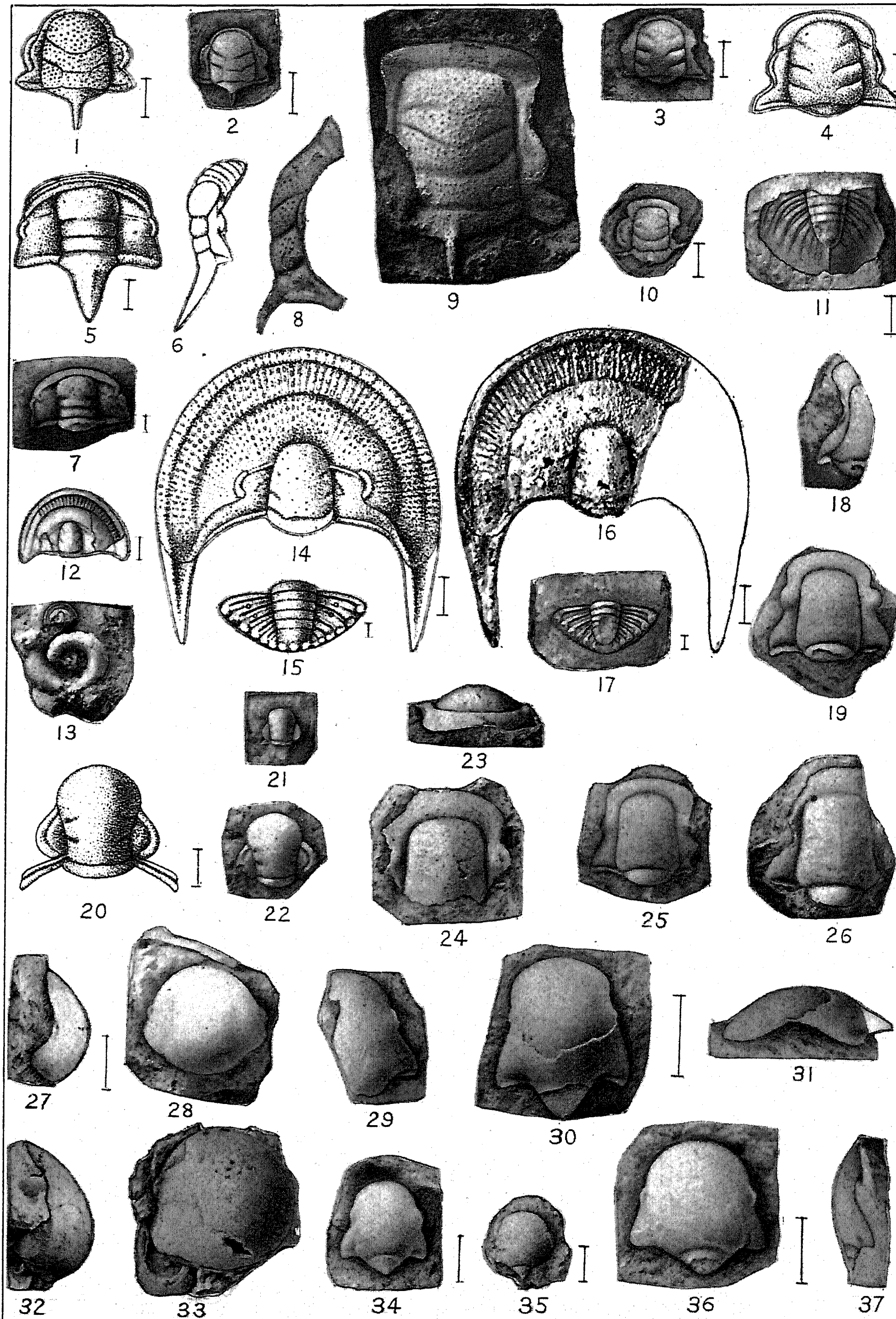
Plethopeltis platymarginatus Ulrich, n. sp.

23-24. Frontal and dorsal views of an incomplete cranidium x 1. Eminence dolomite, locality 102-h, 4 miles west of Eminence, Mo. Holotype, U. S. N. M. No. 83500.

Plethopeltis buehleri Ulrich, n. sp.

18-19. Lateral and dorsal views of a cranidium x 1. Eminence dolomite, locality 100-b, near the old Slater Mine, 1.5 miles east of Eminence, Mo. Cotype, U. S. N. M. No. 83502-a.

25. Dorsal view of another specimen from the same locality x 1. Cotype, U. S. N. M. No. 83502-b.
26. Dorsal view of an imperfect cranidium x 1. Eminence dolomite, locality 102-x, .7 mile southeast of Eminence, Mo. Paratype, U. S. N. M. No. 83503.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Plethometopus convexus (Whitfield)

29. Dorsal view of an incomplete cranidium x 1. Eminence dolomite, locality 103-t, 3 miles southeast of Fredericktown, Mo. Plesiotype, U. S. N. M. No. 83504.

30-31. Dorsal and lateral views of a smaller cranidium x 2. Eminence dolomite, locality 238-n, 0.5 mile east of the St. Francois River, on the Piedmont-Marble Hill road. Plesiotype, U. S. N. M. No. 83505.

Plethometopus modestus Ulrich, n. sp.

34. Dorsal view of a cranidium x 2. Eminence dolomite, locality 103-t, 3 miles southeast of Fredericktown, Mo. Cotype, U. S. N. M. No. 83506-a.

35. Dorsal view of a much smaller cranidium x 2. Eminence dolomite, locality 100-i, 5 miles northwest of Eminence, Mo. Paratype, U. S. N. M. 83508.

36-37. Dorsal and lateral views of a large cranidium x 2. Eminence dolomite, north bank of Current River at old Chicopee Ferry, about 1 mile east of Van Buren, Mo. Paratype, U. S. N. M. 83507.

Stenopilus latus Ulrich, n. sp.

32-33. Lateral and dorsal views of a large cranidium x 1. Eminence dolomite, locality 102-g, 2.5 miles northwest of Van Buren, Mo. Holotype, U. S. N. M. No. 83509.

27-28. Lateral and dorsal views of a small cranidium, doubtfully referred to this species, x 2. Eminence dolomite, locality 100-b, near old Slater Mine, 1.5 miles east of Eminence, Mo. Plesiotype, U. S. N. M. No. 83511.

PLATE XX

PLATE XX

Rhachopea typica Ulrich and Bridge, n. sp.

1. Dorsal view of an average specimen. Cotype, U. S. N. M. No. 83525-a.

2-3. Dorsal and lateral views of a wax squeeze from an unusually perfect internal mould showing the spire and the surface markings. The mould is a paratype. U. S. N. M. No. 83526.

4-5. Ventral and lateral views of another specimen. Cotype, U. S. N. M. No. 83525-b. Specimens shown in figures 1, 4, and 5 are from cherts of the Van Buren formation at locality 102-e, about one mile southeast of Eminence, Mo., in the NW¼ SE¼ sec. 35, T. 29 N., R. 4 W. Specimen shown in figures 2 and 3, from the same horizon, locality 261-o, three miles southeast of Eminence at top of hill on Highway 19, SE¼ NE¼ sec. 1, T. 28 N., R. 4 W.

Rhachopea transitans Ulrich and Bridge, n. sp.

6-7. Dorsal and lateral views of the holotype. U. S. N. M. No. 83527, Van Buren formation, locality 438-r-1 on south slope of hill, along old woods road, .5 mile west of Eminence.

Sinuopea cingulata Ulrich and Bridge, n. sp.

8. Lateral view of a large incomplete specimen. Cotype, U. S. N. M. No. 83528-a.

9-10-11. Lateral, dorsal and umbilical views of a smaller specimen. Cotype, U. S. N. M. No. 83528-b. Both specimens from cherts of the Van Buren formation at locality 102-e, about one mile southeast of Eminence in the NE¼ SE¼ sec. 35, T. 29 N., R. 4 W.

Sinuopea vera Ulrich and Bridge, n. sp.

12-13. Dorsal and lateral views of the holotype. U. S. N. M. No. 83529. Van Buren formation. Same locality as the preceding.

Sinuopea umbilicata Ulrich and Bridge, n. sp.

14-15-16-17. Dorsal and lateral views of the cotypes. U. S. N. M. No. 83530-a-b Van Buren formation. Same locality as the preceding.

Sinuopea basiplanata Ulrich and Bridge, n. sp.

18-19. Ventral and lateral views of the holotype. U. S. N. M. No. 83531. Van Buren formation. Same locality as the preceding.

Hypseloconus compressus Ulrich and Bridge, n. sp.

20-21-22. Lateral, posterior, and dorsal views of the holotype. U. S. N. M. No. 83532. Van Buren formation. Same locality as the preceding.

Hypseloconus ozarkensis Ulrich and Bridge, n. sp.

23-24-25. Lateral, posterior, and dorsal views of a small specimen. Cotype, U. S. N. M. No. 83533-a.

26. Lateral view of a larger specimen. Cotype, U. S. N. M. No. 83533-b. Both from Van Buren formation. Same locality as the preceding.

Dakeoceras subcurvatum Ulrich and Foerste, n. sp.

27-28. Dorsal and lateral views of one of the cotypes. U. S. N. M. No. 83535. Van Buren formation. Same locality as the preceding.

Dakeoceras normale Ulrich and Foerste, n. sp.

29. Lateral view of a paratype. U. S. N. M. No. 83556. Van Buren formation. Same locality as the preceding.

Burenoceras expandum Ulrich and Foerste, n. sp.

30-31. Lateral and apical views of the holotype. U. S. N. M. No. 83536. Van Buren formation. Same locality as the preceding.

Burenoceras pumilum Ulrich and Foerste, n. sp.

32-33. Lateral and apical views of the holotype. U. S. N. M. No. 83537. Van Buren formation, locality 456-p, sec. 13, T. 36 N., R. 3 E., Washington County, Missouri.

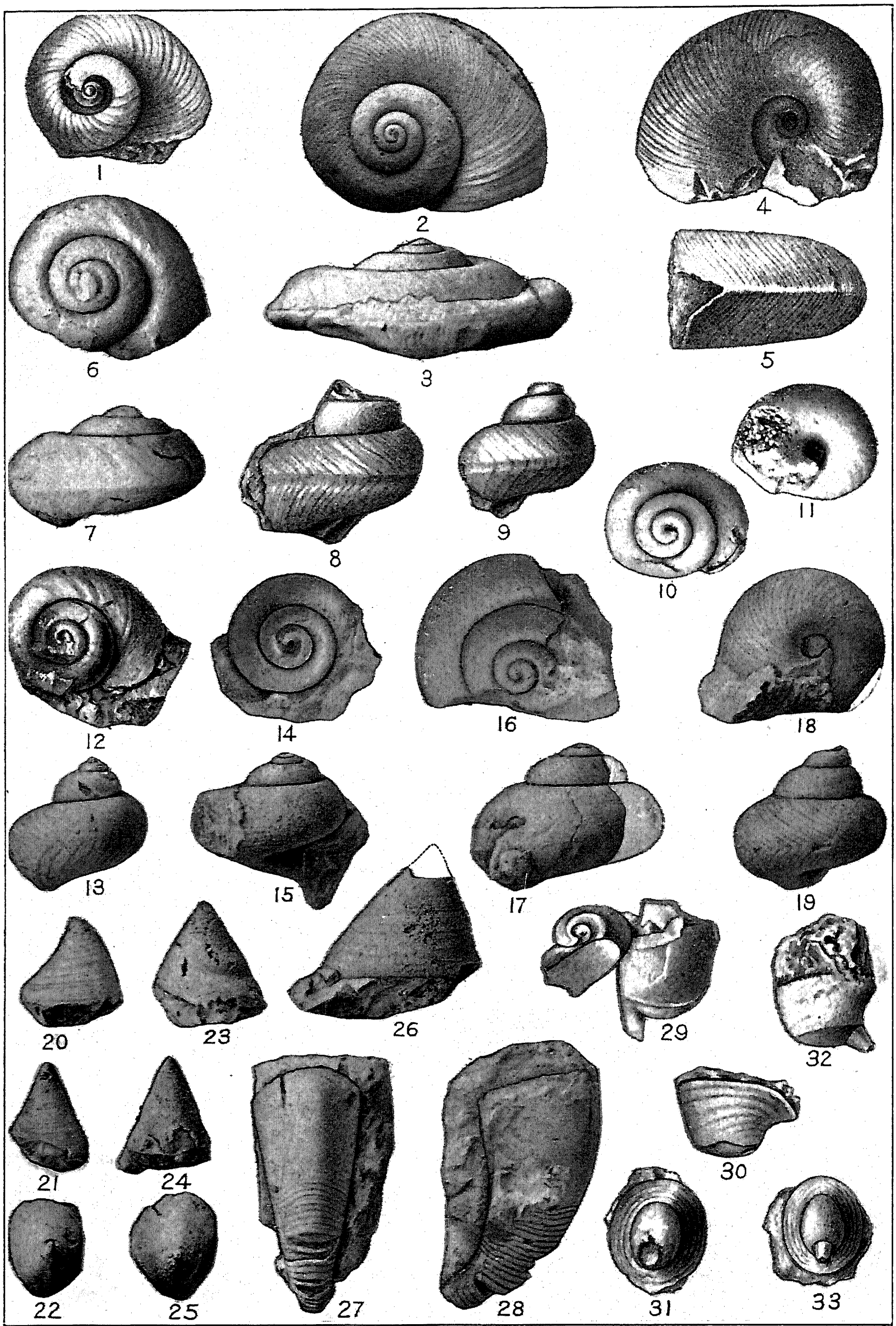
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PLATE XXI

PLATE XXI

Hystricurus missouriensis Ulrich, n. sp.

1-2. Dorsal and lateral views of a cranidium, the holotype. Chert of the Gasconade dolomite, locality 101-v, 1.25 miles north of Decaturville, Mo. U. S. N. M. No. 83538.

Sinuopea regalis Ulrich

3. Lateral view of a cotype. Gasconade dolomite. Locality 238, on Highway 8, 1 mile west of the junction of Huzzah and Dry Creeks, 10 miles east of Steelville, Mo. U. S. N. M. No. 71436.

Ozarkina complanata Ulrich and Bridge, n. sp.

4-5. Dorsal and lateral views of the holotype. Fig. 5 drawn from a photograph. Gasconade dolomite, locality 101-t, near Horner School, 10 miles southeast of Eminence, Mo. U. S. N. M. No. 83540.

Ophileta grandis Ulrich

6. Dorsal view of a specimen from Gasconade dolomite. Locality 238-a, near Boyler's Mill, Miller County, Missouri. Paratype, U. S. N. M. No. 65095.
7. Outline drawing showing the cross-section of the whorl.

Ozarkina typica Ulrich and Bridge, n. sp.

8. Dorsal view of a wax cast made from an internal mould. Residual cherts from the Gasconade dolomite, locality 104-j, 1.5 miles northwest of pegmatite dike at Decaturville, Mo. The internal mould is the holotype. U. S. N. M. No. 83541.

Ophileta supraplana Ulrich and Bridge, n. sp.

9. Dorsal view of a specimen from the Gasconade dolomite of Missouri, exact locality unknown. Paratype, U. S. N. M. No. 83542.
10. Outline drawing showing the cross-section of the last three whorls. x 2.

Gasconadia putilla (Sardeson)

11. Lateral view of an unusually complete specimen, preserving the lip and notch. x 2.
12. Same specimen as seen from the front, natural size. Showing the flaring lip and the depression which marks the position of the tooth. Gasconade dolomite, locality 238-d. Meramec Spring, Mo.
13. View of another specimen showing a complete spire. Same locality as the preceding. Plesiotypes, U. S. N. M. No. 83543.

Cameroceras huzzahense Ulrich and Foerste, n. sp.

14. An unusually perfect specimen showing the living chamber, siphuncle and narrow camerae. x. 8. Gasconade dolomite, locality 238 on Highway 8, one mile west of the junction of Huzzah and Dry Creeks, and 10 miles east of Steelville, Mo. Cotype, U. S. N. M. No. 83544.

Rhachopea grandis Ulrich and Bridge, n. sp.

15-16. Dorsal and lateral views of an unusually perfect specimen. The outer whorl has been restored at one place. Gasconade dolomite, locality 238 on Highway 8, one mile west of the junction of Huzzah and Dry Creeks and 10 miles east of Steelville, Mo. Cotype, U. S. N. M. No. 83545-a.

Euomphalopsis involuta Ulrich and Bridge n. sp.

17-20. Ventral and lateral views of one of the cotypes. U. S. N. M. 83547-b.
19. Portion of the dorsal surface of the same specimen, showing the growth lines and the shape of the apertural notch. x 3. Gasconade dolomite, locality 238-d, Meramec Spring, Phelps County, Missouri.

Euomphalopsis robusta Ulrich and Bridge, n. sp.

18. Ventral view of the holotype. The lip of the specimen is fractured, giving the appearance of a notch. Gasconade dolomite, locality 238-d. Meramec Spring, Phelps County, Missouri. U. S. N. M. No. 83548.

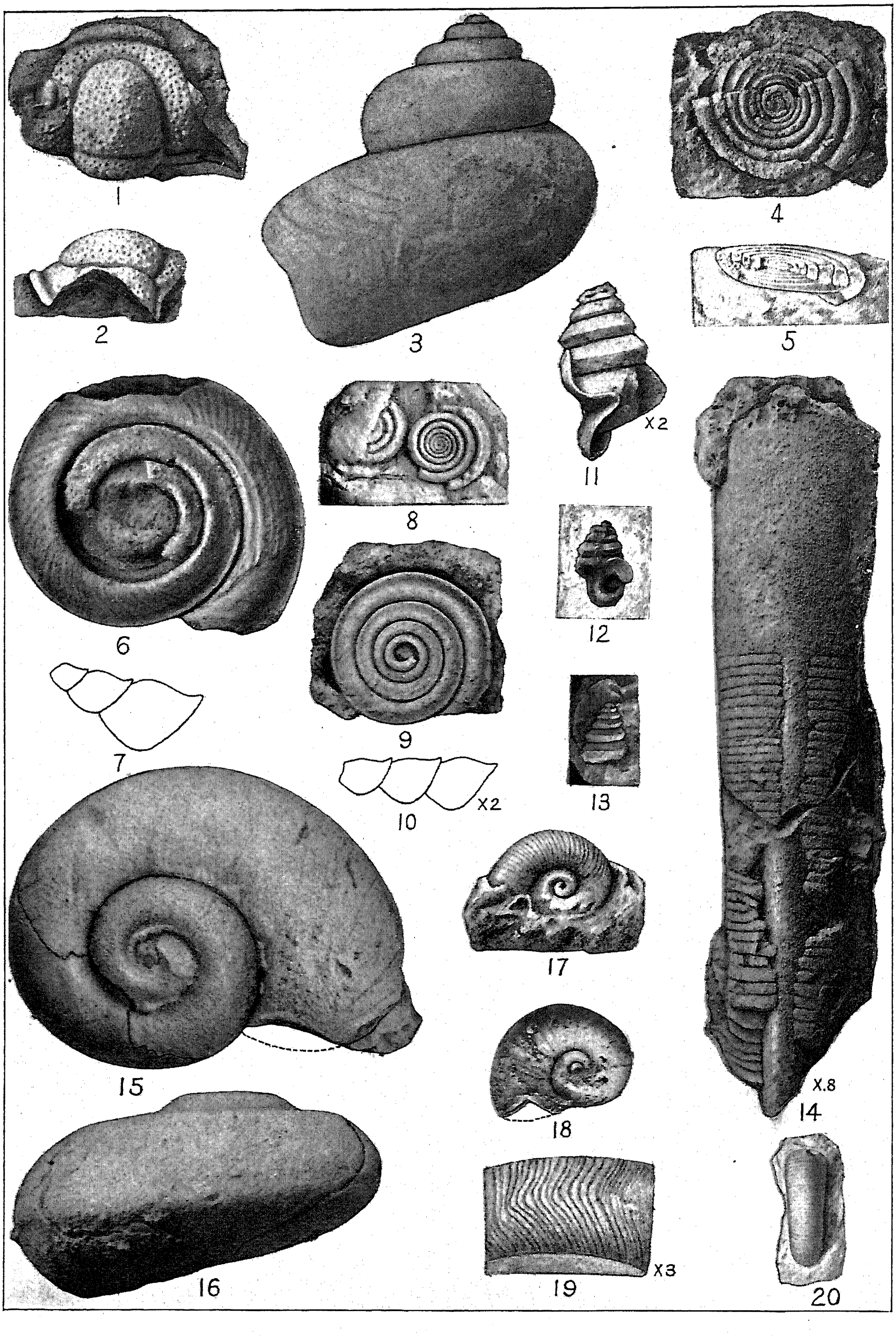
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PLATE XXII

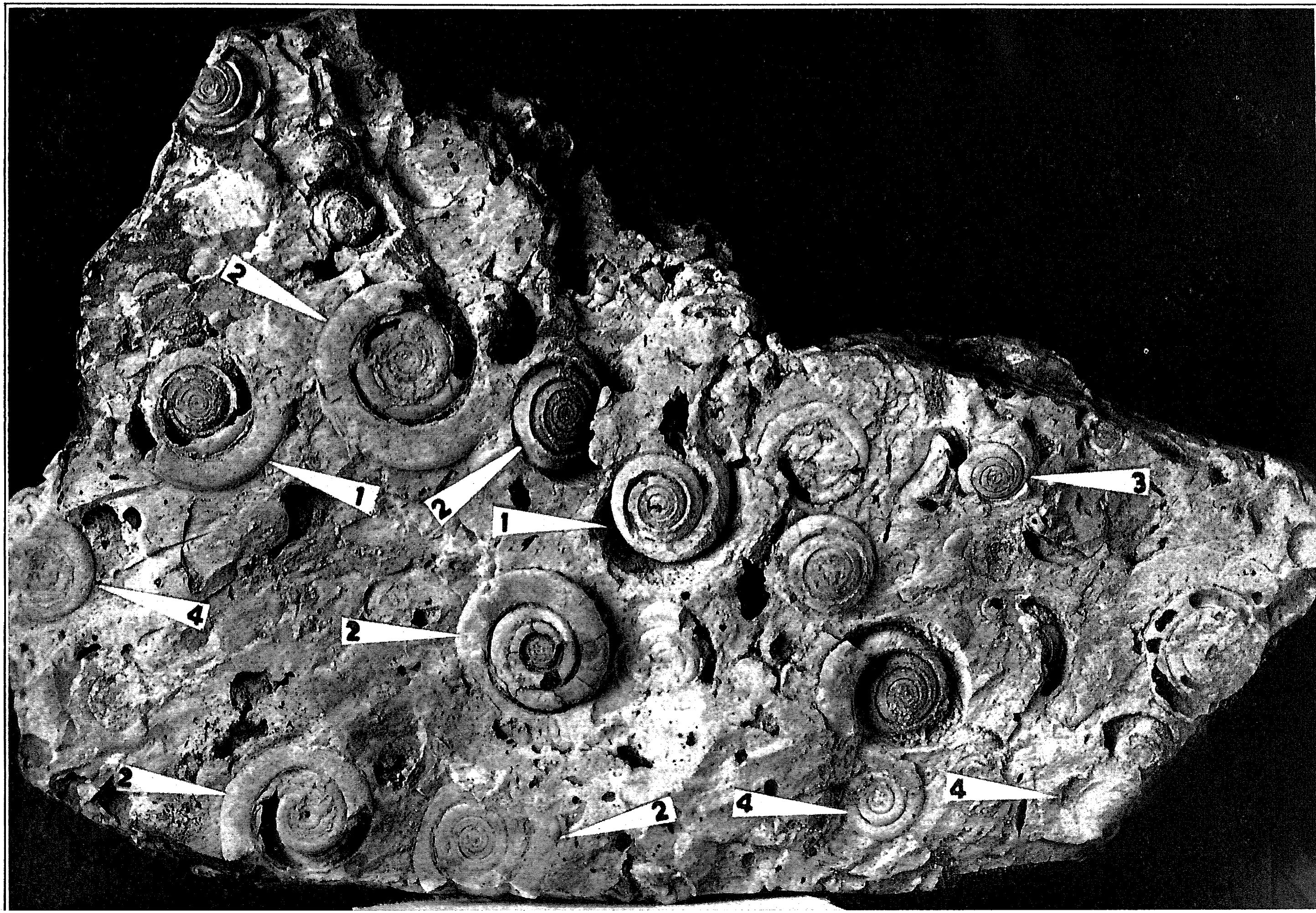
PLATE XXII

Slab of chert showing several species of Lecanospira. x. 5.

1. *Lecanospira compacta* (Salter)
2. *Lecanospira sigmoidea* Ulrich and Bridge, n. sp.
3. *Lecanospira salteri* Ulrich and Bridge, n. sp.
4. *Lecanospira biconcava* Ulrich and Bridge, n. sp.

Roubidoux formation, M. S. M., locality 90.10 in road ditch on divide between Pumpkin Hollow and Carr Creek, Reynolds County, Missouri.

Mo. Sch. Mines, Dept. of Geology No. 3074. J. Bridge, collector.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