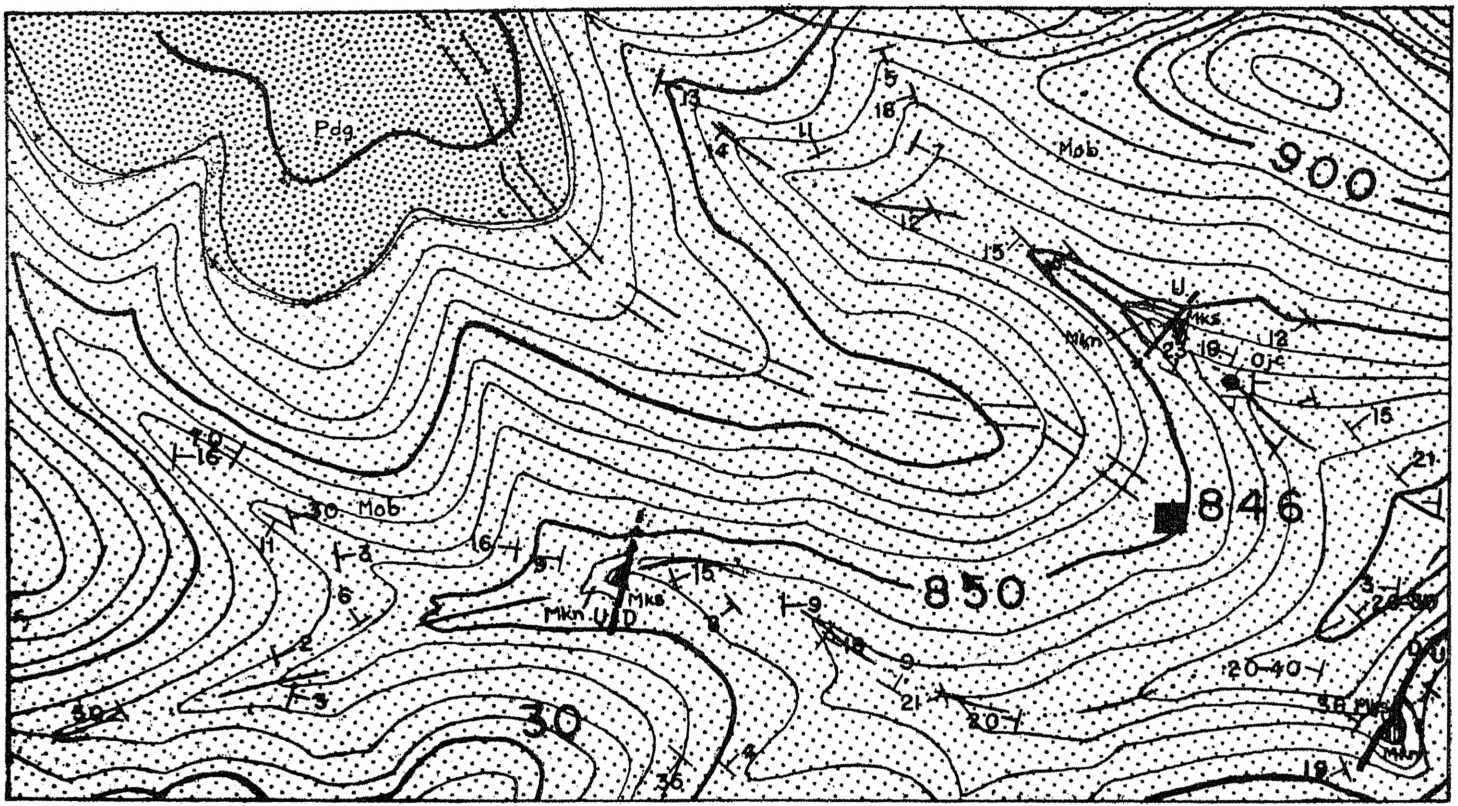


TYPICAL CRUMPLING AND FAULTING

NORTHCENTRAL PART OF Sec. 30, T.37N, R.24W.

LEGEND

▩ Pdg Graydon

░ Mob Burlington

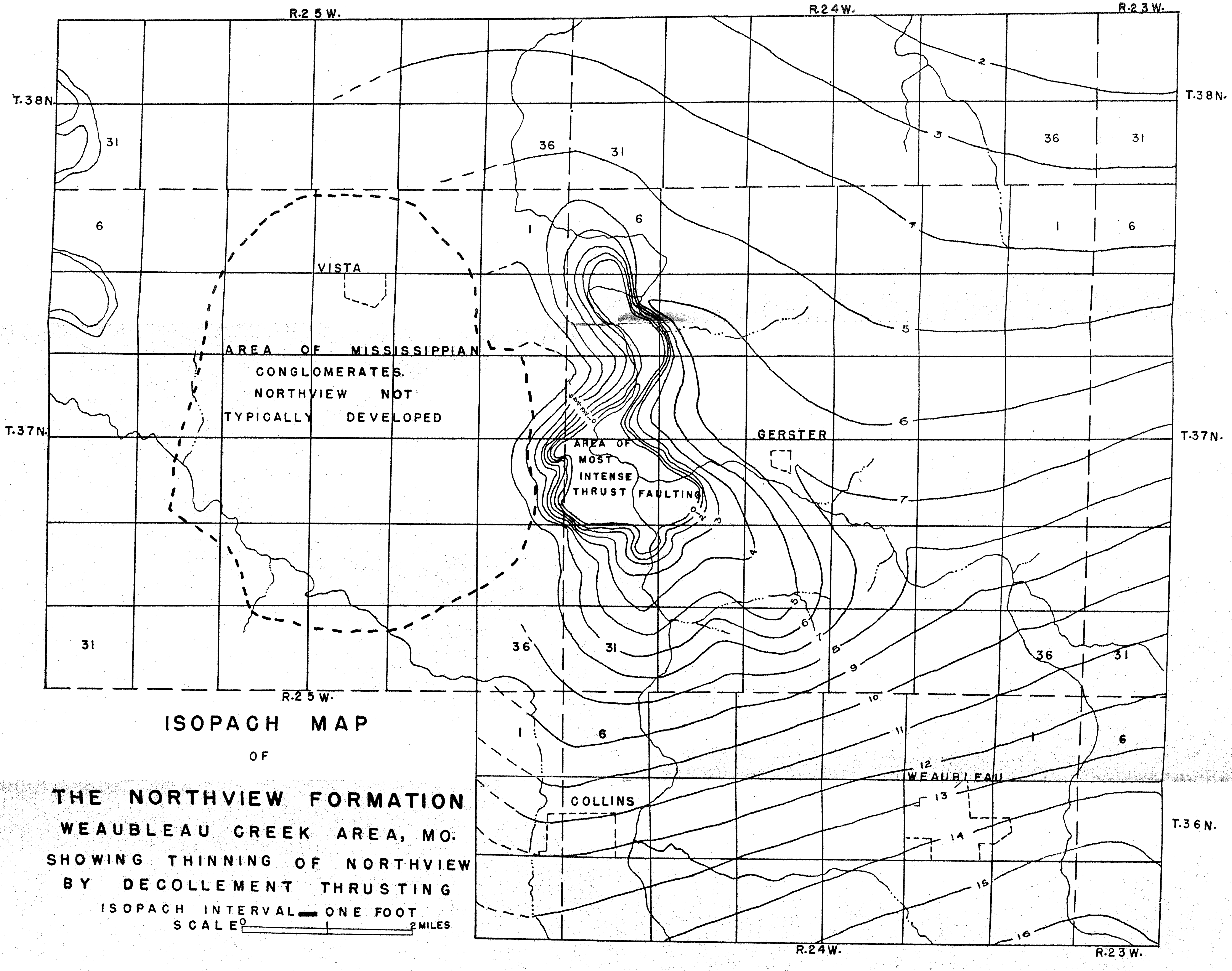
☐ Mkn Northview

▨ Mks Sedalia

● Ojc Jefferson City (Interthrust)

~ Fault

Scale 0 500 1000 FT.



ISOPACH MAP

OF

THE NORTHVIEW FORMATION

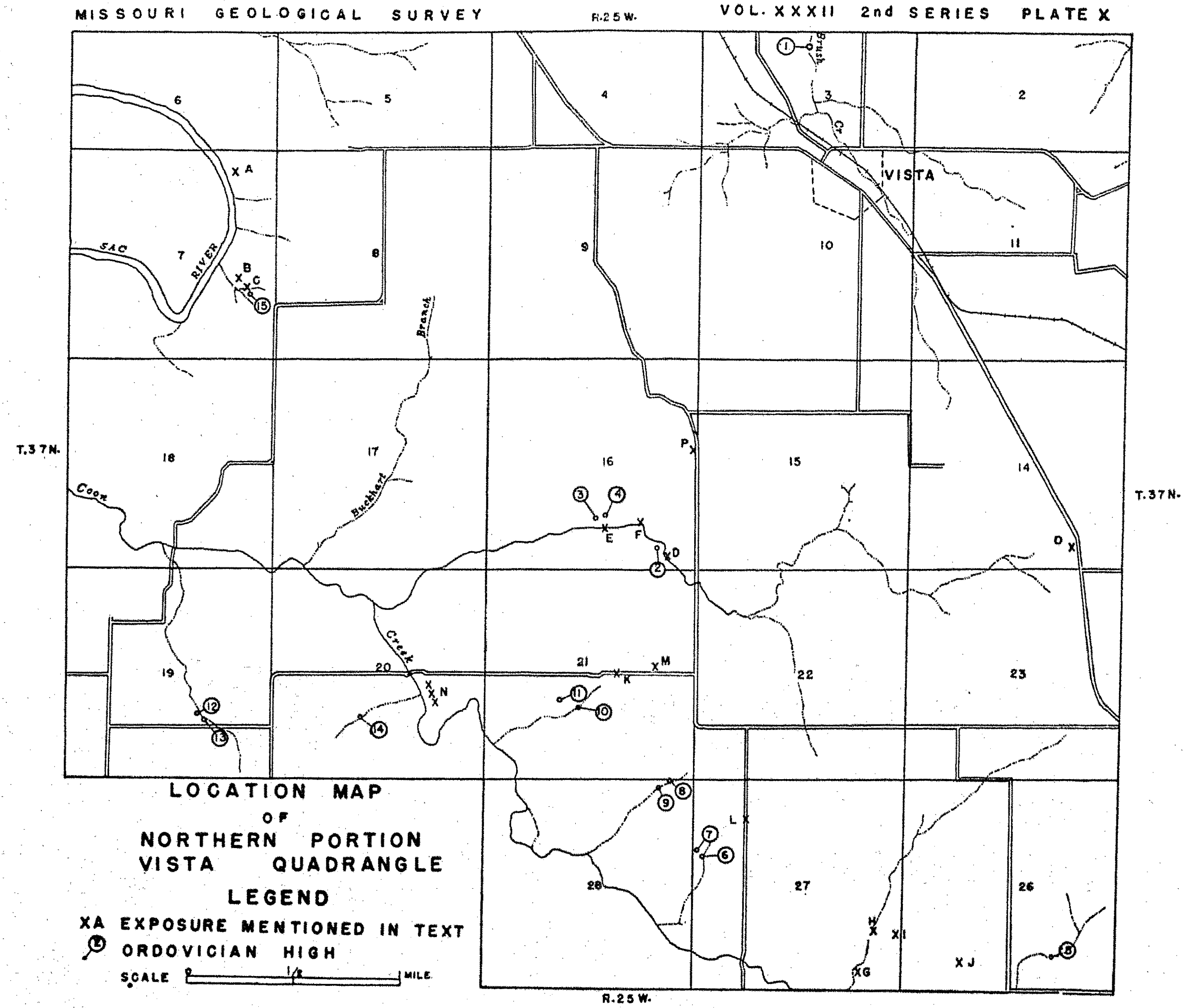
WEAUBLEAU CREEK AREA, MO.

SHOWING THINNING OF NORTHVIEW BY DECOLLEMENT THRUSTING

ISOPACH INTERVAL — ONE FOOT

SCALE 0 2 MILES

MISSOURI GEOLOGICAL SURVEY VOL. XXXII 2nd SERIES PLATE X



LOCATION MAP
OF
NORTHERN PORTION VISTA QUADRANGLE

LEGEND

XA EXPOSURE MENTIONED IN TEXT

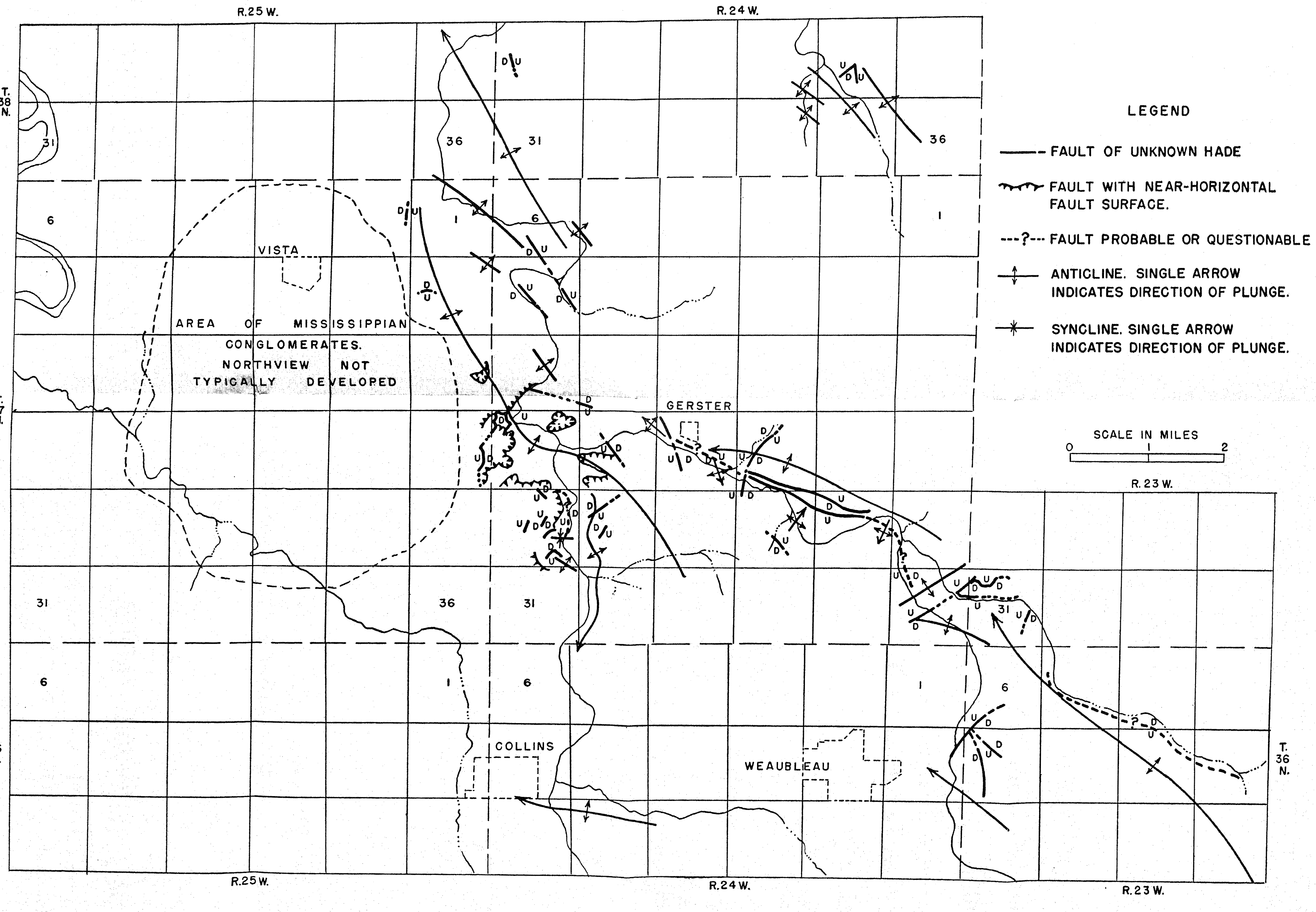
② ORDOVICIAN HIGH

SCALE 0 1/2 1 MILE

TECTONIC MAP OF THE WEAUBLEAU CREEK AREA, MO.

MISSOURI GEOLOGICAL SURVEY

VOL. XXXII 2nd SERIES PLATE XII



THE GEOLOGY OF THE WEAUBLEAU CREEK AREA, MISSOURI

By
THOMAS R. BEVERIDGE

Volume XXXII, Second Series

1951

STATE OF MISSOURI
DEPARTMENT OF BUSINESS AND ADMINISTRATION
Division of
GEOLOGICAL SURVEY AND WATER RESOURCES
EDWARD L. CLARK, *State Geologist*
Rolla, Missouri

4322

MID-STATE PRINTING CO. JEFFERSON CITY, MO.

Imbricate Burlington on near-horizontal thrust surface. NE¼NE¼NW¼SW¼ sec. 19, T. 37 N., R. 24 W.

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LETTER OF TRANSMITTAL

Rolla, Missouri
June 6, 1951

Honorable Forrest Smith
Governor of Missouri
Jefferson City, Missouri

Dear Governor Smith:

I have the honor and pleasure to transmit herewith a report on THE GEOLOGY OF THE WEAUBLEAU CREEK AREA, MISSOURI, by Thomas R. Beveridge.

The data in this report have been compiled during the past four years. The area mapped is one of great structural complexity. The manner in which the rock strata have been deformed is unique in the entire Mississippi Valley region.

This report contributes to an understanding of the geological conditions in west-central Missouri. It will serve as a key area for future detail studies. The area will be of great interest and significance in the future thinking of geologists who may study the problems of structural geology in the Mid-Continent and Mississippi Valley regions.

Respectfully submitted,

EDWARD L. CLARK,
State Geologist

The Geology of the Weaubleau Creek Area, Missouri

by

THOMAS R. BEVERIDGE

ABSTRACT

Proof of the existence of low-angled thrust faults in southeastern St. Clair County is presented. These faults are represented by duplication and elimination of beds and by decollement and imbricate structures. Slices of the Jefferson City formation (Ordovician) which have been thrust through the overlying Mississippian rocks as competent beds are designated as "interthrusts". The compression which produced this faulting is believed to have come from an unknown source to the west.

The Jefferson City is overlain by Kinderhookian rocks which from oldest to youngest are: Sylamore (?), Chouteau, Sedalia, and Northview. Evidence is presented that brown dolomitic beds overlying the Northview are not upper Sedalia as believed by some, but rather, are basal Burlington and therefore Osagean in age. Pennsylvanian (Cherokee) conglomerates, sandstones, and shales unconformably overlie the Mississippian.

In the northeastern part of the Vista quadrangle, Mississippian rocks are breccia-conglomerates with a dolomitic matrix. Field evidence shows that structural or topographic highs of Jefferson City furnished fragments which were incorporated in Mississippian strata. In the Vista quadrangle, there is also possible evidence of an erosional unconformity between the Kinderhookian and Osagean.

INTRODUCTORY STATEMENT

Geologically strategic areas are customarily given precedence in the detailed field mapping program of the Missouri Geological Survey. The Weaubleau area is strategic for the following reasons:

1) Cuts made for the re-routing of Highway U. S. 54 in 1940-42 exposed obvious faults, folds, and fractures. These deformations and their extensions in the Weaubleau area were

considered worthy of study because of the possibility of ore deposits in such a geologically favorable environment, and the need to know more about the details of the deformation.

Furthermore, the presence of faults and folds complicates both the logging and interpretation of cuttings from water wells and the prediction of suitable aquifers for the future development of ground water supplies. Detailed field mapping is desirable and often a prerequisite to both interpretation of cuttings and to predictions of future ground water resources.

2) Very few detailed data have been published concerning the structural and diastrophic history of this portion of Missouri and it was hoped that further knowledge of the origin of the Ozark Anticlinorium might be gained in an investigation of the local structural patterns and mechanics of deformation as related to the structure of the Ozarks.

3) Only limited studies had been made of the detailed lower Mississippian stratigraphy in the general area in and surrounding the Weaubleau area. This field study is but part of a regional investigation of the lower Mississippian now in progress. The present report has established tentative stratigraphic units which may be used in the mapping of neighboring areas.

The majority of the field work for this report was done during the summers of 1947 and 1948 and results were used as a doctoral dissertation at the State University of Iowa.[1] Further intermittent field work during 1949-50 resulted in a revision of some of the writer's views as expressed in the 1949 dissertation. Therefore, the present report introduces modifications and expansions of the original dissertation.

ACKNOWLEDGMENTS

The writer wishes to express his indebtedness to Dr. Edward L. Clark, State Geologist, who suggested the problem, and gave freely of his time for field conferences. His invaluable suggestions and spirited interest aided greatly in the stratigraphic orientation and structural interpretation of the area.

The faculty of the Geology Department of the State University of Iowa contributed many helpful criticisms and suggestions. Special thanks are due to Prof. A. C. Trowbridge who

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[1] Beveridge, T. R., The geology of the Weaubleau quadrangle, Missouri: State Univ. of Iowa, unpublished Doctoral dissertation, Iowa City, Iowa, 1949.

supervised the writing of the original report. Prof. J. J. Runner contributed many suggestions for the interpretation of complicated structures and spent a day in the field with the writer.

Staff members of the Missouri Geological Survey gave much aid in the preparation of the report: Walter V. Searight aided in field identification and classification of Pennsylvanian rocks; Jack James photographed several exposures, and Earl McCracken aided in microscopic identification of well cuttings.

Crinoids from the basal Burlington were identified by Dr. L. R. Laudon of the University of Wisconsin. His contribution was invaluable, for many of the specimens represent new species and could be identified only by an expert.

GEOGRAPHIC LOCATION

The area of the report is in the northern part of southwestern Missouri. It includes the whole of the Weaubleau quadrangle, a north-south mile-wide strip of the westerly-adjoining Vista quadrangle, an east-west strip approximately three-fourths a mile wide of the Iconium quadrangle to the north, and slightly more than one square mile in the southeast corner of the Osceola quadrangle to the north.

The major part of the area is in southeastern St. Clair County and approximately 14 square miles lie in western Hickory County. The latitudinal limits are 37° 52′ 30″ N. and approximately 38° 40′ 30″ N.; the longitudinal limits 93° 30′ W. and approximately 93° 38′ 35″ W.

Locations of larger cities and highway distances relative to Collins in the southwest corner of the Weaubleau quadrangle, are as follows: Kansas City, 115 miles to the northwest; Clinton, 39 miles to the northwest; Jefferson City, 117 miles to the northeast; and Springfield, 59 miles to the south by southeast.

Two major highways cross the area; Highway U. S. 54 crosses the southern portion of the quadrangle in an east-west direction, and Missouri Highway 13 crosses the southwestern corner in an approximately north-south direction.

East-west gravel Highway FAS "T" which crosses the northern part of the area connects Missouri Highway 13 with Missouri Highway 83 via Gerster. Highway FAS "E", also gravel, links Weaubleau with Humansville and Missouri Highway 13 to the south.

The St. Louis and San Fransisco (Frisco) Railway which runs diagonally through the center of the quadrangle affords connections with Kansas City and Springfield.

Only three towns lie in the mapped area: Weaubleau, population 439, in the southeastern portion of the quadrangle on Highway U. S. 54 and the Frisco Railroad; Gerster, population 110, in the northwest central portion, also on the Frisco; and Collins, population 193, at the intersection of Highways 54 and 13 in the southwestern corner.

PREVIOUS WORK

Neither county nor quadrangle geologic reports have been published for St. Clair or Hickory counties. The literature refers to the lead and barite production near Hermitage in Hickory County (15 miles east of Weaubleau) and the coal production near Vista and Osceola, St. Clair County (eight and thirteen miles respectively north of Collins). The lack of known mineral resources in the Weaubleau area may account in part for the few and scattered references to the geology of the area.

The literature generally implies that the northern portion of the Springfield Plateau is structurally simple. This preconception is undoubtedly responsible for the lack of purely academic structural studies in the area.

The evolution of the geologic maps of Missouri shows that the majority of the Weaubleau area had probably never been mapped, even by reconnaissance methods, until 1939. On various state geological maps published up to 1939, the bulk of the outcrops in the quadrangle are mapped as Cambrian, Ordovician, or Silurian (Ordovician of today), whereas Mississippian and Pennsylvanian rocks dominate.

Apparently the discrepancies in the early state geologic maps were due to a lack of field contact with the area rather than to erroneous stratigraphic interpretations; exposures of typical Pennsylvanian sandstones and conglomerates and of Mississippian crinoidal Burlington limestones are plentiful.

Swallow,[2] in 1855, published a north-south geological section from Osceola in St. Clair County to Fremont (now Stockton) in Cedar County. This section lay about eight miles west of the

---

[2] Swallow, G. C., The first annual report of the Geological Survey of Missouri: Geol. Survey of Missouri, p. 204, pl. XIV, 1855.

west boundary of the Weaubleau quadrangle and included "Carboniferous Encrinital Limestone" (present Burlington limestone).

In 1873-74, Broadhead[3] noted the occurrence of lead and zinc ores in southeast St. Clair and northern Hickory County. Winslow,[4] in 1874, made a traverse along the Osage River from Osceola to Jefferson City. He mapped the "Silurian" (present Ordovician) as cropping out in or near the northern portion of the Weaubleau area.

The occurrence of zinc on Little Weaubleau Creek, just east of the edge of the Weaubleau quadrangle was mentioned by Gallaher[5] in 1900. That he was aware of the stratigraphic sequence is demonstrated in his recognition of the Chouteau and Burlington formations at this exposure.

Asphaltic Burlington limestone in the NE¼ sec. 30, T. 38 N., R. 23 W., a short distance northeast of the Weaubleau quadrangle, was described by Wilson[6] in 1922.

Hoffman,[7] in 1927, described two sections in this area as part of a regional stratigraphic investigation. One is located "southwest of Gerster where the Collins road crosses Weaubleau Creek". This section is probably located in the SW¼NW¼ sec. 21, T. 37 N., R. 24 W., on the northwest side of the road at the bridge. Another section is located "near Weaubleau", probably on Weaubleau Creek just east of the town.

Although Moore[8] described a number of sections in St. Clair County, especially in and near Osceola, none of his published sections lies within the Weaubleau area.

The Kansas Geological Society Field Conference Guidebook[9] of 1932 contains a detailed description of the lower Mississippian exposed in the SE¼ sec. 6, T. 36 N., R. 23 W., along the now partly abandoned road near Highway U. S. 54.

---

[3] Broadhead, G. C., Report on the Geological Survey of the State of Missouri, including field work of 1873-74: Missouri Geol. Survey, p. 528, 1874.

[4] Winslow, Arthur, Lead and zinc deposits: Missouri Geol. Survey, vol. VI, pt. I, pp. 358-378, 1894.

[5] Gallaher, J. H., Preliminary report on the structural and economic geology of Missouri: Missouri Bur. Geol. and Mines, vol. 13, p. 160, 1900.

[6] Wilson, M. E., The occurrence of oil and gas in Missouri: Missouri Bur. Geol. and Mines, 2nd ser., vol. 16, p. 183, 1922.

[7] Hoffman, O. L., The Chouteau Limestone in central Missouri: Unpublished Master's Thesis, Univ. of Kansas, pp. 34-36, 1927.

[8] Moore, R. C., Early Mississippian formations in Missouri: Missouri Bur. Geol. and Mines, 2nd ser., vol. 12, 283 pp., 13 pls., 1928.

[9] Moore, R. C., and others, Sixth Annual Field Conference Guidebook, Kansas Geological Soc., p. 33, 1932.

A thesis by Rhodes[10] covering the geology of a small area near Humansville represents the mapped area nearest to the Weaubleau quadrangle. Her map extends northward from Humansville, in Polk County, to within three miles of the south boundary of the Weaubleau quadrangle. However, the stratigraphic interpretations of the present writer are so different from those of Rhodes that little use could be made of her described sections.

Kaiser[11,12] describes many sections in southwestern Missouri, but only one (Stratigraphic Section no. 60, Appendix, 1946), in the lower Burlington, along the south side of Highway U. S. 54, just east of Collins, lies in the Weaubleau area.

Bretz[13] has described in detail a Pennsylvanian deposit in what he regards as a filled sink traversed by Highway U. S. 54 in the W½ sec. 12, T. 36 N., R. 24 W.

The latest geological map of Missouri,[14] published in 1939, reflects the information gathered in the Survey's subsurface program and is fairly accurate on a gross scale. However, it shows faulting in neither St. Clair nor Hickory counties, and its portrayal of the Ordovician outcrop pattern demonstrates that the area was considered to be underlain by gently dipping strata.

Nowhere in the literature has the writer found any suggestion of the complex structure that exists in this area; previous publications have implied that this portion of the Springfield Plateau is structurally simple, and that only gentle folds interrupt the west-dipping strata.

PHYSIOGRAPHIC LOCATION

All investigators except Branson[15] have included the Weaubleau area on the western flanks of the Ozarks.

One of the earliest detailed physiographic classifications of Missouri was proposed by Marbut[16] who included the Weaubleau

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[10] Rhodes, M. L., Physical geology of an area near Humansville, Missouri: Unpublished Master's thesis, University of Missouri, 1939.

[11] Kaiser, C. P., Stratigraphy of Lower Mississippian rocks in southwestern Misouri: Unpublished Doctoral dissertation, Univ. of Kansas, pp. 1-120, 1946.

[12] Kaiser, C. P., Stratigraphy of Lower Mississippian rocks in southwestern Missouri: Am. Assoc. Petroleum Geologists Bull., vol. 34, no. 11, pp. 2133-2175, 1950.

[13] Bretz, J H., Orgin of the filled sink structures and circle deposits of Missouri: Geol. Soc. America Bull., vol. 61, no. 8, pp. 800-801, 1950.

[14] Buehler, H. A., Geological Map of Missouri, scale: 1:500,000: Missouri Geol. Survey and Water Resources, 1939.

[15] Branson, E. B., The geology of Missouri: Univ. of Missouri Studies, vol. 19, no. 3, pp. 350-55, 1944.

[16] Marbut, C. F., Physical features of Missouri: Missouri Geol. Survey, vol. 10, pp. 14-109, pl. II, 1896.

area in the "Springfield Structural Plain" of the Ozark upland. This plain was described as being separated from the more rugged "Salem upland" to the east by the east-facing "Burlington escarpment". This escarpment was named from one of its components, the Mississippian Burlington formation. However, Marbut realized the difficulty of tracing this escarpment northward from more southerly portions of southwestern Missouri, for in discussing the "Springfield Structural Plain" he says:[17]

> "In the neighborhood of Wheatland, in Hickory County, and also north of the Osage River, where it is not cut by tributaries of the latter stream, it is a broad, gently undulating upland rising gradually and imperceptibly on one side into the Ozark Dome and descending on the other into the lowland to the west. It is merely a strip across the slope of the dome that is not differentiated by pronounced physical features, from the higher or lower parts of the dome on each side of it."

In Plate II[18] he draws the north-south line separating the "Springfield Structural Plain" from the "Salem upland" as following the Mississippian-Ordovician contact which parallels the west side of the Pomme de Terre River. The north-flowing Pomme de Terre is essentially a subsequent stream, following closely the regional contact of the Ordovician-Mississippian, and thus his boundary is justified by the gross outcrop and stream patterns in lieu of a pronounced escarpment.

Adams[19] follows Marbut's classification but prefers to call the "Springfield Structural Plain" the "Springfield Upland", although he says:[20]

> "The Springfield Upland is essentially a structural plain developed on the surface of the Mississippian limestones."

Purdue and Miser[21] abandoned the term "Burlington Escarpment", arguing that such a stratigraphically restrictive name is inappropriate because of the various formations involved. They proposed the geographic term Eureka Springs Escarpment after the town of that name in northwestern Arkansas. This designation is accepted by the Missouri Geological Survey.

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[17] Marbut, C. F., op. cit., p. 63, 1896.

[18] Marbut, C. F., op. cit., p. 32, 1896.

[19] Adams, G. I., Physiography and geology of the Ozark region: U. S. Geol. Survey 22nd Ann. Rept., pt.. 2, pp. 69-75, 1901.

[20] Adams, G. I., op. cit., p. 74, 1901.

[21] Purdue, A. H., and Miser, H. D., Description of the Eureka Springs and Harrisonville quadrangles, Arkansas, Missouri: U. S. Geol. Survey Atlas, Eureka Springs-Harrison fol. no. 202, pp. 1-2, 1916.

Sauer[22] also follows the dividing line of Marbut but designates the "Salem Upland" as the "Central Plateau."

No great departure is made from previous classifications of the Ozarks in Fenneman's compilation.[23]

Branson[24] does not recognize the Springfield Plateau, and draws the west line of the Ozark Region near the Eureka Springs Escarpment, calling the area west of this line the "Old Plains", thus placing the Weaubleau quadrangle outside the Ozarks. He uses the higher degree of stream entrenchment and dissection as criteria for identifying the Ozark Region.

The writer agrees with Branson and does not include the Weaubleau area in the Ozarks. The Eureka Springs Escarpment is considered to be the western boundary of the Ozarks and to lie approximately six miles east of the east border of the report area. This escarpment as defined for this report is crossed at right angles by Highway U. S. 54, 1.2 miles east of Wheatland in Hickory County. It forms the western edge of the highly dissected part of the Pomme de Terre valley and also the most persistent regional Ordovician-Mississippian outcrop contact. To the west of this line the topography is not deeply dissected; to the east, streams flow in relatively deep valleys.

To the north, this escarpment forms a west-pointing V up the Osage River to the vicinity of Osceola.

STAGE OF REGIONAL DEVELOPMENT

The surface as a whole is in late youth of the present erosion cycle. The roughness and local relief are the greatest where faulting and folding are most intense, as well as in the downstream portions of major stream valleys. Thus in the northwest portion of the area the inter-stream divides are relatively small and tributaries are numerous, creating a topography which is near maturity.

It might be argued that this highly dissected area is rougher because of its extreme downstream location within the watershed of Weaubleau Creek. This is true in part, but it has been found that stream patterns of the report area are closely related

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[22] Sauer, C. O., The geography of the Ozark Highland of Missouri: Geog. Soc. Chicago Bull., vol. 7, pp. 138-43, Jan., 1920.

[23] Fenneman, N. M., Physiography of Eastern United States, pp. 631-662, pl. VI, McGraw Hill Book Co., New York and London, 1938.

[24] Branson, E. B., op. cit., pp. 350-55, 1944.

to structural patterns and that there are more tributaries where the rocks have been more intensely folded, faulted and fractured.

The maxium local relief within the quadrangle is 200 feet between the west bluffs and creek bed at the junction of South Fork Weaubleau Creek with the main channel of Weaubleau Creek. The maximum difference in altitudes within the area as a whole is 310 feet. The lowest altitude is 715 feet in the valley of Weaubleau Creek in sec. 36, T. 38 N., R. 25 W.; the highest altitude is 1025 feet in the SE¼ sec. 13, T. 37 N., R. 24 W.

The relatively flat, broad upland areas, locally called "prairies", are in a large part underlain by Pennsylvanian sandstones and conglomerates which are relatively resistant, especially to solution. These uplands are best preserved in the south-central and northern portions of the quadrangle. The bulk of the outcrops in the more highly dissected portions are limestones and cherty dolomites.

KARST TOPOGRAPHY

Karst topography is pronounced in several localities. One of the better examples is near the center of the NE¼ sec. 7, T. 36 N., R. 23 W. On the north side of the east-west road several small sinks appear to be relatively recent in origin, for the bounding soil walls are nearly vertical. These sinks do not exceed fifteen feet in diameter. Depths could not be determined, for the cavities have been filled with brush and debris to prevent loss of livestock. On the south side of the road sinks have been developed in east-west joints of the Burlington limestone. The larger of these fissures are up to four feet in width and thirty feet in length. These also have been artificially filled and depths could not be determined. However, one fissure is at least eleven feet deep and has nearly vertical walls. The proximity of joint sinks and circular collapse sinks suggests strongly that a part of the karst topography is due to differential solution along joints with later collapse of the more constricted upper portions into underlying caverns.

Other sinks, larger in diameter, but less than ten feet in depth, are located in the center of sec. 1, T. 36 N., R. 24 W., and in the center of the N½ sec. 28, T. 37 N., R. 24 W.

STREAM DEVELOPMENT

The major stream in the area is Weaubleau Creek which enters in the southeast corner and leaves the northwest corner. It joins the Osage River four miles north of the northwest corner of the mapped area. The average gradient of Weaubleau Creek is 8.4 feet per mile. Important tributaries to Weaubleau Creek are South Fork and Little Weaubleau Creek.

Bear Creek, which rises in this area, also flows northward into the Osage River. Coon Creek, in the southwest portion of the quadrangle, enters the Osage via the Sac River which lies to the west of the area.

Entrenched meanders of the Osage River, whose valley lies within five miles north of the Weaubleau quadrangle, have been much-discussed in the literature.[25,26,27,28,29] The consensus of opinion is that the Osage is not in its first cycle, and that there has been peneplanation over the Ozark area. Thus it might be expected that larger streams of the Weaubleau area, if in the same cycle as the Osage, would flow in valleys which show little regard for structural control.

Such is not the case. Within the area, large portions of the courses of Weaubleau Creek and of its two major tributaries, South Fork and Little Weaubleau, follow patterns determined to a large extent by folding and faulting (See Plates XI and XII).

East of the town of Weaubleau, Weaubleau Creek parallels a fault which crosses Highway U. S. 54. It parallels or follows the trace of a fault from sec. 36, T. 37 N., R. 24 W., to a point south of Gerster. In sec. 19, T. 37 N., R. 24 W., it is deflected sharply to the north where it encounters a structural high of resistant Jefferson City dolomite. In sec. 7, T. 37 N., R. 24 W., the creek parallels a fault and turns to the right at an acute angle in the NE¼ of section 7 where it meets Burlington limestone capped by Jefferson City thrust slices.

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[25] Davis, W. M., The Osage River and the Ozark Uplift: Science, vol. 21, pp. 225-27, 1893; Science, vol. 22, pp. 276-79, 1893.

[26] Winslow, Arthur, The Osage River and its meanders; Science, vol. 22, pp. 31-32 and 152-153, 1893.

[27] Hershey, O. H., River valleys of the Ozark Plateau: Am. Geologist, vol. 16, pp. 294-300, 1895.

[28] Marbut, C. F., op. cit., pp. 108-109, 1896.

[29] Tarr, W. A., Intrenched and incised meanders of some streams on the northern slope of the Ozark Plateau in Missouri: Jour. Geology, vol. 32, pp. 583-590, 1924.

Other examples of structural control of streams are as follows:

(1) Little Weaubleau Creek in sec. 31, T. 37 N., R. 23 W., and sec. 36, T. 37 N., R. 24 W., follows a fault trace. Mapping in the Hermitage quadrangle to the east has shown that this northwest-flowing stream follows either the northeast flank of an anticline or possibly the trace of a fault for nearly six miles headward from its confluence with Weaubleau Creek.[30]

(2) The tributary in secs. 23 and 26, T. 37 N., R. 24 W., follows a fault trace.

(3) The tributary in W½ sec. 21, T. 37 N., R. 24 W., on the southeast side of the bridge, follows a fault trace.

(4) The tributary in SW¼ sec. 29, T. 37 N., R. 24 W., parallels a fault trace.

(5) South Fork Weaubleau Creek, just west of location 4, follows a fault trace and parallels the west flank of a north-south trending anticline.

(6) The lower portion of Clear Creek in E½ sec. 7, T. 37 N., R. 24 W., follows a fault trace.

(7) The tributaries in W½ sec. 19, T. 37 N., R. 24 W. and E½ sec. 24, T. 37 N., R. 25 W., follow fault traces and terminate near fault-line scarps.

No data are available to suggest that the Osage meanders are structurally controlled. It is believed that the streams of the Weaubleau area originated in a later cycle than did the Osage. Therefore, these smaller streams conform to structural patterns which do not affect the present course of the rejuvenated Osage.

The major streams of the Weaubleau area are in the stage of maturity in the cycle of valley development.

The topographic map alone gives only a partial history of stream development. The asymmetrical cross-sectional valley profile is not necessarily developed solely by lateral shiftings of the stream channel but, rather, in many localities, by faulting. The more gently sloping valley wall is in several cases either a dip slope, truncated dip slope, or the downthrown block of a fault. Precipitous valley walls or heads have locally been developed by fault-line scarps.

At least two streams, Coon Creek in the southwest portion of the quadrangle and Tanyard Branch in secs. 24 and 13, T. 37 N., R. 25 W., occupy channels which were originally carved in early or pre-Pennsylvanian time. Basal Pennsylvanian shales

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[30] Schroeder, E. R., The geology of a portion of the Hermitage quadrangle, Missouri: Unpublished Master's thesis, State University of Iowa, Plate II, February, 1950.

and sandstones may be traced almost continuously along the stream beds or lower valley walls. Yet limestones of Mississippian age form the topographically higher portions of the valley walls. Apparently these two valleys were inherited from partly re-excavated ancient stream valleys which had been filled in part by soft shales and weakly indurated sandstones.

Exposures of Pennsylvanian rocks in the W½SE¼ sec. 7 and the E½NE¼ sec. 16, T. 36 N., R. 24 W. in the bank of South Fork Weaubleau Creek may represent ancient sink fillings which have been exposed by erosion.

The effects of solution are demonstrated by the forms of tributaries which head in limestones as contrasted with those which originate in sandstones. Many of the tributaries whose valley walls are composed of limestone have abrupt heads which probably represent pre-existing cylindrical sinks truncated parallel to their vertical axes by erosion. Other valleys may be the result of solution along joint and shear zones.

Tributaries in the E½SE¼ and the E½NE¼ sec. 24, T. 37 N., R. 25 W. originate near a fault-line scarp, suggesting that other small parallel streams which head at a line roughly normal to their valleys may also have developed at unrecognized fault-lines or joint systems.

Streams which head in Pennsylvanian sandstones do not exhibit the abrupt sharpening of concavity found in the headward end of the longitudinal profiles of streams in soluble limestone.

Marbut[31] and Purdue[32] have described typical Ozark Plateau stream valleys in Missouri and northern Arkansas respectively. The "Trough" valleys are described by Marbut as shallow wide troughs with rounded valley walls covered with residual chert fragments, valley floors closely resembling flood plains, and a usually boulder-cluttered stream bed. Purdue portrayed "Canyon" valleys as steep-sided, very straight, and heading abruptly in what appear to have been pre-existing sink-holes. Streams are seldom visible in the upper portions and surface water is ordinarily insufficient to remove residual chert. "Canyon" valleys of Marbut are formed in larger permanent streams or by the collapse of the roofs of underground streams.

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[31] Marbut, C. F., op. cit., pp. 88-91, 1896.

[32] Purdue, A. H., Valleys of solution in northern Arkansas: Jour. Geology, vol. 9, pp. 47-50, 1901.

Some of the ephemeral tributaries of the Weaubleau area conform closely to the "Canyon" type described by Purdue. The larger streams fit in part the description of the Marbut "Trough" type, although the steep-bluffed valley along the lower portions of Weaubleau Creek is in complete harmony with neither of the descriptions, for one valley wall is precipitous and the opposite is gently-sloping. This Weaubleau Creek profile, however, is typical of the stage of maturity, and the gently-sloping valley walls are in some cases slip-off slopes developed by downward and lateral cutting of meanders.[33]

In summary, the stream valleys of the Weaubleau area are of varied origins and cannot be included in any single physiographic classification. The profusion of residual as well as transported chert indicates the great power of differential solution in degradation.

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[33] Tarr, W. A., op. cit., pp. 590-597, 1924.

CHAPTER II

STRATIGRAPHY

GENERAL STATEMENT

Mississippian rocks predominate in the Weaubleau area (See Geologic Map, Plate XI). These rocks lie unconformably on the Jefferson City formation of the Canadian series. The bulk of the Jefferson City is exposed in or near major stream valleys where these valleys cross anticlines or faults. Thrust faulting has carried small slivers of Jefferson City into upland areas. Although these isolated slivers are quantitatively unimportant, they are of great structural significance.

Pennsylvanian (Cherokee) sandstones and conglomerates cap the uplands, and in the extreme western portion of the quadrangle they are the predominate outcrop. Pennsylvanian shales and sandstone form the floors of some of the valleys in this western portion.

The Jefferson City formation is predominately a cherty dolomite. The Mississippian rocks (Kinderhookian and Osagean) are composed predominantly of non-cherty to cherty limestone, although the Kinderhookian limestones are locally dolomitic, and the Northview formation of the Kinderhookian is composed of siltstone and shale.

Upland gravels of Tertiary (?) age are exposed at several localities. Depositional terraces in stream valleys are probably Pleistocene to Recent in age.

ORDOVICIAN SYSTEM

CANADIAN SERIES

ROUBIDOUX FORMATION

The Roubidoux formation which underlies the Jefferson City, does not crop out in the Weaubleau area. Missouri Geological Survey well logs record but two water wells in which it was encountered, both in the town of Weaubleau.

The Ashcroft well in the NW½ NW¼ SW¼ sec. 12, T. 36 N., R. 24 W. (Curb elevation 985 ft.) entered the Roubidoux at a depth of 390 feet and ended in this formation at 441 feet. At

Weaubleau High School in the NE¼ SE¼ NW¼ sec. 11, T. 36 N., R. 24 W., (curb elevation 1009 ft.) Roubidoux was struck at a depth of 385 feet; the well bottomed in this formation at 430 feet depth.

JEFFERSON CITY FORMATION

Name.—In 1894, Winslow[34] named the Jefferson City formation after exposures in the Missouri River bluffs near Jefferson City. He considered this formation to be Silurian in age and included it in the Gasconade limestone. He designated the 1st Saccharoidal sandstone (present St. Peter) of previous reports as the Roubidoux, and thus had Roubidoux immediately overlying Jefferson City.

Ulrich[35,36] limited the Jefferson City formation by differentiating the respectively younger Cotter and Powell as formations overlying the Jefferson City. The Moreau, which had been defined as underlying the original Jefferson City, was given the name Roubidoux, and that classification has persisted.

In the present paper, no attempt is made to differentiate the Cotter from the Jefferson City and the name Jefferson City is used in an unrestricted sense. The upper part of the Jefferson City, as used in this paper, may include some Cotter in the extreme eastern part of the area. However, exposures are so few and poor that it is considered impractical to attempt to differentiate the Cotter in field mapping in this area.

Distribution.—The outcrop area of the Jefferson City formation is about three square miles but exposures are relatively few. The best exposures are on the north side of the east-west road east of Gerster in secs. 21 and 22, T. 37 N., R. 24 W., and at the southwest tip of the spur in the NE¼ sec. 19, T. 37 N., R. 24 W. The east-facing bluffs in the W½ sec. 19 are formed by Jefferson City which rises to nearly one hundred feet above Weaubleau Creek. However, in these moderately steep bluffs, much of the outcrop is covered.

Thickness.—The base of the Jefferson City does not crop out in the area. Records of the two wells in the town of Weau-

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[34] Winslow, Arthur, Lead and Zinc deposits: Missouri Geol. Survey, vol. VI, pt. I, pp. 331, 373, 375. 1894.

[35] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, Plate 29, 1911.

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

bleau which penetrated this formation from top to bottom give thicknesses of 200 to 205 feet.

Lithology.—Cherty dolomite predominates in the Jefferson City. Although the writer was unable to zone this formation, it was found that the uppermost ten to twenty feet in many localities are composed of a slabby white dolomite or typical "cotton rock".[37] The slabs are from an inch to three or four inches in thickness and have undulating to rough bedding surfaces. In the underlying beds, various lithologic types are repeated, but exposures are so poor that regular repetition could not be determined.

The Jefferson City dolomite is predominantly massive to thick-bedded, buff to brown, very tough, and weathers to rounded surfaces. In many gently-sloping stream beds, it is nearly impossible to discern any bedding. White to buff medium-grained quartzitic sandstones constitute a quantitatively minor portion of the formation but are diagnostic in identifying float or isolated exposures of Jefferson City.

The cherts of the Jefferson City are invaluable in field mapping, for they form much of the float of this poorly exposed formation and can be megascopically distinguished from cherts of younger formations. Diagnostic chert types are:

(1) Oolitic chert: Blue to white, weathers out as brown to gray blue angular boulders up to a foot in diameter. Superficially some samples resemble quartzite, for they are vitreous to glassy on fresh surfaces. Individual oolites average 0.5 mm. to 0.75 mm. in diameter and have white centers.

(2) Nodular chert: The nodules are commonly ellipsoidal, with major axes averaging four to six inches in length, the intermediate axes three to four inches, and the minor axes one to two inches. Cross sections show concentric banding; these bands are from one-eighth to one-fourth an inch in thickness and are of varying colors—usually white alternating with brown, blue, or purple. Characteristically the exteriors are white in color and are vitreous to dull in luster. Fresh interior surfaces vary from opaline to agate-like in appearance.

(3) Chert bands: Bands of chert averaging an inch to two inches in thickness are common in the brown, rough surfaced

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[37] "Cotton rock," as used in Missouri, is a white to buff fine-grained argillaceous dolomite.

dolomite. These bands are parallel to bedding planes, and exposures have been traced along the bedding in plan view over an area of six by ten feet. This chert is white opaline in appearance, and thin chips are somewhat translucent. It is a great aid in identifying small patches of Jefferson City isolated by thrust faulting.

(4) Brecciated chert: Brecciated chert is common in much of the Jefferson City. Characteristically it is light to dark blue in color and vitreous to waxy in luster. Fragments vary from microscopic size up to three inches in maximum dimension. The average size is about one inch or slightly less in maximum dimension.

Detailed Sections.—

SE¼ SE¼ NE¼ sec. 21, T. 37 N., R. W. Base of section begins in ditch on north side of road and top is on hillside north of road:

Chouteau	Feet	Inches
(6) Limestone, gray, finely crinoidal, medium-bedded, forms low ledge.	1	11
Jefferson City		
(5) Partly covered. Alternating float and poorly-exposed ledges of brecciated dirty brown dolomite, buff quartzitic sandstones which are white on interior fresh surface, and oolitic blue to white chert which is light brown on weathered surface.	26	2
(4) Dolomite, cream-colored to white ("cotton rock"), fine-grained, moderately resistant. In beds three to seven inches thick. Forms ledge	4	4
(3) Dolomite, buff, fine-grained, tough and resistant. Massive, but shows faint bedding in upper portion. Discontinuous partings of dull white tripolitic chert one-eighth inch to one-half inch thick. A few banded nodules of similar chert up to four inches thick and ten inches long, parallel to bedding.	9	6
(2) Dolomite, light buff, hard, fine-grained. Highly fractured and relatively non-resistant. Contains elliptical chert nodules averaging six inches in length. Nodules white on outer surface, concentric bands of blue and white chert on inner surface. Silty dolomite partings in bedding up to four inches thick, but very discontinuous.	4	2
(1) Dolomite, buff. Resistant and hard, conchoidal fracture. Beds six to eight inches thick. Con-		

	Feet	Inches
tains brecciated blue-gray chert, most of which is parallel to bedding and varies from razor edge to four inches in thickness. . . . . (concealed-road level)	5	1
Total exposed thickness	49	3

SW¼SW¼NE¼ sec. 19, T. 37 N., R. 24 W. beginning at base of southwest tip of spur and continuing northeast on southeast side of spur. (Jefferson City dips N. 40°-75° E. at 7°.)

Jefferson City	Feet	Inches
(7) Large tumbled blocks of dark brown Jefferson City dolomite lying on weathered surface. . . .	—	—
(6) Dolomite, dark brown on weathered surface, buff on fresh surface; thick-bedded to massive; exceptionally tough and resistant. Forms prominent ledge. Very irregular surface produced by low mounds averaging one-sixteenth inch in height and one inch in diameter. Contains chert breccia and bands. Brecciated chert blue and waxy, fragments up to two inches in maximum dimension. Opaline chert bands average one-half inch to one inch thick; thin chips of which are translucent.	7	1
(5) Dolomite, buff, fine-grained. Weathered edges of beds contain fine striae parallel to bedding. Beds average ten inches thick. Moderately resistant and hard. Contains cream-colored to brown chert nodules.	8	2
(4) Dolomite, cream-colored, thin-bedded, fine-grained, moderately hard, and resistant. Beds two to four inches thick. (Typical "cotton rock").	14	10
(3) Dolomite (partly concealed), deep buff, fine-grained, hard and resistant. Irregularly medium-bedded. Dirty gray chert breccia up to two inches in maximum demension.	5	4
(2) Dolomite, light buff to dirty gray, fine-grained. Resistant, weathers to subangular surface. Beds of upper portion one inch to one foot thick, lower portion more massive. Contains no chert.	10	8
(1) Dolomite, buff, fine-grained, resistant, hard and irregularly bedded. Contains brown to blue oolitic chert as both bands and nodules. Bands from one inch to thirteen inches thick. . (base concealed)	5	7
Total exposed thickness	51	8

Topographic Expression.—Typically, hillside outcrops of Jefferson City are more than half covered, but the formation can be recognized by chert and dolomite float and by ledges exposed at intervals. Most Jefferson City slopes are gentle enough to permit easy climbing. This type of topographic expression is created by beds of various resistance which weather to produce terraced slopes.

Paleontology.—Fossils are scarce in the Jefferson City, and gastropods were the only forms seen. The one locality where gastropods are relatively plentiful is in a subdued ledge of brown dolomite at the foot of the south-facing slope in the SE¼ NE¼ NW¼ SW¼ sec. 19, T. 37 N., R. 24 W. The low-spired gastropods from this ledge are tentatively identified as representatives of *Orospira* and *Ophileta*.

Stratigraphic Relations.—Bridge[38] reports a slight unconformity between the Roubidoux and overlying Jefferson City in portions of eastern Missouri. The Roubidoux-Jefferson City contact is concealed in the Weaubleau area.

Despite the great time represented by the unconformity between the Jefferson City and the overlying Mississippian rocks, the contact surface has negligible local relief and can safely be used as a datum for structural interpretations in the area. No evidence of channeling was seen, and local beveling of subjacent beds is negligible.

The northeastern portion of the Vista quadrangle is exceptional, for the Jefferson City surface is apparently one of considerable relief and various Mississippian formations lap onto Jefferson City highs. This unusual area is discussed in Chapter IV.

MISSISSIPPIAN SYSTEM

KINDERHOOKIAN SERIES

General Statement.—The stratigraphic subdivisions of the Kinderhookian used in this report were tested by field mapping and proved to be of sufficient local persistence and reliability for use in structural interpretation. Although lower Mississippian regional work now in progress[39] has suggested changes in nomenclature and relative ranks of Kinderhookian rock units, those units used in the original mapping of the quadrangle are retained for the present report. Because it is probable that both

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[38] Bridge, Josiah, Geology of the Eminence and Cardareva quadrangles. Missouri Bur. Geol. and Mines, 2d ser., vol. 24, p. 147, 1930.

[39] Beveridge, T. R., and Clark, E. L., Manuscript in preparation.

ranks and names of some of these units will be changed as a result of this regional study, the Kinderhookian nomenclature used in the following pages should be considered as tentative.

In the present report, the long and complicated history of Kinderhookian nomenclature is reduced to a minimum and reserved for the more extensive paper in preparation. Likewise, no discussion of the marked changes in thicknesses and facies of the Kinderhookian of western Missouri is included.

Name.—The present Kinderhookian series was considered to be Devonian (Chemung) until 1861 when Meek and Worthen[40] recognized that these strata are younger and named the Kinderhook group from exposures near Kinderhook, Illinois.

The Chouteau, Sedalia, and Northview formations were included in the Easley group of the Kinderhookian series in 1948.[41] The type section for this group is at Easley Station on the Missouri, Kansas and Texas Railroad in Boone County, Missouri.

It is believed that the Sylamore formation which is here considered to be of early Kinderhookian age underlies the Chouteau in the Weaubleau area. However, no exposures of this very thin sandstone and/or shale were found. Its possible existence is marked by a deep clay-filled re-entrant representing three to ten inches of covered interval between the uppermost exposed Jefferson City and the lowermost exposed Chouteau. This sandstone is present in adjacent areas.

Detailed Section.—The best exposure of the Kinderhookian is in the S½NE¼NE¼ sec. 13, T. 36 N., R. 24 W. This exposure begins in the bed of Weaubleau Creek 200 feet downstream from the concrete bridge and continues eastward up the east valley wall. (Plate I-B) The upper portion of the Kinderhookian is better exposed in the first west-flowing tributary to the north. The complete Kinderhookian, with the exception of the basal three feet or less of the Chouteau is exposed at this locality.

The section to the above given location is as follows:

Burlington	Feet	Inches
(14) Dolomite, brown, silty, calcitic. Forms low overhanging ledge.	2+	

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[40] Meek, F. B., and Worthen, A. H., Remarks on the age of the Goniatite limestone at Rockford, Indiana: Am. Jour. Sci., 2nd ser., vol. 32, pp. 167-178, 1861.

[41] Weller, J. M., and others, Correlation of the Mississippian formations of North America: Geol. Soc. America Bull., vol. 59, p. 101, 1948.

		Feet	Inches
Northview			
(13)	Shale, bule-gray, silty, soft, non-resident. Nodular, irregular bedding. Forms re-entrant beneath Burlington ledge.	6	11
(12)	Siltstone, dark buff on weathered surface, light buff on fresh surface. In beds six inches to one foot thick. Soft but somewhat resistant. Contains worm burrows (?) and cauda-galli markings. Separations of blue silty shale up to four inches thick.	2	9
(11)	Shale, blue-gray, silty, irregular bedding. Soft, non-resistant and partly covered. Abundant limonitic pellets on weathered slope.	5	6
	Total thickness of Northview	15	2
Sedalia formation			
(10)	Limestone, slightly silty and dolomitic, buff on weathered surface, gray on fresh surface. Fine-grained and forms hard, resistant rounded ledge. Contains abundant solitary corals, *Hapsiphyllum (Homalophyllites) calceolus* which stand out in relief on surface. Blue to gray fossiliferous nodular chert lenses four to six inches thick at top of formation.	8	3
(9)	Limestone, buff to gray, silty and dolomitic, rather massive. Hard and resistant with irregular bedding surface. Contains calcite-filled vugs up to six inches in diameter.	9	1
(8)	Limestone, buff on weathered surface, gray on interior. Sub-lithographic, thick-bedded, hard.	5	2
(7)	Limestone, dolomitic, fine-grained, massive, weathers to resistant rounded ledge. Buff on weathered surface, interior gray. White elliptical chert nodules up to six inches long.	4	1
(6)	Dolomite, massive rounded ledge. Buff, silty, gray on fresh surface. Contains vugs with calcite filling and white quartz rosettes which average two inches in diameter.	2	5
(5)	Limestone, buff on weathered surface, buff to gray on fresh surface. Very silty and grades laterally into siltstone. Laminated to medium-bedded, soft, non-resistant. Contains scattered small crinoid columnals.	4	3
	Total thickness of Sedalia	33	3
Chouteau formation			
(4)	Limestone, gray to light buff on weathered surface, darker on fresh surface, forms top bed of resistant ledge. Very silty at transitional		

		Feet	Inches
	contact with Sedalia. Finely crinoidal; columnal content inversely proportional to silt content.	1	7
(3)	Limestone, gray, crinoidal, thin-bedded, resistant. Contains nodular lenses of chert up to five inches thick which are waxy in luster and blue in color; outer portion relatively dull and white. Limestone is silty and argillaceous with shale partings but contains a local lens of finely crystalline, gray, massive slightly dolomitic limestone three feet thick and thirteen feet long.	4	2
(2)	Limestone, light buff to gray on weathered surface, gray on fresh surface. Finely crinoidal, thin-bedded with shale partings. Contains *Cleistopora typa* (Winchell) and several species of *Cryptoblastus* near down-stream terminus of exposure. Contains a few limonite and pyrite concretions up to one inch in diameter. Forms slight ledge.	3	9
(1)	Limestone, gray, highly crinoidal, slightly argillaceous, thick-bedded, resistant. Contains widely spaced continuous joints which intersect at angle of nearly ninety degrees.	2	6
	(Base concealed in stream bed)		
	Total exposed thickness of Chouteau	12	0

CHOUTEAU FORMATION

Name.—Swallow[42] originally defined the Chouteau formation at Chouteau Springs, Cooper County, Missouri, and divided it into upper and lower lithologic units.

In 1928 Moore[43] restricted the term Chouteau to include only the lower limestone unit of Swallow's Chouteau and named the upper cherty dolomites and limestones the Sedalia formation, after the town of Sedalia in Pettis County, Missouri.

In the present report, the Chouteau is considered to be the equivalent of the Chouteau (restricted) as defined by Moore. It appears to be a direct correlative of the Compton limestone of southwestern Missouri.

Distribution.—Significant exposures of the Chouteau are confined to the valleys of Weaubleau Creek, Little Weaubleau Creek,

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[42] Swallow, G. C., The second annual report of the Geological Survey of Missouri: Geol. Survey of Missouri, pp. 101-103, 1855.

[43] Moore, R. C., Early Mississippian formations in Missouri: Missouri Bur. Geol. and Mines, 2d ser., vol. 12, pp. 149-154, 1928.

South Fork Weaubleau Creek and to near the mouths of tributary streams. Locations of pertinent individual exposures are given in the discussion of detailed sections.

Thickness.—The basal and top contacts of the Chouteau are not visible at any one exposure in the area. The most accurate measurement of thickness was made in the NW¼SE¼NE¼-NE¼ sec. 27, T. 37 N., R. 24 W., on the west bank of the southwest-flowing tributary. Here the thickness is between 12 and 14 feet. At the Weaubleau Creek section of the Kinderhookian described on page 28, the Chouteau is at least 12 feet thick. This is probably a nearly complete thickness, for the lowest exposed beds correspond in lithology to the basal several feet at other exposures. Well records show from 10 to 15 feet of Chouteau, and an average thickness of 12 to 13 feet appears to be quite reliable.

There is little noticeable variation in stratigraphic thickness throughout the quadrangle, but thrust faulting has removed the upper portion of the Chouteau at some localities, and in a few exposures, the whole of this formation is missing.

Determined thicknesses vary slightly because the contact with the overlying Sedalia is transitional. As this contact is traced a short distance laterally, typical Chouteau limestone lithology can be seen grading horizontally into basal Sedalia silty dolomite or limestone. This transition facies does not exceed two to three feet in thickness, and structural interpretations based on the contact appear to be reliable.

Lithology.—The Chouteau is a gray, finely crinoidal, predominately thin-bedded, argillaceous, nodular limestone. Individual crinoid columnals in most samples average between two and three millimeters in diameter. On freshly broken surfaces, these columnals are sub-resinous in luster.

The clay content is concentrated in calcareous shale partings and laminae which alternate with slightly argillaceous, highly crinoidal limestone laminae and thin beds. Because the limestone beds become shaly laterally as well as vertically, weathered ledges commonly have nodular bedding and contain numerous minute ledges and re-entrants, so that in edge view these ledges have a washboard-like appearance.

Throughout the Weaubleau area, the upper two-thirds of the Chouteau is thinner bedded and more argillaceous than the lower third. The lower individual beds are approximately a foot thick and the shaly partings are subdued. Commonly these lower beds contain persistent joints which are especially conspicuous where basal Chouteau floors stream valleys.

Chert is not abundant in the Chouteau. However, lenticular, dark blue-centered fossiliferous chert with white to gray exteriors is present in the uppermost two to three feet of the Chouteau at the following localities:

(1) NW¼SE¼SE¼NE¼ sec. 12, T. 36 N., R. 24 W. at the base of the east bank of Weaubleau Creek.
(2) S½NE¼NE¼ sec. 13, T. 36 N., R. 24 W. on the east bank of Weaubleau Creek.
(3) NE¼NW¼NW¼SW¼ sec. 19, T. 37 N., R. 24 W. on the south side of lane, north of farm house.

This Chouteau chert is identical in apperance with that of the overlying Sedalia formation and it should be emphasized that these two formations cannot be differentiated solely by the character of the cherts.

Much of the silica in the Chouteau is apparently secondary and is represented by silicified crinoid columnals which are abundant in insoluble residues. Siliceous nodules and silicified patches and mottling are abundant throughout the formation.

At most localities, the lower thick beds are slightly glauconitic. Marble-sized nodules of pyrite are common, and in weathered exposures, the surrounding rock has been stained by oxidized products of this pyrite.

Detailed Sections.—The lithology of the Chouteau is so consistent throughout the quadrangle that detailed sections other than that given in the Kinderhookian section on page 28 would be superfluous. Other relatively complete Chouteau exposures are at the following localities:

(1) NW¼SE¼NE¼NE¼ sec. 27, T. 37 N., R. 24 W., at the base of a low east-facing bluff, a few yards south of fault line, on the down-thrown side.
(2) Both north and south from south line, sec. 25, T. 37 N., R. 24 W. in east-facing bluff of Weaubleau Creek.
(3) SW corner, SE¼SW¼NW¼ sec. 21, T. 37 N., R. 24 W., on the south bank of Weaubleau Creek, underneath and west from bridge.
(4) East-flowing tributary in SE¼NE¼ sec. 30, T. 37 N., R. 24 W. Also in the east-facing bluff north from the tributary mouth to the winding east-west road near north line of section 30.
(5) SW¼SW¼SW¼ sec. 22, T. 37 N., R. 24 W. on the south-facing slope on the north side of the east-west county highway.

Topographic Expression.—In stream beds, the Chouteau is exposed as a slabby pavement with minute waterfalls which increase in height as progressively lower beds are beveled. On gentle hill sides, low Chouteau ledges or slumped slabs three to four feet thick commonly interrupt the slopes which are in many cases otherwise covered. Overhanging ledges are formed on many of the unmantled bluff faces, and slight re-entrants are common at the base of the formation. These re-entrants between lowermost exposed Chouteau and uppermost exposed Jefferson City probably are an expression of the relatively non-resistant Sylamore sandstones and shales.

Paleontology.—The Chouteau is abundantly fossiliferous. However, many of the fossils are fragmentary. This is especially true of the crinoids, for although columnals constitute a large part of the rock, complete calyces are rare. Brachiopods are moderately abundant and well-preserved. Fragments of bryozoans and trilobites are less common. The best guide fossils for field mapping are the small species of the blastoid genus *Cryptoblastus*. Although this genus extends through the Kinderhookian and into the Osagean, no representatives were found in the overlying Sedalia formation, and but one from the Northview. *Cryptoblastus* is ubiquitous and serves to identify the Chouteau by its quantitative superiority over specimens in the younger formations of the quadrangle.

The small, easily recognized coral *Cleistopora typa* (Winchell) is a secondary aid in field mapping. Several specimens were found in the Northview but none in the Sedalia.

Stratigraphic Relations.—There is no evidence within the quadrangle of an unconformity between the Chouteau and the overlying Sedalia. The lithological contact is transitional, and the faunas are similar. The main faunal contrast is in the relative quantities of individual species common to the two formations.

SEDALIA FORMATION

Name.—In 1928, Moore[44] restricted the Chouteau as defined by Swallow[45] to include only the lower limestone unit of Swallow's Chouteau. Moore designated as the Sedalia, the upper

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

[45] Swallow, G. C., op. cit., app. 101-103, 1855.

cherty limestones and dolomites of Swallow's Chouteau. The Sedalia formation is named from the town of Sedalia in Pettis County, although the type section is at the Sweeney quarry near Clifton City in Cooper County.

Distribution.—Exposures of the Sedalia are nearly continuous along Weaubleau Creek and near the mouths of tributaries from the point where it enters the quadrangle to the vicinity of section 19, T. 37 N., R. 24 W. where thrust faulting has locally removed much of the Kinderhookian. From section 19 on north and west, the Sedalia is poorly-exposed because of the structural low which Weaubleau Creek crosses. More specific locations of good exposures are listed under the heading "Detailed Sections".

Thickness.—The average thickness of the Sedalia is between 30 and 35 feet as shown in the following field measurements:

(1) SW corner, SE¼SW¼SW¼NW¼ sec. 21, T. 37 N., R. 24 W., on the south bluff of Weaubleau Creek, 50 yards west of bridge: thickness, approximately 31 feet.

(2) SW¼NW¼SW¼ sec. 19, T. 37 N., R. 24 W. along southeast side of lane: thickness, 35 feet, 4 inches.

(3) SE¼SW¼NE¼NW¼ sec. 6, T. 36 N., R. 23 W. along the trail going south down the bluff of Weaubleau Creek: thickness, 32 feet, 9 inches.

(4) Center, SW¼ sec. 26, T. 37 N., R. 24 W. on the west bluff of Weaubleau Creek: thickness, approximately 41 feet. (True thickness may be less, for the top and bottom contacts used were nearly 150 yards apart horizontally.)

(5) S½NE¼NE¼ sec. 13, T. 36 N., R. 24 W., in the east bluff of Weaubleau Creek, 200 feet down-stream from concrete bridge: thickness, 33 feet, 3 inches.

The Sedalia is apparently quite uniform in thickness and differences in measurements are in large caused by slight dips and by the transitional nature of the Chouteau-Sedalia contact.

Lithology.—The Sedalia is a gray to buff limestone which in many localities is dolomitic and slightly silty. Nodular chert, quartz rosettes, and calcite-filled vugs are common throughout the formation. In general, the limestones and dolomites are finely crystalline and approach lithographic textures. Thick to massive beds are characteristic, especially in fresh exposures. However, weathering causes these beds to break down to flagstone dimensions and weathered silty beds are in some cases very shaly in appearance.

Although weathered exposures are commonly buff to brown in color, most of the fresh surfaces are gray and no section can be accurately described without chipping off the weathered exterior. The highest magnesium concentration is as a rule in the uppermost beds, and these beds, as a result, are in some cases buff in color, even on fresh surfaces. Where these uppermost beds are not dolomitic, nearly the entire section of Sedalia may consist of gray cherty limestone. The uppermost 5 to 10 feet are very silty in many exposures, but not in all.

Kaiser[46] differentiated three lithologic "zones" of the Sedalia: a "lower non-cherty zone", a "middle cherty zone" and an "upper non-cherty zone". His differentiation is not applicable in the Weaubleau area. Chert nodules and nodular chert lenses are common at the base and the top of the Sedalia, and in some localities are absent in the middle beds. For example, the Sedalia of the Kinderhookian section on Weaubleau Creek in the S½NE¼NE¼ sec. 13, T. 36 N., R. 24 W. contains the maximum amount of chert near the base and in the uppermost bed. The middle beds contain but little chert.

The chert of the Sedalia is characterized by its blue-black to grey waxy-lustered core and a white, sub-vitreous outer layer which is from one to two inches thick. Much of the chert is lenticular, but in a somewhat nodular form, and in some exposures it has a dumbbell shape in edge view. These chert lenses are from two to eight inches in thickness, and none was seen with a horizontal extent of over ten feet.

The chert breaks into polygonal columns normal to the bedding. Such fragments are commonly from two to four inches in diameter when found as residual float. Highly weathered fragments are dark buff and superficially resemble some of the Burlington cherts. These two cherts may be distinguished not only by the contrast of their fauna, but also by the relationship of the fossils to the matrix. Sedalia fossils, composed of chert, are so "fused" with their chert matrix that they cannot be separated by chipping; fractures extend through the fossils rather than around them. Many of the Burlington chert fossils (including casts) are delineated from their chert matrix by bound-

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[46] Kaiser, Charles P., Stratigraphy of lower Mississippian rocks in southwestern Missouri: Am. Assoc. Petroleum Geologists Bull., vol. 34, no. 11, pp. 2146-2150, 1950.

ing surfaces of weakness; when the matrix is struck with a hammer, fractures surround the fossils and excellent specimens are released intact.

The chert content of the Sedalia varies from a trace to a little over twenty-five per cent, but the average content is probably but slightly over ten per cent. Within intervals of chert concentration, nearly fifty per cent of the beds may be chert, although the chert percentage for the total section is much lower.

The basal two to five feet of the Sedalia, where weathered, are commonly thin-bedded to shaly and slightly silty. These beds are not as highly crinoidal as those of the underlying Chouteau.

Generalized physical contracts between the Chouteau and Sedalia are as follows:

CHOUTEAU	**SEDALIA**
1) Highly crinoidal.	1) Slightly to non-crinoidal.
2) Highly argillaceous with many shaly partings.	2) Some beds are argillaceous, but the clay content is not concentrated in shaly partings as in the Chouteau, but rather, is more evenly distributed to give argillaceous beds an earthy appearance.
3) Thin, nodular bedding.	3) Massive to very uneven bedding.
4) Most of silica represented by silicified patches and organic remains.	4) Much true chert and many quartz rosettes.
5) Weathers to dirty white or gray.	5) Commonly weathers to buff or brown.
6) Calcite-filled vugs are rare.	6) Calcite-filled vugs are common.
7) Weathers to form flat slabby beds. Many minute terraces where the beds are beveled by erosion or weathering.	7) Weathers to form rounded uneven surfaces.
8) The silt content is generally concentrated in shaly partings.	8) The greatest silt concentration is in the uppermost 10 feet, although these beds are not silty at all localities.

A lithologic variation of interest is the presence of a thin layer of finely crinoidal limestone at the very top of the formation, directly beneath the Northview formation. This layer, two to eight inches in thickness, is identical to the highly crinoidal beds of the Chouteau and can be distinguished only by stratigraphic relations and the presence of numerous specimens of the solitary horn coral *Hapsiphyllum (Homalophyllites) calceolus.* This bed is well-developed at the following three exposures:

(1) SE corner, NE¼SW¼ sec. 6, T. 37 N., R. 24 W.
(2) On the northeast side of road, southwest of bridge near the center of the north line, NW¼SW¼ sec. 21, T. 37 N., R. 24 W.
(3) On the east side of lane in the SW¼NW¼SW¼ sec. 19, T. 37 N., R. 24 W.

Detailed Sections.—One exposure of Sedalia has been described in the Kinderhookian section on page 28. This section contains the lowest percentage of chert of any exposure studied in detail. Otherwise it is very typical and is the best easily-accessible exposure known in the area.

East side of the lane in the SW¼NW¼SW¼ sec. 19, T. 37 N., R. 24 W.

Northview formation	Feet	Inches
(7) Shale, blue, silty.	2+	
Sedalia formation		
(6) Limestone, buff on surface, resinous color and luster on interior. Highly crinoidal and contains scattered specimens of *Hapsiphyllum (Homalophyllites) calceolus.*	0	5
(5) Limestone, slightly dolomitic, buff on weathered surface, gray on interior. Hard and resistant, fine-grained. Undulating bedding, beds average six inches in thickness. Weathers to rounded surface. Contains scattered blue chert nodules up to five inches in diameter.	12	4
(4) Concealed.	3	6
(3) Limestone, finely crystalline, buff on weathered surface, gray on interior. Resistant and hard. Beds vary from one to six inches in thickness. Blue nodular chert lenses up to seven inches thick and three feet long.	5	11
(2) Chert and limestone, interbedded (partly concealed). Blue chert nodules up to eight inches thick and three feet long, buff, gray, white and blue in color. Matrix of silty buff to gray sub-lithographic limestone.	8	8
(1) Limestone, buff, silty, dolomitic, thin-bedded and non-resistant. Contains less silty cream-colored partings three to six inches thick. Becomes shaly at base.	4	6
(Underlain by poorly exposed Chouteau limestone).	—	—
Total thickness of Sedalia	35	4

Other easily-accessible exposures of Sedalia are at the following localities:

(1) South side of Highway U. S. 54, 100 yards north of center of south line sec. 6, T. 36 N., R. 23 W. Here, the base of the Sedalia is not exposed. However, the contact with the overlying Northview is well-defined. Also the billowy weathered beds of the Sedalia are typically developed.

(2) Frisco Railway cut in the NE¼NE¼ sec. 19, T. 37 N., R. 24 W. The twenty-one feet of Sedalia exposed are predominantly gray fine-grained to sub-lithographic limestones with interbedded lenticular cherts.

(3) North side of Highway FAS "T" in the SE corner, NW¼NE¼NE¼ sec. 20, T. 37 N., R. 24 W. About ten feet of very cherty Sedalia limestone is exposed in the roadside cut.

(4) Frisco Railway cut in the SW¼SW¼SW¼ sec. 26, T. 37 N., R. 24 W. This exposure is nearly 150 yards in length. Nearly 30 feet of Sedalia is exposed, and the shaly partings are especially evident. The contact with the Northview is toward the south end. On the north end, the middle and lower beds are highly cherty. The contact with the Chouteau is not exposed.

(5) West bluff of the south - flowing stream in the NW¼SE¼NE¼NE¼ sec. 27, T. 37 N., R. 24 W. A nearly continuous section is exposed from the Jefferson City through the Chouteau and about 20 feet of Sedalia. Nodular chert forms approximately 20 per cent of the Sedalia. This is an excellent locality for studying Chouteau-Sedalia contrasts.

(6) On the west side of the steep-graded road in the NW¼NE¼NW¼SW¼ sec. 21, T. 37 N., R. 24 W. The Chouteau is exposed under the bridge, but the contact with the Sedalia is covered. Approximately 20 feet of cherty, fine-grained Sedalia is exposed between the Northview above and the covered interval below.

(7) East wall of South Fork Weaubleau Creek, at and upstream from the junction with Rock Creek in the SE¼NW¼NW¼ sec. 32, T. 37 N., R. 24 W. Nearly 30 feet of Sedalia are present. The contact with the Chouteau is below stream level, but Northview caps the bluff.

Topographic Expression.—Along major streams the Sedalia forms low bluffs, some of which are too steep for easy climbing. However, away from major stream valleys, Sedalia slopes are in general, gentle. Because it is overlain by the relatively non-resistant Northview, the top of the Sedalia is commonly marked by a structural terrace or bench. This bench is most pronounced in the southern part of the quadrangle where the Northview is thickest.

Paleontology.—The solitary horn coral *Hapsiphyllum (Homalophyllites) calceolus* (White and Whitefield) is a very useful guide fossil for field mapping. Although it is also found in the Chouteau, Northview, and Burlington, it is, with the exception of the Northview, much less abundant in these formations. It is abundant in the Sedalia, especially in the upper portion at and near the Northview contact. These corals stand out in clusters in relief on rounded surfaces of the Sedalia. These fossils made it possible for the writer to distinguish the upper fine-grained limestones of the Sedalia from fine-grained limestones of the Burlington in areas of extensive faulting and poor exposures.

Locally, brachiopods form a coquina of thin-bedded limestone in the upper Sedalia. However, the bulk of the brachiopod fossils are found in the cherts. Because the chert fossils are intimately fused with their matrix, specimens ordinarily cannot be studied in three dimensions. No one locality is particularly fossiliferous and collections represent a great number of exposures.

A contrast between the faunas of the Sedalia and Chouteau lies in the numerical superiority of *H. calceolus* and the brachiopods in the Sedalia and the abundance of *Cryptoblastus* species and crinoid remains in the Chouteau.

Stratigraphic Relations.—There is no local evidence of unconformity either above or below the Sedalia. The Chouteau contact is transitional, and the Northview contact, although in general, well-defined, appears to be conformable. The dark blue-centered cherts, typical of the Sedalia, are present, although in minor amounts, in the upper Chouteau. The Chouteau-like facies of finely crinoidal limestone in uppermost Sedalia beds further suggests the close relationships of the two formations.

The fauna of the Chouteau and Sedalia appear similar and to represent facies change rather than any time interval between the two formations.

NORTHVIEW FORMATION

Name.—In 1855, Swallow[47] recognized the "Vermicular Sandstone" (present Hannibal) in central and eastern Missouri. He considered the lithologically similar beds of southwestern Missouri in Polk and Greene counties to be a continuation of the

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[47] Swallow, G. C., op. cit., pp. 101-105, 1855.

Hannibal. Weller[48,49] studied the fauna of the "Vermicular Sandstone" of southwestern Missouri in 1899, and in 1901, proposed the name Northview sandstone and shale for exposures at Northview in Webster County, Missouri.

Shepard[50] did not recognize the name Northview, and considered this formation an extension of the Hannibal.

Moore[51] accepted the Northview and the term is now in good standing, although Branson[52] considers it but a member of the Chouteau.

Distribution.—In a map prepared by J. G. Grohskopf and published by Branson,[53] the Northview is shown as extending from the extreme southwestern corner of Missouri to Saline and Pettis counties in west-central Missouri.

Although several sections have been described previously in the Weaubleau area, every description fails to differentiate the Northview. The Northview is called "Sedalia" in Stop 19 of the Kansas Geological Society Field Conference[54] (SW¼SE¼ sec. 6, T. 36 N., R. 23 W.).

Both Branson[55] and Kaiser[56] described the same (?) section five miles north of the Weaubleau quadrangle (near Corbin) in the NE¼NE¼ sec. 8, T. 38 N., R. 24 W., St. Clair County (Iconium quadrangle). They also failed to differentiate six feet of Northview siltstone and shale. Branson includes this formation in the Chouteau (unrestricted) and Kaiser places it in the Sedalia at this locality. Branson,[57] in describing an exposure of Northview near Brighton, in southern Polk County, says:

> "This is the northernmost outcrop where Northview sandstone and Northview shale have been found in the same section."

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[48] Weller, Stuart, Kinderhook faunal studies; I. The fauna of the Vermicular Sandstone at Northview, Webster Co., Missouri: St. Louis Acad. Sci. Trans., vol. 9, pp. 9 and 51, 1899.

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

[50] Shepard, E. M., Key to the rocks and geological horizons of Greene County, Missouri: Bull. Bradley Geol. Field Sta., Drury oll., vol. 1, pt. 1, pp. 53-57, 1904.

[51] Moore, R. C., op. cit., pp. 122-127, 1928.

[52] Branson, E. B., The geology of Missouri: Univ. of Missouri Studies, vol. 19, no. 3, p. 193, 1944.

[53] Branson, E. B., op. cit., p. 183, 1944.

[54] Moore, R. C., and others, Sixth Annual Field Conference, Kansas Geological Soc., p. 33, 1932.

[55] Branson, E. B., Stratigraphy and paleontology of the lower Mississippian of Missouri: Univ. of Missouri Studies, vol. 13, no. 4, p. 13, 1938.

[56] Kaiser, C. P., op. cit., p. 2145, 1950.

[57] Branson, E. B., op. cit., pt. I, p. 10, 1938.

Both Northview siltstone and Northview shale are present together in numerous individual exposures within the Weaubleau quadrangle nearly 50 miles to the north of Brighton.

The Northview is partly exposed on both valley walls of Weaubleau Creek east and south from the town of Gerster to the southeast corner of the report area. Although it was without doubt present over all of the quadrangle, thrust faulting has completely eliminated appreciable areas of Northview in the northwestern portion of this quadrangle. Also, regional thinning to the north reduces the thickness to between two and three feet in the northern limits of the Weaubleau area and natural exposures are rare. Because natural exposures of the Northview are generally poor, the formation is best studied in artificial cuts.

Lithology.—In the type area to the south, the Northview consists of an upper siltstone and a lower shale member. The two members differentiated in the more southerly portion of Missouri have no well defined stratigraphic position in the Weaubleau area. Quantitatively, siltstones are more important in the upper portion, but they are not persistent and grade both vertically and laterally into shales.

The siltstones are cream-buff to reddish-brown. These latter colors are especially well developed in areas which have been burned over by prairie or forest fires. Cauda-galli or "rooster tail" markings of plant (?) origin are distinctive but not omnipresent in the thicker siltstone beds. Likewise, worm burrows (?) and external molds are diagnostic but not found in all exposures of the siltstone.

The siltstone beds are generally soft but comparatively resistant, and weather out as blocks on grass-covered slopes. Weathering has in some cases resulted in case hardening of the siltstones and produced especially tough slabs. These slabs have retained their porosity within the outer shell and when struck with a hammer, produce a hollow ringing sound. Many such slabs floor the bed of South Fork Weaubleau Creek in the NW¼SW¼NW¼ sec. 5, T. 36 N., R. 24 W., 150 yards upstream from a ford crossing.

Dolomitic siltstone beds are likewise much harder and more resistant than the unweathered and non-calcareous siltstones. Such dolomitic beds are well-exposed in the south central part of the SE¼SW¼SE¼ sec. 30, T. 37 N., R. 24 W., in the bed of the east-flowing stream. Here the Northview was competent enough to resist the stresses of low-angled thrusting and overlies younger Burlington limestone.

Shales and shaly siltstones, where not covered, are characteristically gray to light blue or green in color. Limonite and hematite pseudmorphs after both pyrite and marcasite weather out on shaly slopes as twinned cubes and cockscomb clusters. Pellets of limonite and concretionary silica which average a little less than a centimeter in maximum dimension are also particularly abundant on these slopes.

In the NE¼SE¼SE¼NE¼ sec. 31, T. 37 N., R. 24 W., on the south bank of the east-flowing stream, poorly-exposed silty Northview shales contain thin discontinuous lenticular plates of limestone. These light buff limestones are from two to three inches thick, non-fossiliferous, and appear to be secondary in origin.

Similar flat plates of concretionary limestone one-fourth to one-half inch thick have weathered out of Northview shales on the south side of Highway U. S. 54 in the SW¼SW¼SE¼ sec. 6, T. 36 N., R. 23 W.

Detailed Sections.—One detailed section of the Northview is described in the Kinderhookian section of page 28.

Low ledge on south side Highway U. S. 54, SE¼SW¼NW¼NW¼ sec. 7, T. 36 N., R. 23 W.

Burlington formation	Feet	Inches
(6) Limestone, dolomitic, brown, silty.	3+	
Northview formation		
(5) Shale, gray, silty, soft, non-resistant. Limonite pellets on weathered surface.	3	11
(4) Siltstone, light-buff. Soft but resistant and forms ledge. Contains cauda-galli markings and minute worm burrows (?). In beds up to 21 inches thick. Grades laterally into thin-bedded siltstone and shale.	1	9
(3) Shale, blue-gray, locally clay-like. Soft and non-resistant.	1	10
(2) Siltstone, light buff. Soft but resistant. Weathers out as large blocks up to nearly two feet thick. Contains numerous pelecypod molds and casts.	2	2
(1) Siltstone, gray, thin-bedded, non-resistant. Blocky fracture.	2	1
(Concealed)	—	—
Total exposed thickness of Northview	11	9

Other good exposures of the Northview are at the following localities:

(1) Both sides of Highway U. S. 54 in the W½SW¼SE¼ sec. 6, T. 36 N., R. 23 W. Here a complete section is exposed and upper and lower contacts are sharp.

(2) Stream bed of South Fork Weaubleau Creek in the NW¼SE¼SE¼ sec. 7, T. 36 N., R. 24 W. Upstream from Highway U. S. 54 bridge. Soft but resistant siltstone beds with numerous cauda-galli predominate in this exposure. The upper and lower contacts are concealed.

(3) NW¼SW¼SE¼SW¼ sec. 28, T. 37 N., R. 24 W. where Rock Creek crosses anticline. A complete section of shale and shaly siltstone is exposed in the north bank of the creek.

(4) North side of Highway FAS "T" in the SW¼NE¼NW¼ sec. 22, T. 37 N., R. 24 W. A complete section is also present here. Because of the gentle slope, the exposure has considerable areal extent.

(5) NW¼NE¼NE¼SE¼ sec. 13, T. 37 N., R. 25 W., on both sides of road. Because of thrust faulting, Northview overlies Burlington. The medium-bedded siltstone facies is dominant at this exposure. To the northeast, 500 yards downstream from the concrete slab across Tanyard Branch, the Northview exposed in the south bank of Tanyard Branch is a blue-gray silty hackly shale.

(6) NW Corner, NE¼NE¼SW¼ sec. 23, T. 37 N., R. 24 W. in bed of south-flowing stream. Both siltstones and shales are present. The contact with basal Burlington silty dolomitic limestone is clearly and sharply exposed on the east bank of the stream.

(7) Frisco Railway cut in the E½SW¼SW¼SW¼ sec. 26, T. 37 N., R. 24 W. Silty shale predominates but varies laterally to a thin-bedded siltstone facies. The majority of the siltstone is in the lowermost four feet of Northview. Both upper and lower contacts are well-exposed.

Thickness.—The Northview reaches its maximum thickness of between 70 and 80 feet to the south, in Polk, Greene, Dade, and Webster counties. Regional thinning to the north is reflected in the Weaubleau area as shown on the Isopach Map (Plate VIII). The thickest measured section of 15 feet, 2 inches is in the NE¼SE¼NE¼NE¼ sec. 13, T. 36 N., R. 24 W. The thinnest exposure not believed to have been affected by thrust faulting is near the center of the south line, SE¼SW¼NE¼ sec. 1, T. 37 N., R. 25 W., in the south sloping ravine. The concealed distance between uppermost exposed Sedalia and lowermost exposed Burlington is 5 feet 2 inches.

As shown on the Isopach Map, thrust faulting has thinned and completely eliminated the Northview over part of the report area.

Topographic Expression.—The Northview is expressed topographically by gentle slopes. These slopes are grassy, and in many localities the soil is relatively light in color. Seeps and gullies are not infrequent along Northview slopes, and the soil usually is moist after lower and higher portions of the slope have dried out.

In the eastern and southern portion of the quadrangle, blocks of siltstone weather out and form valuable guides in mapping this poorly exposed formation. In the western portion, both the siltstone beds and the formation as a whole are thin, and float is so scarce that the Northview is difficult to map.

Paleontology.—Three "fossils" are especially useful in field mapping of the Northview. They are the worm (?) burrows and molds *Scalarituba missouriensis* Weller and *S. welleri* Branson, and the plant (?) fossils *Spirophyton,* more commonly referred to as cauda-galli or "rooster tails".

Pyritic, limonitic and siliceous fossils are locally abundant on weathered slopes, but are in general poorly preserved as internal molds. Small brachiopods and gastropods predominate on these slopes, and pelecypod remains are not uncommon in the thick-bedded siltstones.

The most fossiliferous localities of the area are as follows:

(1) Southwest-facing slope in the SW¼SW¼SE¼ sec. 6, T. 36 N., R. 23 W. on the southeast side of Highway U. S. 54. This is the most fossiliferous exposure of the area. The majority of the fossils are limonitic brachiopods and gastropods.

(2) Low ledge on the south side of Highway U. S. 54 in the SE¼SW¼NW¼NW¼ sec. 7, T. 36 N., R. 23 W. Pelecypod casts and molds are fairly abundant in the thick-bedded siltstones.

(3) North side of Highway FAS "T" in the SE¼NW¼SE¼ sec. 22, T. 37 N., R. 24 W. Several pelecypod remains and a trilobite fragment were found in the reddish-brown siltstone float.

Stratigraphic Relations.—The uppermost beds of the Northview apparently overlie the Sedalia throughout west-central Missouri. To the south and east of the Weaubleau quadrangle, a Northview facies appears within the Sedalia as well as upon it. The interfingerings of Northview become increasingly dominant over the Sedalia facies as traced to the southeast, and in northern Polk County, ten miles southeast of the report area, the Sedalia facies is absent and the thickness of the Northview is approximately equal to the combined thickness of Northview and Sedalia in St. Clair and western Hickory counties.

The Weaubleau area is very close to the area of Northview-Sedalia interfingering; four miles south of the mapped area, almost a third of the Sedalia is Northview facies. Such interfingering of Sedalia cherts and dolomites with Northview siltstones and shales is well-exposed along Highway FAS "E" where it climbs the south valley wall of Panther Creek in the SW¼NW¼ sec. 2, T. 35 N., R. 24 W., Hickory County.

This interfingering demonstrates the close relationships of the two formations, and suggests that deposition was continuous and that the Northview represents a facies change from limestones to siltstones and shales.

OSAGEAN SERIES

BURLINGTON FORMATION

Name.—Swallow[58] in 1855 recognized the "Encrinital limestone" in Missouri. Owen[59] had previously designated this formation at Burlington, Iowa, as the "Encrinital group of Burlington". In 1857 Hall[60] proposed the shorter name "Burlington limestone". This name has endured and subsequent workers have established more refined boundaries and faunal zones in the Burlington.

Distribution.—Burlington limestone forms the bulk of the outcrop area and is at least partly exposed in nearly all the major stream and tributary valleys.

Lithology.—Much of the Burlington in the Weaubleau area is highly and coarsely crinoidal limestone, white to gray in color on both fresh and weathered surfaces. Some beds, especially those which are dolomitic, are buff to brown. The formation varies from thin to massive-bedded. In general, bedding is distinct and rather even. The lithology is generally uniform, and few persistent lithologic sub-units can be differentiated.

Within the area, the upper part, at least 100 feet from the base, is highly cherty. Such cherty beds are especially evident in the adjacent portions of sections 1 and 2, T. 37 N., R. 25 W. The large amounts of residual Burlington chert throughout the area demonstrate the high chert content of the Burlington in its original thickness.

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[58] Swallow, G. C., op. cit., pp. 97-100, 1855.

[59] Owen, D. D., Description of Carboniferous rocks in Iowa: Geol. Survey Wisconsin, Iowa and Minnesota, pp. 90-140, 1852.

[60] Hall, James, Observations upon Carboniferous limestone of Mississippi Valley: Am. Assoc. Adv. Sci. Proc., vol. 10, pt. 2, pp. 53-57, 1857.

Cherts of the Burlington are variable in color and form. They are, to a great extent, highly fossiliferous, and thus easily identified. Intense weathering produces dull tripolitic cherts which are especially porous if highly fossiliferous.

Portions of the Burlington are locally finely crystalline to lithographic, and are difficult to distinguish from the Sedalia in isolated unfossiliferous exposures. Thin-bedded, finely crinoidal Burlington can likewise be easily confused with the Chouteau on the basis of lithology alone. In general, the Burlington limestone is more coarsely crinoidal and less argillaceous than the Chouteau. Also, fresh surfaces of crinoidal Burlington are, because of the presence of purer calcite in columnals, lighter in color than the resinous-lustered crinoidal Chouteau.

Basal Burlington Beds.—Brown, silty, dolomitic limestone beds lying above the Northview and below typical white to gray crinoidal Burlington are, in this report, considered to be basal Burlington.

These beds have been the subject of contention in other areas. Many early geologists included these beds in the Burlington and were supported by Springer[61] who said (using Chouteau in the unrestricted sense):

> "The upper part of what in Missouri is called the Chouteau is the same thing as the lower Burlington beds in Iowa."

The present writer has studied a number of sections described by Moore[62] and found that he includes the beds in question in the Sedalia.

Branson[63] considers these beds to be Burlington, for he says:

> "Moore (1928) united the upper part of the Chouteau and the lower part of the Burlington into a member which he called the Sedalia."

Branson[64] mentions a quarry "about 25 miles northeast" of one of Moore's sections of the Sedalia and says:

> ". . . . the typical white lower Burlington appears at one end of the quarry and the brown at the other end of the quarry, the same beds being involved in both. It is very common to have the lower 20 to 25 feet of Burlington vary from white to brown in short distances, and there seems to be no reason for separating the brown from the regular Burlington."

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[61] Springer, Frank, The Crinoidea Flexibilia: The Smithsonian Insttiution, Publ. 2501, p. 196, 1920.

[62] Moore, R. C., op. cit., 1928.

[63] Branson, E. B., op. cit., p. 199, 1944.

[64] Branson, E. B., op. cit., p. 202, 1944.

At Stop 19 of the Kansas Geological Society,[65] the description of an exposure in the SW¼SE¼ sec. 6, T. 26 N., R. 22 W., identifies as "Sedalia" seven feet of strata that the writer considers to be basal Burlington; the section includes the underlying Northview in the "Sedalia".

Kaiser[66] described but one section in the Weaubleau quadrangle, and this does not go below the more typical gray Burlington. However, throughout his report, he apparently agrees closely with Moore and considers the brown beds above the Northview to be Sedalia.

The brown beds are considered to be basal Burlington by the present writer for the following reasons:

(1) The faunas (especially the crinoids) are typical of the lower Burlington.
(2) These beds are locally highly and coarsely crinoidal.
(3) Thicknesses of these beds vary greatly laterally, yet they appear to be conformable with and grade both vertically and horizontally into more typical Burlington.
(4) This lithology is repeated vertically within the gray to white highly crinoidal Burlington.
(5) In the course of a regional study of the lower Mississippian, the writer has seen none of the blue-gray chert so common to the Sedalia in these brown beds.

The following crinoid fauna was identified by Laudon[67] from collections from these beds:

Actinocrinites n. sp.
Agarocrinus cf. *A. planoconvexus* (Hall)
Batocrinus sp.
Cactocrinus clarus (Hall)
Cactocrinus n. sp. aff. *C. multibrachiatus* and *C. proboscidialis*
Cactocrinus n. sp.
Eutrochocrinus n. sp. aff. *E. Christyi* (Shumard)
Platycrinus sp.

One specimen represents a new genus and species of form originally described as *Batocrinus curiosus* Rowley. However, this specimen although closely related to *Batocrinus* is considerably different and probably an *Actinocrinites*.

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[65] Moore, R. C., and others, op. cit., p. 33, 1932.
[66] Kaiser, C. P., op. cit., pp. 2133-2155, 1950.
[67] Laudon, L. R., Written communication dated May 3, 1949.

Laudon states that this fauna comes from a very low portion of the Burlington which was not generally available to early collectors. Thus most of the specimens represent new species. Collections were made from the following three localities where basal Burlington beds are well-exposed and sufficiently weathered so that the fragile calcitic specimens could be removed:

(1) SE¼SE¼SE¼NW¼ sec. 12, T. 36 N., R. 24 W., on the southeast side of Highway U. S. 54 on the southwest bank of southeast-flowing stream from 10 to 20 yards downstream from the highway culvert; from 3 to 8 feet above the Northview-Burlington contact.

(2) The north bank of Rock Creek where it crosses a small anticline in the NW¼SW¼SE¼SW¼ sec. 28, T. 37 N., R. 24 W.; from one to three feet above the Northview-Burlington contact.

(3) Ditch on the south side of Highway U. S. 54 in the NW¼NW¼SE¼SE¼ sec. 7, T. 36 N., R. 24.; approximately 5 to 15 feet above concealed Northview-Burlington contact.

Fossils common to indisputable Burlington, such as brachiopods, zaphrentoid corals, and low spired gastropods of the genus *Straparolus* are common down to the Northview contact.

Lithology of Basal Burlington.—The brown, silty dolomitic limestone beds of the basal Burlington vary from one to fifteen feet in thickness and lateral variations in thickness are pronounced. They weather out as large, resistant rounded to angular slabs which slump onto the underlying Northview siltstone and shale. Vugs and joints filled with calcite are common, and where solution has removed this calcite, rough pitted surfaces are developed. Although these beds superficially resemble some beds of the Sedalia, calcite is in general more thoroughly distributed throughout the basal Burlington and commonly imparts a continuous sheen to fresh surfaces.

The lowermost Burlington is not as irregularly-bedded as the Sedalia, and where weathering has attacked the usually massive beds, the even bedding is obvious. However, radiating columnar aragonite concretions are not uncommon, and in some localities produce a nodular bedding.

The silt of the basal Burlington is identical in microscopic appearance with that of the upper Sedalia and Northview. Therefore, the Kinderhookian-Osagian break must be drawn within the vertical range of silt in studying insoluble residues of well cuttings. Original cuttings are much more diagnostic in determining this boundary, for in general, the contrast between Northview siltstones and shales and basal Burlington silty dolomitic limestone is sharp.

Detailed Sections of Basal Burlington.—Northeast corner of Gerster on the north side of east-west road at the junction with road to south. NE¼SE¼NE¼NW¼ sec. 21, T. 37 N., R. 24 W.

(Covered)

Burlington formation		Feet	Inches
(8)	Limestone, gray, coarsely and highly crinoidal; medium-bedded. Alternately covered, but grades into silty buff limestone in lower three feet.	6	9
(7)	Limestone, buff, slightly dolomitic and silty; moderately and coarsely crinoidal. In single even bed.	0	9
(6)	Shale, buff, like (2).	0	1
(5)	Limestone, brown, dolomitic and silty; moderately crinoidal. In single even bed.	0	8
(4)	Shale, buff, like (2).	0	3
(3)	Dolomite, brown, silty; impregnated with calcite along minute joints and fractures; slightly crinoidal. In single even bed.	0	6
(2)	Shale, buff to gray; very calcareous and silty. May represent decomposed silty dolomite.	0	2
(1)	Dolomite, buff, silty, slightly crinoidal, laterally weathers to a shaly bed. Single, even bed		

(Underlain by silty Northview shale which forms re-entrant)

2) Limb of small anticline in the south bank of Tanyard Branch in the NW¼SE¼SE¼NE¼ sec. 13, T. 37 N., R. 25 W. (Plate I-A)

(Concealed)

Burlington formation		Feet	Inches
(5)	Limestone, gray, thoroughly and coarsely crinoidal; flaggy bedding.	4	7
(4)	Limestone, buff, thoroughly and coarsely crinoidal, thin-bedded.	2	1
(3)	Limestone, buff, slightly dolomitic and silty, moderately and coarsely crinoidal, also contains brachiopod and coral remains. In single even bed, but tends to weather to thin beds.	0	8 - 15
(2)	Limestone, buff, shaly, dolomitic, silty.	0	3 - 8
(1)	Dolomite, brown, silty, moderately crinoidal; impregnated with calcite. Single even bed forms even contact with Northview below.	2	2

(Underlain by silty Northview shale)

Other good exposures of basal Burlington not previously mentioned are as follows:

(1) Both sides of cut in Highway U. S. 54, center NE¼SE¼SW¼ sec. 6, T. 36 N., R. 23 W. Approximately five feet of massive, fossiliferous brown dolomite is well-exposed. The contact with the underlying Northview is sharp. Basal Burlington in contact with the Northview is intermittently exposed along this highway for slightly over a quarter of a mile on either side of this exposure.

(2) North bluff of Weaubleau Creek on the west side of a small north-working gulley in the NE¼SW¼NE¼NW¼ sec. 7, T. 37 N., R. 24 W. Twelve feet of massive pitted brown slightly fossiliferous basal Burlington dolomite forms the crest of this bluff. One to two feet of Northview is poorly exposed a few yards below the fork in the gully.

(3) Bed of north-flowing stream in the NW¼NE¼NW¼ sec. 1, T. 36 N., R. 24 W. Fossiliferous brown dolomite and dolomitic limestone is continuously exposed for 100 yards upstream and downstream from the north line of section 1. Calcite-filled vugs are abundant.

Thickness of Burlington.—The thickest Burlington is in the NW¼ sec. 1, T. 37 N., R. 25 W. where 153 feet were measured. Pennsylvanian rocks lie unconformably on the deeply eroded Burlington, and in some exposures, the whole of the Burlington has been eroded away so that Pennsylvanian rocks lie directly on the Kinderhookian.

Because the lithology of the basal brown silty beds of the Burlington is transitional into typical gray Burlington limestones, measured thicknesses of these basal beds are variable. However, the average is approximately ten feet.

Topographic Expression.—Topographic expressions of the Burlington are variable. Steep cliffs are formed on the convex sides of stream bends and gentle slopes where weathering predominates over erosion. Where the Northview is thick, reentrants or structural benches are not uncommon at the base of the Burlington.

Paleontology.—In this report, no detailed study of the fauna, other than the crinoids of the basal beds, has been made. Crinoid columnals are abundant and generally diagnostic, and well-preserved calyces are not unusual. Brachiopods, blastoids, corals, and low-spired gastropods form the bulk of the remaining fossils.

Stratigraphic Relations.—The Burlington-Northview contact is even and sharp. The silty basal beds of the Burlington may represent a reworking of the Northview. Although there is no strong physical evidence within the mapped area of an erosional unconformity, what may be such an unconformity is exposed in the Vista quadrangle (Chapter IV). The major Kinderhookian-Osagean contrast is faunal, especially in the evolution of the crinoids. The problem of Burlington conglomerates resting on Ordovician is discussed in Chapter IV.

PENNSYLVANIAN SYSTEM

DESMOINESIAN SERIES

CHEROKEE GROUP

Name.—Classifications of Pennsylvanian rocks have been revised so frequently that it is considered impractical to give a detailed history of the nomenclature in this report.

The name Cherokee[68] has been generally accepted since its introduction to describe rocks in Cherokee County, Kansas. Only two units of the Cherokee, the Dederick subgroup (undifferentiated) and the overlying Graydon formation crop out in the Weaubleau area.

DEDERICK SUBGROUP (UNDIFFERENTIATED)

Name.—The Dederick[69] was originally designated as a shale member of the Cherokee formation and named for exposures in the vicinity of Dederick, Vernon County, Missouri.

In Missouri, it is now regarded[70] as a subgroup of the Cherokee group. Regional correlations are insufficient to determine positively the position of the Weaubleau area Dederick within the subgroup.

Distribution.—Exposures are sufficiently continuous to suggest that the Dederick floors the entire length of the Coon Creek valley floor in the extreme western part of the report area. Two other exposures outside of this stream valley are described under the heading **Lithology**.

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[68] Haworth, Erasmus, and Kirk, M. Z., The Neosho River section: Kansas University Quarterly, vol. 2, pp. 104-115, 1894.

[69] Greene, F. C. and Pond, W. F., The geology of Vernon County: Missouri Bur. Geol. and Mines, 2d ser., vol. 19, pp. 40-44, 1926.

[70] Searight, W. V.: Oral communication.

Lithology.—Much of the Dederick is a dark-colored shale, in some localities carbonaceous to coal bearing, in others micaceous and silty.

The only locality where an appreciable thickness of the Dederick shale is exposed in place is in Tanyard Branch just west of the center of sec. 24, T. 37 N., R. 25 W. Six feet of dark gray to green silty shale is exposed between the bottom of the stream and the overlying Graydon sandstone. This shale has a nodular bedding, is highly micaceous, and contains pyrite.

Plates of black, micaceous Dederick shale from one-fourth to one-half inch thick are abundant as float in Coon Creek directly west of the town of Collins. The source of this float is not known, but the shale has not traveled far, for the plates are very angular and are concentrated locally. The two major concentrations of this float are at the northwest corner of sec. 18, T. 36 N., R. 24 W., and 200 yards upstream from this point. Similar float concentrations are in Coon Creek on both sides of the south line, SW¼NE¼NE¼ sec. 1, T. 36 N., R. 25 W.

Black shale, carbonaceous and fissile to coaly, forms a large part of the dump heap from an abandoned coal prospect shaft on the south side of Coon Creek in the NE¼SW¼SW¼SW¼ sec. 36, T. 37 N., R. 25 W. No data are available on this caved-in prospect shaft other than the fact that it was sunk near the turn of the century.

A sandstone of uncertain position forms the west bank of Coon Creek in the SE¼SE¼NE¼NE¼ sec. 12, T. 36 N., R. 25 W. The five feet of micaceous sandstone exposed is thin-bedded to laminated with carbonaceous partings. Iron oxide has produced red to brown colors and is also present as small limonitic concretions. The correlations of this exposure are uncertain because it contains sandstone concretions or fossils suggestive of *Conostichus broadheadi*.[71] However, the type *Conostichus* beds are younger than the Graydon, which overlies the Dederick.[72,73]

It is not known whether the *Conostichus*-like beds on Coon Creek are correlative with the *Conostichus* beds of Vernon County; the form may not be a fossil and therefore may not be diagnostic, or it may have a greater range than now believed.

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[71] White, C. D., Fossil flora of the lower Coal Measures of Missouri: U. S. Geol. Survey Mon. 37, pp. 12-13, plate 2, 1899.

[72] Greene, F. C. and Pond, W. F., op. cit., p. 47, 1926.

[73] Searight, W. V., Oral communication.

These sandstones may represent either Dederick or Graydon or may be transition beds between the two.

Thickness.—The thickness of the Dederick is not known, for the base is concealed. The maximum exposed thickness is six feet.

Topographic Expression.—Typically the Dederick floors broad valley flats of present streams whose valleys were apparently originally carved in early or pre-Dederick time and later re-excavated in Dederick fill. Coon Creek and Tanyard Branch are excellent examples of this type of valley, for although their upper valley walls are composed of Mississippian rocks, the valley floors are formed by Dederick and Graydon rocks.

Paleontology.—Although the carbonaceous beds of the Dederick are composed of plant remains, these remains are so fragmental that they are generally unidentifiable.

Spores were obtained from low-grade Dederick coal exposed on the waste heap of an abandoned coal test in the NE¼NW¼-NW¼ of sec. 28, T. 37 N., R. 24 W. These spores were studied by Mart P. Schemel of the Missouri Geological Survey and tentatively correlated with upper (?) Dederick subgroup spores from Horse Creek at Milford, Barton County, Missouri.

Stratigraphic Relations.—The Dederick is unconformable on deeply eroded Mississippian rocks. The relations of the contact with the overlying Graydon are not known.

GRAYDON FORMATION

Name.—The "Graydon Springs sandstone and conglomerate" originally[74] comprised Pennsylvanian rocks exposed at Graydon Springs in Polk County, Missouri, and was extended for use in Lawrence, Dade, and Greene counties, Missouri. The name was later shortened to Graydon by Shepard.[75,76]

The Missouri Geological Survey now considers the Graydon to be equivalent to the lower Clear Creek[77,78] of Vernon County,

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[74] Winslow, Arthur, Lead and zinc deposits: Missouri Geol. Survey, vol. 7, pt. 2, pp. 422-425, 1894.

[75] Shepard, E. M., A report of Greene County: Missouri Geol. Survey, 1st ser., vol. 12, p. 124, 1898.

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

[77] Broadhead, G. C., Report on the Geological Survey of the State of Missouri, including field work of 1873-1874: Missouri Geol. Survey, pp. 69, 100, 122, 1874.

[78] Greene, F. C., and Pond, W. F., The geology of Vernon County: Missouri Bur. Geol. and Mines, 2d ser., vol. 19, pp. 44-47, 1926.

Missouri. However, the name Clear Creek is not valid, for it is preoccupied by a Devonian limestone.[79]

Distribution.—The Graydon extends discontinuously over a large part of southwestern Missouri. It caps much of the flatter area of upland "prairies" in the Weaubleau quadrangle and is the dominant exposure in the western part of this area. In general, it is poorly exposed. Much of the Graydon was mapped on the evidence of sandy or iron-stained soils.

The most continuous exposures are along both sides of Missouri Highway 13 from the SW¼ sec. 31, T. 37 N., R. 24 W., northward to beyond the town of Vista.

Lithology.—Conglomerates, sandstones, and clays or shales are important facies of the Graydon. Some of the conglomerates are the result of reworking of pre-existing rocks, but many of the angular fragments appear to be unabraded residual surface material cemented together. Although the particle size averages within the gravel range, fragments up to nearly a foot in diameter are not unusual. Mississippian, especially Burlington, cherts are especially abundant in this conglomerate. The cementing material of iron oxide colors the conglomerate red to brown, and has locally made the rock very tough and resistant. Although bedding is not everywhere visible, slabs averaging approximately two feet in thickness are common as isolated residual blocks. The best exposure of the conglomeratic phase is in the SW¼SW¼SW¼ sec. 25, T. 37 N., R. 25 W. The basement of a recently built house at this location has been blasted out of this conglomerate which serves as a foundation. Another excellent exposure is in the SW¼SW¼NE¼ sec. 8, T. 36 N., R. 24 W.

Most of the Graydon is sandstone. The rock varies from fine to coarse grained, thin-bedded to massive, quartzitic to friable, and brown or red to buff or white. Red to dark-brown is the common color. Sandy red to brown soils were the basis for mapping large areas of these poorly exposed beds. Ordinarily these sands, especially where thin-bedded, are micaceous.

Fairly good exposures of Graydon sandstone are in the central portion, N½ sec. 13, and the N½SW¼ sec. 24, T. 37

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[79] Worthen, A. H., Geology of Illinois: Illinois Geol. Survey, vol. 1, pp. 126-129, 1866.

N., R. 25 W. At both localities, the reddish-brown sandstone is thick-bedded and moderately resistant, weathers to gently-rounded surfaces, and is slightly cross-bedded.

Pennsylvanian clay is exposed on the west bank of South Fork Weaubleau Creek in the center S½SE¼ sec. 7, T. 36 N., R. 24 W. The five feet of blue clay in this bank contain large clusters of marcasite, part of which has weathered to an earthy red oxide.

Exposures of the Graydon are insufficient to determine a distribution pattern of the three facies or to construct a paleogeographic map useful as a possible clue to depositional environments.

Thickness.—Thicknesses of Pennslyvanian strata are extremely variable because of the relief of the surface on which these rocks were deposited and because of post-Cherokee erosion. A thickness of nearly 140 feet is exposed in the N½ sec. 24, T. 37 N., R. 25 W. The thicknesses of Pennsylvanian in the upland areas of the central and eastern portion of the quadrangle vary from 10 to 40 feet. In the extreme western portion of the area, thicknesses probably exceed a hundred feet in some places.

Paleontology.—The conglomerates of the Graydon contain Mississippian fossils in the component fragments of chert and limestone. No Pennsylvanian fossils other than spores and carbonaceous material were found.

Stratigraphic Relations.—The Graydon is the youngest indurated formation exposed in the area. Where the Dederick is absent, Graydon rocks lie on the deeply eroded Mississippian or Ordovician. As will be shown in the discussion of structural geology, it is believed that there is a marked angular unconformity between Pennsylvanian and highly disturbed pre-Pennsylvanian rocks in this quadrangle.

TERTIARY (?) SYSTEM

Pennsylvanian conglomerates weather to form gravels which, where located on the uplands, are very difficult to differentiate from gravels laid down by post-Pennsylvanian streams on an old erosion surface.

Upland gravels found in two localities are at least post-Graydon in age, for they contain subangular to rounded pebbles, cobbles, and boulders composed of red micaceous Graydon sandstone.

A reservoir pit in the SE¼SW¼SW¼SW¼ sec. 21, T. 37 N., R. 24 W. at an elevation of approximately 950 feet exposes seven feet of unconsolidated, unbedded gravel.

Several subangular to rounded Pennsylvanian cobbles were found in the W½NW¼NW¼ sec. 7, T. 37 N., R. 24 W., at an elevation of approximately 820 feet.

The area of study is so small that it is dangerous to attempt interpretations of regional erosional history. It is known that the topographic surface of the Ozarks bevels structure, and widespread upland gravels give additional evidence of plural erosion cycles. There has been very little recent work on the physiographic history of the Ozarks, but the concensus of opinion is that there was middle to late Tertiary peneplanation followed by uplift.[80,81,82]

Flint,[83] who has published the most recent opinion on erosion cycles in the Ozarks, believes the uplift was post-(Eocene)-Wilcox and pre-glacial.

Tertiary streams probably were little-controlled by the small-scale structure of the Weaubleau quadrangle. But following uplift and rejuvenated erosion, newer small streams are believed to have developed courses intimately related to structural trends.

QUATERNARY SYSTEM

Terraces.—Poorly preserved and exposed terraces probably of Pleistocene or Recent age are visible at the following localities:

(1) SW¼NW¼ sec. 26, T. 37 N., R. 24 W., 830-840 feet elevation.
(2) SW¼ sec. 22 and NE¼ sec. 27, T. 37 N., R. 24 W., 800-810 feet elevation.
(3) SW¼NW¼ sec. 20, T. 37 N., R. 24 W., 790-800 feet elevation.
(4) SE¼SE¼SE¼ sec. 19, T. 37 N., R. 24 W., 770-800 feet elevation.
(5) SE¼SE¼ sec. 1, T. 37 N., R. 25 W., 750-760 feet elevation.

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[80] Marbut, C. F., Physical features of Missouri: Missouri Geol. Survey, vol. 10, pp. 11-109, 1896.

[81] Tarr, W. A., Intrenched and incised meanders of some streams on the northern slope of the Ozark Plateau in Missouri: Jour. Geology, vol. 32, no. 7, pp. 583-600, 1924.

[82] Shaw, E. W., Quaternary deformation in southern Illinois and southeastern Missouri (Abstr.): Bull. Geol. Soc. Amer., vol. 26, p. 68, 1915.

[83] Flint, R. F., Ozark segment of Mississippi River: Jour. Geol., vol. 49, no. 6, pp. 626-640, 1941.

Because of the cover, the composition of these terraces was not apparent. Some gravels are visible, but no evidence of bedding could be seen.

There may have been minor uplifts since the late Tertiary (?) rejuvenation, but the only well-defined terrace system is from 20 to 30 feet above present stream levels.

Residual chert mantles much of the area, but the flood plains contain considerable fertile alluvium.

CHAPTER III

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Weaubleau area lies on the western flank of the Ozarks and is underlain by rocks which regionally dip gently to the west.

Faulting is shown in neither St. Clair nor Hickory County in the 1939 geological map of Missouri.[84] This same map does show that the Weaubleau area lies on the west flank of a local shallow elliptical structural basin whose major axis trends in a northwesterly direction. This basin has partly preserved the lower Mississippian from erosion. However, the detailed geologic mapping of the quadrangle has revealed Ordovician exposures not shown on the state geologic map and suggests that the basin is shallower than indicated on the state map.

The rocks of the Weaubleau area are over a large part of the area fractured, faulted, and folded. In the north central and extreme southwestern portions of the area these deformations appear to be less pronounced. However, in these two portions, as well as in the upland prairie regions, the lack of exposures of formations lower than the Pennsylvanian or Burlington makes it practically impossible to detect faults or continuous folds. Also, the surface of the erosional unconformity between the Pennsylvanian and Mississippian is so uneven that this contact cannot be used as a structural datum. This axiom is demonstrated in the relationship of Pennsylvanian fills in stream valleys; in Coon Creek in the southwestern portion of the area, the Dederick shale is locally more than one hundred feet lower topographically than the Mississippian-Pennsylvanian contact on the adjacent upland, yet there is no basis for explaining this relationship by faulting.

The throws of faults within the area are not known to exceed 80 feet. Displacement along the planes of thrust faults is much greater, but because of lack of sufficient exposures, only minimum values can be determined.

Fracturing and folding are locally so intense that directly measured strikes and dips can prudently be projected but short

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[84] Buehler, H. A., Geological Map of Missouri, scale: 1:500,000: Missouri Geol. Survey and Water Resources, 1939.

distances, and caution must be observed in reconstructing structural patterns from the attitudes of isolated exposures. A number of strike and dip directions determined in a traverse of less than a hundred yards may almost "box the compass" in their variations. Dips greater than 30° are not uncommon, and some beds are vertical and overturned in the area of thrust faulting.

Faults can be traced but relatively short distances and in many cases of obvious faulting, data are insufficient to determine the trends of fault traces. This situation is in part due to the lack of exposures, but it also results from the fact that the faults are apparently very short in linear extent.

Interpretations of the structural pattern are complicated by the lack of a preferred orientation in the trends of many of the folds and faults. A northwest-southeast grain appears to predominate, yet many of the trends do not fit this grain.

The Geologic and Tectonic maps (Plates XI and XII) are somewhat misleading, for they show the greatest amount of faulting and folding in stream valleys and practically none in the upland areas. Although stream valleys follow fault patterns closely, there is no reason to believe that the uplands are not faulted. However, the amount of displacement is so small in all the mapped faults that float and soils on the upland do not reflect the probable but unmappable deformations. Also the extensive deformation eliminates the possibility of using drag as evidence of a fault zone, for practically any exposure might, unwisely, be used as evidence of the nearness of a fault. Unfortunately (for the gologist), streams have not cut below the Burlington in the prairie areas. Even where the Burlington is well exposed, faulting within the formation cannot be detected without a detailed study of faunal assemblages, for with the exception of the basal Burlington, the writer was unable to distinguish any persistent lithologic units. It is believed that the most intensive faulting was post-Burlington and pre- or middle Pennsylvanian; therefore, the Pennsylvanian deposits have probably covered many of the pre-existing deformations.

The writer has attempted to be conservative in mapping faults. Without doubt there are many more faults within the areas of comparatively good exposures, as well as in areas of few exposures, but none has been mapped unless there is strong supporting evidence.

As will be shown in this chapter, the structure of the Weaubleau area is believed to be primarily the result of compressive forces. The deformations are best discussed by dealing first with the geographic portion of the area which displays positive proof of these compressive forces, and later, with general structure of the quadrangle as a whole.

AREA OF INTENSIVE THRUST FAULTING

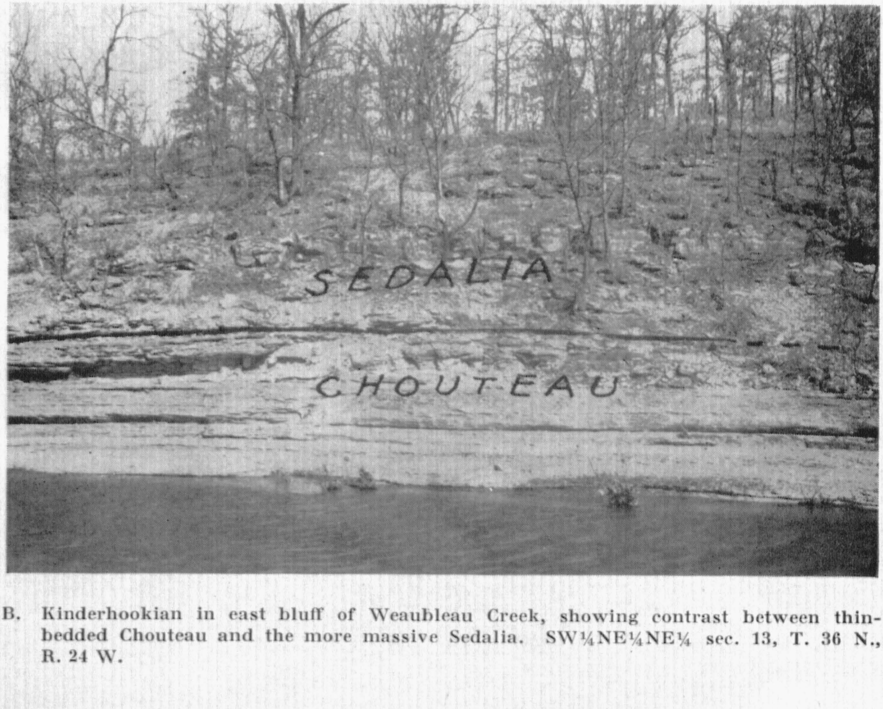
This area includes the following sections: 6, 7, 18, 19, 20, 29 and 30, T. 37 N., R. 24 W., and 13 and 24, T. 37 N., R. 25 W. Evidences of compressive forces are discussed under the following categorical headings.

Duplication of Section.—Thrust faulting has duplicated the stratigraphic sequence in the S½SE¼NE¼ of sec. 13, T. 37 N., R. 25 W. Small fensters of Burlington protruding through Northview siltstone have been exposed by the grading of the country road which crosses Tanyard Branch at this point. The lowest fenster is 17 feet above the concrete slab stream crossing, on the south side of the creek, on the southwest edge of the road. Other patches of Burlington protruding through Northview lie on the opposite side of the road several feet uphill.

The stratigraphic sequence exposed in the road from the concrete slab south up a steep hill and turning to the southeast is as follows (Uncorrected for dip N. 70° W. at 10°):

	Thickness	
Burlington	Feet	Inches
(6) Limestone, coarsely crinoidal, dirty white (to top of hill—not measured).................		
(5) Limestone, dolomitic, buff, slightly crinoidal.	2	6
(4) Party covered...........................	5	0
Northview		
(3) Siltstone, buff, soft, laminated beds alternating with slabs six to eight inches thick. Contains cauda-galli markings and *Scalarituba missouriensis.* Small fensters of white, finely crystalline to crinoidal Burlington limestone exposed in roadbed and shoulder at from 17 to 23 feet above concrete slab.................	18	6
Burlington		
(2) Partly covered crinoidal limestone above concrete slab crossing.........................	7	0
Northview (?)		
(1) Clay, silty, green, soft. Exposed in bottom of water hole on west side of concrete slab....	2	0

A. Anticline and thrust fault in Tanyard Branch. NW¼SE¼SE¼NE¼ sec. 13, T. 37 N., R. 25 W.



B. Kinderhookian in east bluff of Weaubleau Creek, showing contrast between thin-bedded Chouteau and the more massive Sedalia. SW¼NE¼NE¼ sec. 13, T. 36 N., R. 24 W.

Another expression of this thrust is well exposed in the southeast bank of Tanyard Branch, 500 feet downstream from the same concrete slab (Plate I-A).

The core of a small anticline exposed in transverse section is composed of blue-gray Northview silty shale; the periphery is of Burlington limestone. In the creek bed, under the southwest limb of this fold, typical crinoidal Burlington limestone is exposed beneath the Northview. The northeast flank of the fold has a dip of N. 50° E. at 15° as measured on the Burlington limestone, and the poorly-exposed southwest limb dips to the southwest at approximately 50°, indicating that the axial plane dips to the northeast. The contact friction of thrusting is interpreted as having steepened one limb of the fold, protecting the anticlinal core of Northview silty shale. Underthrusting from the west is assumed because it is believed that the incompetent Northview would have a greater chance for preservation if it was passive and underthrust by the more competent Burlington than it would if it actively over-rode the Burlington. The Northview siltstone exposed in the roadway shows no evidence of distortion other than lack of horizontality, and it would be difficult to transmit horizontal forces through this siltstone without crumpling it, as would be the case in overthrusting. It is remarkable that the Northview could be so undisturbed even by underthrusting but the evidence of low-angled thrust faulting is indisputable and duplication by underthrusting is the more logical assumption.

A continuation of the small anticline described is possibly expressed on the steep slope in the NE¼NW¼SE¼NE¼ of the same section 13, T. 35 N., R. 25 W., just south of the house on the east side of the road. In a partial exposure, Burlington limestone forms a horseshoe-shaped outcrop pattern, the open end facing to the south. If this exposure is considered as an extension of the anticline exposed in Tanyard Branch, the axial trace of this structure is approximately N. 20° W. Furthermore, if underthrusting in a direction approximately normal to the axial trace is assumed, the underthrust moved in the direction N. 70° E.

The maximum amount of horizontal movement in this thrust could not be determined because of lack of exposures, but a minimum of 530 feet was measured.

The stratigraphic section is duplicated in the bed and south bank of the east-flowing tributary in the south central part of the SW¼SW¼SE¼ sec. 30, T. 37 N., R. 24 W. (Fig. 2). Tough, dolomitic buff-colored "vermicular" Northview siltstone in place overlies coarsely crinoidal gray Burlington limestone. The source of the Northview is not known; exposures are insufficient to determine whether it was thrust through and upon the Burlington as an isolated slice or whether it was emplaced by a low-angled thrust and remains as a minute klippe or nappe of less than ten square yards in exposed area.

Thrusting of Older Rocks Through Younger.—Further evidence of thrust faulting is offered by the numerous examples of isolated beds of older rocks, especially Jefferson City, which have apparently been thrust *through* younger Mississippian strata. In the following discussion, these foreign slices are designated as *interthrusts.* This term connotes a genetic relationship to underthrusts and overthrusts, but is restricted to thrust slices which have apparently penetrated beds in the course of their emplacement.

The structural relationships of interthrusts are best exposed on the southeast flank of the spur which extends southwest to near the center of sec. 19, T. 37 N., R. 24 W. (Fig. 1). A well-exposed sequence of Jefferson City dipping N. 40° E. at 7° forms the southeast tip of this spur and is exposed at the surface northeastward to the shallow saddle of the spur. Near the center of the ridge, 192 feet northeast of the saddle, a remnant of Chouteau lies on the Jefferson City. Intensely crumpled Burlington lies directly on Chouteau at a point 340 feet east of the center of the saddle, and this unusual contact, which is believed to be the result of very low-angled thrust faulting, can be traced along the southeast side of the spur for almost 300 feet to the northeast. A "sliver" of Jefferson City dolomite overlain and underlain by highly contorted Burlington is exposed in vertical section on the southeast side of the spur, 580 feet northeast of the center of the saddle. This "sliver" is 75 feet in exposed length and 12 feet thick. The apparent dip is 7° to the northeast and the southwest end terminates in Burlington limestone. This tough, thick-bedded brown dolomite is identical in appearance with the Jefferson City dolomite exposed in normal sequence at the southwest tip of the spur. The bedding within the "sliver" is distorted but readily traceable with the exception of the southwestern treminus which is crumpled. Because of soil cover, the source of this "sliver" is unexposed. However, it can be traced southeast and down the apparent dip almost to relatively undisturbed Jefferson City.

This "sliver" is considered to be the best example of an interthrust. It is believed to have been emplaced, in some unknown manner, by thrust faulting. Two other hypotheses of origin, namely clastic dikes and unreduced pinnacles of Jefferson City in the Mississippian seas, are untenable.

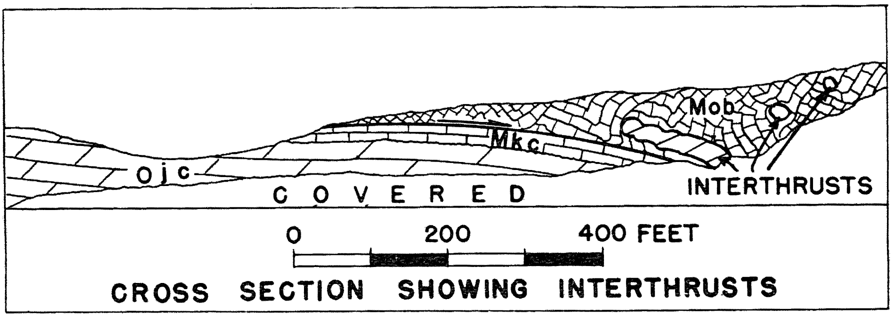


Figure 1. Southeast flank of southwest-pointing spur in the SW¼NE¼ sec. 19, T. 37 N., R. 24 W.

Ojc = Jefferson City. Mkc = Chouteau. Mob = Burlington.

Newsom[85] and Jenkins[86] have summarized types and origins of clastic dikes. The majority of these dikes are believed to have originated as precipitated, clastic (unindurated), or plastic flow fillings or injections.

At least one known exception to the modes of origin listed above is given by English,[87] who in describing a "sandstone reef", says:

> "This sandstone, however shows bedding and was evidently forced up through the shales as a rigid mass during the folding of the beds."

Jenkins[88] does not agree with English and believes the sandstone ". . . . was injected as a plastic mass".

The Jefferson City dolomite interthrust described above is composed of material which entered the host rock as an in-

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[85] Newsom, J. F., Clastic dikes: Geol. Soc. America Bull., vol. 14, pp. 227-268, 1903.

[86] Jenkins, O. F., Sandstone dikes as conduits: Am. Assoc. Petroleum Geologists Bull., vol. 14, no. 4, pp. 411-421, 1930.

[87] Englsh, Walter, Geology and petroleum resources of northwestern Kern County, California: U. S. Geol. Survey Bull. 721, pp. 25-26, 1921.

[88] Jenkins, O. F., op. cit., p. 418, 1930.

durated and relatively competent rock. Bedding is well-preserved, and brecciation is negligible. The most crumpling and brecciation is confined to the southwest or assumed fore end of the slice.

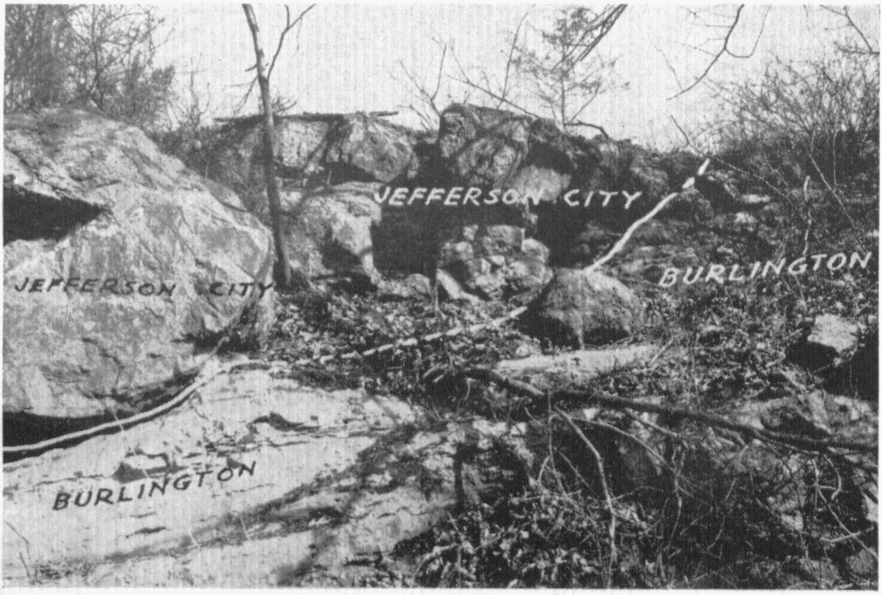
There are several strong objections to assuming that the slice of Jefferson City represents an unreduced pinnacle in the Mississippian seas. It is very doubtful that a pinnacle inclined at an angle of 7° (the apparent dip of the interthrust) could persist into Burlington time without snapping off and falling. The lack of conglomeratic facies in the surrounding Mississippian rocks and the lack of truncated beds in the interthrust apparently preclude the existence of the interthrust as a pinnacle in Mississippian seas. A nearly horizontal thrust surface appears to separate the Chouteau and the greatly distorted superjacent Burlington; yet this interthrust, which penetrates the intensely folded Burlington, is not greatly folded and could not have been emplaced until post Burlington time.

A smaller, less well-exposed interthrust essentially identical to the interthrust just described in lithology, apparent dip, and exposed thickness, lies 50 feet north of the above-mentioned interthrust. This Jefferson City dolomite has also penetrated Burlington limestone but is more brecciated at its upper exposed end and in this fore portion is identical in appearance to interthrusts of the quadrangle which do not show discernible bedding.

Two interthrusts exposures, also in Burlington limestone, lie 150 and 270 feet respectively north of the lowermost portion of the smaller interthrust just described. These interthrusts also are on the southeast flanks of the ridge, but are visible only in plan view, for the hill slope is gentle and they protrude only two to three feet above the surface. They are composed of somewhat brecciated buff dolomite and show no visible evidence of bedding.

The lithology is identical with that of the bulk of the interthrusts, i.e., a tough, buff-brown rough-surfaced dolomite. Beds vary from one to three feet in thickness and contain seams of white opal-like chert from one-half to three inches in thickness.

An exposure which superficially resembles the conventional conception of duplication of the section by thrust faulting, but which is believed to be an interthrust is in the crest and upper face of the southwest-facing bluff of Weaubleau Creek in the



A. Sill-like interthrust of Jefferson City in north bluff of Weaubleau Creek. SW¼NW¼NW¼ Sec. 7, T. 37 N., R. 24 W.

B. Jefferson City interthrust on south-sloping hillside in SE corner, SW¼NW¼SW¼ sec. 20, T. 37 N., R. 24 W.

SW¼NW¼NW¼ sec. 7, T. 37 N., R. 24 W. (Location No. 25, Plate XI). As viewed in vertical section in the cliff face, a mass of lens-shaped Jefferson City forms the crest of a low bluff composed of Burlington limestone. This lens of Jefferson City overlying Burlington is approximately eight feet thick at the thickest or central part and twenty-five feet wide (Plate II-A).

This Jefferson City is known to overlie Burlington over part of its extent and it is apparently surrounded by Burlington over much of its extent as seen in plan view. This is believed not to be a typical overthrust, but rather, a sill-like interthrust exposed by erosion of the overlying Burlington beds. At the top of the bluff, midway in the northeast-southwest exposure line of the Jefferson City, the dolomite has apparently been halted in its southeastward movement by a buttress of Burlington limestone. At this point, the thrust slice has failed to reach the present bluff edge and has draped around the barrier of Burlington. The Burlington which has locally halted the movement of the Ordovician rock dips S. 47° E. at 40°-80°, and apparently was rotated into its present position by the pressure of the advancing Jefferson City.

If the Ordovician had advanced as a surface sheet, it might have climbed over this obstacle. Regardless of whether this thrust was confined or unconfined, its relations to the barrier offer strong evidence in favor of a movement toward the southeast.

There are several other exposures of Jefferson City either on or in the Burlington along the more gentle slope near and inland from the bluff line in this portion of section 7. The expression "on or in" is used because it could not be determined whether these small patches of dolomite are typical interthrusts, or whether they are very small rootless patches overlying the Burlington. Sixty-five feet northwest of the point on the bluff overlooking the acute right hand turn of Weaubleau Creek in the NW¼ sec. 7, a structure which resembles a dike-like form of interthrust is exposed. (Location No. 23, Plate XI.) Here a linear exposure of buff-brown Jefferson City dolomite, 15 feet in maximum width and 50 feet in length (dimensions in plan view) is surrounded by poorly exposed Burlington limestone. Because of the poor exposure of this limestone, it is impossible to determine whether this limestone has been penetrated by the Jefferson City or whether it is overlain by the older rock. The elongation of this outcrop is N. 45° E. Because the dip is thought to be nearly vertical, the writer believes this structure is a dike-like interthrust.

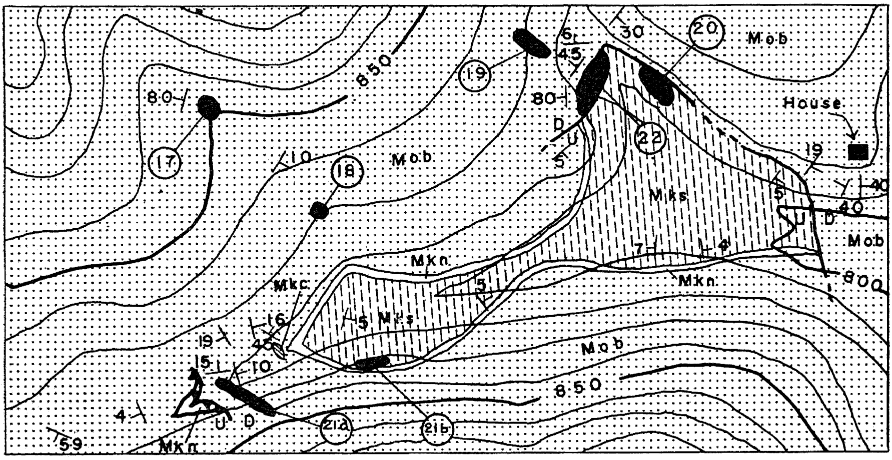
Patches of Ordovician on or in the Mississippian are also exposed a few yards east of the west section line of the same section 7, T. 37 N., R. 24 W., just back from the bluff edge (location no. 26); in the forked gully near the center of the N½NW¼ sec. 7 (location no. 34); and on the crest of the hill southwest of the center of section 7 (locations nos. 28 and 29) overlooking the bluff. The Jefferson City in the forked gully, just below the fork, is definitely on the Mississippian (upper Sedalia and Northview) and is preserved as a large block of the usual buff-brown dolomite, at least five feet thick, ten feet long and six feet wide. The bedding is hardly distorted, but because of its position in the gully, this Ordovician is probably not in place. It is probably residual, for its angularity precludes any appreciable lateral transportation.

The Ordovician on the crest of the hill near the center of the same section 7 (locations nos. 28 and 29) is also definitely on rather than *in* the Burlington. The dolomite of these blocks is lighter buff in color and has a smoother surface and finer grain than that of the majority of the Ordovician thrust slices. Several of the blocks are composed of a light brown quartzite. In size, these blocks vary, but they average about six feet in the three dimensions. There is no evidence that they have come through the underlying Mississippian, and they are interpreted as being remnants of a slice thrust from the west.

Structures interpreted as interthrusts are well-exposed and easily accessible in the SW¼SE¼ sec. 30, T. 37 N., R. 24 W. (See detailed map, Fig. 2.) As shown in this plate, (locations nos. 17 to 22) these interthrusts have produced domes at several localities.

That the intruded rocks surrounded by Mississippian rocks are Jefferson City, there is no doubt. At location no. 20, over an area 25 feet wide by 50 feet long, a mass of quartzite, buff on the weathered surface, whiter on the interior, is exposed. To the west, across the gully at locations nos. 19 and 22, the interthrusts are composed dominantly of very tough brown, lumpy-surfaced dolomite and subordinately of quartzite. Both types of lithology are also common in exposures of undisturbed Jefferson City.

Typical blue-white oolitic chert which is diagnostic of Jefferson City and occurs in no lower Mississipian within the area (with the exception of the atypical Burlington breccia or conglomerate) is present at location no. 18, in conjunction with the common tough, brown, lumpy-surfaced dolomite.



STRUCTURAL RELATIONSHIP OF INTERTHRUSTS
SW 1/4 SE 1/4 SEC-30, T.37N. R.24W.

LEGEND

⬚ Mob BURLINGTON
▥ Mks SEDALIA
☐ Mkn NORTHVIEW
▨ Mkc CHOUTEAU
(32)—● JEFFERSON CITY INTERTHRUSTS
⊢10 DIRECTION AND AMOUNT OF DIP
▼▼▼ NEAR-HORIZONTAL THRUST FAULT
—···— FAULT OF UNKNOWN HADE
SCALE 0 500 1000 FEET

Figure 2.

At location no. 21a the interthrust is dike-like in the exposed portion. This exposure is 110 feet in length, 25 feet wide, and the beds strike N. 45° W. At the southeast end, the usual buff-brown dolomite contains thin partings of diagnostic opaline-like white chert, varying in thickness from one-fourth to one-half inch. In this large slab, definite bedding as determined by the chert bands and general layered appearance of the dolomite, is easily recognizable. The dip determined on this slab is SW at 46°. This slab is not brecciated and bedding is undistorted, indicating that it penetrated the Mississippian as a competent, rigid slice and therefore is not analogous to the conventional conception of "clastic dikes".

Interthrusts typically have no strong topographic expression and exposures are most prevalent in stream valleys where bedrock is not mantled. Because of their low relief, interthrusts are difficult to photograph. A striking exception is the excellent exposure in the SE corner, SW¼NW¼SW¼ sec. 20, T. 37 N., R. 24 W. (location no. 2, Plate XI). Here, on the south-facing slope, jagged warped masses of white quartzite protrude from the hillside to a height of as much as three feet above the ground (Plate II-B). This quartzite shows but faint bedding and appears to have been greatly distorted in penetrating the Kinderhookian and Burlington. These quartzite masses cover an area approximately fifty feet in diameter. The poorly exposed Burlington limestone immediately outside the interthrust area strikes concentrically to the periphery of this area and dips 20° to 45° from the center of the circle.

Characteristically, surface exposures of interthrusts are roughly circular to elliptical in plan view, varying in maximum diameter from a yard or two up to fifty feet. They have, in many of the exposures, penetrated through the Kinderhookian (52 to 60 feet true thickness) as well as the thickness of the Burlington limestone lying between the surface soil and Kinderhookian contact. The source horizon within the Jefferson City is not known for certain, for the dolomite and quartzite beds found in the dikes are repeated in several horizons in well-exposed undisturbed Ordovician sections.

Several truncated structural domes, ranging from between twenty and one hundred yards in surface diameter and identical in appearance to those formed by interthrusts, were found in the Weaubleau area. However, no Jefferson City could be found at the surface center of these domes. Such small near-circular structures are difficult to explain by uniform lateral compression toward a common center, and are believed to represent the surface expression of interthrusts which failed to reach the present surface of the Burlington limestone but did ascend sufficiently to produce these small domes.

Examples of such erosionally truncated domes are exposed at the following locations:

(1) Near the center of sec. 29, T. 37 N., R. 24 W., just west of the north-south center line on the north bank of a small creek and a few yards east of a concrete well. Here a small dome of Burlington limestone contains brown basal Burlington at the surface center, and stratigraphically higher white crinoidal Burlington forms the flanks.

(2) South line of the SE¼ sec. 19, T. 37 N., R. 24 W., on the northwest side of the intermittent stream at 810 to 820 feet elevation; Burlington limestone dipping away from common center at angles of from 15° to 40° is exposed over an area of about 50 yards diameter.

(3) From the 800 to 840-foot contours on the ephemeral stream in the SE¼SW¼NE¼ sec. 30, T. 37 N., R. 24 W.; a partial exposure of dome at least 100 yards in surface diameter. Faulting has exposed Sedalia limestone in the southern portion of this dome; the remaining exposures are Burlington limestone.

It is impractical to describe every interthrust in the area, but typical examples have been given. In summary, the following facts and assumptions should be noted:

(1) The interthrusts are composed of Jefferson City dolomite or quartzite, the former rock being more common. The cherts interbedded within these interthrusts are definitely not Mississippian in age and are identical to the oolitic and opal-like cherts of the Jefferson City.

(2) Interthrusts are confined to the portion of the area which is characterized by intense crumpling, fracturing and thrust faulting and are believed to be the result of compressive forces.

(3) Interthrusts are known to have penetrated more than 60 feet of lower Mississippian as competent slices in a number of cases. The preservation of both bedding and chert partings precludes the possibility of plastic injection used to explain many "clastic dikes".

(4) Interthrusts are confined to the region of intense thrusting. It is believed that slices of Jefferson City were driven into the lower Mississippian because the Jefferson City is relatively competent. The lower Mississippian rocks relieved lateral pressures by crumpling and developing imbricate structure; the tougher dolomites of the Jefferson City did not in all cases crumple, but rather developed thrust faults and compensated for the shortening in part by thrusting through the lower Mississippian rocks. (Fig. 3.)

(5) The belt of interthrusts is nearly six miles long and slightly less than two miles wide. The trend of this belt is to the northwest.

(6) The lack of greater linear extent along the strike of individual interthrusts is not explained by field evidence. Although several of the interthrusts are dike-like in their surface exposures,

the majority are roughly circular as viewed in plan, suggesting that they penetrated the host rock as slivers rather than broad sheets.

(7) Small local domes in the lower Mississippian which show no exposed Jefferson City are believed to be the surface expressions of interthrusts which failed to reach the present ground level.

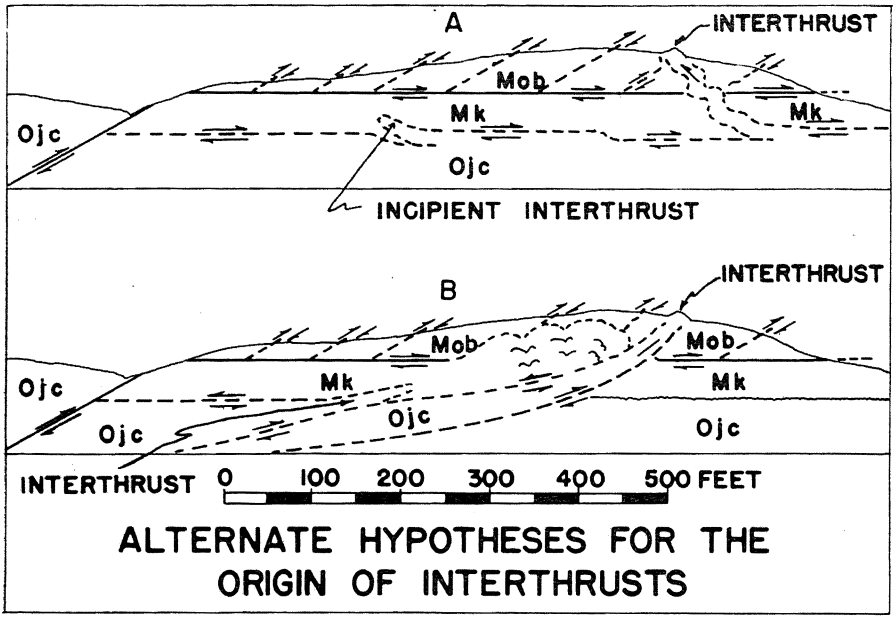


Figure 3. Ojc = Jefferson City. Mk = Kinderhookian. Mob = Burlington.

(8) Sill-like interthrusts are known to exist. Therefore, the writer believes that the exposures of Jefferson City which superficially resemble overthrusts are slices of interthrusts which either reached the surface and extruded as essentially horizontally moving competent masses, or that they are sill-like interthrusts exposed by erosion. The latter interpretation is favored because the slices appear in one example to have moved as beds confined on both top and basal surfaces; because sill-like interthrusts have been found in the quadrangle; and finally, because extruded slices would probably have been removed by erosion.

(9) In several cases, the interthrusts are known to penetrate intensely crumpled Burlington; yet these interthrusts are not distorted and therefore could not have existed as unreduced highs of Jefferson City in the Mississippian seas. The lack of conglomeratic facies in the Mississippian rocks at their contacts with interthrusts suggests that interthrusts whose structural relations are concealed are likewise post-Burlington in age.

(10) It is possible that some of the pinnacles of Jefferson City in the area of Mississippian conglomerates (Chapter IV) are interthrusts.

DECOLLEMENT AND IMBRICATE STRUCTURE

Decollement structure, as developed in the Jura Mountains type area, consists of sheets of sedimentary rocks which have been stripped from underlying beds and folded and faulted independently. Such structure is typically produced by horizontal thrusting which finds relief in upper beds which are separated by incompetent beds from the lower relatively undisturbed beds.

The Burlington appears to be the major formation subjected to such independent folding. In addition to being intensely crumpled, the Burlington apparently contains numerous intraformational thrust faults expressed as imbricate structure.

These intraformational thrust faults within the Burlington are neither mappable nor visible. However, it is logical and necessary to assume that they exist, for in numerous localities Burlington stands on end over areas as much as a thousand feet wide, measured normal to the strike. In such areas, the computed apparent thickness so far exceeds the normal stratigraphic thickness that repetition of the section is obvious.

Kinderhookian formations are completely or in part absent in areas of most marked decollement structure. It is believed that these beds were eliminated by the lateral thrusting force which produced the decollement.

Listed below are the several zones of weakness which facilitated the development of decollement structure:

(1) The Northview formation as a whole.

(2) The thin-bedded silty dolomite at the base of the Sedalia.

(3) The thin-bedded limestones of the upper Chouteau.

(4) The Sylamore (?) formation or the Jefferson City-Chouteau contact.

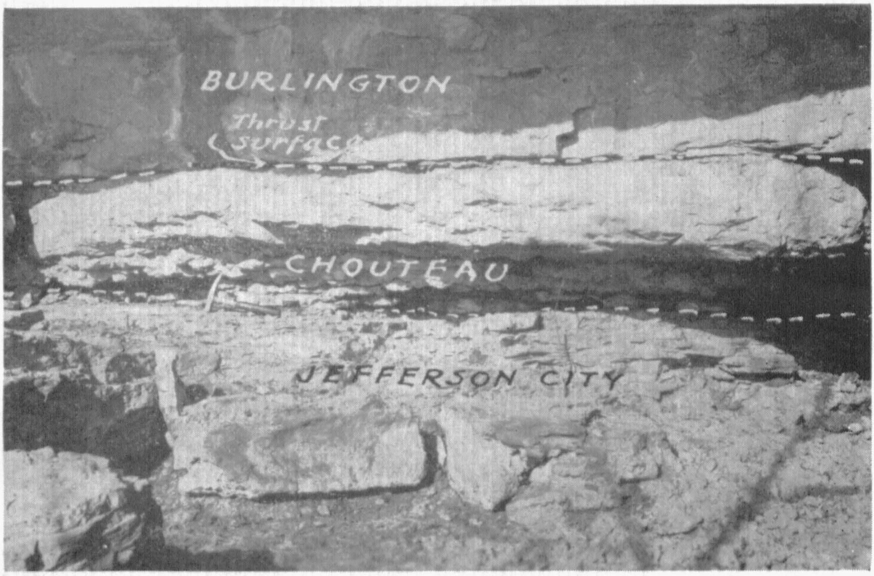
The isopach map of the Northview (Plate VIII) shows the marked thinning and elimination of this siltstone and shale formation in the areas of decollement structure. Although the Northview does thin regionally to the north, the local thickness pattern does not conform to the regional pattern, and the Northview is much thinner in the intensely faulted area than in the less disturbed areas surrounding it. Locally the Northview has been eliminated completely, along with all or almost all of the remainder of the Kinderhookian.

The results of decollement faulting which has eliminated complete formations are best observed in the east-facing bluff in the NE¼NE¼NW¼SW¼ sec. 19, T. 37 N., R. 24 W. (Frontispiece and Plate III-A). The sharply-defined fault surface (in edge view) at this exposure is 67 feet above the bed of the small north-flowing stream at the base of the cliff.

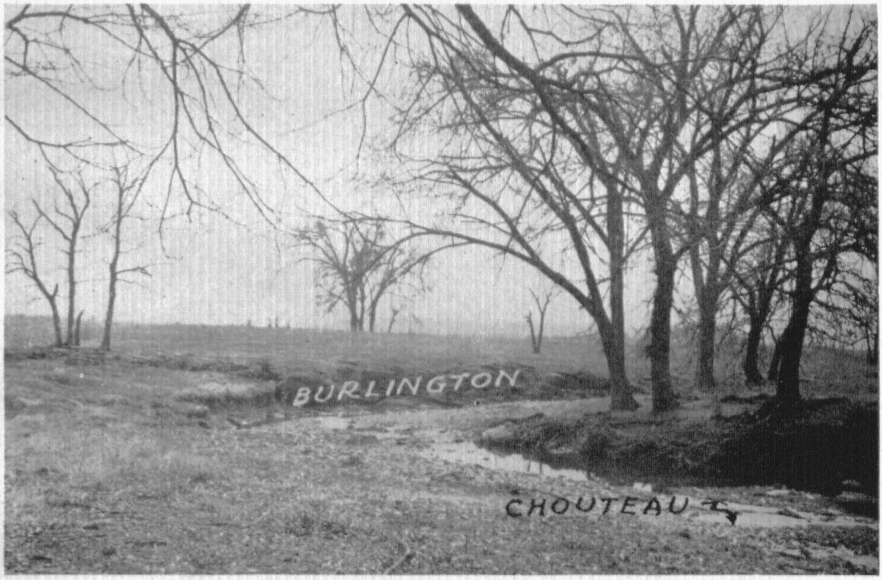
The following partial section shows the effect of this fault in eliminating beds:

Burlington	Feet	Inches
(5) Limestone, white, coarsely crinoidal, medium-bedded, contains small fragments of brown chert breccia. Forms overhanging ledge. (To top of cliff)	20 (est.)	
(4) Fault gouge: Clay, gray, somewhat fissile, soft (A very inconspicuous break which superficially resembles a normal sedimentary contact in some exposures)		½-2
Chouteau		
(3) Limestone, gray-white on weathered surface, waxy blue-gray on fresh surface; very nodular in upper portion; finely crinoidal, non-cherty, glauconitic, argillaceous	2	2
Sylamore (?)		
(2) Re-entrant filled with decomposed limestone and soil		6
Jefferson City		
(1) Dolomite, light-buff, beds one to six inches thick; nodular partings of pink-gray chert one-half to two inches thick. Beds of dolomite weather out to form slabs	5	4
(Covered, patchy exposures of Jefferson City dolomite and quartzite to foot of cliff)		

The whole of the Northview and Sedalia, and a large part of the Chouteau have been removed by thrust faulting. The fault surface is essentially parallel to the underlying beds over an appreciable area. Although exposures are rather poor, Ordovician float can be traced vertically to within a few feet of exposures of Burlington limestone along the various valley walls in the northern two-thirds of the W½W½ of sec. 19, T. 37 N., R. 24 W., and in the extreme eastern portion of sec. 24, T. 37 N., R. 25 W. The fault surface is essentially horizontal in the western part of its exposure but dips to the east or northeast in the eastern part. (See Cross Section A-B-C, Plate XI).



A. Edge view of near-horizontal thrust surface. East-facing bluff in NE¼NE¼NW¼-SW¼ sec. 19, T. 37 N., R. 24 W.



B. Fault-line scarp in southwest-flowing stream. Center NW¼NW¼NW¼ sec. 26, T. 37 N., R. 24 W.

Decollement faulting in this area appears to be later than the higher angle thrust faulting. In the northwestern portion of the NW¼ sec. 19, T. 37 N., R. 24 W., the Kinderhookian, which lies in a graben between two north-south strike faults has in part been spared destruction from decollement faulting. This relationship suggests that some of the movement of the higher angle thrust faults which formed the graben was earlier than the decollement faulting. However, the decollement fault surface appears to have been warped by the faults which formed the graben. Thus there may have been further movement along the western graben fault surface after the decollement faulting.

Decollement structure and the accompanying elimination of beds are well exposed on the southeast side of the southwest-pointing spur in the SW¼NE¼ sec. 19, T. 37 N., R. 24 W. (Fig. 1). At the southwest tip and northeastward for approximately 200 yards to the shallow saddle of this ridge, Jefferson City, which dips N. 40° E. at 7°, is exposed at the surface.

A few yards northeast of the lowest portion of this saddle, crumpled and faulted Burlington lies on less-disturbed Chouteau, which in turn overlies gently-dipping Jefferson City. All of the Sedalia and Northview are missing, and at several points along the southwest side of the ridge, the Chouteau is absent so that Burlington lies on Jefferson City. The edge of this fault surface can be followed for nearly 250 yards to the northeast along the side of the ridge until it is covered by rubble. The apparent dip of the fault surface is nearly parallel to the apparent dip of the Jefferson City, or N. 40° E. at 7°.

Rucked-up and faulted Burlington caps this spur from the above-mentioned contacts with the Jefferson City or basal Chouteau eastward to the SW¼NW¼NE¼ sec. 19, T. 37 N., R. 24 W. From the center of the SW¼NE¼ sec. 19, the northeast-dipping Kinderhookian thickens to a nearly complete undisturbed section in the railroad cut in the NE¼NE¼ sec. 19, indicating that the low-angled thrust surface or surfaces transect the Kinderhookian beds. It is believed either there is more than one low-angled fault surface or that if there is but one surface, this surface is faulted or has a marked change in dip as traced to the northeast. One of these conditions must exist, for as previously mentioned, the apparent dip of the fault surface calculated at the Burlington-Jefferson City or Burlington-lower Chouteau contact near the southwest end of the spur is N. 40° E.

at 7°. The highest exposed elevation of this contact is 800 feet, yet nearly 500 yards northeast of this contact, down the projected apparent dip, the Burlington-Kinderhookian contact at the railroad cut is at an elevation of between 820 and 830 feet. This railroad cut contact is also probably represented by a thrust surface, for the Northview is either very thin or absent. Exposures are insufficient to determine whether this is but one warped or faulted thrust plane or whether there are two independent fault surfaces.

The portion of this spur lying in section 19 contains more spectacular and concentrated proof of the existence of thrust faulting than any other area of similar size known within the report area or southwestern Missouri as a whole. Here, comparatively good exposures show the development of imbricate structure, the elimination of beds by thrust faulting, and the existence and structural relations of the unique interthrusts.

Other localities where decollement structure is well exposed are as follows:

(1) Southwest flank of bluff in the SW¼SW¼SW¼ sec. 20, T. 37 N., R. 24 W. At the 840-850 foot level, greatly disturbed Burlington rests almost directly on Sedalia. Here almost all the Northview has been removed, for it has a maximum possible thickness of one foot represented by a covered interval.

(2) Nose of north-pointing spur in the SW¼NE¼SW¼ sec. 19, T. 37 N., R. 24 W. At the 832 foot level, intensely crumpled Burlington rests directly on Jefferson City. The fault surface is essentially horizontal at this locality, but is not parallel to the bedding; as this contact is traced to the south on the west side of the spur, a constantly increasing section of the Kinderhookian is exposed, and near the head of the ravine on the west side of the spur, the complete section, with the possible exception of the Northview, is intact. True dip as measured on the Chouteau in the ravine floor is S. 40° W. at 9°.

(3) Although exposures are poor, the presence of angular Ordovician float in vertical proximity to Burlington suggests elimination of at least a portion of the Kinderhookian along the valley wall of West Fork Weaubleau Creek southeast from exposure no. 2 to near the south line of section 19, T. 37 N., R. 24 W.

The imbricate structure of the Burlington limestone is believed to have resulted from compressional forces which probably came from a westerly direction. It is generally assumed the rocks involved in imbricate structure dip in the direction from which the thrusting originated; e.g., if the imbricate strata dip to the west, thrusting was from west to east.

The general lack of preferred orientation of dips and strikes of Burlington involved in decollement and accompanying imbricate structure has obscured or complicated the trends of the structural pattern. Westerly dips apparently predominate in sections 19 and 20, T. 37 N., R. 24 W. along the west bluff line of Weaubleau Creek and on the southwest-pointing spur in the NE¼ sec. 19. This westerly-dipping Burlington is believed to be imbricate; however, because tops and bottoms of beds cannot be distinguished, imbricate structure might possibly be confused with superficially identical structures produced by isoclinal folds so tightly compressed they have snapped along axial planes.

No evidence of tightly compressed isoclinal folds was seen, and therefore, it is assumed that in many cases steeply-dipping Burlington beds are imbricate. Because these beds have a slightly preferred westerly orientation of dips, it is believed that their attitude lends supporting evidence of compression from the west.

No direct field evidence could be found to explain the absence of a large part of the Kinderhookian. There are at least three possible explanations:

(a) An erosional unconformity exists between the basal Chouteau and the Burlington.

(b) A large part of the Kinderhookian has been removed by solution.

(c) Thrust faulting has in some manner stripped off and removed the missing beds.

The Mississippian sedimentary breccia-conglomerates in the Vista quadrangle to the west (Chapter IV) indicate the existence of Ordovician highs in the Kinderhookian-Osagean seas. There is possible evidence of a late Kinderhookian-pre-Osagean erosional unconformity which would be necessary to explain the missing Kinderhookian beds in the area of decollement structure, for Kinderhookian fragments were found in the breccia-conglomerates. However, in the area of decollement structure, there are no conglomerates. Also, if such an unconformity is assumed, the unconformable contact is topographically lower than the normal sequence of Kinderhookian in surrounding areas.

For example, Burlington lies on Ordovician at the tip of the north-pointing spur in the SW¼NE¼SW¼ sec. 19, T. 37 N., R. 24 W. The elevation of this contact is 832 feet. Yet less than a quarter of a mile to the west in the SW¼NW¼SW¼ sec. 19, the Kinderhookian is present in its normal thickness of approximately fifty feet. The Chouteau-Jefferson City contact is at an elevation of 835 feet. A complicated scheme of diastrophic events would be necessary to explain an assumed unconformity separated from the conglomerate area to the west by a barrier of uneroded Kinderhookian rocks.

It is improbable that the Kinderhookian was removed by solution; chert is quantitatively very important in the Sedalia, and the Northview contains much clastic quartz. It might be assumed that differential pressure resulting from thrust faulting has locally increased the solubility of adjacent rocks. But that such solution would remove great quantities of chert and quartz, yet fail in some cases to act upon the lower Chouteau limestones is unlikely. In addition, there is no known silification within the area to account for the disposal of any solute.

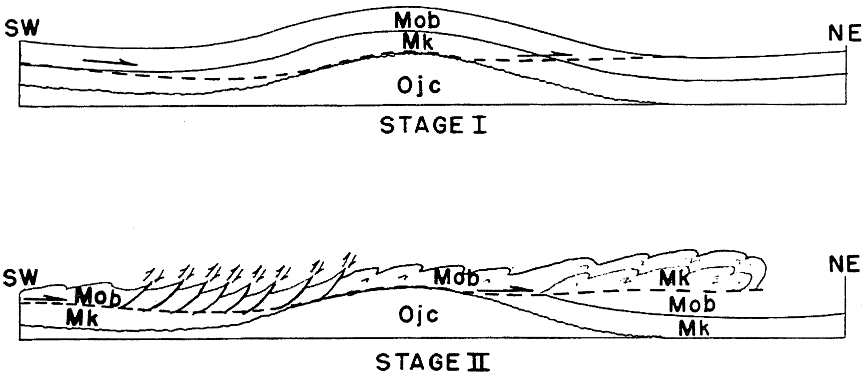
It is believed that the elimination of beds over large areas is the result of very low-angled thrust faulting. In all known exposures, the interval of the missing beds is represented by the decollement fault surface, and rocks above this surface are highly contorted; those below are less disturbed.

The method by which thrust faulting may have removed beds is not evident. The missing beds were not incorporated in the imbricate beds overlying the decollement fault surface, for these imbricate beds are composed solely of Burlington limestone.

Fig. 4 shows a possible manner of emplacing Burlington directly on Jefferson City. This hypothesis is supported by the fact that the structural high of Jefferson City in and surrounding sec. 19, T. 37 N., R. 24 W. coincides with the area where beds of Kinderhookian are most completely eliminated. It is believed that thrust faulting to the west of section 19 followed the incompetent Northview beds. But when this nearly horizontal thrust reached the structural high in and near section 19, it attempted to maintain its nearly horizontal motion and cut through the Kinderhookian to the highly competent Jefferson City. On the east side of the high, the thrusting again cut through the Mississippian and produced a postulated duplication of the section.

The assumed duplicated beds are not visible; they may have been destroyed by erosion, or they may be concealed.

Over the area as a whole, the Burlington shows evidence of decollement. Dips taken on this formation vary greatly in magnitude and direction within short distances, (Plate IX) yet older fromations underlying these crumpled beds are not so intensely crumpled. Therefore, strikes and dips determined on the Burlington must be used with the greatest of caution in determining underlying structures.



DIAGRAMATIC STRUCTURE SECTION
SHOWING METHOD BY WHICH THRUST FAULTING MAY HAVE LOCALLY ELIMINATED KINDERHOOKIAN BEDS

Figure 4. Ojc = Jefferson City. Mk = Kinderhookian. Mob = Burlington.

Displacement of Faults.—The horizontal displacement of the decollement faults could not be directly determined. However, if beds are eliminated in the manner postulated in Fig. 4, a minimum movement of one mile is necessary. At least another mile of movement is probably required to produce the imbricate structure and crumpling in the Burlington, so a minimum horizontal displacement of two miles is not unlikely.

Higher angled faults have relatively small throws. For this reason, the amount of dip of the fault surfaces could not be determined with available exposures.

The NNE-trending fault in the E½NE¼ sec. 30, T. 37 N., R. 24 W. has a minimum throw of 45 feet where the trace crosses the road near the north line of section 30. Probably, the maximum vertical displacement is not more than 60 feet. None of the higher angled faults in the western portion of the Weaubleau area has a throw of over 70 feet.

FAULTS OF UNKNOWN HADE

Throughout the mapped area of approximately 100 square miles are numerous faults. With the exception of the nearly horizontal thrust faults, the hade of fault surfaces is not known and whether these faults are compressional or tensional is not directly determinable.

It is believed that the faults of unknown hade are predominately the result of compressive forces because of their nearness to an area of intensive thrusting and because of the apparent development of decollement structure throughout much of the Weaubleau area. A widespread extent of decollement structure is suggested by the general crumpling of the Burlington and by the thinning of the Northview toward the area of intense thrust faulting.

That the numerous faults of unknown hade are of compressive origin is further suggested by the type of associated drags; beds faulted into juxtaposition have not developed the S-type drag usually developed by tensional faulting; rather, in many exposures they dip either mutually into or mutually from fault surfaces to form faulted chevron folds. Well-exposed examples of such faulted chevron folds are at the following localities:

(1) Southwest-trending fault in the W½ sec. 22, T. 37 N., R. 24 W. This structure is best exposed along the north side of Highway FAS "T" in the NW¼SW¼ sec. 22, T. 37 N., R. 24 W. In the upthrown block on the west side of the south-flowing stream, Jefferson City and Chouteau beds dip from ten to fifteen degrees to the southeast toward the fault trace which the stream follows. On the east side of the fault, downthrown Sedalia beds dip at approximately ten degrees to the northwest toward the fault trace. Beds dip toward the fault trace from both sides at the probable continuation of this fault in the south bluff of Weaubleau Creek in the extreme SW corner of sec. 22, T. 37 N., R. 24 W.

(2) South bluff of Little Weaubleau Creek in the NW¼SE¼NE¼ sec. 36, T. 37 N., R. 24 W. Exposures are insufficient for accurate determination of dips, but beds on the east side of the fault dip toward the fault trace at angles of at least 20°. The displacement at the bluff is slight, probably not over ten feet. In the west-central part of the same section 36, the vertical displacement is between twenty and thirty feet where Sedalia is faulted against

beds of the Burlington which lie immediately above the basal brown beds. The Geologic Map (Plate XI) shows the dip toward the fault line from both upthrown and downthrown sides.

(3) Westerly-trending fault in the NW¼NE¼SE¼ sec. 30, T. 37 N., R. 24 W. Chouteau on the north or upthrown side dips into the fault trace at 26°. Sedalia on the downthrown side dips into the fault trace at approximately 20°. The throw is between ten and twenty feet.

(4) Beds on the upthrown side dip away from the fault trace on the east side of the north-trending fault which bisects the W½W½W½ sec. 7, T. 36 N., R. 23 W. This fault is exposed in a cut on the south side of Highway U. S. 54 where Northview is faulted against Burlington. The throw at this point is approximately ten feet.

(5) A half-mile south of this point, the upthrown east side of the fault forms a conspicuous west-facing escarpment and beds on this east side dip to the east at 8°. The throw at the fault line a few yards west of the escarpment is between fifty and sixty feet. Beds on the west or downthrown side have variable dips; at some points along the fault line they dip into the fault line, at others they dip away from the line.

Faults of the area characteristically have small throws of less than seventy feet and short linear extent. Two of the faults other than decollement faults can be traced for nearly two miles but the majority cannot be traced over a half a mile.

These two longest known faults are on the north side of and parallel to Weaubleau Creek in secs. 22, 23, 26, and 27, T. 37 N., R. 24 W. The more northerly of these two faults is the more continuously exposed. In the NE¼SW¼ sec. 22, T. 37 N., R. 24 W., on the south side of Highway FAS "T", Burlington which dips to the southwest at from 15° to 20° is faulted against Sedalia on the north. This fault line is exposed at intervals to the center of the NW¼NW¼NW¼ of sec. 26, T. 37 N., R. 24 W., where basal Chouteau in the bed of a southwesterly-flowing stream is faulted against Burlington to the south. The minimum calculated throw at this point is 67 feet, the maximum known throw of the area. This downthrown Burlington has formed a conspicuous low escarpment as shown in Plate III-B. An easterly continuation of this fault is well expressed in the SW¼NE¼-SW¼NE¼ sec. 26, T. 37 N., R. 24 W., between the road corner where downthrown Burlington is exposed and a hundred yards to the north and forty feet higher where Northview siltstones are exposed in the roadbed. In the first south-draining valley to the east of these siltstones, the fault is expressed as a zone comprising three step faults with Sedalia faulted against Northview.

The long fault paralleling and between Weaubleau Creek and the fault described above cannot be as precisely located. Its existence is postulated in the S½ sec. 22, T. 37 N., R. 24 W., on the north side of Weaubleau Creek because Burlington beds on the north side of the assumed fault line dip from 15° to 20° to the southwest and this dip cannot be projected to the south bluff of the creek where Kinderhookian beds are exposed. This fault can be located to within less than a yard in the face of the southeast-facing bluff in the NE¼SE¼NE¼NE¼ sec. 27, T. 37 N., R. 24 W. Cherty Sedalia beds on the south are faulted against coarsely crinoidal Burlington beds on the north, indicating a throw of between twenty and thirty feet. Exposures are insufficient for determination of the direction of dip of the fault surface but are sufficient to demonstrate that the dip is nearly vertical. To the northwest from this point for nearly half a mile, exposures in the stream tributary to Weaubleau Creek are sufficient to permit tracing of the fault with reasonable accuracy. To the southeast, the continuation of the fault line is suggested in the NW corner, NE¼SW¼NE¼ sec. 26, T. 37 N., R. 24 W., where the Burlington is exposed at the road corner and at a ford across Weaubleau Creek 200 yards to the southeast. The Chouteau is exposed at only 15 feet lower elevation. Folding or faulting is required to explain this condition and because dips of exposed rocks do not project to fit the stratigraphic sequence, faulting is suggested.

The fault which follows approximately the bed of Little Weaubleau Creek in sec. 31, T. 37 N., R. 23 W., and in the SE¼NE¼ sec. 36, T. 37 N., R. 24 W., has 50 feet of throw at the north-south road crossing of this creek near the center of the W½ sec. 31. This fault may extend upstream discontinuously for nearly four miles to the southeast from the east edge of the Weaubleau quadrangle, as mapped by Schroeder[89] (See Tectonic Map, Plate XII).

It is impractical to describe every fault in the area in detail. Most of the extremely short faults shown on the geologic and tectonic maps are recognizable only in stream beds and the throw is so slight, (in some cases less than fifteen feet) or the linear extent so short and the outcrops so poorly exposed that

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[89] Schroeder, E. R., The Geology of a portion of the Hermitage quadrangle, Missouri: Unpublished Master's thesis, State University of Iowa, Plate II, 1950.

they cannot be followed along their trace for more than ten to twenty feet. Therefore the strike of these short faults as mapped is very approximate.

There is, however, a marked northwesterly zone of faulting in addition to the trend represented by interthrusts and decollement structure (See Tectonic Map, Plate XII).

This zone of northwesterly-trending faults is expressed in the southeast end by the fault which Little Weaubleau Creek follows; in the middle portion it is expressed by the two faults paralleling Weaubleau Creek east of Gerster; and its northern extremity is represented by the faults followed by Clear Creek and by Weaubleau Creek in sec. 7, T. 37 N., R. 24 W. The total length of this zone is twelve miles, including that portion which extends four miles southeast of the Weaubleau quadrangle along Little Weaubleau Creek. The trend is N. 53° W. or approximately parallel to the major faults of southwestern Missouri.

FOLDS

Despite the intensity of compression within the area, the folds which are large enough to map on the 1/24,000 quadrangles have small closures of less than a hundred feet and are mappable for distances of less than seven miles along their trends.

Anticlines are generally more conspicuous than the synclines. The synclines are typically bisected by faults and the axial traces of the syclines correspond approximately with fault traces. Therefore, in order to preserve clarity, the majority of the synclines are not shown on the Tectonic Map. Furthermore anticlines are more conspicuous than synclines because in several cases, beds between the flanks of anticlines are horizontal and there is no pronounced axial trace of intervening synclines.

In the following discussion, width of folds is defined as the distance between the points where flanks of an individual fold reverse dip or become horizontal. This distance is measured normal to the strike of the fold and in this report is measured between points on the Kinderhookian-Osagean contact. In cases of near-horizontal thrusting eliminating beds on folds, this contact must be reconstructed. The height of folds will refer to the vertical distance between axes of adjacent synclines and anticlines measured on the Kinderhookian-Osagean contact or that contact reconstructed.

Because the major folds of the area are essentially symmetrical and have nearly vertical axial planes, the crest lines and axial traces are essentially identical. The maximum computed fold height is 105 feet at the crest of the northwest-trending anticline in sec. 19, T. 37 N., R. 24 W. The width of this fold at this point is at least a mile and a half but the maximum is indeterminable because of lack of control. The northwest-trending anticline which passes through the center of T. 36 N., R. 23 W., has a height of 40 feet in section 6 and a width of two miles in section 15.

The majority of the folds have heights of less than fifty feet as shown in the following examples:

(1) South-plunging anticline in western halves of secs. 29 and 32, T.37 N., R. 24 W. The height is 50 feet and the width is slightly over a quarter of a mile in the vicinity of the common section line of the SW¼ sec. 29 and the NW¼ sec. 32.

(2) Northeast-trending anticline in the N½ sec. 36, T. 37 N., R. 24 W. The height is 40 feet; the width three quarters of a mile.

(3) Northwest-trending anticline on the north side of Weaubleau Creek in secs. 21, 22, 23, 25, 26, and 27, T. 37 N., R. 24 W. The height in the SM¼ sec. 23 is 30 feet and the width is approximately a mile.

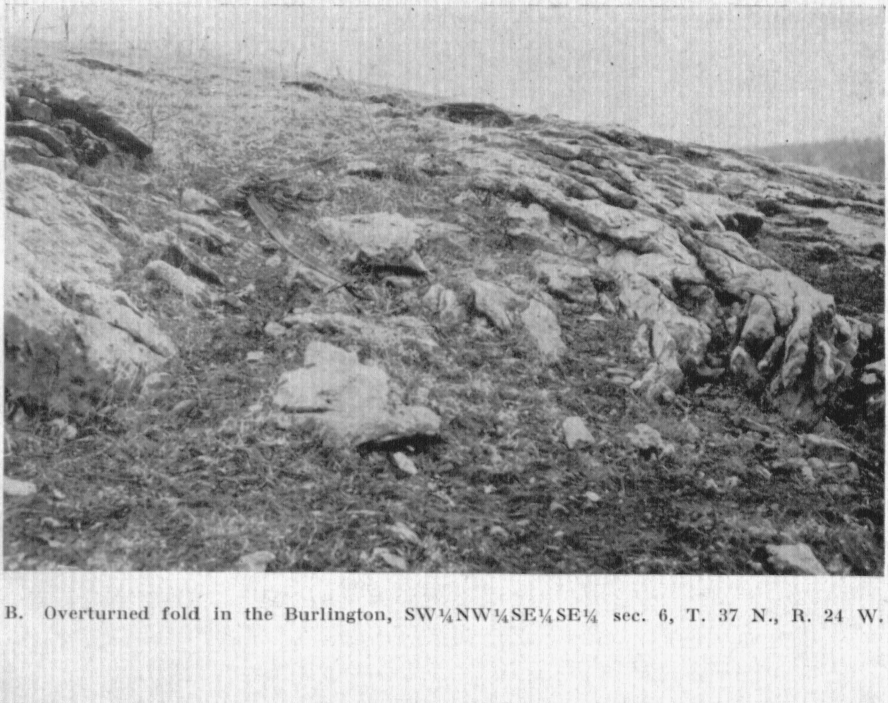
(4) Northwest-trending syncline which originates in sec. 6, T. 37 N., R. 24 W., and plunges to the northwest beyond the mapped area. In sec. 6, the height is 45 feet. The width near the northern boundary of the map is at least three miles.

Although folds shown on the tectonic map are characterized by gently dipping flanks, many of the minor folds display more dramatic evidence of compression such as overturned beds and chevron folds.

A typical small chevron fold is shown in Plate IV-A. The origin of this fold is not known. It may be the direct result of lateral compression in the Burlington or it may have resulted from an interthrust which failed to reach the surface but created a sharp fold above or in advance of its fore end.

An overturned fold is exposed in the SW¼NW¼SE¼SE¼ sec. 6, T. 37 N., R. 24 W., on the east end of a spur composed of Burlington limestone (Plate IV-B). This anticline trends N. 80° W. and is overturned on the northeast flank.

A. Chevron fold in the Burlington, NW¼NW¼SW¼SE¼SE¼ sec. 30, T. 37 N., R. 24 W.



B. Overturned fold in the Burlington, SW¼NW¼SE¼SE¼ sec. 6, T. 37 N., R. 24 W.

AGE AND CAUSES OF DEFORMATION

The major faulting in the Weaubleau area was post-Burlington—pre-Dederick. There are two lines of supporting evidence:

(1) Burlington and older beds are intensely deformed, but the Dederick and Graydon are but slightly disturbed.

(2) Some streams which parallel the present structural grain of the area occupy valleys which were originally excavated in pre-Dederick time and partly filled with Dederick shales. These shales are relatively undisturbed and it is therefore believed that the major structural trends of the area are pre-Dederick in age. Tanyard Branch and Coon Creek exemplify this history.

No faulting was seen in Pennsylvanian rocks. Bretz[90] explains erratic dips in the Pennsylvanian in a cut along Highway U. S. 54 as resulting from collapse into a sink structure. The only other two known exposures of steeply-dipping Pennsylvanian are in stream valleys and could easily have assumed erratic dips as a result of being let down by solution of underlying and surrounding limestones.

Rather steeply dipping beds of Graydon were found in Rock Creek, 200 yards north of the south line of the SW¼ sec. 34, T. 37 N., R. 24 W., where beds of sandstone which show no visible evidence of cross-bedding dip S. 26° E. at 31°. In the S½SE¼-NE¼ sec. 8, T. 36 N., R. 24 W., in a ravine, near the head, Graydon sandstone dips N. 18° W. at 17°. The bulk of the poorly exposed Pennsylvanian strata are gently dipping.

Within the area, little can be determined as to the ultimate cause of the intense deformations of the Mississippian and older rocks. It is certain that these deformations were caused by near-horizontal compressive forces, and there is strong evidence that these forces moved in a northeasterly direction.

The presence of the dolomitic Mississippian conglomerates immediately to the west of the most intensely faulted area suggests that compressive forces were transmitted through the massive conglomerates and found relief in the normal bedded rocks to the east. The structural grain of the Weaubleau area trends northwest or parallel to the regional structure of western Missouri. Therefore it is believed that the deformations of the Weaubleau area are not the result of any peculiar local tectonics

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[90] Bretz, J H., Origin of the filled sink structures and circle deposits of Missouri: Geol. Soc. America Bull., vol. 61, no. 8, pp. 800-801, 1950.

but rather, are a particularly intense expression of compressive forces which determined much of the structure of western Missouri.

For the sake of convenience, references to earlier views regarding the tectonics of Missouri will include the Springfield Pleateau and therefore the Weaubleau area in the Ozarks. Although the present writer considers the Springfield Plateau to lie outside of and on the western margin of the Ozarks, the majority of earlier writers included the Springfield Plateau in the Ozarks and their views are best presented by temporarily following their physiographic classifications.

The literature commonly refers to the Ozark Plateau as a "dome", or less frequently, as an anticlinorium, and some writers prefer to use the genetically unrestrictive term "uplift".

Broadhead[91] considered the Ozarks to be a "quaquaversal" uplift, implying that they were a product of tension (?).

Keys[92] also suggested that the Ozarks originated from vertical movement, and he was supported by Haworth[93] who stated that the Ozark uplift was monoclinal and that forces acting radially rather than tangentially resulted in stretching of strata, rather than crumpling.

Adams[94] is one of the few writers, both past and contemporary, who does not consider the Ozarks to be a tensional dome. In 1901 he said (page 94):

> "The prevailing conception that the Ozark region is dome shaped, although perhaps helpful, is apt to be misleading. While this term may describe its general configuration, it should be borne in mind that the structure is complex and cannot be explained as the result of any one movement or period of oscillation. The faulting phenomena of the region have not been studied as yet in sufficient detail and widely enough to allow them to be grouped with reference to their relations to each other and the region in general or the causes producing them.
>
> .....The most important and widespread action in the Joplin region in particular has been brecciation, and this can hardly have taken place except in connection with movements of beds one upon another in a manner resulting from compressive forces."

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[91] Broadhead, G. C., The geological history of the Ozark Uplift: Am. Geologist, vol. 3, pp. 6-13, 1889.

[92] Keys, C. R., Characteristics of Ozark Mountains: Missouri Geol. Survey, 1st ser., vol. 8, pp. 341, 345, 1895.

[93] Haworth, Erasmus, Relation between Ozark uplift and ore deposits: Geol. Soc. America Bull., vol. 11, pp. 231-240, 1900.

[94] Adams, G. I., Physiography and geology of the Ozark region: U. S. Geol. Survey 22d Ann. Rept., pt. 2, pp. 92-94, 1901.

Later investigators,[95, 96] although aware that the present structure of the Ozarks resulted from more than one uplift, have clung to the term "dome" despite Adams' warning of the danger of implying simplicity of structural form in describing the Ozarks as a dome.

According to Giles,[97]

> "The Ozark dome is a broadly oval geanticline with axis trending southwestward through south-central Missouri into Oklahoma."

However, Plate 2 (p. 40) of his paper shows the axes of the major anticlines and synclines of the Ozarks as trending northwest-southeast. The same pattern is shown in the Tectonic Map of the United States.[98]

The northwesterly trend of these folds superimposed on the northeasterly elongation of the Ozarks suggests a complexity of structural history. However, these northwesterly trending anticlines and synclines are known to be at least late Mississippian, and in some cases, post-Pennsylvanian in age.

These folds have been described in various parts of western Missouri and the Tri-State district by Shepard,[99] Siebenthal and Smith,[100] Hinds and Greene,[101] Fowler,[102] Weidman,[103] and others. Fowler and Weidman concur in considering these flexures to be of compressional origin but do not state the source of the pressure. They describe both northeast-and southeast-trending folds, and Fowler[104] states that:

> ". . . . . the rocks were compressed and shortened in a general north-south direction and elongated in an east-west direction."

Little is recorded regarding the origin of faults in the Ozarks. The majority of investigators have considered the faults to be

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[95] Dake, C. L., and Bridge, Josiah, Early diastrophic events in the Ozarks (abstract): Geol. Soc. America Bull., vol. 38, pp. 157-158, 1927.

[96] Fenneman, N. M., Physiography of eastern United States: New York and London, McGraw Hill Book Co., pp. 631-662, 1938.

[97] Giles, A. W., Structural features of the Mississippi Valley region and their relation to mineralization: Geol. Soc. America Special Papers, no. 24, p. 44, 1939.

[98] Committee on Tectonics, Division of Geology and Geography, National Research Council: Tectonic Map of the United States, Published by Am. Assoc. Petroleum Geologists, 1944.

[99] Shepard, E. M., A report on Greene County: Missouri Geol. Survey, 1st ser., vol. 12, pp. 144-148, 1898.

[100] Siebenthal, C. E., and Smith, W. S. T., Description of the Joplin district (Missouri-Kansas): U. S. Geol. Survey, Geol. Atlas, fol. 148, pp. 9, 198, 1907.

[101] Hinds, Henry, and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geol. and Mines, 2d ser., vol. 13, Plate 23, 1915.

[102] Fowler, G. M., Structural control of ore deposits in the Tri-State lead and zinc district: Geol. Soc. America Special Papers no. 24, pp. 53-60, 1939.

[103] Weidman, Samuel, Structure of the Miami-Picher district: Geol. Soc. America Special Papers no. 24, pp. 49-53, 1939.

[104] Fowler, G. M., op. cit., p. 57, 1939.

tensional, resulting from vertical movements. Fowler and Weidmand believe many of the faults of the Tri-State district are shear faults, i.e., the result of compression.

Three previous references have been made to reverse or thrust faults in Missouri:

Shepard[105] in describing a fault in Greene County says:

> "The hanging wall is higher than the foot wall; the reverse of what is usually the case."

Post-Mississippian thrust faults in the eastern portions of Perry and Cape Girardeau counties in southeastern Missouri are described by Flint.[106] The hades of these thrust are small, "nowhere reaching an angle greater than 30 degrees".

Weller and St. Clair[107] mapped post-Pennsylvanian thrust faults in Ste. Genevieve County, also in southeastern Missouri, and clearly differentiated them from late Devonian faults which were considered to be normal.

Low-dipping thrust faults are recorded only within the Weaubleau area. However, little detailed field mapping has been recorded in this portion of the Ozarks and undoubtedly, more extended work will show that the Weaubleau area is not unique. It should also be borne in mind that in general, the throw of faults in southwestern Missouri is small, ordinarily less than 200 feet. For this reason, it is difficult to differentiate the hanging wall and footwall, and conservative geologists would usually map these faults as normal faults unless there was evidence to the contrary.

Clark[108] states that the major diastrophic activity in southwestern Missouri was post-St. Louis (Middle Meramec) and pre-Graydon (Cherokee) for in Dade County, the St. Louis limestone is preserved on the downthrown side of the Chesapeake fault, and Pennsylvanian deposits locally conceal the fault.

Because the Weaubleau trends conform with the regional trends of southwestern Missouri, Clark's dating of the Chesapeake fault might be applicable for a more precise dating of faulting in the Weaubleau area.

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[105] Shepard, E. M., op. cit., p. 155.

[106] Flint, R. F., Thrust faults in southeastern Missouri: Am. Jour. Sci., 5th ser., vol. 12, pp. 37-40, 1926.

[107] Weller, Stuart, and St. Clair, Stuart, Geology of Ste. Genevieve County, Missouri: Missouri Bur. Geol. and Mines, 2nd ser., vol. 22, pp. 264-266, 1928.

[108] Clark, E. L., The St. Louis formation in southwestern Missouri: Missouri Geol. Survey and Water Resources, 59th Bienn. Rept., 1935-1936, App. 4, pp. 1-13, 1947.

Evidence of earlier tectonic activity between the Weaubleau area and the Missouri-Kansas line is presented on pages 97-98.

Although the compressive forces that affected the Weaubleau area appear to have originated from the southwest in Oklahoma and Kansas, there is at present, insufficient data to determine the ultimate source of these forces.

CHAPTER IV

ORDOVICIAN-MISSISSIPPIAN RELATIONS IN THE VISTA QUADRANGLE

General Statement.—The geologic map of the Weaubleau Creek area includes a mile-wide north-south strip of the westerly-joining Vista quadrangle. Mississippian conglomerates were found in this strip and further investigation was necessary to the west of the area shown on the geologic map to determine the source, stratigraphic relations, and distribution of these conglomerates.

The following observations resulted from the reconnaissance study of that portion of the Vista quadrangle lying north of Highway U. S. 54 and west from the area shown on the geologic map to the Sac River:

(1) Approximately 17 square miles of both Kinderhookian and Osagean rocks are conglomeratic. Within this area, included fragments are derived predominantly from the Ordovician (See Plate X).

(2) There are a number of Ordovician (Jefferson City) highs in the area. Mississippian rocks abut against these highs.

(3) Physical evidence of an erosional unconformity between Kinderhookian and Osagean rocks is suggested in an exposure in the east bluffs of Sac River.

The distribution of Mississippian conglomerates is shown on Plate XII. The area delineated for these conglomerates includes only the area where Kinderhookian as well as Osagean rocks are conglomeratic. Conglomeratic Osagean rocks are believed to have a greater lateral extent than outlined on the map because of an unconformity at the base of the Burlington. Unless otherwise specified, conglomerates discussed in the following pages will be those of the area where both Kinderhookian and Osagean rocks are conglomeratic.

The fragments in the conglomerates are not Ordovician fragments grouted into the Mississippian. The fact that the Mississippian fossils in the matrix are relatively undistorted and unabraded indicates that the foreign material was incorporated at the time of deposition of the Mississippian.

Kinderhookian Conglomerates.—The Burlington is the dominant outcrop of the Mississippian conglomerates. Although ex-

Kinderhookian showing facies changes from normal to conglomeratic lithology. SW¼NE¼SW¼SE¼SE¼ sec. 16, T. 37 N., R. 25 W.

posures of the Kinderhookian are relatively few, they are sufficient to demonstrate that the Chouteau and Sedalia are conglomeratic and that Ordovician rocks were a local source of clastics into at least Osagean times.

The best exposure of Kinderhookian conglomerates is in the S¼NE¼SW¼SE¼SE¼ sec. 16, T. 37 N., R. 25 W., in the southwest bank of the northwest-flowing stream (Plate V and loc. D, Plate X). Where this stream strikes bed rock on the west side and swings to the north, the Chouteau is a typical nodular, argillaceous, finely crinoidal limestone. Downstream and down the apparent dip of 15° to 20° to the northwest along the low bluff face, the normal Chouteau facies grades laterally into a massive conglomerate with a buff dolomitic matrix. Superficially this conglomerate resembles the Jefferson City but the matrix is crinoidal and contains forms of *Cryptoblastus* typical of the Chouteau. Jefferson City fragments in the conglomerate consist of opaline and oolitic chert and fragments of gray to brown dolomite.

Gray-buff irregularly-bedded Sedalia limestone is exposed at the northwest end of this low bluff. This limestone is slightly dolomitic and silty and the beds, which are from six to twelve inches thick, contain numerous lenses of typical blue-centered lenticular chert. This Sedalia is non-conglomeratic and appears to be slightly faulted and downthrown relative to the conglomeratic Chouteau to the southeast.

Upstream, or southeast from the normal non-conglomeratic Chouteau mentioned above, this low bluff of Chouteau passes into a conglomerate facies and contains boulders of Jefferson City as large as two feet in diameter.

Conglomeratic Chouteau is exposed in the bed of this same stream in the center of the E½NW¼SW¼SE¼ sec. 16, T. 37 N., R. 25 W. (loc. E, Plate X). This Chouteau in the stream bed at an abandoned ford dips S. 50° W. at 20° to 30° and is overlain by cherty Sedalia in the south bank of the stream. The Chouteau varies laterally as well as vertically from a typical crinoidal nodular limestone to a conglomeratic thick-bedded dolomite. At this exposure, the Chouteau near the Sedalia contact is so coarsely crinoidal that it might easily be confused with Burlington were it an isolated exposure.

Conglomeratic Sedalia is exposed 200 yards upstream from the ford exposure (loc. F, Plate X). This Sedalia is intensely sheared and demonstrates that post-Kinderhookian diastrophism was active in this area.

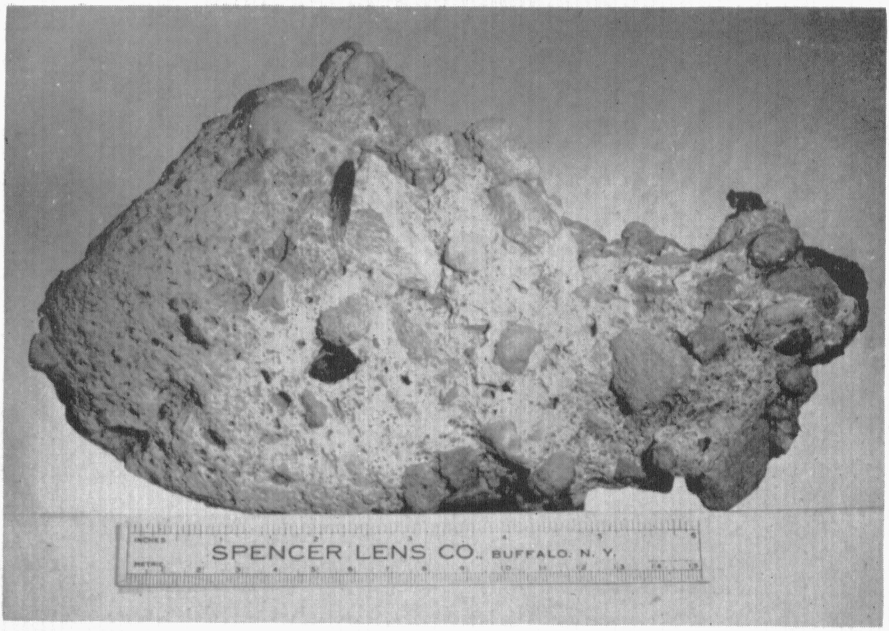
The only other Kinderhookian exposure seen in the conglomerate area is in the SE¼ sec. 27, T. 37 N., R. 25 W., in the bed of the southwesterly-draining stream which enters Coon Creek near Nance Cemetery. One exposure of slightly conglomeratic, finely crinoidal, argillaceous Chouteau limestone is in the stream bed 100 yards north of the south section line (loc. G, Plate X). The other Chouteau exposure is in the bed of the same stream at an east-west ford crossing a quarter of a mile north of the south section line (loc. H, Plate X). This exposure of Chouteau is also but slightly conglomeratic. East from the ford, a buff to greenish silty shale (Northview) is exposed in ditches on either side of the east-west abandoned road which fords the creek. This shale is exposed about halfway from the top of the road grade to the ford 150 yards east of the ford (loc. I, Plate X).

Burlington Conglomerates.—The Burlington conglomerates consist of both angular and rounded fragments of Jefferson City enclosed in a dolomite or dolomitic limestone matrix (Plate VI-A and B). Although these fragments are predominately of conglomerate dimensions, they range from silt size to boulder dimensions.

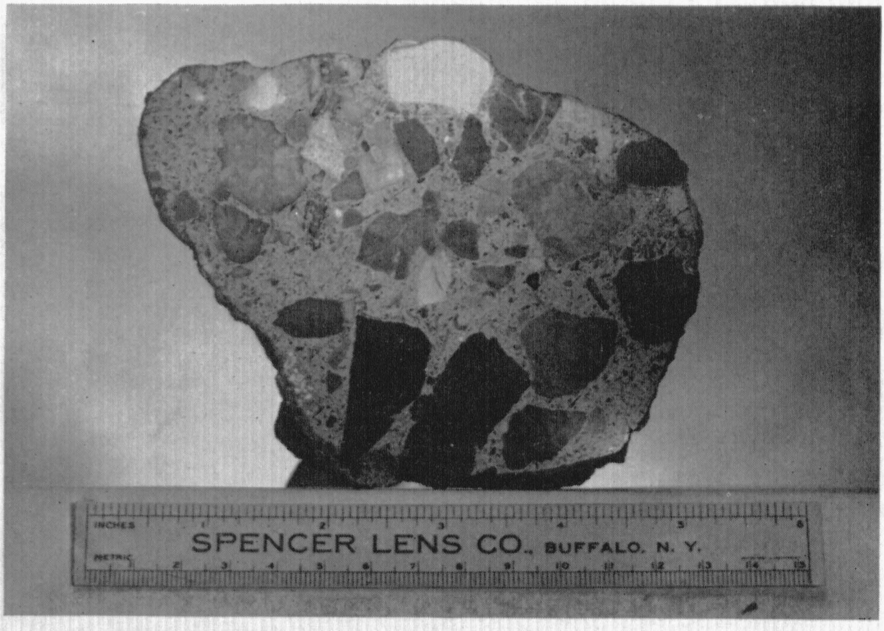
Typically, on weathered exposures, calcitic fossils in the dolomitic matrix have been removed by solution and a porous rock results. The bedding is the least pronounced where the dolomite content is the highest, and massive beds of Burlington from 10 to 15 feet thick are not uncommon. In general, the dolomitic conglomerates are buff to brown and the color is darkest where the dolomite content is highest.

Cherts of Burlington age in the conglomerate area are less vitreous than those in the normal Burlington. Commonly, these cherts weather out as "cannon balls" and some of the spheroidal nodules contain a single concave depression which gives them a shape similar to a partly collapsed rubber ball. Such cherts in place in conglomeratic Burlington are exposed in the bed of the south-draining stream in the center, S½SW¼ sec. 26, T. 37 N., R. 25 W. (loc. J, Plate X). Residual "cannon ball" cherts are exposed along the east-west road in the NE corner, NW¼-NW¼SE¼ sec. 21, T. 37 N., R. 25 W. (loc. K, Plate X).

PLATE VI



A. Weathered specimen of Burlington conglomerate.



B. Polished section of Burlington conglomerate.

Chert is the dominate foreign material in the Burlington conglomerate. These chert fragments are so distinctive that there is no doubt that they were derived from the Ordovician. However, the fragments are so plentiful in the conglomerates that they may lead to mis-identification of the host rock; e.g., insoluble residues of the Mississippian conglomerates are practically identical with those of some Ordovician rocks and residual cherts of the conglomerates might easily lead to the erroneous mapping of covered conglomerate areas as Ordovician.

The conglomeratic Burlington is so widespread that it is impractical to enumerate all of the good exposures. Some of the especially well-exposed or easily accessible exposures are as follows:

(1) Along the west side of the road in the SE¼NW¼NW¼ sec. 27, T. 37 N., R. 25 W. (loc. L, Plate X). Here there are marked facies changes both vertically and laterally from conglomeratic dolomite to relatively pure crinoidal limestones. The conglomerate facies is exposed in a cut on the west bank of the road; the non-conglomeratic limestone facies crops out a few yards to the south on the south-sloping valley wall.

(2) On the north side of the road on the south line, SW¼SE¼NE¼ sec. 21, T. 37 N., R. 25 W. (loc. M, Plate X). Large blocks of dolomitic conglomerate have been excavated during road improvements and lie along the fence line.

(3) A few feet east of the road culvert in the bed of the east-draining stream in the NW¼SW¼NW¼SW¼ sec. 13, T. 37 N., R. 25 W. The Burlington is very crinoidal and but slightly dolomitic. Included fragments of Jefferson City are both angular and rounded.

(4) East valley wall of Coon Creek in the NE¼NW¼SE¼ sec. 20, T. 37 N., R. 25 W. (loc. N, Plate X). Massive Burlington dolomites form a steep low bluff from the bridge upstream to near the east line of section 20. Foreign fragments are less conspicious than in exposures previously listed but this an an excellent exposure in which to observe the lack of bedding in the dolomite and the development of pitted lithology by solution of calcitic fossils.

(5) West side of Missouri Highway 13 in the southwest-flowing stream in the NW¼SW¼SE¼SE¼ sec. 14, T. 37 N., R. 25 W. (loc. O, Plate X). This exposure is not unusual but deserves special mention because it is within a few steps of the highway.

(6) Along the north-south section line road dividing secs. 16 and 17, T. 37 N., R. 25 W. Very coarse-grained conglomerates have been exposed by grading on the west side of the road, 75 yards north of the center-section lane to the west (loc. P, Plate X). There are also good exposures in the southwest-draining stream valley which is crossed by the section line road 100 yards south of the same lane entrance.

Source of Mississippian Conglomerates.—The presence of abundant fragments of Jefferson City in both Kinderhookian and Osagean rocks suggest that there were highs of Jefferson City in the early Mississippian seas which furnished material for the Mississippian conglomerates.

Because some fragments of the conglomerate are very angular and some are of boulder size, it is believed that the source of these fragments was local. Furthermore, the concentration of the conglomerates in an elliptical area of approximately seventeen square miles suggests that the source was local rather than regional. Exposures of what may be source highs of Jefferson City are discussed under the heading, **Jefferson City Highs** (pages 94-97).

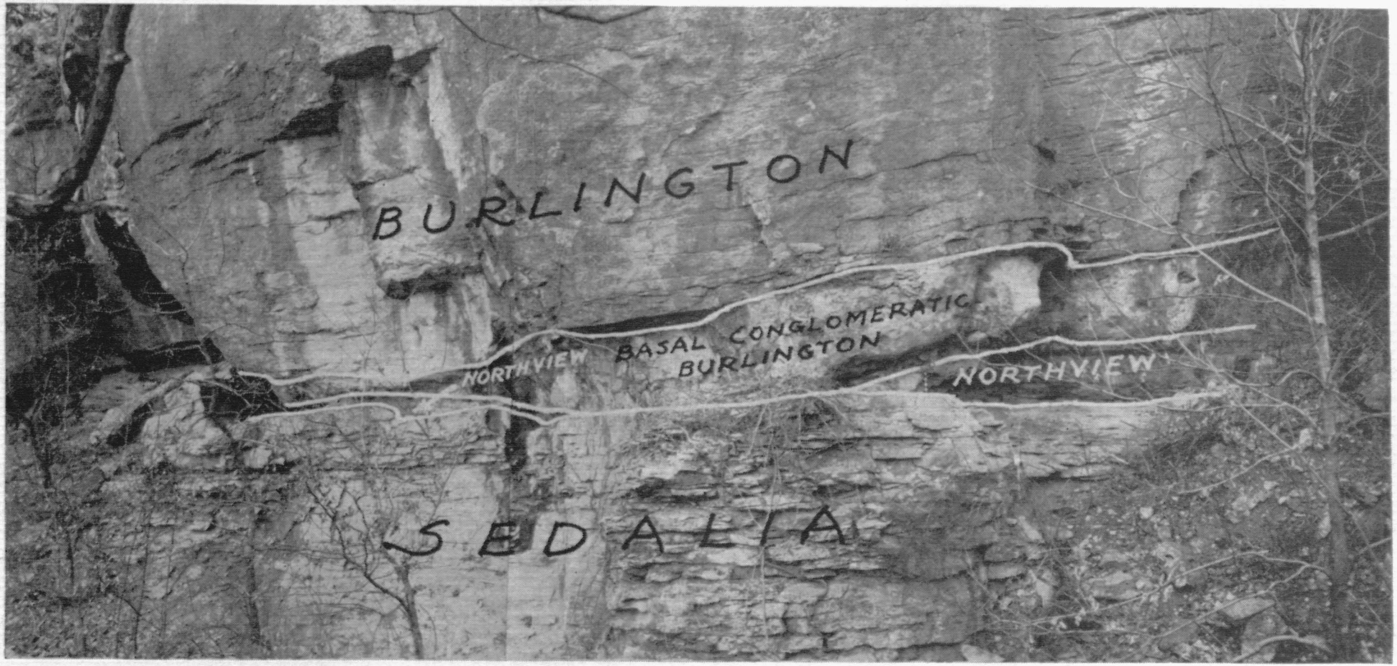
Possible Kinderhookian-Osagean Unconformity.—What may be a Kinderhookian-Osagean unconformity is exposed at two localities near Sac River.

One exposure is in the east bluff of Sac River in the NW¼SW¼NE¼NE¼ sec. 7, T. 37 N., R. 25 W. (loc. A, Plate X and photograph, Plate VII). The lower part of the section consists of typical non-conglomeratic Chouteau and Sedalia. The uppermost bed of the Sedalia is a highly fossiliferous limestone which varies laterally from a brachiopod conquinite to a finely crinoidal limestone. This bed varies from a featheredge to nearly a foot in thickness.

It is overlain by the Northview which is represented by a re-entrant at the base of the nearly vertical Burlington bluff. The Northview is a buff to greenish gray shaly dolomitic siltstone overlain by "vermicular" blocky siltstone. The Northview varies from a trace to three feet in thickness within short lateral distance and the upper surface is very uneven.

The basal beds of the Burlington vary laterally from the common silty dolomitic brown beds to clean coarsely crinoidal gray limestone. Included in the basal beds are blocks of Northview siltstone, Ordovician oolitic chert and much rubble, including a boulder of brecciated Jefferson City three by five feet in exposed dimensions. This boulder is exposed in the reentrant at the extreme left side of Plate VII.

From this point along the bluff line in both directions for at least half a mile, the Northview is generally less than a foot thick and at many points is but a featheredge parting between the Burlington and Sedalia.



Kinderhookian-Osagean unconformable (?) contact in east bluff of Sac River. NW¼SW¼NE¼NE¼ sec. 7, T. 37 N., R. 25 W.

An uncomformity at the base of the Burlington is suggested by the following evidence:

(1) The fragments of Northview and older rocks in the basal rubble of the Burlington.

(2) The irregular upper surface of the Northview which regionally is relatively even.

(3) The unusual thinness of the Northview which from projected regional isopachs should be between four and six feet thick.

(4) The lack of uniform development of the brown beds at the base of the Burlington which vary from a featheredge to five feet in thickness.

(5) The matrix of the basal Burlington breccia-conglomerates is in part apparently undisturbed, suggesting that foreign fragments were introduced by normal deposition before the matrix was indurated.

There is also a suggestion of near-horizontal thrust faulting (decollement) at the base of the Burlington. Kinderhookian beds are relatively undisturbed but Burlington beds are independently crumpled and distorted. Such deformations are exposed along the Sac River bluff line for a quarter of a mile north of the locality shown in Plate VII. Masses of bedded Jefferson City as much as twenty feet long and five feet thick lie at or near the base of the Burlington at several localities along this quarter-mile stretch. These large bedded masses are more probably interthrusts than boulders or blocks of sedimentary origin.

The second exposure of what may be a Kinderhookian-Osagean unconformity and/or a near-horizontal thrust fault is in the northeast wall of a tributary to Sac River eastward to an overhanging ledge where the northernmost feeder enters this tributary in the NE¼SW¼NE¼SE¼ sec. 7, T. 37 N., R. 25 W. (loc. B-C, Plate X). Fig. 5 shows the stratigraphic relations at this point. Conglomeratic basal Burlington is exposed ninety-four feet northwest of the overhanging ledge which is point C of Fig. 5. Included in this conglomerate are fragments of fine-grained gray limestone which closely resemble the Sedalia. Burlington beds near the northwest end of Fig. 5 are crumpled independently of the underlying Kinderhookian.

It is impossible to say whether the beveling of the Kinderhookian is the result of thrust faulting or an angular unconformity. The writer believes both conditions may have contributed to the beveling.

Jefferson City Highs.—Within the Vista quadrangle are a number of highs of the Jefferson City formation which are believed to protrude through the Mississippian in some cases and in other cases to have Burlington overlying them.

A review of stratigraphic and structural relations believed to be present in the Weaubleau Creek area and the Vista quadrangle presents the following four hypotheses to explain such Jefferson City highs:

(1) They are relic highs of Ordovician which were present in the Mississippian seas and furnished material for Mississippian conglomerates.
(2) They are interthrusts.
(3) They are the result of near-horizontal thrust faulting which has emplaced Burlington directly on the Jefferson City.
(4) They are the result of an erosional interval between the Kinderhookian and Osagean during which the Kinderhookian was completely removed at some localities so that the Burlington was later deposited directly on Jefferson City.

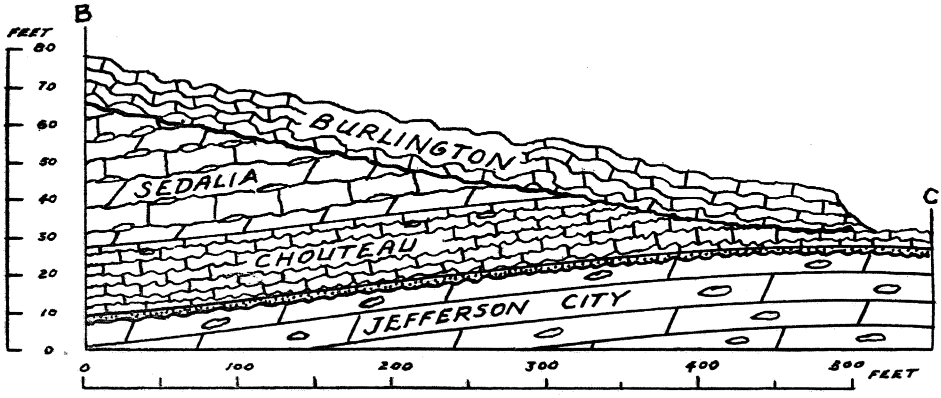


Figure 5. Cross section between Locations B and C of Plate X, showing unconformity and/or thrust surface between Kinderhookian and Osagean. NE¼SW¼NE¼SE¼ sec. 7, T. 37 N., R. 25 W.

There are two types of Jefferson City highs in the Vista area: one type is the pinnacle or dike-like exposure surrounded by Mississippian rocks. The other type is represented by relatively large areas in which the stratigraphic interval between the Jefferson City and the Burlington appears to be too small to allow for a complete section of the Kinderhookian. In some cases, this interval is so small that it is suspected that Burlington rests directly on Jefferson City.

Pinnacle or dike-like exposures are discussed below by number corresponding to location numbers given on Plate X.

Loc. 1, bed of Brush Creek in the NE corner, NE¼NW¼SE¼ sec. 3, T. 37 N., R. 25 W. The total extent of this Jefferson City exposure is less than ten square yards. It is a buff sacchroidal dolomite with no discernible bedding. Conglomeratic Burlington limestones and dolomites are exposed to within three yards of the Jefferson City and apparently abut against it.

Loc. 3 and 4, south-facing valley wall in the SW¼SW¼NW¼SE¼ sec. 16, T. 37 N. R. 25 W. A high of tough brown Jefferson City dolomite rises forty feet above the stream bed to the south where conglomeratic Kinderhookian and Osagean rocks are exposed. This high can be traced to the west along the valley wall for 200 yards, and the distribution of exposures is dike-like. The beds are nearly vertical in dip and some are highly brecciated. The best exposure at the east end of the dike lies on the projected strike of the previously-discussed Kinderhookian beds at exposure E in the creek bed to the southeast. Exposures are insufficient to determine whether the Burlington abuts against the flanks of this Jefferson City high.

Because the Jefferson City high lies on the projected strike of the Kinderhookian beds, it may be that the dip of these Kinderhookian beds is a result of the high. This dip of 20° to 30° may be a flexure resulting from production of the high after induration of the Kinderhookian.

Loc. 5, along the southeast bluff of the south-flowing stream in the NE¼SW¼SW¼SE¼ sec. 26, T. 37 N., R. 25 W. There are several small exposures of nearly horizontal Jefferson City near the base of the low bluff and conglomeratic Burlington is exposed down to within ten feet vertically of the Jefferson City.

Loc. 8 and 9 in the bed of the southwest-draining stream in the NE¼NW¼NE¼NE¼ sec. 28, T. 37 N., R. 25 W. Brown lumpy massive Jefferson City dolomite is overlain by a silty conglomeratic buff dolomite. This dolomite is slightly crinoidal and known to be Mississippian, but whether it is Kinderhookian or Osagean is not known. Conglomeratic and dolomitic Burlington limestones are exposed fifty yards downstream from exposure 9.

Loc. 11, in the bed of the southwest-draining stream, NE corner, SW¼NE¼SW¼ sec. 21, T. 37 N., R. 25 W. Tough brown, thick-bedded Jefferson City dolomite which varies from horizontal to 10° in dip is exposed to within five yards laterally of dolomitic Burlington conglomerate.

Loc. 12 and 13 in the west valley wall of the north-draining stream in the SW¼SE¼NW¼SE¼ sec. 19, T. 37 N., R. 25 W. Pinnacles of nearly vertical thick-bedded brown Jefferson City dolomite are exposed to within ten yards of essentially horizontal non-conglomeratic Burlington limestone.

Loc. 15 in the bed of the northwest-draining ravine in the NW¼SW¼-SE¼NE¼SE¼ sec. 7, T. 37 N., R. 25 W., five yards upstream from

> the waterfall into the main ravine. Nearly vertical beds of thick-bedded brown Jefferson City dolomite are surrounded by coarsely crinoidal Burlington limestone. This Burlington is slightly conglomeratic but contains fragments of dense limestone which appear to be intraformational rather than foreign. The Burlington is essentially horizontal except at the waterfall where it dips sharply to the northwest into the master ravine. This dip may be slump into the basin below.

At several localities, there are relatively large areas where the stratigraphic interval between the Burlington and the Jefferson City is too small to allow for a complete section of Kinderhookian which typically averages fifty-five feet in thickness.

One such example is along the valley wall of Coon Creek in the E½ sec. 28, T. 37 N., R. 25 W. The valley wall bluffs are Jefferson City which is essentially horizontal. Yet in the slopes above the bluff edges are conglomeratic Burlington which is exposed to within twenty feet vertically of the Jefferson City. It is believed that local dips are not sufficient to allow for a normal section of Kinderhookian between the Burlington and Jefferson City.

In the SE¼SE¼NE¼ sec. 33, T. 37 N., R. 25 W., along the north-south line road between sections 33 and 34, normal nonconglomeratic crinoidal Burlington limestone is exposed. In the northeast-draining ravine on the east side of this same road, Jefferson City crops out twenty feet lower than the Burlington. In the NE¼SE¼SE¼NE¼ sec. 33, T. 37 N., R. 25 W., 200 yards north of the Burlington exposure last mentioned, the Ordovician is exposed ten feet higher than the Burlington to the south. Dips are practically horizontal and the reconstructed Kinderhookian interval may be zero.

Nonconglomeratic Burlington limestone is within ten to twenty feet vertically of Jefferson City in the center of the SE¼NW¼SE¼ sec. 19, T. 37 N., R. 25 W. The Burlington is exposed on the north side of the road in the spur between two north-flowing streams; the Jefferson City is in the bed of the stream on the east side of the spur.

With the data available, it is impossible to determine the origin of any individual Jefferson City high.

Undoubtedly, some of these highs are relic unreduced islands which stood in the Mississippian seas and furnished clastic material for conglomerates. The writer sees no other possible explanation for the conglomerates.

Other Jefferson City highs may well be post-Burlington interthrusts rather than relic islands. Exposures most likely to be interthrusts are those with nearly vertical beds lying outside the conglomerate area (e.g., locations 12, 13, and 15, Plate X). It is also possible that some relic islands may be interthrust-like in origin and originated in Burlington times as thrust slices through Kinderhookian sediments into the Burlington seas.

Relatively large areas where the Burlington is stratigraphically too close to the Jefferson City are probably not interthrusts. The lack of apparant crumpling of the Burlington is an argument against low-angled thrust faulting eliminating Kinderhookian beds. Therefore, it is believed that the Kinderhookian is thinned or absent either because of an erosional unconformity between Kinderhookian and Osagean.

DIASTROPHIC HISTORY OF THE VISTA QUADRANGLE

Well records[109] show the existence of a pre-Cambrian structural high northwest of Nevada, Missouri, approximately fifty miles west of the Vista area. Cambrian sediments thin as much as 300 feet over this high.

Regional subsurface studies by McCracken[110] show that a pre-Mississippian broad structural high extends from the area of the pre-Cambrian high eastward to the Weaubleau area. At least 200 feet of Jefferson City and the overlying Cotter sediments were eroded from this high in pre-Mississippian time.

The Mississippian conglomerates of the Vista quadrangle are considered to be products of this post-Cotter diastrophism. The conglomerates are unknown in any other Mississippian rocks of equivalent age in Missouri. It is believed that the post-Cotter diastrophism of the Vista quadrangle was active into very late Devonian. Such an age is suggested because there was not sufficient time for reduction of these highs before invasion of the Mississippian seas. It is even possible that diastrophism was locally expressed in early Mississippian by production of interthrusts into the Burlington seas. Further unrest is locally expressed by a possible Kinderhookian-Osagean erosional unconformity.

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[109] Skillman, M. W., Pre-Upper Cambrian sediments of Vernon County, Missouri: Missouri Geol. Survey and Water Resources, Rept. Inv. No. 7, pp. 15-17, 1948.

[110] McCracken, Earl, Manuscript in preparation: Missouri Geol. Survey and Water Resources, Rept. Inv. no. 13, Plate III, 1951.

From the data given, it is believed that diastrophism was intermittently active in a zone of weakness between the Weaubleau Creek area westward to the Missouri-Kansas line over a great period of geologic time.

There was pre-Cambrian and post-Cotter folding and uplift. Local post-Cotter folding or faulting in the Vista quadrangle may have been as late as late Devonian or even early Mississippian. Unrest between Kinderhookian and Osagean times is suggested by a possible erosional unconformtiy. Diastrophism culminated in the Weaubleau Creek area with post-Burlington—pre-Cherokee thrust faulting.

Such a zone of weakness may well be in the pre-Cambrian basement rock which is more competent to transmit stresses great distances than the relatively thin veneer of Paleozoic rocks.

CHAPTER V

ECONOMIC GEOLOGY

Limestone.—No quarries are now in operation in the Weaubleau quadrangle. Burlington limestone was formerly quarried in the SE¼SE¼ sec. 7, T. 36 N., R. 24 W., on the south side of Highway U. S. 54. The limestone was used mainly for the building of this highway in 1940-42. Another small abandoned quarry on the west side of South Fork Weaubleau Creek in the NW corner NE¼SE¼ of the same section has not been in operation for a number of years.

The Burlington in these quarries appears to be quite pure and the overburden is thin. Agricultural limstone could be quarried at these two easily accessible localities.

Boswell Bluff in the adjoining eastern corners of sec. 31, T. 37 N., R. 24 W. and sec. 6, T. 36 N., R. 24 W., would in all probability be an excellent quarry site. Nearly a hundred feet of relatively pure Burlington limestone is exposed under a thin overburden of residual gravels. The lane just south of the bluff is on bedrock over most of its extent westward to the north-south road, and year-round hauling would be feasible.

Coal.—Near the turn of the century, some exploration for coal was undertaken in the Weaubleau quadrangle. According to local residents, much of the exploration was done by farmers who dug pits and drifts.

It was stated that none of these tests was productive. Heaps of carbonaceous Dederick shale are still visible near some of the prospects.

Locations of abandoned prospects are as follows:

(1) Immediately east of the west section line road, SW corner, NW¼NW¼ sec. 1, T. 36 N., R. 24 W. (Pit)
(2) Near the head of the north-flowing ravine, center NE¼NW¼-NW¼ sec. 28, T. 37 N., R. 24 W. (Drift)
(3) Center SW¼ sec. 29, T. 37 N., R. 24 W. (Drift into east facing valley wall)
(4) Center sec. 24, T. 37 N., R. 24 W. (Drift)

Lead.—Apparently lead has never been mined in the Weaubleau quadrangle. Scattered test pits are at numerous localities in the Burlington, but the writer knows of none which was productive.

Galena has been reported at the following two localities:

(1) NE¼SE¼SW¼ sec. 12, T. 36 N., R. 24 W., from the east-facing bluff of Burlington limestone, just east of the house. The locality was visited and no source of reported float could be found.

(2) Near center of north line SW¼ sec. 20, T. 37 N., R. 24 W. Galena float was reported from Jefferson City "cotton rock" at stream level of north-facing bluff. The writer could find no galena.

Gravel.—There is no commercial gravel production in the Weaubleau quadrangle.

Poorly sorted, highly cherty stream gravels in limited quantities are accessible for the local use at the following localities:

(1) Creek bed near the center, N½ sec. 16, T. 36 N., R. 24 W.
(2) Rock Creek in the SE¼ sec. 29, T. 37 N., R. 24 W.
(3) Bear Creek near the private road crossing, E½ sec. 2, T. 37 N., R. 24 W.

Ground Water.—Many farms on the Pennsylvanian sandstones of the uplands obtain water from dug wells averaging about thirty feet in depth. However, such wells are not reliable during severe droughts, surface contamination is a hazard in the permeable sandstones, and some of the waters are distasteful to outsiders because of their iron and sulphur content.

Water from the Burlington is high in $CaCO_3$ content and the formation is unpredictable as a producer, for the presence of adequate water is dependent on the degree of subsurface fracturing and solution.

The Kinderhookian rocks are in general not good aquifers. Springs from the Northview are sources of water for some farms, but the yield is low and unreliable in these springs as well as in wells sunk into the Northview.

If insufficient water is present in the Burlington, wells must be drilled into the Jefferson City or even the Roubidoux for reliable production. Table 1 includes all wells for which useful data in either cuttings or drillers' logs are available.

TABLE 1, WELL DATA IN THE WEAUBLEAU CREEK AREA

Name and Location	Date Drilled	Curb Elevation	Total Depth	Gallons per Minute	Static Water Level	Draw-down	Producing Formations	Remarks
S. A. McCool NW-SE-SW 7-36-23	1950	926	150	2 @ 82′ 4 @ 130′ 6 @ 150′	32	—	Jefferson City	Bottom 75′ below top Ordovician
Glenn Jennings SE-NE-SW 11–36–24	1947	970	361	3	130	37	do	Bottom 150′ below top Ordovician
Arthur Ashcroft NW-NW-SW 12-36-24	1947	985	441	18	125	7	Robidoux	Bottom 51′ below top Roubidoux
William Lively Center, SE 11-36-24	1910	985	155	—	141	—	Sedalia (?)	Base of Sedalia (?) Driller's log
Weaubleau High School NE-SE-NW 11–36–24	1938	990	430	15	125	20	Roubidoux	Bottom 45′ below top Roubidoux
C. E. Boswell SW 1–36–25	1940	908	222	15	90	—	Jefferson City	Bottom 67′ below top Ordovician
Fay Peterman SW-NW-SE 6-36-24	1940	916	108½	1	28	—	Northview	Top of Northview
M. J. Meyers NE-SE-SE 18-37-24	1944	800	203	5	—	—	Jefferson City	Bottom 153′ below top Ordovician
State Life Ins. Co. NW-SE-SW 32-27-24	1942	855	144	20	34-88 (?)	do		Bottom 74′ below top Ordovician

Surface Water.—During the dry summer of 1947, Weaubleau Creek was flowing at the surface only downstream from section 19, T. 37 N., R. 24 W. Much of the creek and all of its tributaries from this point upstream contained visible water only in the deep water holes.

Obviously natural supplies of surface water are not reliable for stock watering during dry seasons. Stock ponds in the Pennsylvanian uplands have been surprisingly successful; the clay hardpan at the base of the Pennsylvanian forms a perched water table and an impervious base for ponds. Other ponds have been successfully dug into the Burlington or have been created by damming natural catchment areas.

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