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Geology of the northwest quarter of the Washington Quadrangle, Missouri

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GEOLOGY OF THE NORTHWEST QUARTER OF THE WASHINGTON QUADRANGLE, MISSOURI

BY

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A

THESIS

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Associate Professor of Geology

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INTRODUCTION

This report presents the results of detailed mapping of the geology of the northwest quarter of the Washington Quadrangle, Missouri.

Extensive mapping and stratigraphic work have been done in St. Louis and St. Charles Counties to the east and in Callaway and Boone Counties to the west. These two well studied areas are separated by approximately 45 miles. This study adds geologic information to the area immediately between the above locations.

In this area a gentle regional dip to the north permits a study of sediments ranging in age from lower Ordovician in the south to late Paleozoic and Pleistocene on the Dissected Till Plains to the north.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Professor A. C. Spreng who acted as advisor on the thesis and supervised the field work. The Missouri Geological Survey aided financially with field expenses, and Dr. T. R. Beveridge, State Geologist, who made available well log data, (unpublished) manuscripts, visited the area, and made many helpful comments on the study. Professors O. R. Grawe and F. G. Bonorino aided on various parts of the study. Mr. B. R. Doe made available a sedimentary analysis (unpublished) of the upper part of the St. Peter sandstone of the area. Mr. T. W. Holland did the photographic work and assisted with elevation determinations.

Previous work.-- G. C. Broadhead (1873) made the first reconnaissance through Warren County. Twelve sections within the northern half of the Washington Quadrangle are described. The geology and economic possibilities of the county are discussed.

C. L. Dake includes an outcrop map of the St. Peter sandstone through St. Charles and Warren Counties in his sand and gravel report of Missouri (1918). Thicknesses of the St. Peter at several localities in the Washington quadrangle and an analysis of this sandstone from Section 1, Township 45 North, Range 3 West are given. A short discussion on the economic possibilities of the sandstone in the county is made.

Clay deposits within the Washington quadrangle and adjacent areas were discussed by Wheeler (1896, pp. 193, 215-218, 429, pl. II) and McQueen (1943, pp. 37, 117). A map showing all the known clay pits in Warren and adjacent counties at the time of publication is included in McQueen's report.

G. W. Crane (1912, p. 343) mentions a hematite pit in the west half of Section 21, Township 46 North, Range 2 West.

E. B. Branson (1922) gives a general discussion on the occurrence of Devonian formations in Warren County.

R. C. Moore (1928, pp. 91-92) describes two Mississippian sections in the Warrenton quadrangle south of the city of Warrenton.

E. B. Branson and M. G. Mehl (1933, pp. 55-56, 78-79) report collecting conodonts from the Jefferson City and Joachim formations in the thesis area.

Recent geologic mapping in the general area has been done by J. F. Schindler (1951) in the Augusta quadrangle and E. A. Goodrich (1952) in the Hermann quadrangle.

E. R. Larson (1951) described a Plattin limestone section near Dutzow about five miles east of the thesis area in the Augusta quadrangle.

Present work.-- Field work for the problem was carried on during the summer of 1955. A United States Geological Survey 15 minute topographic map of the Washington quadrangle was used as the base map. The final geologic map was doubled in scale from 1/62,500 to 1/31,250. Mapping was done with a Brunton compass and Locke handlevel.

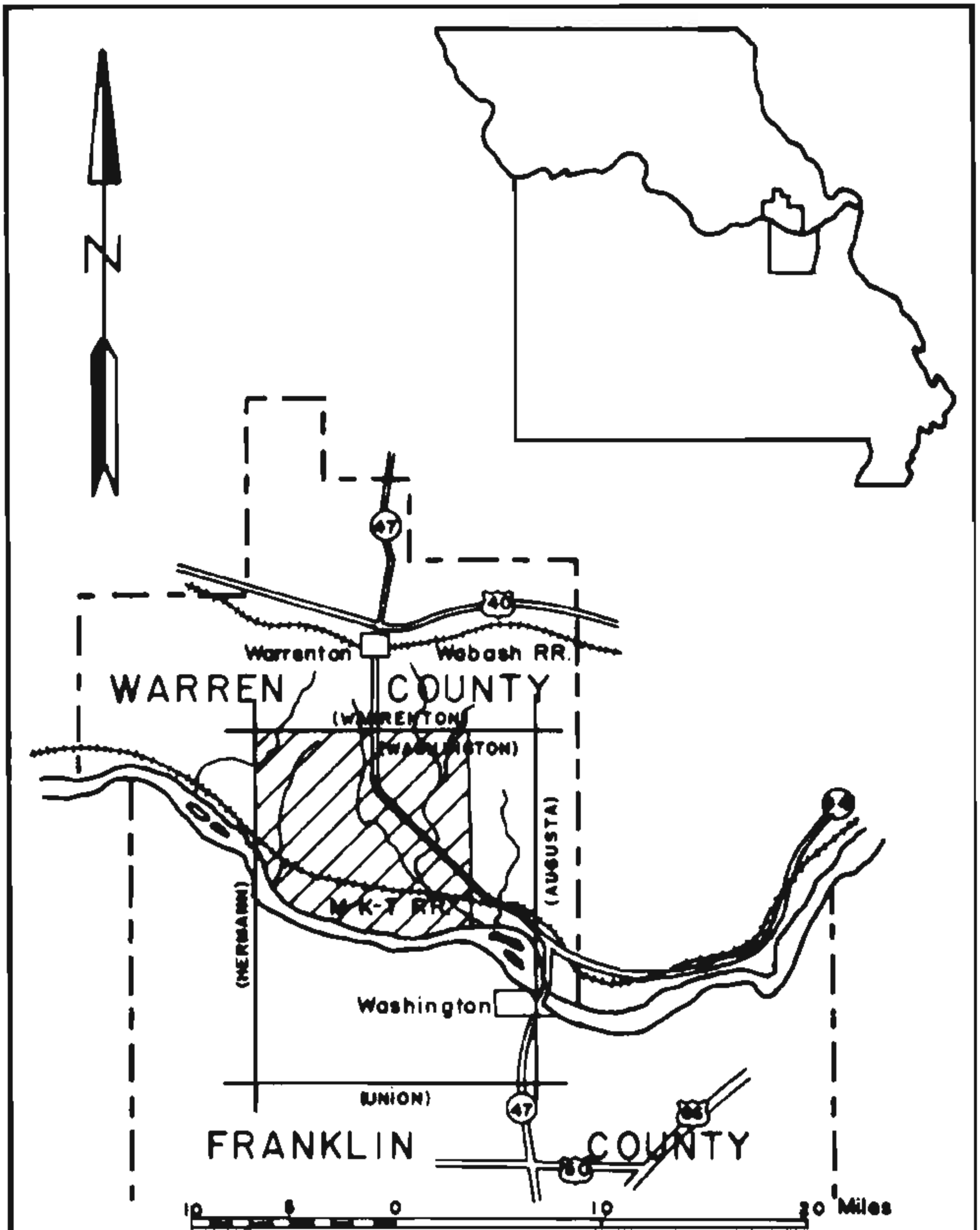
Elevations of contacts were handleveled in from bench marks or suitable reference points (i.e. road intersections, stream junctions, road levels, etc.). Contacts were plotted on the base map and probable contacts interpolated between these points.

Several attempts tc obtain elevations by using the aneroid altimeter were made but fluctuations of barometric pressure made the method too inaccurate where only one altimeter was in use. During the fall of 1955 the elevations of several formational contacts were obtained by using two altimeters and making corrections. Elevations checked so closely with results obtained earlier by handleveling that it was deemed unnecessary to check all contacts in the area with the altimeter.

Logs of wells drilled within and around the area were consulted.

GEOGRAPHY

Location and size.-- The area of the report comprises approximately 85 square miles in south central Warren County, Missouri. It lies in the northwest quarter of the Washington quadrangle. The area is bounded on the east by 91° 05' and on the west by 91° 15' west longitude; on the north by 38° 45' north latitude and on the south by



LOCATION OF WASHINGTON AND SURROUNDING QUADRANGLES

MAPPED AREA SHADED

Fig. I

the Missouri River. The greatest east-west width is nine miles; the greatest north-south length is about 10 miles.

Culture.-- One major highway, Missouri Highway 47, traverses the area; it crosses north-south through the east quarter of the area. Warren County Highway "C", an all weather gravel road, crosses the southern part, east-west, along the Missouri River floodplain. Highway "N", partially blacktopped, runs diagonally across the south-east part. Pinckney Ridge Road, in the western quarter, crosses north-south connecting Highway "C" with the town of Warrenton to the north. With the exception of Highway 47 and parts of Highway "N", all other roads in the area are loose-surface gravel.

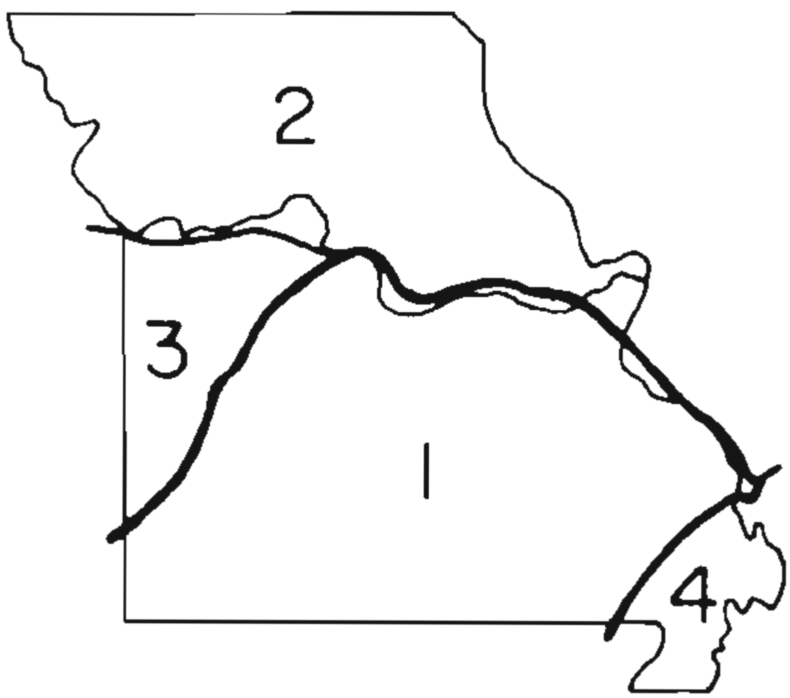
The Missouri-Kansas-Texas Railroad essentially parallels the Missouri River bluffs along the southern boundary.

The area is sparsely populated and there are no large towns within its immediate limits. Five small farming communities are located in the southern portion; Holstein, the largest, population 150, is in the south central part along Highway "N"; Peers, population 25, and Treloar, population 59, are along the M-K-T Railroad and Highway "C"; Concord Hills, population 50, is in the southeast quarter and Hopewell is at the junction of Highways 47 and "N".

Washington, population 6850, is the largest town in the quadrangle. It is located south of the Missouri River in Franklin County and is about eight miles southeast of the area mapped. Marthasville, population 347, the largest town in the quadrangle north of the river, lies about one mile east. Warrenton, population 1584, is approximately four and a half miles north of the area.

Primarily the southern half is under cultivation; the northern part is mostly in forest cover with the level ridge tops and larger

FIG. 2 PHYSIOGRAPHIC DIVISIONS OF MISSOURI (After Fenneman, 1946)



1- Ozark Plateau Province

2- Dissected Till Plains Section (Central Lowlands Province)

3- Osage Plains Section (Central Lowlands Province)

4- Mississippi Alluvial Plains Section (Coastal Plain Province) valley bottoms in fields. General farming and stock grazing are the main sources of livelihood.

Several small quarries have been operated in the Ordovician dolomites and limestones for agricultural lime, road metal and local building purposes. Clay deposits occur in the northern half of the quadrangle and supplement the local income. Small scale logging operations are scattered throughout the wooded areas.

PHYSIOGRAPHY

Regional setting.-- The Washington quadrangle is located on the northern border of the Ozark Plateau Province (Fenneman, 1938, pp. 361-362 and 1946; Branson, 1944). Figure 2 shows the major physical divisions of the state. The rocks underlying the northern flank of the province belong primarily to the Ordovician. However, some Devonian, Mississippian and Pennsylvanian rocks underlie the Ozark Plateau in the eastern part of the state (Branson, 1944, p. 351).

The history of the Ozark Plateau Province is marked by several cycles of uplift. The area was domed at the close of the Paleozoic and has remained a land mass since. A post-Paleozoic uplift of slight magnitude took place in late Pliocene (Fenneman, 1938, p. 661) followed by deep downcutting at the beginning of the Quaternary.

The Till Plain section which was produced by Pleistocene glaciation does not extend into the Washington quadrangle. The boundary with the Ozark province is not clearly defined and the two divisions generally interfinger along an irregular border.

The thesis area lies in the Ozark Plateau Province. Within the area three minor physiographic subdivisions are present: The Missouri River floodplain, an elevated terrace, and a deeply dissected upland region.

The Missouri River floodplain, two to three miles wide, extends along the southern border of the area. It has been produced by aggradation of this stream since Pleistocene time. The floodplain is bounded both on the north and south by nearly vertical bluffs of Jefferson City dolomites.

Extending northward from the bluffs and developed essentially upon the top of the Jefferson City formation is a one to two mile wide terrace. This terrace parallels the present floodplain, but narrows toward the southeast. The outcrop area of the St. Peter sandstone marks the northern terminus of the terrace. Its average elevation is 650 feet with a gentle slope toward the southeast. A few spurs of younger rock extend out onto the terrace. This terrace was probably developed during the late Pliocene uplift and was left elevated by subsequent Quaternary downcutting by the Missouri River.

North of the elevated terrace and comprising the greatest areal extent of the area mapped is the highly dissected upland region. Several broad stream valleys extend northward through the area. Nearly level ridge tops, all at approximately the same elevation, parallel the stream valleys and represent the post-Paleozoic peneplanation. The relief in the northern region averages 250 to 300 feet. The peneplained surface also slopes gently toward the east side of the quadrangle. The uplands are in a late youthful stage of development.

The northern boundary of the Ozark Plateau Province is being shifted northward into the Dissected Till Plains section by continuing headward erosion.

Topography and drainage.-- The topography of the northwest quarter of the Washington quadrangle grades from a broad flat floodplain along the southern border into a rugged, hilly area caused by deep entrenchment of an old peneplained surface in the north. The elevated terrace is moderately dissected and has a gently rolling surface. The maximum relief in the area is about 480 feet. The highest point is along Pickney Ridge Road in the west half of Section 13, Township 46 North, Range 3 West where a small knoll rises above the 940 foot contour line. The highest reference elevation is in the southwest quarter of the same section at a 941 foot bench mark. The lowest point is a 480 foot depression on the Missouri River floodplain in the east half of Section 35, Township 45 North, Range 2 West. The lowest reference elevation is a 488 foot bench mark along the Missouri, Kansas and Texas Railroad at the base of the Jefferson City bluff in the north central part of Section 26, Township 45 North, Range 2 West.

Outstanding relief features in the area, aside from the ridges and deep valleys in the northern half, are the dolomite bluffs along the Missouri River floodplain, sandstone bluffs along Charrette and Dry Fork creeks, and several isolated hills in the south central part. A conspicuous, irregular, east-west trending ridge extends through Sections 7, 8, and 9, Township 45 North, Range 2 West, and joins with Pinckney Ridge, trending north-south, in Section 1, Township 45 North, Range 3 West. This ridge is isolated from the uplands by Pepplemeyer Branch, a tributary of Dry Fork Creek.

The major streams in the area from east to west are: Charrette Creek, along the eastern border of the area; Dry Fork, about center of the area; Smith Creek near the western border; and a small portion of Lost Creek in the extreme northwest corner of the quadrangle. All of the above flow to the south and are tributaries to the Missouri River.

Smith Creek is the only stream that originates within the area. The others all rise in the broad upland plains area in the Warrenton quadrangle to the north.

Charrette Creek is the largest stream in the area. It has a gradient of about ten feet per mile throughout most of the area, decreasing as it flows out onto the Missouri River floodplain. It has developed a slight floodplain which increases in width from about 0.1 mile in the north, 0.3 miles in Section 2, Township 45 North, Range 2 West, to approximately 0.5 miles in Sec. 23, Township 45 North, Range 2 West, where it enters the Missouri River floodplain. The stream meanders across its floodplain throughout its course in this area and is in the mature stage of development.

Dry Fork, the second largest stream in the area, has also developed a small floodplain along its course. The floodplain ranges from 0.1 mile in the extreme north to 0.4 miles in Section 4, Township 45 North, Range 2 West. It joins the Charrette Creek in the southeast quarter of Section 15, Township 45 North, Range 2 West. A floodplain approximately one mile wide has been developed at this junction. The gradient of Dry Fork varies from 20 feet per mile in the north to about five feet per mile near its junction with Charrette Creek. The stream course is fairly straight in the north half with meanders beginning after joining with Pepplemeyer Branch in Section 5, Township 45 North, Range 2 West. Dry Fork is in an early mature stage throughout most of its course in this area.

Smith Creek, a much smaller and shorter stream than the two previously mentioned, rises in Sec. 23, Township 46 North, Range 3 West, becoming a perennial stream in Section 34, Township 46 North,

PLATE I

A. View, looking south, of the elevated terrace. Hills in the background are in the south side of the Missouri River.

B. View, looking southwest, of the dissected uplands.

Range 3 West, where it is joined by a tributary from the east. A floodplain of 0.1 to 0.2 miles wide has been formed along parts of the stream course. The gradient of Smith Creek is about 40 to 60 feet per mile. It is in a late youthful stage in the southern part grading northward through early youth to infancy.

Only one and one half miles of Lost Creek crosses the Washington quadrangle. This stream is in a mature stage and has a floodplain 0.2 miles wide.

The pattern of the tributaries to the above streams is dendritic. The gradient of these tributaries is as high as 80 feet per mile. There is a general decrease in gradient where the tributary streams cross from the St. Peter outcrop region onto the Jefferson City formation.

The major stream valleys are filled with alluvium varying from 0 to 15 feet thick.

STRATIGRAPHY

General statement.-- Exposures in the area mapped range in stratigraphic position from Lower Ordovician (Canadian) to Middle Pennsylvanian (Desmoinesian), with only the Silurian System not represented.

Beds of Middle and Upper Ordovician Series predominate and are exposed from the Missouri River bluffs to the northern boundary of the quadrangle. Dolomites, sandstones and limestones are the characteristic rock types and they constitute more than two hundred feet of thickness.

A few isolated outcrops of Devonian limestone (Callaway) occur in the northern portion of the area.

Mississippian residual cherts cap the Ordovician and Devonian rocks on the hills and along ridge tops in the northern half, Range 3 West, where it is joined by a tributary from the east. A floodplain of 0.1 to 0.2 miles wide has been formed along parts of the stream course. The gradient of Smith Creek is about 40 to 60 feet per mile. It is in a late youthful stage in the southern part grading northward through early youth to infancy.

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Mississippian residual cherts cap the Ordovician and Devonian rocks on the hills and along ridge tops in the northern half.

Slumpage of these cherts and a thick soil cover usually obliterate the contact of the Mississippian with the underlying rocks.

Pennsylvanian sandstone and clays occur sporadically on the uplands. Both occur in sink structures. The sandstone is found mainly in float along the hillsides and at the heads of gullies, with bedded sandstone occurring at the flanks of exposed clay pits. In addition to exposures in open pits, clays weather out at the heads of gullies and along their flanks.

A few Pleistocene glacial erratics were found along Lost and Charrette creeks.

The lower reaches of the larger stream valleys are filled with alluvium with only a few bedrock exposures in the most northerly reaches. The Missouri River bottom is filled with a thick deposit of alluvium. Loess caps the Missouri River bluffs at a few widely separated areas.

FIG. 3

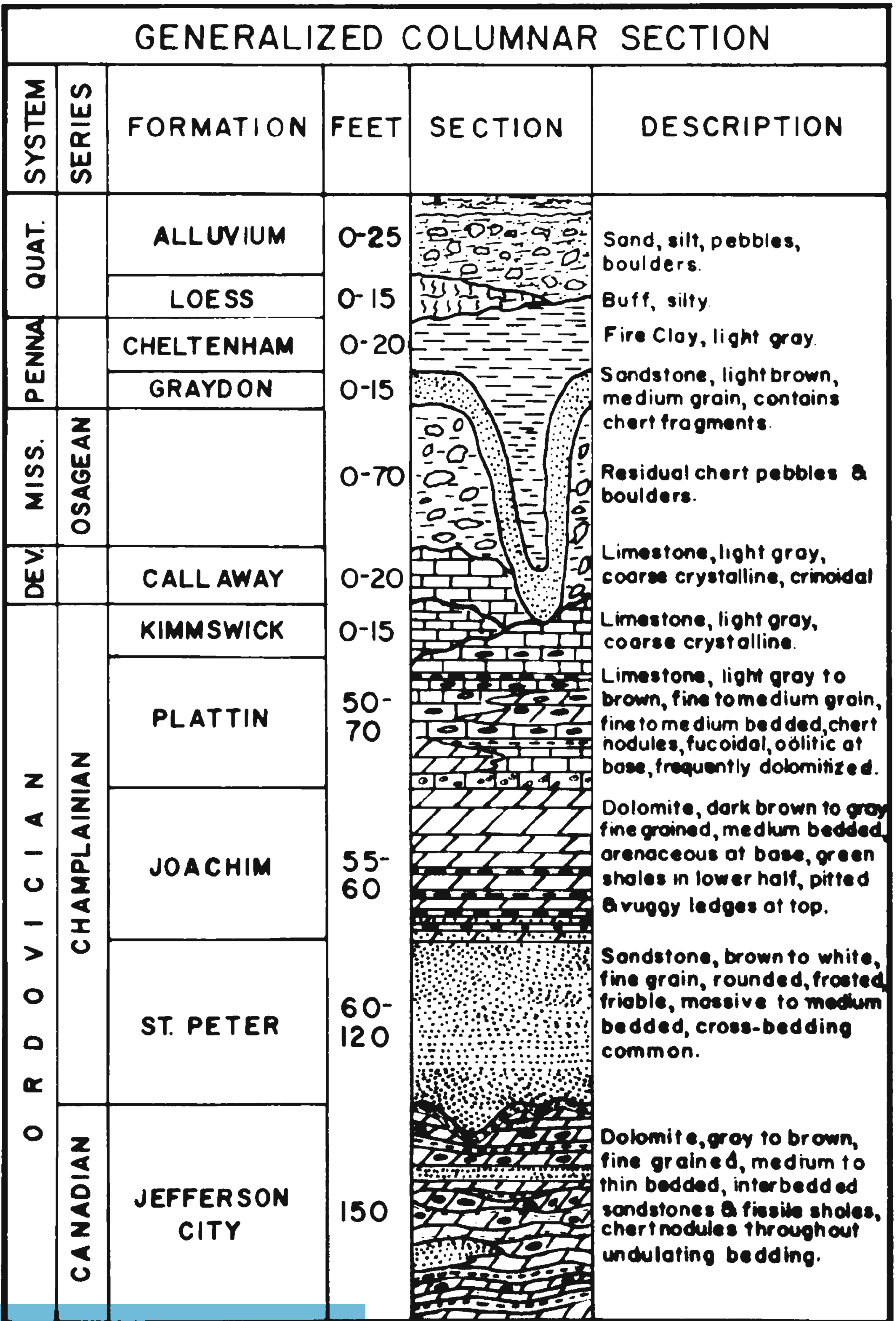
GENERALIZED COLUMNAR SECTION
SYSTEM
SERIES
FORMATION
FEET
SECTION
DESCRIPTION
QUAT.
ALLUVIUM
0-25
Sand, silt, pebbles, boulders.
LOESS
0-15
Buff, silty
PENNA.
CHELTENHAM
0-20
Fire Clay, light gray
GRAYDON
0-15
Sandstone, light brown, medium grain, contains chert fragments.
MISS.
OSAGEAN
0-70
Residual chert pebbles & boulders.
DEV.
CALL AWAY
0-20
Limestone, light gray, coarse crystalline, crinoidal
ORDOVICIAN
CHAMPLAINIAN
KIMMSWICK
0-15
Limestone, light gray, coarse crystalline.
PLATTIN
50-70
Limestone, light gray to brown, fine to medium grain, fine to medium bedded, chert nodules, fucoidal, oölitic at base, frequently dolomitized.
JOACHIM
55-60
Dolomite, dark brown to gray fine grained, medium bedded, arenaceous at base, green shales in lower half, pitted & vuggy ledges at top.
ST. PETER
60-120
Sandstone, brown to white, fine grain, rounded, frosted, friable, massive to medium bedded, cross-bedding common.
CANADIAN
JEFFERSON CITY
150
Dolomite, gray to brown, fine grained, medium to thin bedded, interbedded sandstones & fissile shales, chert nodules throughout undulating bedding.

TABLE I

Nomenclatural history of the Jefferson City
(Refer to the Bibliography for complete references)

1855 - Swallow, G. C.,	Second Magnesian Limestone.
1873 - Broadhead, G. C.,	Second Magnesian Limestone (Warren County, Missouri).
1894 - Winslow, A.,	Jefferson City Limestone.
1898 - Keyes, C. R.,	Winfield Dolomite (Lincoln County, Missouri).
1915 - Ulrich, E. O. and Bassler, R. S.,	Differentiation of the Jefferson City. formation into the Jefferson City (lower), Cotter and Powell (upper) formations.
1921 - Dake, C. L.,	Suggested Jefferson City Group for the tripartite division.
1928 - Weller, S. and St. Clair, S.,	Established Ulrich's tripartite division of the Jefferson City for Missouri in the literature.
1944 - Cullison, J. S.,	Further subdivided the Jefferson City (restricted) into the Rich Fountain (lower) and Theodosia (upper). Both were given formational status and the term Jefferson City used as a group for only these two formations.

ORDOVICIAN SYSTEM

CANADIAN (LOWER) SERIES

JEFFERSON CITY FORMATION

(UNRESTRICTED)

Previous usage.-- Prior to 1894 the name Second Magnesian Limestone (Swallow, 1855, pp. 121-125; Shumard, 1855, Franklin County Report, p. 162; Broadhead, 1873, Warren County Report, pp. 55) was applied to the sequence of rocks now termed Jefferson City, Cotter and Powell in Missouri.

Winslow (1894, pp. 331, 373) proposed the term Jefferson City for exposures of these rocks along the southern bank of the Missouri River from "...the mouth of Moreau to Gray's Creek ..." above Jefferson City, Missouri. Winslow included all the beds underlying the Saccharoidal or Crystal City (St. Peter) sandstone and overlying the Moreau (Roubidoux) sandstone. However, on his table Winslow had the Saccharoidal sandstone equivalent to the Roubidoux sandstone.

Ulrich (1911, pl. 27, & 1915, pl. 2) redefined the limits of the Jefferson City and proposed a division into three formations; the Jefferson City (restricted) (lower), the Cotter and the Powell (upper), This tripartite division has been accepted and has been in common usage since.

Cullison (1944, pp. 17-32) further subdivided the Jefferson City (restricted) into two formation, the Rich Fountain (lower) and the Theodosia (upper) on faunal differences and a residual chert conglomerate at the base of the Theodosia. Jefferson City was retained as the group name for the two formations. Cullison's division as yet has not been

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Present usage.-- The Missouri Geological Survey uses the tripartite division of Ulrich (1911, 1915) - Jefferson City, Cotter, and Powell formations. Twenhofel and others[1] (1954) accepted Cullison's division of the Jefferson City (restricted).

Application in field mapping.-- The Jefferson City formation as used here includes all the dolomite beds, with interbedded sandstones and shales, exposed beneath the St. Peter sandstone in this area. The name is used in the unrestricted sense, to include both the Cotter and Powell formations. The latter are recognized and differentiated in well logs of the Missouri Geological Survey.

The contact of the Jefferson City formation with the St. Peter formation is concealed by a thick soil cover and it was necessary to interpolate between widely separated exposures of the two formations. It is exposed in ravines, gullies and along roadcuts. Springs at the contact were helpful in mapping. Undercutting of the St. Peter at the contact is apparent in the steeper gullies. A one to three foot green shale bed at the contact contains "honeycombed" white chert pebbles and boulders and rotten chert fragments. An excellent exposure of this shale bed occurs in the northwest quarter of the southeast quarter of Sec. 35, Township 46 North, Range 2 West, along the east side of the road. This unit is considered the top of the Jefferson City formation.

Local topography sometimes is helpful in recognizing the Jefferson

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1. Ordovician Subcommittee of the Committee on Stratigraphy, National Research Council.

City-St. Peter contact, as the slopes typically steepen just above the base of the St. Peter.

Distribution.-- The Jefferson City formation is best exposed on the east-west trending bluffs along the north edge of the Missouri River floodplain, and on smaller bluffs along the lower reaches of the larger tributary streams. The one to two mile wide elevated terrace in the southern half of the quadrangle is underlain by the Jefferson City dolomite but outcrops are concealed by a thick covering of alluvium, residual soil and in some locations, loess. The northernmost exposure of the formation is on Lost Creek in the north central part of Section 15, Township 46 North, Range 3 West, where the contact with the overlying St. Peter sandstone is exposed. North and east of this section the formation dips under the younger rocks. The entire thesis area is underlain by the Jefferson City formation.

Thickness.-- The average thickness of the Jefferson City dolomite exposed in this area is about 130 feet. Exposures along the Missouri River bluffs vary in thickness from 10 to 80 feet. A deep well in the southeast part of the quadrangle that has penetrated the underlying formation shows a thickness of 385 feet of Jefferson City formation (including the Cotter) beneath the floodplain. Deep wells in the Warrenton quadrangle to the north gives thicknesses of 478 to 486 feet for the complete Jefferson City section (thickness includes the Cotter and Powell formations).

The base of the formation does not crop out in the north half of the Washington quadrangle. Wells in the general area show the Jefferson City formation to be underlain by the Roubidoux formation. The log for the city well at Marthasville, Sections 29 and 30, Township 45 North, Range 2 West, gives an elevation of about 115 feet for the contact. A deep well, 1150 feet, recently drilled in the southeast quarter of the northwest quarter of the southeast quarter of Section 26, Township 47 North, Range 2 West, Warrenton quadrangle, about four miles north of the northern boundary of the thesis area, places the Jefferson City-Roubidoux contact at an elevation of about 54 feet below sea level. The Warrenton city well in the northeast quarter of the northwest quarter of Section 28, Township 47 North, Range 2 West, Warrenton quadrangle, gives approximately the same elevation for this contact (51 feet below sea level).

Lithology.-- The predominant lithology of the Jefferson City formation in the area is dolomite. Shales, cherts and sandstone comprise a significant portion of the formation. The dolomite is mainly fine grained, argillaceous in part, "cotton rock" type. Finely crystalline, medium grained and dense are other common textures. The "cotton rock" type is very fine grained with a soft earthy appearance. The color of the fresh surface is light gray weathering to a dark gray or grayish orange. The weathered surface is smooth and blocky. The bedding is fine to medium varying from one-half to six inches but often giving the appearance of being massive on the weathered surface.

The sandy, medium grained dolomite is pale orange on fresh surfaces, weathering to a dark orange. It is frequently finely cross-bedded, and has a rough weathered surface. The dense dolomite shows pitting on the weathered surface. The weathered surfaces of this dolomite vary from smooth to hackly. Light gray to yellowish-gray and orange are the typical colors on the weathered surfaces. Manganese oxide staining is common on outcrops along stream beds. The bedding is very wavy throughout the area and radical changes in the dip occur with short distances. Undulating bedding planes within a single unit give erratic thicknesses of from one to three feet. Limonite mottles, black dendritic patterns, and veinlets and vugs filled with calcite are common throughout the dolomite beds. A few of the beds are sandy in part.

Sandstones occur intermittently as lenses in the formation. The sand is commonly dark brown on the weathered surface. Fresh surfaces are white to light brown in color. Thicknesses vary from two inches to six feet, grading into dolomite both above and below. The quartz sand grains are fine to very fine in size, rounded to subangular and frequently show frosting. The cementing agent is silica except where indurated with calcium carbonate, leached from the overlying dolomites. Iron oxide staining is common on weathered surfaces and frequently causes case-hardening of the sand. Fragments of rotten, light tan to cream colored chert occur sporadically through the sandstone. Bedding varies from fine to massive, the finer bedded sand weathers out in flat "plates" one-half to one inch thick. Sun cracks and ripple markings are common on the thin "plates".

Thin persistent green to bluish green shale partings are a prominent feature on exposures of the Jefferson City formation. They occur along the bedding planes of the dolomite. The thickness of a single parting may vary from one-eighth to two inches over a very short distance. However, they are usually an inch or less in thickness. A prominent shale bed, one to three feet thick, at the top of the Jefferson City formation appears to be continuous over the entire area as it is found underlying the St. Peter formation whereever the contact with that formation is exposed. This shale is light green in color and contains rounded pebbles and boulders of "honeycombed" chert. The chert is light gray to white in color. Some show concentric color banding of shades of gray. The vugs are lined with a quartz druse. Some of the shales are dolomitic and those in juxtaposition with the sandstone layers are arenaceous in part. Unklesbay (1954, p. 20) suggests a secondary origin for the shales in the Jefferson City formation of Boone County and believes them to be the result of solution of parts of the dolomite along bedding planes and the accumulation of residue after solution. On weathering re-entrants are formed along the shale bands and gives the formation a rough surface.

The following measured section is representative of the Jefferson City formation in the northwest half of the Washington quadrangle:

Quarry in the Missouri River bluff in the northeast quarter of Section 23, Township 45 North, Range 3 West.

	Feet	Inches
Quaternary System		
29. Loess, buff, (dark yellowish orange) . . .		
Ordovician System		
Canadian Series		
Jefferson City formation		
28. Dolomite, light gray on fresh surface weathering to a grayish orange; very fine-grained ("cotton rock"); brittle; thin, irregular, blocky bedded, beds one to six inches thick. Lower part cherty and conglomeratic. Upper part thin-bedded, blocky, ("cotton rock") . . .	3	6
27. Dolomite, light gray on fresh surface weathers to a grayish orange, grades from a fine-grained ("cotton rock") at base to fine sandy texture at top; brittle; thinly bedded. Five inches above the base a three inch cross-bedded dolomite band	1	8

	Feet	Inches
26. Dolomite, light gray fresh weathering to a very pale orange; very fine-grained ("cotton rock"); thinly bedded, beds one-half to one inch thick, beds undulating and platy. A green shale band four inches from the top		9
25. Dolomite, light gray on fresh surface, weathers to a yellowish gray; fine sandy texture to dense; thinly bedded, beds $\frac{1}{2}$ to 1 inch thick; blocky, rough weathered surface; contains a few rotten chert fragments, pitted in part . .	1	4
24. Dolomite, very pale yellowish orange on fresh surface, weathers to a dark yellowish or grayish orange; fine to very fine grained; massive, with very thin laminae; contains chert fragments about five mm. in size, finely vuggy, black specks scattered throughout	1	4
23. Dolomite, light gray with pink and yellow mottles on fresh surface, weathers to a pale yellowish orange; fine-grained ("cotton rock"), thinly bedded, beds two inches and less; irregular, blocky and nodular in part. Green shale parting at top	4	6
22. Dolomite, oolitic, very pale orange with pink tinge on fresh surface, weathers to a light brown; very fine sand texture; white chert nodules near base		8
21. Dolomite, light gray to white with yellow mottles on fresh surface weathering to a grayish orange; fine-grained ("cotton rock"); thin-bedded but massive appearing, beds one-fourth inch and less breaking out into two to five inch beds; tan limonite streaks along bedding	1	9
20. Dolomite, very pale orange with pinkish tinge on fresh surface, weathers to a light brown; very fine sandy texture; undulating white chert nodules (4") and lenses (9" to 12") at base and top. Thickness variable		11 to $7\frac{1}{2}$

	Feet	Inches
19. Dolomite, very pale orange on fresh surface weathering to a grayish orange; fine-grained ("cotton rock"); thin to medium bedded, beds one-quarter inch to eight inches thick, undulating bedding planes. Dolomitic green shale band at top	2	2
18. Dolomite, light gray on fresh surface weathering to a grayish orange. Lower seven inches fine-grained ("cotton rock"); thin-bedded. White and tan fragmental chert in a dolomitic cement in upper six inches. Cream colored chert nodular band at top	1	1
17. Dolomite, light gray on fresh surface weathering to a very pale or grayish orange; fine-grained ("cotton rock"); thin to medium bedded, beds one to four inches thick; limonite mottles and black dendrite patterns; very blocky on the weathered surface. Green shale parting at the top	3	8
16. Dolomite ("White Bed"), fresh surface a very light gray, weathered surface white; very fine-grained ("cotton rock"); medium bedded, beds two inches thick. White calcium sulfate coating, leached from top bedding plane. Lower surface is slightly irregular. White coating on bed is persistent throughout the quarry	1	9
15. Dolomite, argillaceous, yellowish gray on fresh surface, weathers to a grayish orange; fine-grained; thin to medium bedded, beds one-half to four inches thick, wavy bedding planes	1	7
14. Dolomite, light gray on fresh surface, weathers to a grayish orange, fine-grained ("cotton rock"); thin to medium bedded, beds one to five inches thick, wavy bedding planes; semi-conchoidal fracture; weathered surface both smooth and jagged. Contains dirty gray chert nodules and streaks or mottles of rotten chert in lower nineteen inches; pitted where chert has weathered out; pits lined with calcite		

	Feet	Inches
crystals and lime mud; three inches above the base a persistent wavy enamel-white brecciated chert band two to four inches thick	3	3
13. Dolomite, light gray on fresh weathering to a yellowish gray; very fine-grained to almost dense; medium bedded at base and top, thin bedded toward center, beds one to four inches in thickness, massive appearing toward the top; upper fifteen inches rough pitted surface (5% pitting); lower part smooth on weathered surface, breaks with semi-conchoidal fracture. 0 to 4 inches slightly dolomitic, brown and green shale split at top; 1/16 inch shale parting nineteen inches above base. Calcite crystals scattered throughout upper part, largest approximately one inch . . .	2	10
12. Dolomite, yellowish gray on fresh surface weathering to a grayish orange; fine-grained; medium bedded, beds two to five inches thick; fissile green shale laminae along bedding planes; dendrites, white staining on weathered face (not as prominent as on "White Bed"), weathered surface smooth to blocky; 1/2 inch brown shale layers at top	1	10
11. Dolomite, light tan with purple mottlings on fresh surface, weathered surface yellowish orange; fine-grained; irregular, undulating bedding; contains white and gray chert bands and nodules, persistent chert band at top three inches thick; green shale layer at top and four inches above base. Both the dolomite and chert are brecciated in part		7 to 10
10. Sandstone, white on fresh surface, weathers to a yellowish brown; grains medium to fine-grained, rounded to subrounded with a few scattered angular grains; streaks and mottles of dolomitic mud; contains small chert nodules and bands of white bluish gray chert five to six inches long		7

	Feet	Inches
9. Dolomite, yellowish gray; fine-grained; thinly bedded in lower part; medium to thin-bedded, beds one-half to three inches thick; rough, jagged blocky weathered surface. Undulating lense-like bed		9 to 14
8. Dolomite, light olive gray on fresh surface, weathers to a grayish orange; fine-grained (dense); irregular thin-bedded, beds one-half to two inches thick; contains white to light bluish gray chert nodules, some of the cherts are brecciated; one to one-half inch green shale partings at base, top, and six inches above the base. Very undulating lense-like bed		12 to 15
7. Dolomite, nodular; yellowish gray on fresh, weathered surface a grayish orange; fine-grained; medium bedded, beds two to seven inches thick; weathered face smooth, breaks blocky. Beds 7 to 28 form part of quarry	1	6
6. Dolomite, very pale orange with pink mottles on fresh surface, weathered surface a dirty gray; fine-grained to slightly sandy texture; thin to medium-bedded, beds one-half to two inches thick, massive appearing, undulating bedding; shale parting at base and top; white chert fragments and foot long bands		10
5. Sandstone, white with green mottles in lower part on fresh surface, weathered surface light brown; fine to very fine quartz grains; medium-bedded, beds one to three inches thick; vuggy; beds in lower eight inches contain green shale laminations	6	0
4. Dolomite, same as bed (2), 4 inches white chert, nodular band near center . . .	11	4
3. Dolomite, light gray with tan streaks on fresh surface, weathered surface a pale yellowish orange; fine-grained ("cotton rock"); medium bedded, beds one to four inches thick, bedding is both slabby and blocky; several green shale partings	3	0

	Feet	Inches
2. Dolomite, pale yellowish brown on fresh surface, weathered surface light gray to dark brown; fine-grained; medium bedded, beds five to twelve inches thick; weathered surface smooth. White oolitic chert nodular band four to seven inches thick at top of bed. Intra-formational conglomerate band of white chert and dolomite pebbles in a dolomite matrix fifteen inches below top of bed. Band is wavy, three to nine inches thick. Two bands of white chert nodules below conglomerate band. Nodules are four to ten inches long	7	6
1. Dolomite, nodular in part, fresh surface whitish gray with light tan mottles, weathered surface pale yellowish orange; fine-grained ("cotton rock"); bedding one inch and less thick; white to dirty gray chert bands and nodules in lower part . . .	5	9
Total	74	2

The base of the section is the road into the quarry. Base of the Jefferson City not exposed.

Paleontology.-- In the thesis area the Jefferson City formation is sparsely fossiliferous. The outlines of high spired gastropods - c f. Hormotoma - occur on several dolomite blocks in a quarry along the river bluffs in the northeast quarter of Section 23, Township 45 North, Range 3 West. Cullison (1944, pp. 47-105) made a study of the megafossils of the Jefferson City. Branson and Mehl (1933, pp. 55-56) collected over a dozen species of conodonts from a road cut in the Jefferson City at the junction of highway 47 and county road "N". A general summary of the fauna of the Jefferson City, Cotter and Powell was given by Branson (1944, pp. 54-55, 57, 61) in his Geology of Missouri.

Stratigraphic relations.-- The base of the Jefferson City formation as already stated is not exposed in the north half of the Washington quadrangle. Deep wells in Warren County show it to be underlain by the Roubidoux formation. The St. Peter sandstone overlies the formation in this and adjacent areas. The upper contact is unconformable and represents a time of erosion. The top surface of the Jefferson City is uneven and the green shale bed at the top contains reworked, highly weathered chert boulders, and pebbles. The elevations of this contact are highly irregular and at several locations (Table III) the base of the St. Peter is below surrounding exposed Jefferson City dolomite. The dolomite dips toward the sandstone where the two are in close proximity. It is apparent from a study of the top of the St. Peter that the sand is filling pre-St. Peter sinks and channels developed in the Jefferson City. Unklesbay (1952, p. 25) states that the Jefferson City-St. Peter interval in Boone County, about 60 miles to the west of Warren County, is represented by 1200 to 1500 feet of sediment in southern Missouri and northern Arkansas.

Age and correlation.-- The Jefferson City (including the Cotter and Powell) formation is at present regarded as upper Lower Ordovician. It has been correlated with various formations in central and eastern North America. Edison (1935, p. 1127) correlates the Missouri formations with the Shakopee dolomite of Minnesota and Iowa, part of the Knox dolomite of Tennessee and Kentucky, and part of the Arbuckle limestone of Oklahoma. More recent and complete correlatives are given on the Ordovician correlation chart of the National Research Council (Twenhofel and others, 1954).

Topographic expression.-- The elevated terrace along the southern border of the area is underlain by the Jefferson City formation. Where the terrace joins the Missouri River floodplain, the dolomite forms prominent vertical bluffs. The terrace itself is sloping gently toward the southeast, and its topography is one of rounded hills and broad valleys resembling a mature stage of development. The relief on the terrace seldom surpasses 100 feet. Bluffs of Jefferson City, 10 to 40 feet in height, extend into the uplands region along the larger stream courses.

PLATE II

A. Quarry in the Jefferson City formation along the Missouri River bluffs in the NE¼, Sec. 23, T. 45 N., R. 3 W.

B. Undulating bedding and solution work in the Jefferson City dolomite along Pepplemeyer Branch in the SE¼, SW¼, Sec. 6, T. 45 N., R. 2 W.

TABLE II

Nomenclatural history of the St. Peter sandstone
(Refer to the Bibliography for complete references.)

Minnesota	
1843 - Nicollet, J. N.,	St. Peter sandstone applied to a sequence of sandstone and limestone.
1847 - Owen, D. D.,	Restricted name St. Peter to the sandstone unit.
Missouri	
1855 - Swallow, G. C.,	First or Saccharoidal Sandstone.
1873 - Broadhead, G. C.	Saccharoidal Sandstone (Warren County, Missouri).
1894 - Winslow, A.,	Crystal City Sandstone (Southeastern Missouri). Roubidoux (misnomer) or Saccharoidal Sandstone (Central Missouri).
1898 - Keyes, C. R.,	Cap-au-Gres Sandstone (Lincoln County, Missouri).
1898 - Gallaher, J. A.,	First to apply the name St. Peter to the Missouri section.
1903 - Ball, S. H. and Smith, A. F.,	Pacific Sandstone.
1921 - Dake, C. L.,	St. Peter Group to include the Everton, St. Peter Sandstone and Joachim formations.

CHAMPLAINIAN SERIES

(MIDDLE SERIES)

ST. PETER SANDSTONE

Previous usage.— The name St. Peter was first used in Minnesota in 1843 by J. N. Nicollet (1843, p. 69). Owen (1847, p. 169) restricted it to the sandstone unit of Nicollet's St. Peter formation.

In the older Missouri reports the term Sacchariodal or First sandstone (Swallow, 1855, pp. 117-121; Warren County Report, pp. 54-55) was widely used. Local names were proposed from time to time (see Table II) for this sandstone.

Gallaher (1898, p. 21) first applied St. Peter to the sandstone in Missouri. Dake (1921, p. 14-28) in a study of the St. Peter used the term St. Peter Group to include both the underlying Everton limestone of southeast Missouri and the overlying Joachim dolomite. Additional studies have been made of the St. Peter by Trowbridge (1927), Thiel (1935) and Edson (1935).

Present usage.— The name St. Peter is used by the Missouri Geological Survey for the sandstone unit overlying the Powell, of southern Missouri, and underlying the Joachim formation. Twenhofel and others (1954) accept the same definition.

Application in field mapping.-- In agreement with usage by the Missouri Geological Survey the St. Peter refers to the massive, fine-grained, frosted sandstone above the green cherty shale beds occurring at the top of the Jefferson City (unrestricted) and beneath the Joachim dolomite. As seen throughout the area, it forms massive, cross-bedded highly jointed, vertical bluffs, many of which are 30 to 60 feet high.

The base of the formation is less frequently exposed than the top. It has been placed above the green shale containing rotten fragments and pebbles of white to dark gray chert.

The top of the St. Peter appears conformably with the Joachim, passing from a pure, white, quartzitic sandstone into a calcareous cemented sandstone transition zone, grading upward into thin beds of arenaceous dolomite and shale layers. The upper boundary of the unit is placed at the top of the calcareous sandstone. An easily accessible exposure of the contact may be seen on the east side of Warren County Highway "N" in the west center part of Section 8, Township 45 North, Range 2 West.

Distribution.-- The St. Peter is the most prominent formation in the north half of the Washington quadrangle and crops out throughout most of the area north of the elevated terrace. The lower limit of the formation is outlined by an abrupt steepening at the north end of the terrace. Only a few isolated remnants of the St. Peter occur on the terrace.

The northernmost outcrop of the St. Peter in this area is located in the north central part of Section 5, Township 46 North, Range 3 West, where bluffs of the sandstone flank both sides of Lost Creek and extend into the Warrenton quadrangle. A complete exposure of the St. Peter found in this section. In the northwest corner of the area, the St. Peter-Joachim contact is exposed in the northwest quarter of the southeast quarter of Section 14, Township 46, North, Range 2 West. North of this contact the St. Peter dips to the northeast under the Joachim.

Thickness.-- The thickness of the St. Peter in the northwest quarter of the Washington quadrangle varies from 60 feet to more than 120 feet. The average thickness in the area is approximately 75 feet. At several locations, sink or channel fillings of St. Peter in the Jefferson City have greatly increased the thickness of the sandstone and fluctuations of 50 or more feet of thickness for the St. Peter occur over very short lateral distances. This variance was noted by Dake (1918, pp. 110, 164) in Warren and Montgomery Counties. Table III lists the locations of the more conspicuous fillings. Logs of deep wells in the Warrenton quadrangle give thickness of from 70 to 100 feet for the St. Peter.

Lithology.-- The St. Peter formation is a very pure quartz sandstone and similiar to that found elsewhere in Missouri. Dake (1921, p. 136) in his analysis of the St. Peter reported the formation to average 98 per cent plus silica. In his sand and gravel report (1918, p. 165) an analysis of the sandstone from Section 1, Township 45 North, Range 3 West, gave a silica content of 99.570 per cent with minor percentages of iron, aluminum, calcium and magnesium oxides. The sand is fine to medium grained, well rounded and frosted.

The quartz grains are fairly uniform in size. Weight percentages of several grab samples from the area showed the minus 40 - plus 60 (0.381 to 0.246 millimeters) mesh to be the predominant size. The smallest size of any consequence is the minus 80 - plus 100 (0.173 to 0.140 millimeters) mesh, and the largest is the minus 20 - plus 40 (0.833 to 0.381 millimeters) mesh. Corroborating analyses were prepared by B. R. Doe (1954) from three channel samples collected from the upper five feet of the formation in the thesis area (Section 35,

TABLE III

Locations of conspicuous St. Peter sandstone fillings in sinks or channels developed in the Jefferson City formation.

Location	Remarks (Amount of St. Peter exposed etc.)
1. SE$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 32, T. 46 N., R. 2 W., (On Dry Fork behind house.)	About 140' exposed. Base below surface. Flanked by Jefferson City formation.
2. S$\frac{1}{2}$ SW$\frac{1}{4}$ sec. 32, T. 46 N., R. 2 W. (House on the St. Peter.)	Large outcropping at house. Base not exposed. Jefferson City nearby.
3. NE$\frac{1}{4}$ SE$\frac{1}{4}$ Sec. 6, T. 45 N., R. 2 W. (Junction of creeks.)	15' on south bank of creek. Base not exposed. Flanked by Jefferson City.
4. SW$\frac{1}{4}$ SW$\frac{1}{4}$ Sec. 6, T. 45 N., R. 2 W. (In creek bed south of house.)	About 120' exposed. Base below surface. Jefferson City 100' to the west.
5. North center Sec. 4, T. 45 N., R. 2 W. (West of hwy. 47 on section line.)	Isolated outcrop about 70' below the exposed contact north and south on highway 47. Exposure about 10' thick.
6. SW$\frac{1}{4}$ SE$\frac{1}{4}$ Sec. 8, T. 45 N., R. 2 W. (In front of house.)	110' exposed. Base below surface. Jefferson City above and to the east of the sandstone.
7. SE$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 7, T. 45 N., R. 2 W. (Along road.)	20' of sandstone exposed on east side of road. Jefferson City on west side. Base of sand not exposed.
8. NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 2, T. 45 N., R. 2 W. (Behind barn east side of road.)	About 130' exposed. Base below surface. Jefferson City 50' to north below house.
9. NE$\frac{1}{4}$ SE$\frac{1}{4}$ Sec. 2, T. 45 N., R. 2 W. (In hog pen.)	About 90' exposed. Contact with Jefferson City exposed. Low elevation. (questionable filling).

Township 46 North, Range 3 West; Sec. 33, Township 46 North, Range 2 West, and Section 8, Township 45 North, Range 2 West).

The grains are basically well rounded but a few are subangular. Secondary enlargement, not uncommon on the larger sizes ($\frac{1}{4}$ millimeter), is probably the reason for the observed angularity of some grains. Pitting and frosting is a distinct feature of the grains throughout the formation.

On the weathered surface the sandstone is commonly case-hardened but where fresh it is very friable. The upper one foot or less is sometimes indurated by carbonate cement leached from the overlying dolomites.

Where fresh, the color of the sand is white to dirty gray. The upper one to three foot transition zone is green- or brown-stained on both fresh and weathered surfaces. Where weathered the color is generally a shade of brown or gray but tinges of green and red are common.

Iron oxide is the common case-hardening agent. Near the top of the formation nodules of sand cemented by iron oxide weather out of the formation and give the generally smooth sand a rough, knobby surface. Occasionally the iron oxide is leached from the nodules but they retain their knobby shape.

The formation gives the appearance of massiveness throughout the area. However, bedding is often as thin as one-quarter inch thick. The thin bedding is best shown where the sandstone is cross-bedded. Some of the lower beds though are massively cross-bedded. Beds 15 to 20 feet thick are not infrequent. Thicknesses are not persistent and the thin bedded sands converge into the more massive units in short lateral distances. The lower half of the formation is, in general, more massively bedded than the upper part. Three to four foot beds are about average thicknesses for the upper portion. Ripple marks occur but are not common in this area.

Paleontology.-- The St. Peter sandstone of this area is unfossiliferous. Workers on adjacent and nearby areas also report it to be unfossiliferous. Dake (1921, p. 26) reported some fossils from the transition beds between the St. Peter and the Joachim in Cape Girardeau County. As far as the writer knows the St. Peter is otherwise unfossiliferous in Missouri.

Stratigraphic relations.-- The St. Peter sandstone lies on an eroded surface of the Jefferson City formation. Variations in thickness and contact elevations illustrates this unconformity. Where this contact with the Jefferson City is exposed, differences in elevation upwards of 50 feet occasionally occur over short lateral distances.

As previously mentioned, fillings of St. Peter sandstone in sinks developed in the Jefferson City are common throughout the area. At Location 1, Table III, a 100 foot wide outcropping of St. Peter is flanked on both the north and south sides by the Jefferson City formation. The base of the sandstone is below the surface and about 140 feet is exposed. North and south of the sandstone and almost in juxtaposition with it, 40 to 50 feet of the Jefferson City forma tion is exposed. The exact nature of the contact on the flanks of the sand filling is not observable. There are no fluctuations in elevation of the upper boundary of the St. Peter across this filling.

Field evidence in the thesis area points to a conformable relationship between the St. Peter and the overlying Joachim formation.

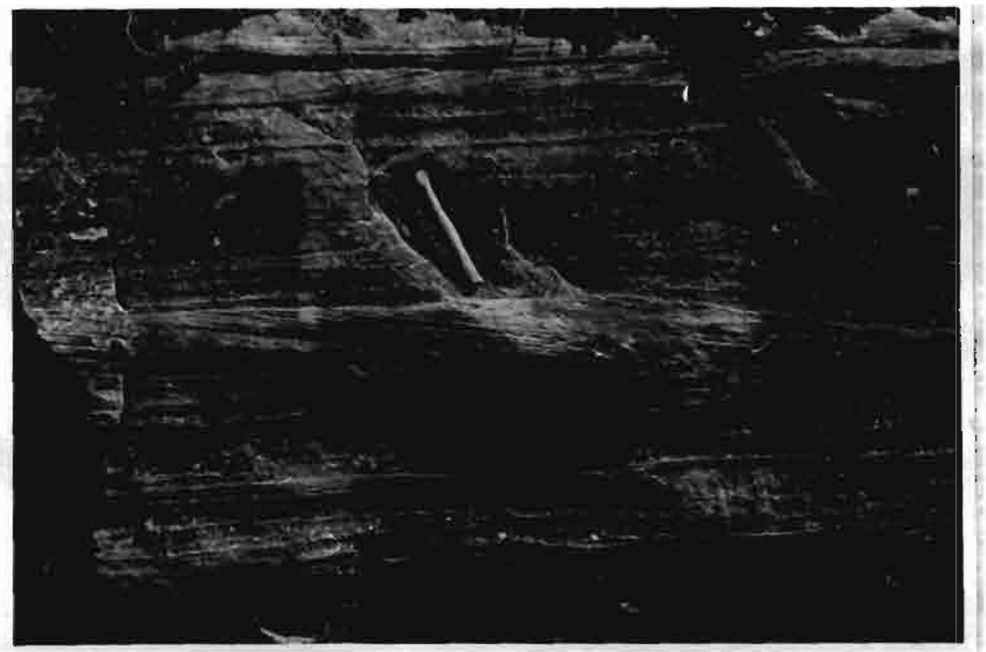
A transition of green calcareous sandstone, one to three feet thick, passes upward into a sandy shale and dolomite. The quartz sand grains in the dolomite and shale are about the same size and nature as the St. Peter sand. Westward in Boone County the formation is unconformably overlain by Devonian limestones (Unklesbay, 1954, p. 28).

Age and correlation.-- The St. Peter sandstone is generally considered to belong to the Chazyan series of the lower Middle Ordovician. Dake (1921, pl. I) correlated the Missouri formation with the St. Peter sandstone of the Upper Mississippi Valley, the Burgen sandstone of the Ozark section and the Simpson formation of the Arbuckle section in Oklahoma, and the Blakely sandstone of the Ouachita section of Arkansas. Edson (1935) on stratigraphic evidence places the St. Peter as post-Beekmantown and pre-Black river. The National Research Council Ordovician chart (Twenhofel, and others, 1954) lists the St. Peter as Chazyan and shows correlatives of the formation in North America.

Topographic expression.-- Outcrops of the St. Peter are usually steep, often vertical, bluffs along the larger streams in the area. The bluffs are protected by a capping of younger dolomite. Where the dolomite has been eroded, erosion on the cross-bedded surface produces smoothly-rounded knobs and gentle slopes. The outcrop belt of the St. Peter sandstone may often be delimited in the area by the concentration of evergreens and cedars on its surface where a thin veneer of soil is present. Where the sandstone is at the surface, there is a general absence of vegetation, and the surface is often covered with green lichens.

PLATE III

A. St. Peter sandstone filling a sink in the Jefferson City formation in the SE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 32, T. 46 N., R. 2 W. Jefferson City dolomite on hill in right background.



B. Cross-bedding in the St. Peter sandstone along east side of road in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 35, T. 46 N., R. 2 W.

TABLE IV

Nomenclatural history of the Joachim.
(Refer to the Bibliography of complete references.)

1855 - Swallow, G. C.,	First Magnesian Limestone.
1873 - Broadhead, G. C.,	First Magnesian Limestone (Warren County, Missouri).
1894 - Winslow, A.,	Joachim Limestone.
1898 - Keyes, C. R.,	Folley Limestone (Lincoln County, Missouri).
1948 - Grohskopf, J. G.,	Division of the Joachim into the Rock Levee (upper) and Joachim (lower) formations.

JOACHIM FORMATION

(UNRESTRICTED)

Previous usage.-- Prior to 1894, the term First Magnesian Limestone was used in Missouri for the sequence of dolomites, limestones and thin shales overlying the St. Peter sandstone and underlying the Plattin limestone (Swallow, 1855, pp. 115-117). Broadhead, 1873, p. 53) used this name for exposures of Joachim dolomite in Warren County, Missouri.

Winslow (1894, pp. 331, 353-353) proposed the name Joachim for the exposures of "... thin, argillaceous, shaly magnesian limestone (JOACHIM) ..." near Plattin Creek, Jefferson County, Missouri. These beds overlie the Crystal City (= St. Peter) sandstone and underlie the Trenton (= Plattin) limestone.

The Joachim recently has been restricted by Grohskopf (1948, pp. 360-363) on the basis of subsurface evidence. He divided the former Joachim into the Rock Levee and restricted Joachim formations. The Rock Levee, above, is bounded at the top by an oolitic bed (basal Plattin) and at the base by a zone of light gray to almost white chert found in insoluble residues. Under this proposal the Joachim was "... restricted to the rocks overlying ... (the) St. Peter and including the chert zone at the top".

Present usage.-- The Missouri Geological Survey recognizes the Joachim - Rock Levee division by Grohskopf (1948). Twenhofel (1954) and others also list these two formations in their correlation charts.

Application in field mapping.-- The Joachim formation, as mapped, consists of a thick sequence of brown dolomites with intercalated green shales in the basal portion. It includes the beds above the

the St. Peter sandstone and beneath the oolitic bed of the basal Plattin formation. Lack of surface expression of the "chert zone" (Grohskopf, 1948, p. 363) prevented a field separation of the Rock Levee and restricted Joachim formations.

The lower boundary of the Joachim usually is concealed along hillsides, but the contact is well exposed along road cuts, dry wash beds and in gullies. Where covered, it is marked by an abrupt change in gradient of the slopes. The base of the Joachim is placed at the top of the calcareous sandstone of the St. Peter.

The Joachim formation extends upward to the oolite and pebble-conglomerate bed at the base of the Plattin limestone. The basal Plattin oolitic and pebble conglomerate bed is generally concealed. The contact is well exposed, however, in a quarry on the west side of Missouri Highway 47 (SE$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 33, T. 46 N., R. 2 W.) and also on a cut along the highway immediately south of the quarry.

The upper part of the Joachim consists of two or three ledge-forming beds of brown, pitted dolomite. The ledges are two to 10 feet thick and commonly are exposed along hillsides. The lowest exposures of Plattin limestone crop out five to 10 feet above the top dolomite ledge. The Joachim-Plattin contact, where concealed, is arbitrarily placed about five feet above the uppermost Joachim ledge.

Dolomitization of the basal Plattin adds to the difficulty of locating the upper boundary. Float was utilized in placing both boundaries where talus and soil cover the contacts.

Distribution.— The Joachim formation is present throughout the uplands region and its outcrop pattern roughly parallels that of the St. Peter sandstone except in the northeastern quarter. Its greater resistance to weathering is important in maintaining the St. Peter bluffs. Many of the hills in the southern part are capped by the Joachim.

Thickness.-- The Joachim averages about 65 feet in thickness throughout the area. On Pinckney Ridge Road (NW$\frac{1}{4}$, Sec. 35, T. 46 N., R. 3 W.) 63 feet was measured; Highway 47 (Sec. 33, T. 46 N., R. 2 W.) 58 feet and in the northwest quarter of Section 14, Township 46 North, Range 2 West, 65 feet.

Two wells in the Warrenton quadrangle give a thickness of 70 feet for the formation, while a third records only 55 feet.

Lithology.-- The Joachim formation is predominantly a fine grained, yellowish orange dolomite. Some beds are argillaceous; others arenaceous. Shale layers are common in the lower 20 feet. Chert is rare.

The dolomite beds in the lower portion are thin- to medium-bedded, fine grained and argillaceous. Quartz sand grains are commonly scattered through the dolomite bed in the lower seven feet of the formation. The sand is fine to medium grained in size, well rounded, and frosted. It was derived from the St. Peter . Grains with secondary growth, common on the larger sand sizes in the St. Peter, appear to be absent on the sand grains in the dolomite. It was probably removed during the reworking of the sand. Concentration of the sandy layers is not restricted to any particular part of a bed; however, they generally occur at the base. The dominant color of the formation is a yellowish orange on both fresh and weathered surfaces.

The upper dolomite beds are fine-grained to finely crystalline. Bedding alternates between medium and massive. The medium beds weather to smooth, blocky surface; the massive beds consistently show a rough pitted surface. When struck with a hammer, the pitted bed frequently have a fetid odor. Both weather to a yellowish brown. On the fresh surface the medium beds are a yellowish orange while the massive beds are commonly a medium gray. Tan vugs are characteristic of the fresh surface of the massive beds. Dark dendritic patterns and limonite mottles are present on the fresh surface of the medium beds. Calcite crystal and veinlets occur throughout the formation.

In the lower half of the formation there are several dolomitic siltstones associated with the green shale layers. There is no apparent gradation from the siltstone into the dolomite beds.

Intercalated with the lower dolomite beds are a large number of green shale layers. In the lower five feet, quartz sand grains are common in the shale. Few of the shales were found to be calcareous.

Highly weathered white to light gray chert pebbles occur at two locations: one is along the hillside in the northwest quarter of the southwest quarter of Section 1, Township 45 North, Range 3 West; the other is at a new cut on Pinckney Ridge Road in the northwest quarter of Section 35, Township 46 North, Range 3 West. At the road cut the chert is in a seven-inch green shale bed about 12 feet above the base of the formation. At the other location the chert is in a dolomitic siltstone 8 to 10 inches thick and about 20 feet above the base. A three-inch green shale bed overlies the siltstone.

The following section is typical of the Joachim formation throughout the area:

Section measured at new cut on the west side of Pinckney Ridge Road in the northwest quarter of Section 35, Township 46 North, Range

3 West.

Ordovician System

Champlainian Series

Plattin Formation	Feet	Inches
35. Limestone, light gray; very fine-grained; fucoidal		
34. Cover	10	0
Joachim Formation		
33. Cover with spotty exposures of dolomite similar to bed 31; dark gray on fresh surface	15	0
32. Dolomite, similar to bed 31; partly thin bedded; breaks into four beds; gray on fresh surface in upper part . . .	7	0
31. Dolomite, yellowish orange on fresh surface, weathers to a dark brown; fine grained; medium to massive bedded, beds 9 to 17 inches thick; thin shale partings break this unit into five beds; coarse grained dolomite 3 feet above base; weathered surface pitted; calcite crystals and veinlets scattered throughout	5	5
30. Shale, blue-green		1
29. Dolomite, pale yellowish orange with dark brown limonite mottles; fine-grained; medium bedded, massive appearing; contains calcite crystals and veinlets black dendritic patterns; a few shale partings in lower 1 foot . . .	3	5
28. Alternating dolomite and shale. Dolomite, yellowish orange, fine-grained; medium bedded, beds 6 to 9 inches a few thin bedded; undulating bedding; shale, blue-green; 1/16 to 1 inch	12	4
27. Dolomite, dark yellowish orange, argillaceous; blocky		5
26. Shale, blue-green		3

	Feet	Inches
25. Siltstone, dolomitic, dark yellowish orange		4
24. Shale, blue green; undulating		1 to 2
23. Dolomite, similar to bed 15; contains some limonite mottles	1	5
22. Shale, blue green		1
21. Mudstone, dolomitic; grayish orange . . .		2
20. Shale, blue green		1
19. Dolomite, yellowish orange; fine-grained; thin to medium bedded; lower five inches fine, rounded, frosted quartz grains . . .	1	1
18. Shale, bluish green, contains weathered white to light gray chert pebbles; chert up to 6 inches at greatest diameter. May be Grohskopf's Joachim-Rock Levee boundary		7
17. Dolomite, similar to bed 15; contains some scattered limonite mottles		9
16. Shale, blue-green color		1
15. Dolomite, grayish orange on fresh surface weathering to a pale yellowish orange; medium to fine-grained; thin bedded		8
14. Shale, blue-green, alternating with dolomitic mudstone layers		3
13. Dolomite, similar to bed 9; thin bedded .		5
12. Shale, blue-green		2
11. Dolomite, similar to bed 9; limonite mottles and small calcite crystals scattered throughout		6
10. Shale, blue-green; undulating		2 to 5
9. Dolomite, pale yellowish orange on fresh surface, weathers to a dark yellowish orange; fine-grained to dense thin-bedded; brittle, breaking with conchoidal fracture; small irregular shale split near top		8

	Feet	Inches
8. Siltstone dolomitic; yellowish orange limonite nodules scattered throughout . .		7
7. Shale, green; undulating		1 to $\frac{1}{2}$
6. Dolomite, argillaceous; pale yellowish orange; fine-grained; brittle; medium bedded at base grading upward into thin bedded; contains calcite crystals and veinlets and black dendritic patterns; $\frac{1}{2}$ inch green shale split 6 inches above base	1	3
5. Dolomite, siltstone, yellowish orange . .		3
4. Dolomite, pale yellowish orange; medium bedded; fine-grained to dense; sandy, at base, quartz grained are rounded, fine-grained, and frosted		6 to 10
3. Shale, blue-green color; undulating		3
2. Dolomite, yellowish orange on fresh surface, weathers to a gray orange; arenaceous in lower 10 inches grading upward into argillaceous, fine grained dolomite; lower half medium bedded, upper part thin to medium bedded – $\frac{1}{2}$ to 3 inches; limonite mottles scattered throughout; undulating green shale layer ($\frac{1}{2}$ to 1 inch) near middle	3	2
1. Dolomite, yellowish orange; alternating with $\frac{1}{2}$ to 1 inch bluish-green shales; fine-grained; thin bedded; contains calcite crystals and veinlets	1	0

St. Peter sandstone

Light green, medium to fine-grained; grains rounded, frosted and pitted; calcareous cement.

Paleontology.-- Fossils are rare in the Joachim formation. Branson and Mehl (1933, pp. 78-79) list thirteen genera of conodonts from the formation collected in the thesis area east of Holstein. Several specimens of ostracods – cf. *Leperditia* – were found in the upper part of the Joachim capping a hill on the section line between

Sections 8 and 9, Township 45 North, Range 3 West. The species has not been determined.

Stratigraphic relations.-- The Joachim-St. Peter relationship has been described under the St. Peter formation. The gradational nature of the contact from sandstone to sandy shales and dolomites and the constancy of elevation, point to a conformable boundary in the thesis area.

The upper boundary is less distinct, as the basal Plattin is generally concealed throughout the area. Where the contact is exposed, the transition from a brown, argillaceous dolomite (Joachim) to a fine-grained, gray limestone (Plattin) appears conformable. At the quarry on Highway 47, previsouly mentioned, four inches of calcareous, green shale occurs above the basal oolitic bed. On the quarry face the shale appears to be a split. Weller and St. Clair (1928, p. 103) report the Joachim-Plattin contact to be marked by a green shale in Ste. Genevieve County. Schindler (1951) reports a three to four inch shale bed at this contact in the Augusta quadrangle about eight miles east of the quarry. In following Ulrich (1939), Grohskopf (1948), and Larson (1951) and placing the Joachim-Plattin boundary at the base of the oolitic bed, the green shales occur in the Plattin and do not represent the formational boundary.

Weller and St. Clair (1928, p. 103) stated the contact to be unconformable and used the green shale bed and varying thicknesses of the Joachim as evidence. Grohskopf (1948, p. 355, fig. 2; 364) showed the Plattin to overlap the Joachim. The presence of oolites and the intraformational conglomerate are suggestive of shallow water deposition and possibly an unconformity (Larson, 1951, p. 2070).

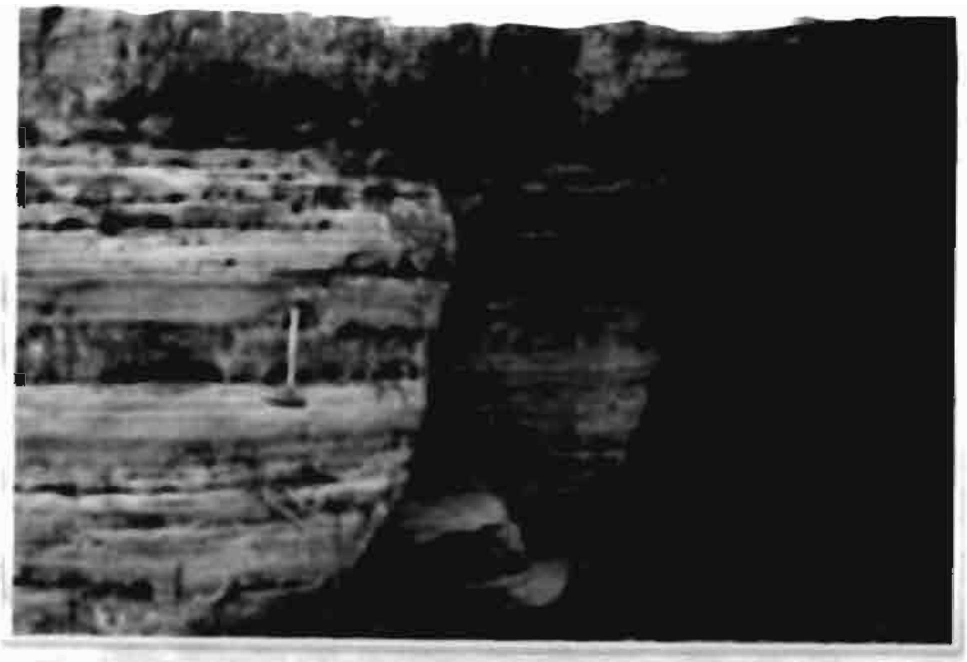
Dolomitization at the base of the Plattin adds to the difficulty of placing this boundary in the field. The oolitic bed was not found to be present as dolomite but the intraformational conglomerate was dolomite in part of the quarry on Highway 47.

Age and correlation.-- Present correlations place the Joachim formation in the Chazyan series of the lower Middle Ordovician. Branson and Mehl (1933, pp. 20-21, 78-79) collected conodonts from the Joachim in the thesis area. From this study, they correlated the Harding sandstone of Colorado with the Joachim. The age designated by them for both formations was lower Middle Ordovician. Edson (1935, p. 1120) gave the Joachim the general position of post-Beekmantown-pre-Black River on stratigraphic position. The Ordovician correlation chart of the National Research Council (Twenhofel and others, 1954) lists the Joachim as upper Chazyan and the Rock Levee as lower Black River. The term Joachim, as used in this report, then ranges from upper Chazyan to lower Black River by present correlations.

The paucity of fossils in the Joachim makes definite placement and correlation difficult and it is necessary to rely on stratigraphic position.

Topographic expression.-- On hillsides and in deep gullies the Joachim dolomite produces steep slopes with prominent ledges near the top of the formation. Where it caps hills and ridges, a nearly flat surface is produced. Evergreens, mentioned as a general boundary guide for the St. Peter, extend up into the lower five or 10 feet of the Joachim where the dolomites and shales are sandy.

PLATE IV



A. Pitting developed along the bedding of the St. Peter sandstone, and re-entrants forming along joints. SE¼, NE¼, SE¼, Sec. 23, T. 46 N., R. 2 W.

B. Pitting and solution work on the upper Joachim dolomite ledge, east side of road in the SE¼, SW¼, NE¼, Sec. 14, T. 46 N., R. 2 W.

TABLE V

Nomenclatural history of the Plattin.
(Refer to the Bibliography for complete references.)

1855 - Swallow, G. C. and Shumard, B. F.,	Black River and Birds-Eye Limestone.
1873 - Broadhead, G. C.,	Black River Limestone and Lower Trenton Limestone (Warren County, Missouri).
1898 - Keyes, C. R.,	Bryant Limestone (Lincoln County, Missouri).
1904 - Ulrich, E. O.,	Plattin Limestone.
1922 - Weller, S. and St. Clair, S.	Separated the Decorah shale from the top of the Plattin.
1939 - Ulrich, E. O.,	Redefined the limits of the Plattin.
1948 - Grohskopf, J. G.,	Redefined the base of the Plattin.
1951 - Larson, E. R.,	Raised the Plattin to group status and defined four distinct formations in the group: Macy (top), Hager, Beckett and Bloomsdale (base).

PLATTIN FORMATION

Previous usage.-- The names Black River and Birds-eye Limestone (Swallow, 1855, p. 114; Shumard, 1855, Franklin County Report, p. 159) were used in Missouri for beds overlying the First Magnesian Limestone (= Joachim) and underlying the Trenton Limestone (= Kimmswick, Decorah and upper part of the Plattin). Broadhead (1873, pp. 50-51), in his Warren County Report, referred rocks now called Plattin to the Black River. The superjacent "Middle and Lower Trenton Limestone" of Broadhead apparently belong in the Plattin as now defined.

The term Plattin was proposed by Ulrich (1904, p. 111) for the "...fine grained limestone formation between the Kimmswick and the 'First Magnesian' [= Joachim] and which has generally been called either Trenton or lower Trenton." The name is from Plattin Creek, Jefferson County, Missouri, along whose mouth the rock outcrops (here considered the type section).

Weller and St. Clair (1928, pp. 104-110) in their Ste. Genevieve County Report, removed the alternating shale and limestone from the top of the Plattin, proposing them as the Decorah formation.

More recently, Grohskopf (1948, pp. 357-359) designated an "Oolitic and Conglomerate zone" found in subsurface work as the base of the Plattin. Locations of surface exposures of this zone in St. Louis, Cape Girardeau, Jefferson, Montgomery and Lincoln Counties are given.

Larson (1951, pp. 2046-2064), in the latest work on this interval divided the Plattin into four formations, and raised the Plattin to group status. His work was done on surface exposures in eastern Missouri. The lower boundary of the group was placed at the base of the oolitic and conglomerate bed as defined by Grohskopf, and the top at the base of the Decorah. The new formations were separated on the presence or absence of fucoids and cherts, and rock textures. They consist of the Bloomsdale (basal), the Beckett (with lower and upper members), the Hager, and the Macy (with the Hook and Zell members). Measured sections, faunal lists, and type localities were given.

Present usage.-- The Missouri Geological Survey currently is using the oolitic and conglomerate bed as the base of the Plattin in subsurface work. The upper boundary is the base of the Decorah.

Twenhofel, and others, (1954) use Larson's proposal for the Plattin limestone in the southeast Missouri section. Their northeast Missouri section lists Plattin limestone.

Application in field mapping.-- The Plattin is a predominantly fine to medium grained fucoidal limestone, overlying the Joachim formation and capped throughout most of the area by residual Mississippian cherts.

The base of the formation, usually concealed, is arbitrarily placed five feet above the highest Joachim ledge. The oolitic and conglomeratic bed, however, is used where present.

The upper boundary is indistinct throughout most of the area. In general it is overlain by Mississippian chert residuum. In a few scattered areas, Devonian limestones are preserved on the eroded Plattin surface. Slumpage of the Mississippian cherts over the Plattin necessitates mapping the top of this formation on float. Pennsylvanian sandstones and clays also rest on the Plattin at several localities.

Distribution.-- This formation roughly parallels the Joachim outcrop area and is found overlying that formation throughout the area. Its most southerly outcropping is on a hilltop in the north central part of Section 16, Township 45 North, Range 2 West, where ten feet of the formation caps the Joachim. Over most of the uplands area the plattin is covered by Mississippian residual cherts.

Thickness.-- Forty-five feet of Plattin is exposed in the Highway 47 quarry. About 35 feet is exposed on old Pinckney Ridge Road (Sec. 35, T. 46 N., R. 3 W.) in the west central part. Along the northern border the Plattin is about 65 to 70 feet thick. The thicknesses along covered slopes is difficult to determine because of slumpage of the overlying residual cherts. Well logs from the Warren quadrangle show thicknesses ranging from 30 to 40 feet for two Warrenton city wells in Section 29, Township 47 North, Range 2 West, to 100 feet for a recently drilled well in the southeast quarter of Section 26, Township 47 North, Range 2 West. The trend of thinning toward the west is maintained in the thesis area. The upper surface of the Plattin is disconformable and could account for the variance in thickness. Grohskopf (1948) and Larson (1951) suggested thinning of the Plattin to the north and northwest by overlap, offlap and convergence within the formation. Grohskopf's work was done on subsurface evidence and Larson's on surface conditions.

Along Pinckney Ridge Road in Section 35, Township 46 North, Range 3 West, the Plattin - Joachim relationship is not clear as the basal Plattin oolitic bed is apparently missing and the lower part of the formation consists of brown slabby limestones, and partially dolomitized beds that may or may not be Plattin. It is possible that some of the lower Plattin may be included in the Joachim giving the low figure for the thickness of the Plattin.

Lithology.— The Plattin formation is mainly a medium to light gray, fine-grained limestone. Throughout the formation, parts of the beds are dolomitized. Chert nodules and bands, and fucoids are two of the prominent features of the formation in the thesis area.

The color of the Plattin is characteristically light gray where weathered and medium gray on the fresh surface. Occasionally the basal beds weather to grayish orange or light brown platy limestone slabs. Fucoid fillings in the medium gray, sublithographic beds are frequently yellowish orange in color. Where the bed has been dolomitized, the weathered color is a pale reddish brown and the fresh typically shows medium gray mottles in a reddish orange to light brown matrix. The gray mottles, believed to be fucoid fillings, were used as a field criteria in differentiating dolomitized Plattin from similiar appearing Joachim beds. The fetid odor of the upper Joachim beds is absent in the dolomitized beds. A red tinge on the limestone, similiar to that of the Devonian Mineola limestone, is present on some Plattin outcrops. This coloration may be caused by calcining of the limestone during forest fires[2]. Similiar discoloring occurs on some Joachim beds.

Fine-grained and sublithographic textures are the common types throughout the Plattin of this area. Many of the upper beds in the northern area are medium-grained or coarse crystalline. Where the bed has been dolomitized, the gray mottles are always finely crystalline. The brownish matrix varies from finely crystalline to sugary. The

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2. Beveridge, T. R., Oral communication.

sublithographic beds break with a subconchoidal fracture.

The formation is dominantly thin to medium bedded. The beds range from two inches to two feet. The average is about six inches. Some massive bedding occurs near the top. A few bedding planes are undulating but are exceptions to the general character of the formation.

Fucoids and chert bands are the outstanding accessory features of the formation. There presence or absence is a distinctive characteristic of Larson's division of the formation. Grohskopf based part of his subsurface zoning of the formation on the chert. With the exception of the basal two or three feet, fucoids are present throughout most of the formation. The average size of the fucoids is about five millimeters but they vary from one to twenty millimeters. The material filling the fucoids is commonly dolomite but may be lime or calcite druse. Frequently the filling material has been leached from the fucoids and the formation takes on an appearance similiar to that of the overlying Kimmswick formation. The holes in the Plattin, though, are much smaller. They resemble intertwining worm borings or tubes. Larson (1951, p. 2071) suggests algal impressions or worm borings for their origin.

Chert nodules are common in the upper part of the Plattin. Their color is generally brown but white chert is often "plastered" on the bedding planes of the limestone. The persistancy of the nodular bands is best seen at the Highway 47 quarry section. The chert was a field aid in distinguishing the dolomitized Plattin from the upper Joachim.

The basal bed of the Plattin is oolitic and contains an intraformational limestone pebble conglomerate or breccia bed in the upper part. The pebbles are elongate and range from 2 to 15 millimeters in length, to 2 millimeters in width. At the Highway 47 quarry, part of the pebbles conglomerate is dolomitized. The size of the pebbles is much smaller (1 to 2 millimeters) than where they are limestone. Larson reports a similiar occurrence near Eureka, Missouri, and suggests penecomtemporaneous alteration or possibly primary origin for the dolomite. Pebble conglomerates are also present in the upper fucoidal beds.

Thin shell beds one-fourth to one inch thick and abundantly fossiliferous thicker beds, one to six inches, are present in the upper part of the formation. The lower part is conspicuously devoid of fossils.

Two green shale beds are present just above the base of the formation. A few primary green shale laminae are present in the upper portion. Red and green shales intercalated with the limestone beds are connected to joints and solution passages and are secondary to the deposition of the limestone.

The weathered face of the Plattin is blocky and rough. Angular fragments break out when it is struck. The dolomite beds are more resistant to weathering than the limestones. Their weathered surface is frequently pitted giving them an appearance similiar to the upper Joachim ledge forming beds. The limestones decay, are coarse grained, and cream colored. Brachiopods, often silicified, project from the surface of the beds on weathering. Solution channelways along the bedding and pitting of the face, caused by downward percolating waters, is common.

The following detailed section is at a quarry on the west side of Highway 47, northwest quarter, Section 33, Township 46 North, Range 2 West.

Mississippian System	Feet	Inches
24. Residual cherts		
Ordovician System		
Champlainian Series		
Plattin Formation		
23. Limestone, light gray on fresh and weathered surfaces; fine-grained; fucoidal, fucoids filled with tan dolomitic and lime mud; brown chert nodules one foot above base. Weathered surface rough as fucoids more resistant to weathering and stand out. Top bedding plane shows solution channelways	3	0
22. Limestone and limestone pebble conglomerate, medium gray on fresh and weathered surfaces; fine grained; fucoidal; rough weathered surface; fossil outlines scattered through; fine to medium bedded; one-half to two inches thick		9
21. Limestone, medium light gray; fine-grained; fucoidal with tan dolomite fillings; scattered shell outlines	1	3
20. Limestone, medium light gray; medium-grained; partly a limestone pebble conglomerate; surface slightly pitted but not fucoidal		6
19. Limestone, light gray on fresh, medium gray on weathered; fine-grained at base grading upward to coarse grained at top; medium bedded, four- to seven-inch thick beds; fucoidal in lower twenty inches becoming weakly fucoidal in upper ten inches. Limestone pebble conglomerate in top five inches.	2	6
18. Limestone, light medium gray; coarse grained in lower five inches, fine-grained in upper five inches; fucoidal, fucoids brown dolomite filled		10
17. Limestone, light gray; fine-grained; medium to thin bedded, beds ½ to 2 inches thick		10

	Feet	Inches
16. Limestone, light gray; fine-grained in lower eight inches becoming coarse-grained at top with fine-grained mottles; chert nodular band along base; shell outlines along the top. Floor of upper quarry	1	1
15. Covered	1	0
14. Limestone, light gray; fine-grained; medium bedded, bed two to six inches thick, massive appearing; two brown chert nodular bands at base, and another 10 inches below top of bed. Six inch shell bed 30 inches above the base - Hormotoma sp., outlines of valves and shell fragments of brachiopods. Shell bed associated with a limestone pebble conglomerate. Fucoidal, fucoids filled with brown sugary textured dolomite	4	2
13. Limestone partially dolomitized, white to light gray grading laterally into chocolate brown where dolomitized; medium to massive bedded, five-inch to one foot beds; non-fucoidal. Two inch thick pebble bed seven inches below top	3	0
12. Dolomitized limestone, brown; fine-grained; bottom seven inches a coarse-grained limestone pebble conglomerate grading upward into dolomite; fine-grained; light gray limestone top four inches, brown chert lense and nodules at top and chert band 10 inches above base	3	4
11. Limestone, light gray; coarse-grained at base grading upward into fine grained; one inch pebble conglomerate three inches below top; shell bed at top . .	2	4
10. Limestone, light gray; fine-grained; medium bedded; fucoidal, silty brown dolomite filling; shell and pebble conglomerate beds	1	3
9. Limestone, light to medium gray; coarse-grained; medium bedded; poor pebble bed at top, one inch thick; faintly fucoidal in lower part	2	2

	Feet	Inches
8. Limestone, light to medium gray; fine and coarse-grained alternating; irregular bedding, medium bedded, massive appearing; fucoidal; white chert nodular band at top and one foot above base	4	8
7. Limestone, light to medium gray; finely crystalline; medium bedded; fucoidal, fucoids filled with tan dolomite; pebble conglomerate at top and eight inches above base; shell beds at top and near middle of bed, brachiopod and gastropod outlines Hormotoma	3	6
6. Limestone, light gray with tan dolomite streaks; pebble bed; has shell outlines at top		3
5. Limestone, light gray with some tan mottles; sublithographic; medium bedded; fucoidal, tan limey dolomitic filling; fossiliferous, crinoid stems and brachiopod outlines along top bedding surface.		
4. Shale, green; calcareous; lense		8
3. Dolomite, reddish brown; fine-grained; medium to thin bedded; pebble conglomerate in part; faintly fucoidal in top three inches	2	0
2. Shale, green; calcareous		4
1. Limestone, oolitic, light gray; fine-grained; thin-bedded		10
Total thickness of Plattin	43	5

Joachim Formation - floor of quarry.

0. Dolomite, yellowish orange, fine-grained; slightly argillaceous . . . .

Paleontology.— The lower beds of the Plattin formation are sparsely fossiliferous. The shell beds mentioned in the detailed section are an inch or less thick and appear to have limited lateral extent. Seldom can more than the outlines of shell be distinguished.

Rafinesquina sp. cf. R. alternata Emmons, Camarella? sp., Hormotoma sp. and bryozoans are common associates of the shell beds.

The upper Plattin, cropping out along the northern border of the area, is abundantly fossiliferous. These beds weather out in one and two inch slabs that resemble coquina. Pionodema subaequata (Conrad) and Rafinesquina alternata Emmons are the most prolific species. Where one predominates, however, the other is very sparse.

Other brachiopod species common to the Plattin formation are Hesperorthis tricenaria (Conrad), Sowerbyella sp. cf. S. punctostriata (Mather), Strophomena sp. cf. S. incurvata (Shepard), Zygospira sp. cf. Z. recurvirostris (Hall), and Rhynchotrema sp. cf. R. minnesotense (Sardeson). The form genus "Orthoceras" represents the cephalopods, Hormotoma sp. and Liospira? sp. the gastropods, Leperditia sp. the ostracodes, and Favistella halli (Nicholson) the coelenterates. Pygidia of trilobites are similar to Bathyurus spiniger Hall. Several species of Calliops are represented in the formation. The brachiopods in the upper beds generally are silicified, the other fossils remaining calcareous on chitinous. Faunal lists for the Plattin have been given by Branson (1944, pp. 76-79) and Larson (1951).

Stratigraphic relations.— The lower boundary of the Plattin formation is discussed with the Joachim formation. The contact in this area, where exposed, appears to be conformable. However, the presence of the oolite and intraformational pebble conglomerate beds is suggestive of a shallow water depositional environment, and may be evidence of an unconformity.

The upper boundary is a disconformity, and the formation is overlain by residual Mississippian cherts throughout most of the area.

Slumping of these cherts conceals the upper surface of the Plattin. In the northwest corner of the area, Devonian limestone overlies the formation, and in places fills erosional pockets or sinks developed in the Plattin. The same is true for the Kimmswick formation where present.

The relationship of the Plattin to the Pennsylvanian sandstone and clay is uncertain. Field observation shows that in most cases the sandstone beds were deposited parallel to the top of the Plattin. However, there are several exceptions to this in the southern part of the uplands, where the sand occurs in depressions in the Plattin. Whether this represents primary deposition, or later let-down of the sand into a sink, is questionable.

Age and correlation.— Present correlations put the Plattin formation either entirely within the Black River substage of the Middle Ordovician (Ulrich, 1939, pp. 106, 108), or partly within the overlying Trenton. DuBois (1945, p. 17) correlated the Plattin of Missouri with the Platteville of Illinois on subsurface evidence. Larson (1951, p. 2074) places his Macy formation (Plattin group) in the Trenton; the other formations of the Plattin group (Hager, Beckett, and Bloomsdale) are considered by him to be Black River. His correlations were based on fauna, metabentonite beds, and fucoids. The Ordovician correlation chart (Twenhofel and others, 1954), followed here, accepts Larson's interpretation. Agnew (1955, p. 1713) suggests correlating the Plattin of Missouri with the Platteville of Iowa and includes it in the Black River. Following this suggestion the Decorah would be basal Trenton in northeast Missouri. The undifferentiated Plattin of this report includes Bloomsdale, Beckett, and possibly Hager equivalents.

Topographic expression.— A gentle slope typifies the Plattin formation, in sharp contrast to the steep profile developed on the Joachim. Exposures are poor along hillsides, but the formation crops out in most gullies. Where rocks are exposed on hillsides, small bluffs develop (5-15 feet high), but their lateral extent generally is less than 30 feet. No topographic break marks the top of the formation, and residual chert commonly covers the upper Plattin.

PLATE V

A. Lower face of quarry in the Plattin limestone showing pitting on the fucoidal phase and jointing. West side of Highway 47, NW$\frac{1}{4}$, Sec. 33, T. 46 N., R. 2 W.

B. Solution channel developed on the bedding of dolomitic Plattin. Gully in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 26, T. 46 N., R. 2 W.

TABLE VI

Nomenclatural history of the Kimmswick.
(Refer to the Bibliography for complete references.)

1855 - Swallow, G. C.,	Trenton Limestone.
1873 - Broadhead, G. C.,	Charette Limestone. (Warren County, Missouri).
1898 - Keyes, C. R.,	McCune Limestone. (Lincoln County, Missouri).
1904 - Ulrich, E. O.,	Kimmswick Limestone.

Present Usage - Missouri Geological Survey - Kimmswick formation.

KIMMSWICK FORMATION

Previous usage.-- In early reports, the Kimmswick formation is termed Trenton and Upper Trenton (Swallow, 1855, pp. 112-114), and the "Receptaculite Limestone" (Shumard, according to Broadhead). Broadhead (1873, p. 49), in his Warren County report, proposed the name "Charette" Limestone for exposures of Kimmswick along Charette Creek, Warren County, Missouri.

Ulrich (1904, p. 111) initiated the term Kimmswick for the crystalline limestones overlying the Decorah formation. The type locality is Kimmswick, Lincoln County, Missouri, where this limestone is quarried. Neither description nor thickness was given.

Present usage.-- Although the names "Charette" Limestone and McCune limestone (Keyes, 1898, p. 61) have priority, Kimmswick is accepted by the Missouri Geological Survey. Twenhofel and others (1954) also use Kimmswick formation for the Missouri section.

Application in field mapping.-- Two isolated outcrops of the Kimmswick formation were noted, but are not practicably mappable. These exposures are preserved in pockets on the erosional surfaces of the Plattin, the subjacent Decorah formation being absent in the area.

Distribution.-- A definite, but incompletely exposed, Kimmswick block is present in the southwest quarter of the northwest quarter of Section 24, Township 46 North, Range 3 West, at the junction of two gullies. Receptaculites oweni was noted in the limestone.

In the southeast quarter of the northeast quarter of Section 20, Township 46 North, Range 2 West, an outcrop about 20 feet long and 10 feet high is similar in lithology to the Kimmswick limestone. Whether this exposure is Kimmswick has not been determined. Downhill from the

KIMMSWICK FORMATION

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Present usage.-- Although the names "Charette" Limestone and McCune limestone (Keyes, 1898, p. 61) have priority, Kimmswick is accepted by the Missouri Geological Survey. Twenhofel and others (1954) also use Kimmswick formation for the Missouri section.

Application in field mapping.-- Two isolated outcrops of the Kimmswick formation were noted, but are not practicably mappable. These exposures are preserved in pockets on the erosional surfaces of the Plattin, the subjacent Decorah formation being absent in the area.

Distribution.-- A definite, but incompletely exposed, Kimmswick block is present in the southwest quarter of the northwest quarter of Section 24, Township 46 North, Range 3 West, at the junction of two gullies. Receptaculites oweni was noted in the limestone.

In the southeast quarter of the northeast quarter of Section 20, Township 46 North, Range 2 West, an outcrop about 20 feet long and 10 feet high is similar in lithology to the Kimmswick limestone. Whether this exposure is Kimmswick has not been determined. Downhill from the exposure, however, float was found containing a characteristic Kimmswick index fossil, *Receptaculites oweni*.

Broadhead (1873, pp. 49-50) reported 26 feet of Kimmswick (as "Charette" Limestone) on Charrette Creek, north of the thesis area, in the Warrenton quadrangle, and only nine feet on Bear Creek about 10 miles to the west. Schindler (1951) reported the occurrence of the formation in the Augusta quadrangle, with thinning toward the west. Goodrich (1952) reported a questionable outcrop of Kimmswick in the northwest part of Warren County. Of three Warrenton city wells (Sections 28 and 29, T. 47 N., R. 2 W.), the logs of two show 15 feet of Kimmswick and 30 to 40 feet of Decorah; the third lists no Kimmswick and about 30 feet of Decorah. A well drilled recently in the southeast quarter of Section 26, Township 47 North, Range 2 West, penetrated 30 feet of the Kimmswick formation and no Decorah.

Lithology and paleontology.-- The rocks of both exposures are coarse to medium grained, and medium gray to grayish-orange where highly weathered. Bedding is medium to thin, and the weathered surface frequently is blocky. Limonite mottling and nodules are scattered in the limestone. Both exposures are deeply weathered and friable. The large tubular openings common in the Kimmswick are absent.

Species collected from the two outcrops include *Receptaculites oweni* Hall, *Eridotrypa* sp. cf. E. *aedilis* (Eichwald), *Rafinesquina alternata* Emmons, *Sowerbyella punctostriata* (Mather), and *Dinorthis* pectinella (Conrad). The bryozoan *Eridotrypa* and the brachiopod *Dinorthis pectinella* (Conrad) are the only species common to both exposures and absent from the Plattin formation.

Stratigraphic relations.-- The Kimmswick in this area unconformably overlies the Plattin formation. It is present because of its protected position in pockets on the eroded Plattin surface. Unconformably overlying the Kimmswick formation are Mississippian chert residuum and possibly Devonian limestone. The presence of the Kimmswick at these two locations shows the area to have been capped by the formation. Other isolated outcrops of the formation probably exist in the area.

Age and correlation.— Ulrich (1939, pp. 106-107) placed this formation in the upper Black River substage. DuBois (1945, pp. 17-21) correlated the Kimmswick formation of eastern Missouri and southern Illinois with the Galena group, placing it in the Trenton substage. Agnew (1955, p. 1713, fig. 3) suggested correlation of the Kimmswick of northeastern Missouri with the Galena of Iowa. The Ordovician correlation chart (Twenhofel and others, 1954) lists the Missouri Kimmswick formation in the Trenton, the position accepted here.

DEVONIAN SYSTEM

UPPER ERIAN SERIES

CALLAWAY FORMATION

Previous usage.-- Broadhead (1873, pp. 46-48) recognized the presence of Devonian limestones in Warren County and referred them to the Hamilton group and "Crinoidal Limestone". Keyes (1894, pp. 30, 43) applied the name Callaway to the Devonian in Missouri, from exposures in Callaway County, and later restriction of the unit has limited it to beds in central Missouri. Branson (1922, pp. 16, 17) referred Broadhead's Hamilton to the Callaway and the Crinoidal Limestone to his Mineola limestone (Branson, 1920).

Present usage.-- The Devonian correlation chart (Cooper and others, 1942) lists Cooper limestone (basal), Ashland limestone, Mineola limestone, and Callaway limestone (upper) for the Upper Erian of Missouri. A recent discussion of the Devonian (Unklesbay, 1952, pp. 30-39; Boone County report) suggests that the Devonian limestones of Central Missouri - Cooper, Callaway, Ashland and Mineola - are all facies of a single formation which he designates as the Callaway.

Application in field mapping.-- Because of the limited extent and size of Devonian outcrops in the area, and variations in lithology of both the Mineola and Callaway limestones, the Devonian has not been separated into facies. Fossils and lithology most closely resemble those of the Callaway, and the beds are mapped as Callaway. The vertical extent of the formation has been exaggerated on the geologic map for purposes of presentation. Some question may exist regarding the continuous belt mapped along Lost Creek, as the formation is not continuously exposed. The outcrops, however, are reasonably closely spaced, and the formation presumably extends beneath the Mississippian residual cherts.

Distribution and thickness.— The most continuous exposures of the Callaway is in Sections 15, 22, 27, and 34, Township 46 North, Range 3 West. Other isolated outcrops are present in the northern part of the area, but are not practically mappable. A large exposure of the formation is present in the northwest quarter of Section 15, Township 46 North, Range 2 West, at the Washington-Warrenton quadrangle boundary, and extends northward into the Warrenton quadrangle.

The formation nowhere exceeds 20 feet in thickness, averaging five feet or less in outcrop. A deep well in the Warrenton quadrangle shows a thickness of 28 feet for the Devonian.

Lithology and paleontology.— The Callaway formation is predominantly a light gray to light yellowish-brown, coarsely crystalline, crinoidal limestone. The texture ranges from fine-grained to medium coarse where weathered. Bedding is commonly medium to thin. The majority of exposures are very highly weathered and friable, but the fine-grained beds weather to a smooth hard surface.

Fossils generally occur in the coarsely crystalline facies. Large crinoid columnals are most abundant. The majority of the fossils, including most brachiopods, have been weathered beyond recognition. Haxagonaria davidsoni (Edwards and Haime), Favosites helderbergiae Hall, F. sp. cf. conicus Hall, F. sp. indet., and Streptelasma? sp. are the most abundant identifiable species. Atrypa reticularis (Linne) and Platyrachella iowensis (Owen) were identifiable brachiopods.

Stratigraphic relations.— The Callaway formation overlies the Plattin unconformably. Like the Kimmswick, it is preserved in pockets on the eroded surface of the Plattin. Several exposures of the Callaway limestone along Lost Creek are in juxtaposition with the Plattin formation. Whether the presence of the Callaway is primary or caused by let-down is questionable. The extent of Callaway inliers suggests primary deposition on the Plattin after erosion of the Kimmswick from the area.

Mississippian residual cherts unconformably overly the formation. Slumping of the cherts obliterates the limits of the formation.

Age and correlation.-- The Devonian correlation chart (Cooper and others, 1942) places the Callaway in the Upper Erian series, equivalent to the Cedar Valley formation of Iowa, the position accepted here.

MISSISSIPPIAN SYSTEM

OSAGEAN SERIES

RESIDUAL CHERTS

The Mississippian System is represented by chert and dark-reddish clay residuum. The chert ranges in size from pebbles to small boulders, generally sub-angular to sub-rounded, with moderately common rounded boulders. It is predominantly reddish-brown to light brown or white. The reddish clay-like soil which incorporates the cherts is similar to the residual soil of the Burlington limestone. The thickness of the chert residuum ranges to 70 feet, with 50 feet being average.

The cherts probably were derived from the Burlington and Chouteau limestones, which contain a high percentage of that material. Outcrops of these formations are present along Lost Creek, in the Warrenton quadrangle, about three miles north of the thesis area. The present thickness of the Osagean limestones to the north could not account for the large amount of chert found to the south. Thus, the limestones were of much greater thickness in this area and have undergone extensive erosion since the close of the Paleozoic. Most of the chert is residual, having been concentrated by removal of the limestone by solution. Some, however, probably has been transported into the area. The presence of Pennsylvanian sediments in sink structures in the chert strengthens the idea of a residual origin for the chert.

Fossils in the residuum are the brachiopods *Torynifer pseudolineata* (Hall), *Echinoconchus* sp. cf. *E. alternatus* (Norwood and Pratten), and *Tetracamera subtrigona* (Meek and Worthen), the trilobite *Griffithides* sp., and the bryozoan *Fenestrellina* sp. The crinoids *Cryptoblastus melo* (Owen and Shumard), *Batocrinus subaequalis* (McChesney), and *Eutochocrinus* christyi (Shumard) indicate a lower Osagean age.

PENNSYLVANIAN SYSTEM

DESMOINESIAN SERIES

CHEROKEE GROUP

The Pennsylvanian System is represented by two formations, the Graydon sandstone and the Cheltenham clay. These occur together throughout the uplands, in pockets in the Mississippian residual cherts, resting on beds as old as the Plattin limestone. Surface expression is generally lacking except along hillsides, where the protective chert cover has been removed.

Application in field mapping.— Because of their similarity of distribution, thinness, and common age, the Graydon sandstone and Cheltenham clay are mapped as a unit. The history of names, usages, and lithology of the formations will be discussed separately. The distribution, thickness, and stratigraphic relations of the formations will be considered as a unit.

Only the larger sandstone outcrops and open clay pits are shown on the geologic map. The size of the pits (sinks) is generally proportional to that of the structure, but is often exaggerated. The shape of the map symbol representing the sink does not necessarily reflect the true outline of the structure.

GRAYDON SANDSTONE

Previous and present usage.— Broadhead (1873, p. 46) described a sandstone in southern Warren County, which from its lithologic and stratigraphic description probably is the Graydon sandstone. He named it the "Red Sandstone". Winslow (1894, pp. 422-425) published the first reference of these strata to the Pennsylvanian. He used the name "Graydon Springs sandstone and chert conglomerate", and credited it to Dr. W. P. Jenny. The name is from a section near Graydon Springs, Polk County, Missouri. Shepard (1898) shortened the term to Graydon sandstone, and McQueen (1943, pp. 33-38) referred to these beds as the "Graydon formation". The form Graydon sandstone is in general use, and is followed in this report.

Lithology and paleontology.— The Graydon is a fine- to very fine-grained, sub-rounded to mainly sub-angular, quartz sand. The fresh sandstone ranges from light brown to almost white. Its weathered surface is generally dark brown or gray. Ferruginous staining and case-hardening by iron oxide are common. The fresh sand is generally friable, but may in part be cemented with silica. Brown, angular chert fragments (Burlington) are frequently incorporated. The bedding is massive and irregular.

The Graydon sandstone is unfossiliferous, although fossils have been collected from the included cherts, which were derived from the Mississippian.

The basal chert conglomerate of the Graydon sandstone is absent in this area. The cherts mentioned above are scattered throughout the sandstone.

Age and correlation.— The age of the Graydon can be determined only by its stratigraphic position. It is considered to be post-Osagean and pre-Cheltenham.

CHELTENHAM CLAY

Previous and present usage.— Broadhead (1873, p. 62) described bedded red, purple, and cream-colored clays in southern Warren County. Wheeler (1896, pp. 246-247) proposed the name "Cheltenham Fireclay Seam" for a fire clay exposed on the uplands in St. Louis County. In

1943, McQueen (p. 39) raised the Cheltenham to formation status. Both the terms Cheltenham formation and Cheltenham clay are in present use. The latter term will be used.

Lithology and paleontology.-- McQueen (1943, pp. 31-71) divided the "Cheltenham formation" into three members. A lower member of dark brown, black, or gray semi-flint and flint clay; a middle member consisting of light gray, semi-plastic clay with local purple and red mottlings at the top and base; and an upper member of light to dark gray plastic clay. No attempt was made to divide the clays of the area into its respective members. The lower member, however, appears to fit most of the clays in the north half of the Washington quadrangle, although some deposits are similar to the middle member.

The clays are predominantly of the flint type throughout the area. They are light gray to cream-colored and break with a very distinct conchoidal fracture, exhibiting sharp splintery edges. Purple, red, and occasionally black mottlings are present. McQueen (1943, p. 68) lists one diaspore pit in Warren County (SE$\frac{1}{4}$, Sec. 16, T. 46 N., R. 2 W.; Washington quadrangle). The other pits in the immediate area contain flint clay.

Mineralogically, the flint clay is composed chiefly of halloysite or kaolinite (Allen, 1937, pp. 11-13).

No fossils were found in the Cheltenham clay in this area. Isolated fragments of fossil wood have been reported from the clay in Boone County.

Age and correlation.-- Stratigraphic position indicates that the Cheltenham is post-Graydon, and the formation is generally referred to the Cherokee.

Distribution and thickness.— The Graydon sandstone and the Cheltenham clay are scattered over the uplands region, extending southward along the ridge tops. They are preserved in sink structures restricted to Plattin and younger formations.

The sandstone is the most prominent feature of the Pennsylvanian sediments and occurs as tumbled masses along hillsides and lining the sink structures. Where the sand is in place, it frequently shows a steep dip toward the center of the sink. The rimrocks show a general outline of the sink. On the upland proper, the sink structures show no surface indication. The sandstone ranges from zero to 15 feet in thickness, with an average of about six feet.

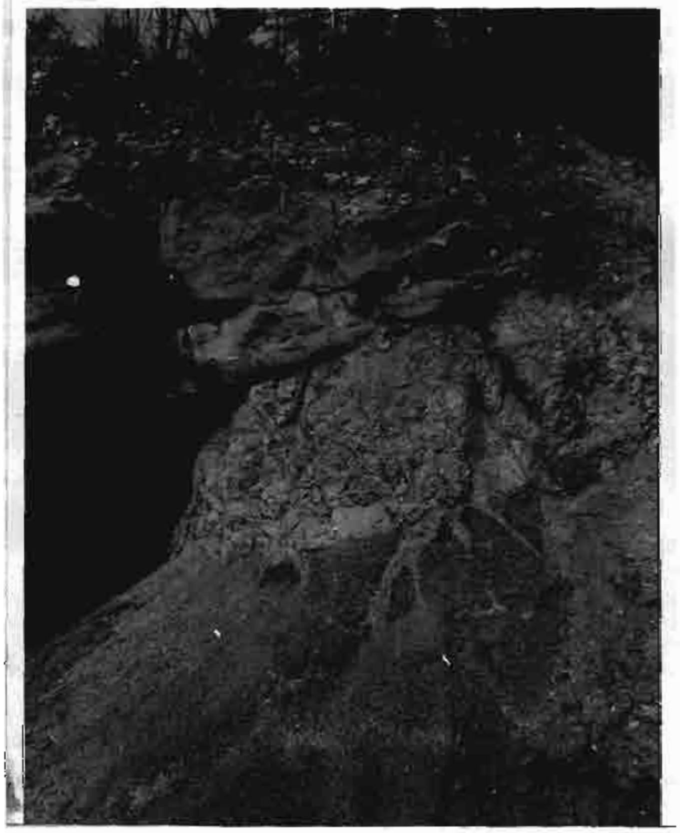
The distribution of the clay is similar to that of the sandstone which it overlies, though exposures are less frequent. Thickness varies from zero to about 15 feet. As the majority of pits in the area are flooded, it is difficult to judge the average thickness for the clays.

Stratigraphic relations.— The Graydon sandstone is unconformably in the residual Mississippian cherts and extends down to, and possibly into, the Plattin limestone. The consolidated sandstone has retained the shape of the sink structure that was produced in the Mississippian limestones, although the latter have since been removed by solution, and the surrounding material is now chert residuum.

The Cheltenham clay lies directly on the Graydon sandstone and forms the core of the sink. Their boundary is very sharp, smooth, and distinct. In other areas, it is reported to be gradational (McQueen, 1943, p. 51).

PLATE VI

A. Graydon sandstone dipping into hillside at sink structure in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 24, T. 46 N., R. 3 W.



B. Graydon sandstone overlying the Cheltenham clay at an open pit in the SE$\frac{1}{4}$, SE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 17, T. 46 N., R. 2 W. West side of Highway 47.

QUATERNARY SYSTEM

LOESS

Deposits of loess, zero to 15 feet thick, rest on the terrace. The deposits are isolated and have a limited lateral extent. The most prominent exposures are on top of the Missouri River bluffs, where some 10 feet lie on the Jefferson City formation. Other deposits, along valleys cut into the elevated terrace, grade laterally into alluvium. C. D. Holmes (in Branson, 1944, p. 334) dates the loess deposits of Missouri as early Wisconsin.

ALLUVIUM

The floodplains of the Missouri River and the lower reaches of the major stream valleys are covered by a thick deposit of alluvium consisting of sand and silt. Northward the size of particles increases, although sand derived from the extensive St. Peter outcrop area is very prominent throughout the entire region. Chert, limestone, and dolomite gravels, and sand comprise the major part of the alluvial deposits. The chert is predominantly Mississippian, but the Jefferson City and Plattin formations also contribute chert to the alluvium. The high percentage of sand in the alluvium gives it the appearance of loess when viewed from a distance. The banks show good sorting and graded bedding in the alluvial material. The alluvium ranges from zero to 20 feet in thickness.

STRUCTURAL GEOLOGY

The structure of the northwest quarter of the Washington quadrangle is relatively simple. The general attitude of the beds is horizontal. The regional picture, however, shows a homoclinal structure with a slight dip to the northeast of approximately 30 feet per mile and a strike of north 55° west. Slight fletures are superimposed on the major structure. A slight accentuation of dip along a line running northwest-southeast near the central part of the area, indicates a slight monoclinal fleture or fold.

The Jefferson City formation has highly undulating bedding surfaces and dips change radically within a short lateral distance. They are local and are probably caused by differential solution of the dolomites.

<u>Sinks</u>.— Sink structures are present in the upper beds of the Jefferson City, Joachim, Plattin formations, and in the Mississippian chert residuum and will occasionally complicate the structural picture. They form through the differential solution and leaching of underlying carbonate rocks, resulting in the collapse or downwarping of the overlying strata.

The largest sinks in the area have been developed in the Jefferson City dolomite with the St. Peter sandstone filling the structure. Several of these fillings have a trough-like appearance and may represent solution valleys.

On the northeast side of such a St. Peter trough filling (NE$\frac{1}{4}$, SE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 32, T. 46 N., R. 2 W.) the Jefferson City dips slightly (6 to 10 degrees) toward the St. Peter. On the south side the beds are relatively horizontal. The beds are relatively horizontal on the north side to within 100 feet of the filling. Table III lists the more obvious of these structures. Outliers of the St. Peter are associated with the sink structures.

The presence of the St. Peter in juxtaposition with the Jefferson City gives the appearance of graben faulting. Since the upper boundary of the St. Peter is undisturbed, the sinks developed penecontemporaneously with deposition of the St. Peter or prior to St. Peter time.

Sinks in the Plattin limestone have apparently caused dolomitization of that formation. Where the Plattin is dolomitized and in superposition with the Joachim dolomite, it is difficult to distinguish between the formations.

The sink structures that developed in the Mississippian limestone are the only ones in the area of commercial note, as they contain Pennsylvanian clay deposits. The limestone has since been removed from the area and the sinks are now present in the residual cherts. These structures are probably post-Pennsylvanian in age as the sandstone dips steeply into them and slickensides frequently occur on the surface of the clay. Surface indication of the sinks is lacking on the uplands, but along hillsides sandstone dipping steeply toward the center partially outlines the structure.

Faults.-- A small fault is present in the Jefferson City dolomite in the southeast quarter of the northwest quarter of the southwest quarter of Section 32, Township 46 North, Range 2 West. Approximately 20 feet of cover obscures the fault trace. The strike of the fault is north 36° east. The displacement is approximately 10 feet with the upthrown side on the south. This fault appears to be genetically related to the St. Peter sink fillings in the south half of the southwest quarter of Section 32, Township 46 North, Range 2 West, and in the northeast quarter of the southeast quarter northwest quarter of Section 32, Township 46 North, Range 2 West. Other small faults occur throughout this formation but the displacement is generally less than five feet.

Joints.— The lower part of the St. Peter sandstone is highly jointed throughout most of the area. The majority of the joints are vertical but a few dip as low as 30 degrees. The greatest number bear north 60° west and north 10° west. Vertical joints are also present in the Plattin limestone but there is no orderly arrangement to their occurrence. The majority strike nearly due north. Much subsurface solution has taken place along the joints.

The alignment of joints in both the St. Peter and Plattin is almost perpendicular to the strike of the regional dip.

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ECONOMIC GEOLOGY

The mineral resources of the north half of the Washington quadrangle are non-metallic. Only fire clay, limestone, and dolomite are exploited commercially.

Fire Clay

The north half of the Washington quadrangle is on the fringe area of the Northern Clay District of east-central Missouri. Fire clays of commercial value are present in sink structures scattered over the northern uplands and extending into adjacent quadrangles. The greatest concentration of open pits is in the northeast and northwest corners of the quadrangle.

Only a very few pits exist south of Township 46 North. South of this township, the hills are generally capped by no more than a thin veneer of residual chert, and erosion has extended down into the Plattin. The ridge tops are narrower and highly dissected, and the probability of extensive clay deposits is slight.

Harbison-Walker Refractories Company, Fulton, Missouri, A. P. Green Fire Brick Company, and Mexico Refractories, Mexico, Missouri, are the largest operators in the county. More than a million tons of clay have been mined from this area.

Limestone and Dolomite

Agricultural lime.-- The Jefferson City is the only formation at present being exploited for agricultural lime.

Only one quarry is in operation at present, but several others have been operated in the past. One quarry was opened in the Plattin formation, but had to be abandoned because an adjacent sink structure cut out part of the formation. All the quarries are small scale operations. Colomites are preferred to the limestones because of the presence of magnesium and increased carbonate equivalent. The quarry now in operation is situated in the northwest quarter of Section 15, Township 45 North, Range 3 West, at the extreme southwestern corner of the area.

Building stone and road metal. — The Joachim dolomite has been the most extensively used for road metal and building stone. It has been quarried on a very small scale for local foundations, and a large quarry was opened in the Warrenton quadrangle (SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 8, T. 46 N., R. 2 W.), during the spring of 1955, for resurfacing Highway 47.

Iron Ore

Several small pits containing hematite occur in sink structures. One is reported by Crane (1912, p. 343) in Section 21, Township 46 North, Range 2 West. None of the deposits have commercial value.

Sandstone

Broadhead (1873, p. 62) and Dake (1918, pp. 163-167) reported on the sand resources of Warren County. The locations advised by Dake for commercial exploitation lie within this area. Transportation by rail is available, as the Missouri, Kansas and Texas Railroad runs about three miles south of the St. Peter outcrop belt, and the Wabash Railroad is about five miles to the north. There has been no commercial exploitation of the sandstone to date.

GEOLOGIC HISTORY

The oldest rocks exposed in the area (the Jefferson City formation) were deposited in the early Ordovician, Canadian epoch. Deep wells record the presence of even lower Canadian rocks and presumably the area is underlain by the complete Missouri section of older rocks.

The sea in which the Jefferson City formation was deposited, was rich in carbonates and contained considerable clay resulting in the deposition of "cotton rock" type dolomites. Sandstone, shales, and cherts were deposited at intervals. Ripple marks, mud cracks, and the presence of oolites are suggestive of shallow, agitated water conditions. Either the environment was unfavorable to life or conditions unsuitable to fossilization as the Jefferson City contains little evidence of marine life.

Near the end of the deposition of the Jefferson City formation shales containing reworked chert boulders were deposited. Then the seas retreated and the area was subjected to erosion and sinks began to develop in the Jefferson City formation.

The sea again invaded the area at the beginning of the middle Ordovician (Champlainian epoch). Essentially pure sandstone (St. Peter) was deposited in this sea, the absence of significant amounts of clays and carbonates suggests a decided change from the depositional conditions of earlier seas. The source of the sand was not local although very minor amounts may have been derived from the sand lenses in the Jefferson City formation. The major source is not known but it was probably derived from the Canadian shield or Potsdam sandstone in the east (Dake, 1921, pp. 207-210). Sand was supplies to the sea by rivers and the reworking would increase the purity of an already relatively pure sandstone such as the Potsdam sandstone.

During St. Peter time over 100 feet of sand was deposited. That it was laid down under marine conditions is substantiated by the presence of marine fossils in Minnesota and the predominence of massive bedding over cross bedding.

The addition of calcium and magnesium bicarbonates and argillaceous material to the sea, and change in the position of the shore line or exhaustion of sand supply brought about a gradation from sandstone to the shales and sandy dolomites of the Joachim formation. The sand grains in the lower dolomite were derived from reworking the St. Peter. There was a probable uplift or regression of the sea after deposition of the Joachim formation, which is indicated by the oolites and intraformational conglomerate at the base of the Plattin formation.

The Plattin sea was rich in calcium bicarbonates and the presence of shell beds and fucoids show that the sea supported abundant life. Minor fluctuations from deep to shallow water during Plattin time are indicated by the presence of intraformational conglomerates scattered throughout the formation in this area.

At the end of Black River time (early middle Ordovician) the area was again uplifted and eroded. The Kimmswick sea (Trenton age) followed and depositional conditions were much like those of the Plattin. The Kimmswick limestone was eroded, prior to middle Devonian time, with only remnants remaining on the eroded surface of the Plattin.

The middle Devonian limestones were deposited on the highly eroded Ordovician surface. Corals, crinoids, and brachiopods were especially abundant. In the middle Devonian the seas withdrew and extensive erosion ensued, again extending down to the Plattin. Only isolated outcrops in pockets on the eroded Plattin surface are preserved.

The Mississippian seas invaded the area and the limestone and chert of the Burlington formation (Osagean) were deposited. The limestone has subsequently been removed by solution leaving only a thick residual deposit of chert. The thickness was great as evidenced by the thickness of the chert residuum. The erosion and chemical solution of these middle Mississippian limestones continued into the Pennsylvanian.

The Pennsylvanian sandstones were then deposited on the Mississippian rocks. Unklesbay (1952, p. 69) suggests deposition from an encroaching sea for the origin of the sandstone. The massive clays overlying the sandstone suggests that the area was covered by a swamp and represents the deposition of highly weathered soils in this stagnant water. Sink development brought the Pennsylvanian sediments into juxtaposition with the Ordovician sediments in many cases.

Toward the close of the Paleozoic (Pennsylvanian) the area was domed and slightly tilted toward the northeast. The surficial Pennsylvanian sediments were subsequently eroded leaving only the isolated deposits protected in the sink structures. This area continued to be eroded during the Mesozoic and early Cenozoic eras producing a peneplain or near peneplain surface.

Several minor uplifts took place following peneplanation. One of these is represented by the terrace in the southern portion of the area mapped. A subsequent uplift, believed to have developed at the end of the Pliocene, was followed by deep entrenchment of the Missouri River. Loess deposits are believed to have been brought into the area during early Wisconsin time. Since Pleistocene there has been some aggradation by the Missouri River along its floodplain.

CONCLUSION AND SUMMARY

1. A geologic map of the northwest quarter of the Washington quadrangle has been prepared.

2. The geology, physiography, and geography of the area has been discussed.

3. The precision with which formational contacts can be delineated depends on the amount of chert cover, the amount of transition between the formations (St. Peter-Joachim), the degree of dolomitization (Joachim-Plattin), and the available paleontologic evidence (Plattin-Devonian).

4. A more detailed study of the St. Peter-Jefferson City boundary is necessary to determine if the low outcrops of the St. Peter represent solution valleys or local sinks.

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VITA

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He served in the Navy from 1945 to 1948 with the Atlantic Fleet.

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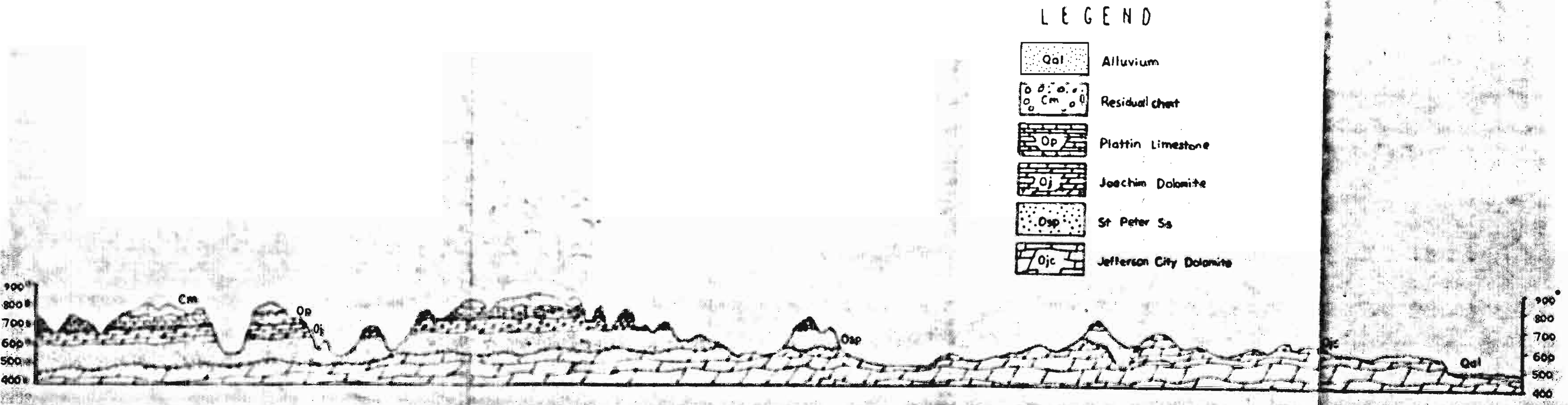

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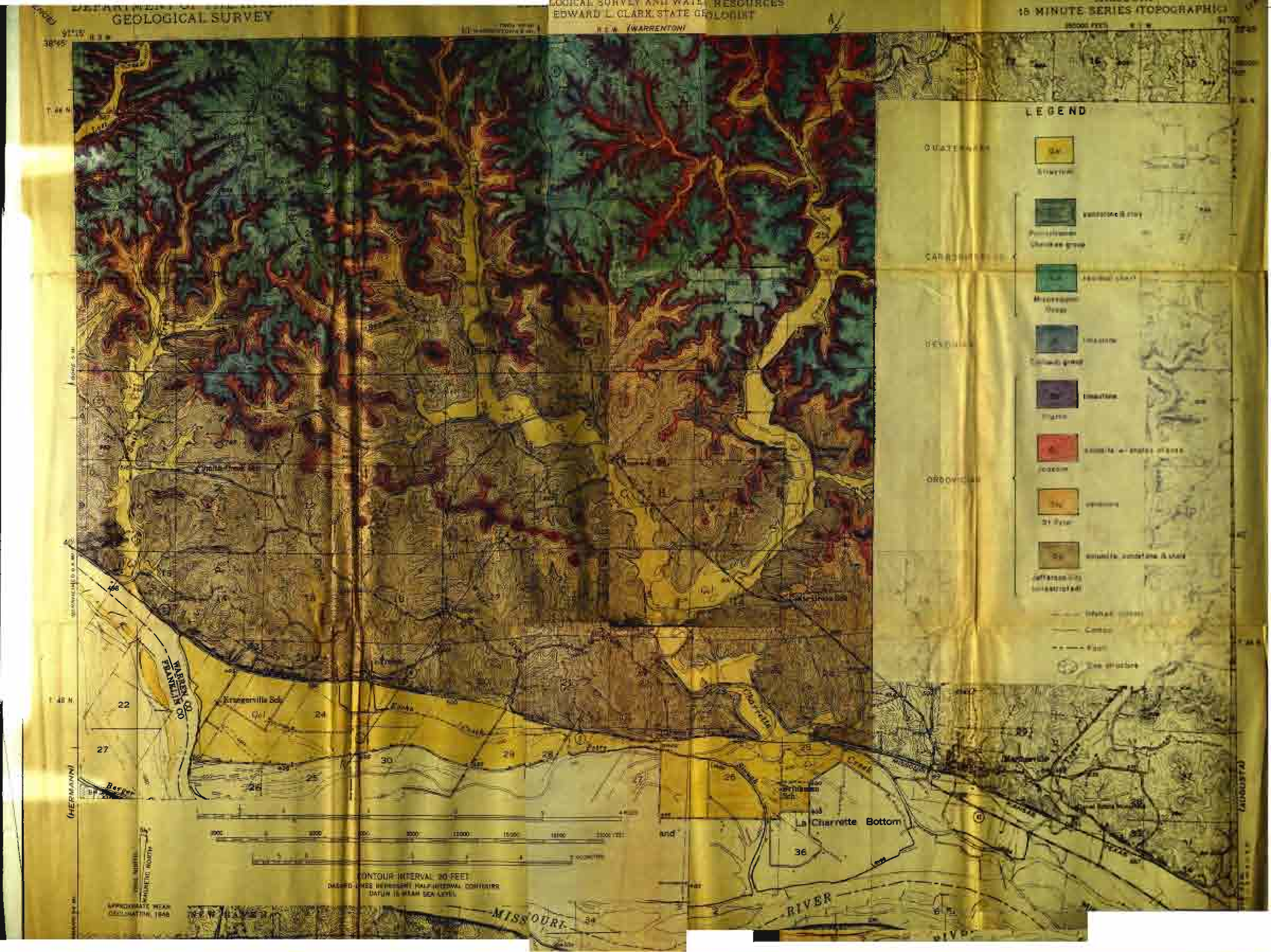
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