Guidebook

Twenty-Sixth Regional

FIELD CONFERENCE

THE KANSAS GEOLOGICAL SOCIETY

Northeastern Missouri and West-central Illinois

REPORT OF INVESTIGATIONS NO. 27

September 1961

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1961

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GUIDE BOOK

Twenty-sixth Regional

FIELD CONFERENCE

The Kansas Geological Society

Northeastern Missouri and West-central Illinois

by

John W. Koenig, James A. Martin and Charles W. Collinson

REPORT OF INVESTIGATIONS NO. 27

September 1961

STATE OF MISSOURI
Department of Business and Administration

Division of
GEOLOGICAL SURVEY AND WATER RESOURCES
THOMAS R. BEVERIDGE, *State Geologist*
ROLLA, MISSOURI

CONTENTS

This Guidebook is gratefully

dedicated

to

MAURICE G. MEHL

...all through my life my facts have had a substratum of truth, and therefore they were not without value. Any person who is familiar with me knows how to strike my average, and therefore knows how to get at the jewel of any fact of mine and dig it out of its blue-clay matrix. My mother knew that art. When I was seven or eight ... a neighbor said to her, "Do you ever believe anything that that boy says?" My mother said, "He is the wellspring of truth, but you can't bring up the whole well with one bucket"---and she added, "I know his average, therefore he never deceives me. I discount him 90 per cent for embroidery, and what is left is perfect and priceless truth, without a flaw in it anywhere."

P. 293--Mark Twain's Autobiography 1924 ed., Vol.I

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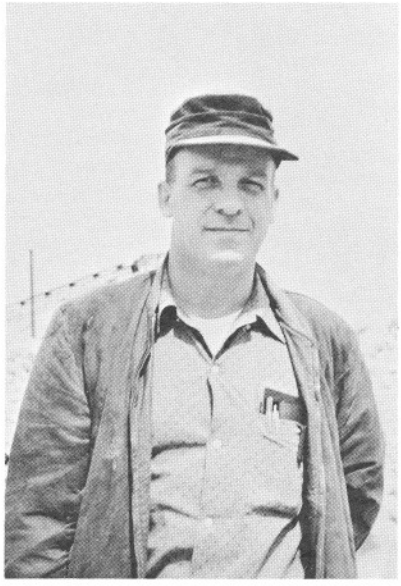

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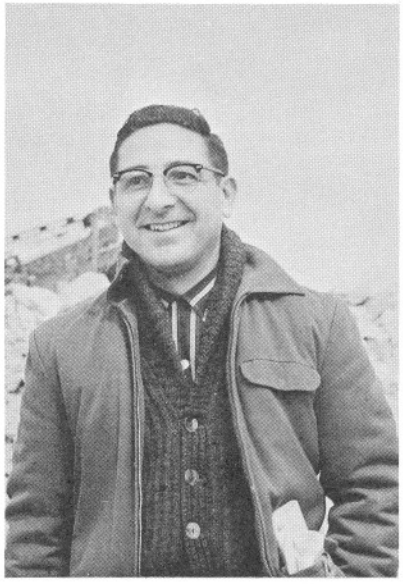

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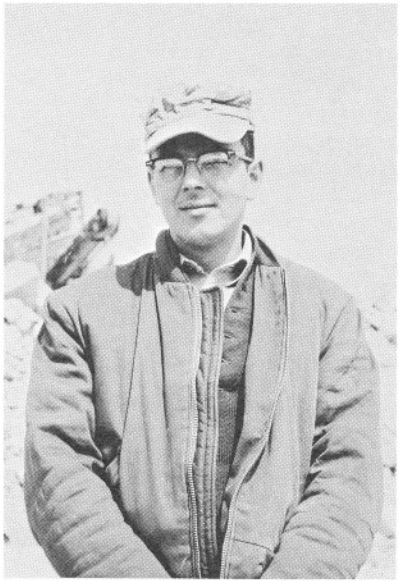

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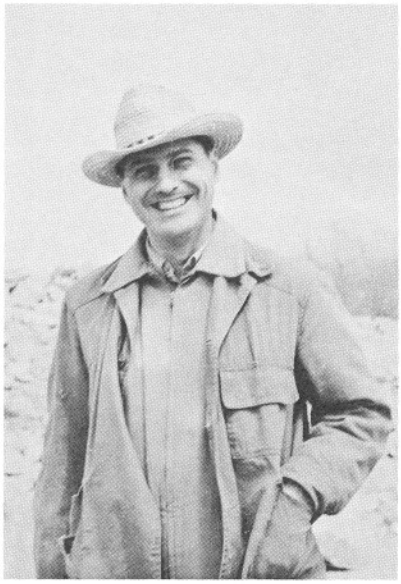

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CONFERENCE PROGRAM

THURSDAY, SEPTEMBER 14, 1961

Registration - - - - - - 3:00 P.M. to 10:00 P.M.

FRIDAY, SEPTEMBER 15, 1961

Breakfast - - - - - - - 6:00 A.M.

Buses Depart Hannibal- - 7:00 A.M.

Evening:

Cocktail Hour - - - - - 5:30 P.M. to 7:30 P.M.

Banquet - - - - - - - - 7:30 P.M. to 9:30 P.M.

SATURDAY, SEPTEMBER 16, 1961

Buses Depart Hannibal- - 7:00 A.M.

Conference Ends- - - - - 1:00 P.M.

* * * * *

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* * * * *

INTRODUCTION

A MOMENT FOR THOUGHT.....

> In the subjects we propose to investigate, our inquiries should be directed, not to what others have thought, nor to what we ourselves conjecture, but to what we can clearly and perspicuously behold and with certainty deduce; for knowledge is not won in any other way.
>
> Rene Descartes 1596-1650

Perhaps this is a moment to pause, reflect, and question the limits of our present knowledge concerning the field relationships of a stratigraphic section that bears singular significance for us all whether we seek the answers to complex problems of finding oil, tracing beds of ore, or reconstructing the history of a major portion of geologic time. Truly, the problems are not separate; they go hand-in-hand. For if we can see and understand from surface evidence what took place eons ago, we can look more diligently for similar evidence in the subsurface search for metals and oil. Hutton's theory that "the present is a key to the past" suggests the coinage of a similar phrase, "the surface is a key to the subsurface".

As geologists and scientists, we have a responsibility to learn as far as possible the dividing line between that which is geologic truth and that which is personal theory or mere speculation. The present adverse criticism of the geologic profession, perhaps, harks back to the geologist "out on a limb" who could not back up his opinions with sufficient facts. Such criticism is valid if we geologists refuse to supplement our knowledge and keep abreast of new academic as well as technical achievements in the profession. What better way to gain facts and strengthen judgment than to make first-hand observations of surface geology under the leadership of those whose life business it is to study and record field relationships. It is not meant to imply that any man or group of men has all the answers to all the problems, but a careful comparison of data and ideas and generous contributions of our own thinking will lead us to the answers to our individual problems.

We are indeed fortunate in having the opportunity to meet this fall under the tutelage of men of the Missouri and Illinois Geological Surveys who are experts on the areas over which our field trip will be conducted. We sincerely hope that this field conference of the Kansas Geological Society will be beneficial to you and enable you to "perspicuously behold and with certainty deduce" the answers to your problems.

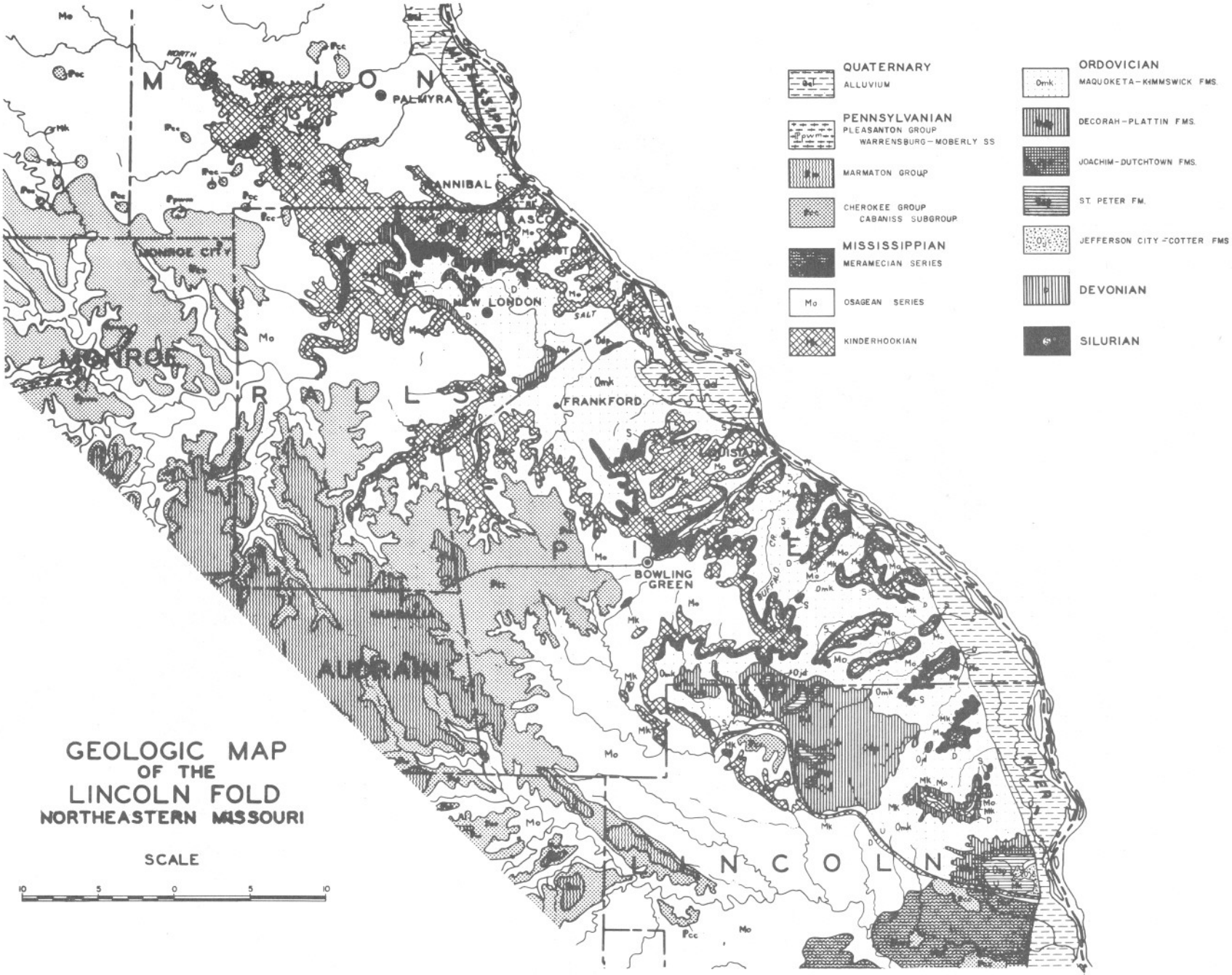
Field Conference Committee

ACKNOWLEDGMENTS

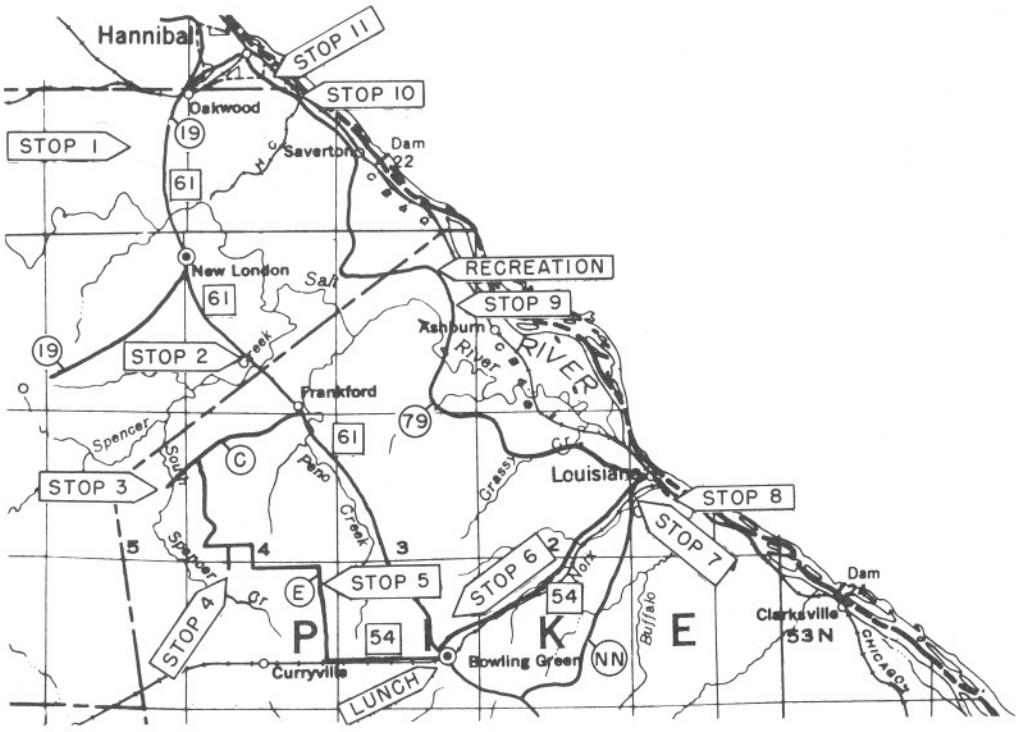
On behalf of the Kansas Geological Society, the Twenty-Sixth Field Conference Committee sincerely thanks the members of the Missouri and Illinois Geological Surveys whose labors have resulted in the excellent material contained in this guidebook. These workers, together with the people assigned to various sub-committees, deserve high praise for their cooperative efforts.

Thanks are due, also, to Mary L. Barnes of the Mary L. Barnes Secretarial Service who typed the guidebook; to Robert L. Maley of the Skelly Oil Company and to draftsmen of the Kansas Geological Survey for assistance in preparing illustrations for publication.

For their generous contributions to the comfort and pleasure of the conference participants, we are especially grateful to the following companies: Schlumberger Well Surveying Corporation; Western Testing Company; Seis-Tech Exploration Company, Inc.; The Halliburton Company; Central Exploration Company; and Lane-Wells Company.



GEOLOGIC MAP OF THE LINCOLN FOLD NORTHEASTERN MISSOURI



Route map - First day of field conference.

FIRST DAY OF FIELD CONFERENCE

Friday, September 15, 1961

Hannibal, Bowling Green, Louisiana, Ilasco Area

Driving distance: 102.5 miles

Departure time, 7:00 A.M., C.S.T. Place, Mark Twain Hotel

Log prepared by John W. Koenig and James A. Martin
Missouri Geological Survey and Water Resources

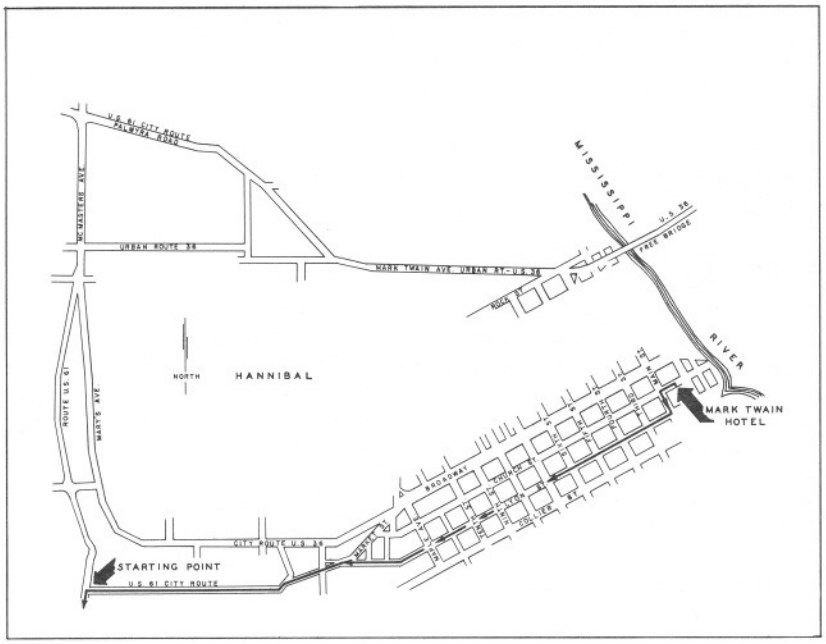


Fig. 1 -- Directions from Mark Twain Hotel to Starting Point.

Upon leaving the parking lot of the Mark Twain Hotel, turn left onto Church Street. At the stop sign on Main Street turn left and go one block south to Lyon Street which is U. S. Hwy. 61, City Route. Turn right at the intersection and proceed west on Lyon. At the intersection of Lyon and Market Streets bear left and continue west on Market Street (Fig. 1). Just beyond this intersection to the right, there is an excellent exposure of Pleistocene deposits. The following account of this exposure is taken from an unpublished manuscript on the geology of the Hannibal Quadrangle prepared in 1955 for the Missouri Geological Survey by James H. Williams.

> North of Bear Creek which is immediately to the south of us in the south half of sections 35 and 36, T. 57 N., R. 5 W., and in section 31, T. 57 N., R. 4 W., there is a probable preglacial valley that was subsequently filled. Exposures indicate that the valley has an east-west trend and that it was cut through the Burlington limestone and the upper part of the Hannibal formation. The floor of the valley is concealed, but its depth is indicated by exposures of 60 to 80 feet of valley fill. It is doubtful if the valley depth was much more than 80 feet.
>
> The valley is filled with stratified silt, sand, and gravel, and small boulder deposits that are cross bedded and well sorted in some places. They consist predominantly of rounded sand-sized, milky, quartz grains but include a few clear quartz, rose quartz, chert, feldspar, and hornblende grains. Scattered gravel and boulder erratics of igneous and metamorphic origin occur at a few localities, especially in the western part of the valley fill. These larger fragments are stratified and sorted with the finer material. The westernmost exposure in the SE 1/4 NE 1/4 SE 1/4 sec. 35, T. 57 N., R. 5 W., shows a less degree of sorting than the exposures to the east in the SE 1/4 NE 1/4 NE 1/4 sec. 31, T. 57 N., R. 4 W., along the Bear Creek

bluffs on the north side of Market Street between Oakwood and Hannibal. Numerous exposures crop out in the bluffs and small valleys north of the street.

Along the exit route from downtown Hannibal to the Starting Point at U. S. Hwy. 61 where Oakwood Station is located, we will be traveling just north of and parallel to Bear Creek. The lower part of the Burlington formation forms a bluff along the creek from Hannibal to Oakwood, and since 1868 the non-cherty coarsely crystalline white limestone in the lower 25 to 35 feet of this bluff has been quarried for the manufacture of lime. At one time, as many as three lime companies operated along the bluff, but today only the Marblehead Lime Company which began operations in 1902 is actively engaged. The company produces quicklime, hydrated lime, and crushed stone for mineral food, concrete aggregate, and agricultural limestone. Some of the quarries along the bluff are underground because of the high cost of stripping some 25 to 50 feet of cherty limestone from above the producing level.

STARTING POINT: Junction of U. S. Hwy. 61 and U. S. Hwy. 61, City Route.

Mileage Cum.	Mileage Diff.	
0.0	0.0	STOP! Dangerous intersection. Turn left (south) on U. S. 61 -- entering Ralls County. Ralls County was named after Daniel Ralls (1785-1820) whose fame rests chiefly upon the last political act of his life. In 1820, during the election of Missouri's first two United States Senators. David Barton won without contest, but Thomas H. Benton's election was strongly opposed. Daniel Ralls, representative from Pike County, lay seriously ill at his lodging place, but learning of Benton's plight, he had four husky negroes bear him on a stretcher to the assembly hall. "If I should faint," he ordered, "recover me there, and by no means take me out before I have given my vote." He cast his vote, important in the election of Benton, and died in Benton's St. Louis home, October 30, 1820. A few weeks later, the legislature named Ralls County, newly formed from Pike County, in his honor.
0.2	0.2	Overpass, Wabash and C. B. & Q. Railroad.
0.5	0.3	Bear Creek bridge.
0.8	0.3	Burlington limestone on left.
1.2	0.4	Junction of State Rd. HH and U. S. Hwy. 61.
1.3	0.1	Grandview Cemetery on left.
2.4	1.1	Lathrop Stables on right. Lathrop Stables - Well #1 NE NE sec. 14, T. 56 N., R. 5 W., Ralls Co. Elevation 691 ft. Yellow, sandy clay..... 0 - 40 Mississippian-Devonian Grassy Creek - bluish-gray shale... 40 - 65 Devonian Dolomite..... 65 - 100 Limestone..... 100 - 135 Sandstone..... 135 - 155 Limestone and sandstone..... 155 - 159 T.D.
2.5	0.1	Davy Davis well on left. Davy Davis - Well #1 NE NE sec. 14, T. 56 N., R. 5 W., Ralls Co. Elevation 684 ft. No samples..... 0 - 30

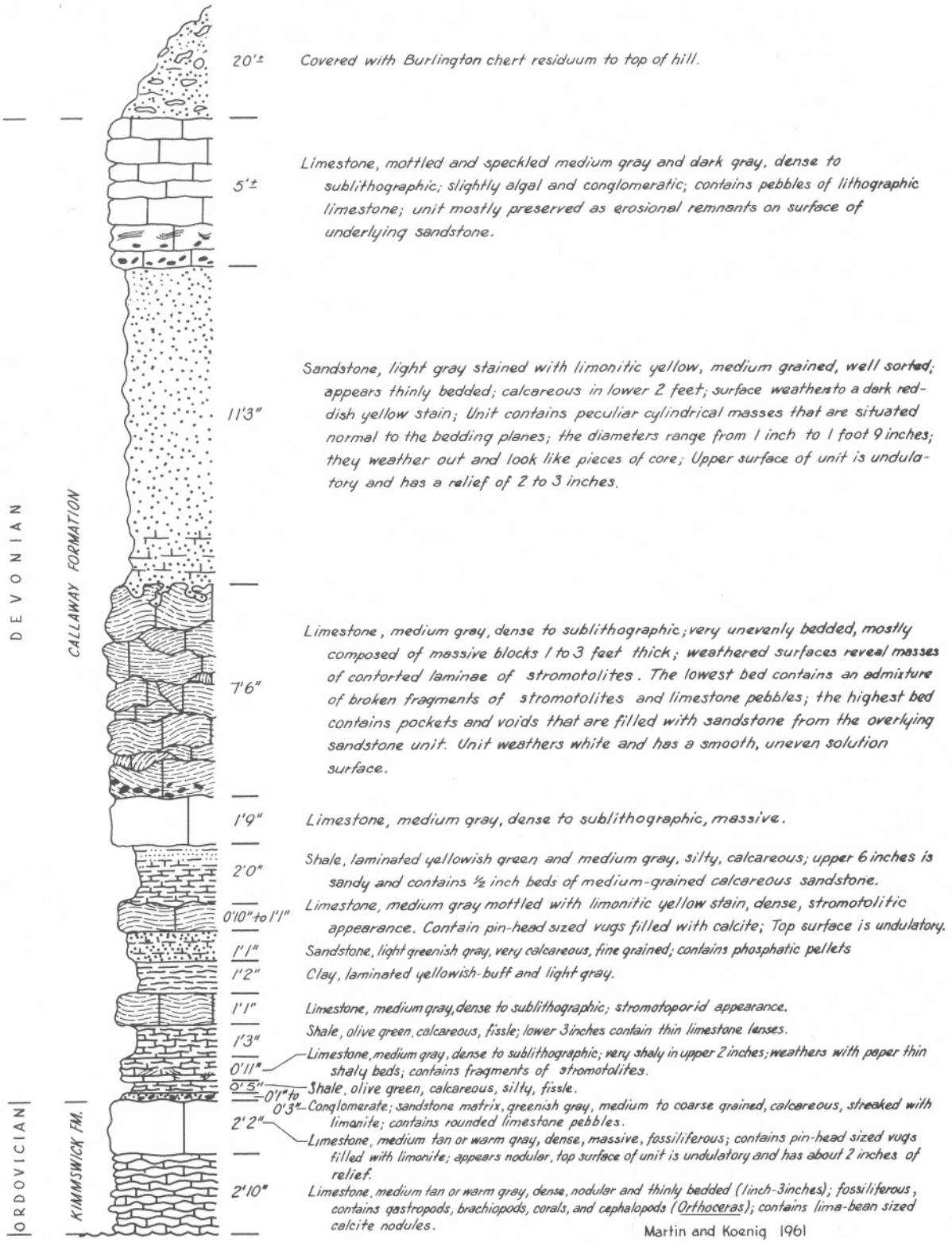


Fig. 2 -- STOP 1. Location: SE SW Sec. 15, T. 56 N., R. 5 W., Hannibal Quadrangle, Ralls County, Missouri.

		Devonian-Mississippian			
		Louisiana.....	30	-	40
		Grassy Creek.....	40	-	55
		Devonian			
		Dolomite.....	55	-	80
		Limestone.....	80	-	100 T.D.
3.3	0.8	Junction of State Rd. M and U. S. Hwy. 61. Turn right (west) on State Rd. M.			
4.3	1.0	Kimmswick limestone in gully on right and left.			
4.7	0.4	Devonian sandstone on right.			
4.8	0.1	STOP 1 - (30 minutes) - James H. Williams.			

SE SW sec. 15, T. 56 N., R. 5 W., Ralls County. This locality demonstrates some of the varied lithologies encountered in the Devonian rocks of the Lincoln fold area. In 1941 when this locality was visited by geologists of the Fifteenth Annual Field Conference of the Kansas Geological Society, it was pointed out that the Devonian carbonate rocks below the sandstone belonged to the Cooper formation and those above to the Callaway. It was also suggested that the thick sandstone in the upper part of the outcrop "is at, or near, the horizon of the Hoing sand from which oil is obtained in the Plymouth-Colmer (sic) pools of McDonough County, western Illinois," (McQueen and Hinchey, 1941, p. 65).

Since 1941, because of the work that was done in 1952 by Unklesbay on the Devonian of Boone County and by James H. Williams in 1955 on the Devonian of this area (Hannibal Quadrangle), it has become apparent that the Devonian rock types of central and northeastern Missouri are too varied in character and too nonpersistent laterally or vertically to be assigned to specific formational units. They are, instead, regarded as facies of the Callaway formation, which is the classificatory status given to the entire Devonian succession in this area.

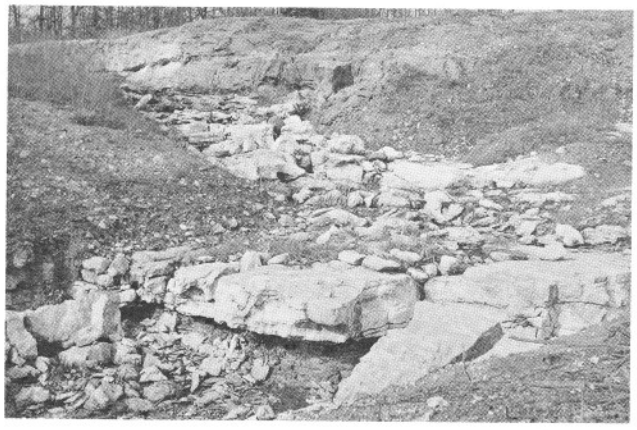


Fig. 3 -- STOP 1. Callaway formation exposed in spillway of a small lake on State Rd. M about 2 miles east of U. S. Hwy. 61; SE SW Sec. 15, T 56 N., R. 5 W., Ralls County, Missouri.

As pointed out by Williams (1955), a wide range of lithologies in the Devonian can be easily demonstrated within a few miles of this locality. About 2 1/2 miles due west, the Callaway consists of about 55 feet of light olive-gray, fine-grained to lithographic limestone, with some friable sandstone and stromatolitic limestone near the base. About 2 1/2 miles due east, the fine-grained limestone thins to about 30 feet, becomes conglomeratic, and is interbedded with siltstone, claystone, shale, and sandstone, and a few miles farther to the southeast, it becomes very conglomeratic, sandy, and in some areas, oolitic. Much of the conglomerate is composed of boulders, cobbles, and pebbles of Noix oolite from the Cyrene member of the Edgewood formation (Silurian), lithographic limestone, and chert of unknown stratigraphic origin. Accompanying features include scattered occurrences of mud cracks, ripple marks, and localized concentrations of corals, not to mention the peculiar cylindrically shaped, sandstone structural features which are so abundant in the outcrop at this locality (Fig. 4).

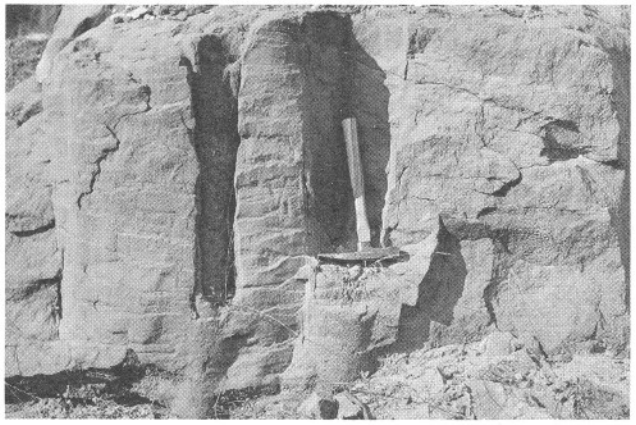


Fig. 4 -- STOP 1. Cylindrical sand-core structure in the upper sandstone unit of the Callaway formation in SE SW Sec. 15, T. 56 N., R. 5 W., Ralls County, Missouri.

5.3	0.5	Kimmswick limestone in gully on right and left.
6.3	1.0	Junction of State Rd. M and U. S. Hwy. 61. Turn right (south) on U. S. Hwy. 61.
7.9	1.6	Kimmswick limestone in roadcut to base of hill. abandoned quarry on right in river bluff.
8.6	0.7	Salt River bridge.

Salt River is known through the frontier expression "to row a man up Salt River", which came to mean to defeat him or make him otherwise uncomfortable particularly in reference to political candidates. The expression supposedly originated with reference to a Missourian who, repeatedly beaten at the polls, moved father and farther up Salt River, either as evidence of his discomfiture or in the expectation of finding more friendly voters.

8.9	0.3	Decorah limestone and shale in roadcut. This locality is approximately on the crest of the Lincoln fold, and is the northernmost exposure of the Decorah in Missouri. It is a well known fossil collecting locality and was STOP 33 of the Fifteenth Annual Field Conference of the Kansas Geological Society in 1941.
10.3	1.4	New London city limits.

New London, founded in 1819 by William Jamieson, an English engineer, is a trading and shipping point for farm produce. A majority of the homes were built in the 1860's and 1870's, though a few are older. The Ralls County Courthouse, built in 1857-58, was chosen to represent Missouri courthouses at both the New York and San Francisco World Fairs in 1939. Its Classic-Revival facade of four Tuscan columns supporting a pediment surmounted by an octagonal cupola was reproduced on the facade of the Missouri Building at each fair. Each room contains a large fireplace, and the wings, designed in the style of the original building, are recent additions. The former Century Hotel or PURDOM TAVERN, on the highway south of the courthouse, was erected in 1829. Senator Thomas Hart Benton is said to have stayed here often and spoke on many occasions from this hotel balcony.

10.6 0.3 Ralls County Courthouse on left.
Ralls Co. Courthouse - Well #1
NW sec. 6-, T. 55 N., R. 4 W., Ralls Co.
Elevation 653 ft.

No samples	0 - 50
Ordovician	
Kimmswick	50 - 75
Decorah	75 - 90
Plattin	90 - 110
Joachim	110 - 135
St. Peter	135 - 140 T.D.

11.3 0.7 Junction of Missouri Hwy. 19 and U. S. Hwy. 61.
Proceed straight ahead (south) on U. S. Hwy. 61.

14.2 2.9 Rocky Point School on left.

15.1 0.9 Fisher Cave, 0.6 miles east on road to left.

Fisher Cave, which is located less than a mile east of the highway at this point, is one of the 898 known caves in the state of Missouri. It is described in detail by J. Harlen Bretz (1956, pp. 429-430) as a cave of phreatic origin that has been worked over by vadose streams from ceiling to floor. The cave entrance is a spectacular arch 90 feet wide and 20 feet high that commands a prominent position in the 100-foot bluff above Spencer Creek valley. Most of the water which issues from the cave mouth and plunges down a 30-foot waterfall to the valley below is evidently drawn into the cave through three large elongate sinkholes that converge toward the cave, back on the summit of the bluff. The cave is mostly in the Kimmswick limestone, but its floor cuts down into the upper part of the Plattin-Decorah.

15.6 0.5 Sinkhole on right, in Kimmswick formation.

15.9 0.3 Sinkholes on right and left, in Kimmswick formation.

16.4 0.5 STOP 2 - (30 minutes) - H. B. Willman and J. A. Martin.

SE SE Sec. 21, T. 55 N., R. 4 W., Ralls County. This stop is approximately on the crest of the Lincoln fold and is the northernmost Champlainian sequence in Missouri. The lithologies seen here are fairly characteristic of these formations throughout the east-central part of the state.

Subdivisions of the Joachim and Plattin have been made by Grohskopf (1948) and Larson (1951) and will be made by Templeton and Willman (Illinois Geological Survey, publication inpress) who also subdivide the Decorah and Kimmswick. Figure 7 shows the various classifications of these units at this stop.

At the upper (north) end of the roadcut, there is a dominantly medium to coarse crystalline, massive bedded Kimmswick limestone. A conglomerate of rounded elongate pebbles and cobbles from the Decorah or Plattin formations are present in the basal bed. Crinoid fragments, brachiopod shells and shell fragments, and Bryozoa are common in the lower beds exposed here. The characteristic fossil Receptaculities, which is common in the upper part of the formation, is rare in these lower beds. The most distinctive feature of the limestone in this area is the "honeycomb" or interconnected tubular openings in the weathered surface of the limestone.

Complete well sections of the Kimmswick give a thickness of from 100 to 150

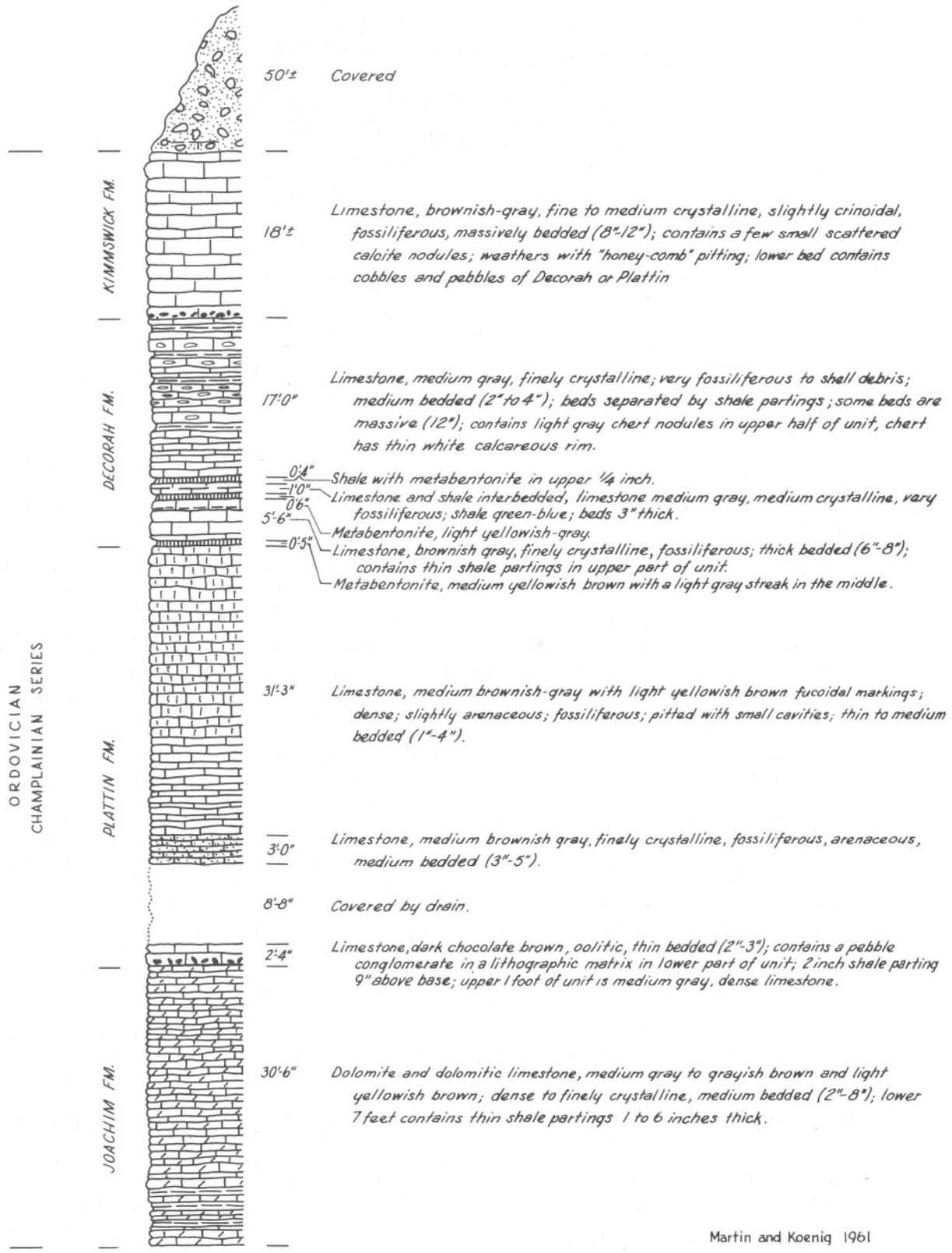


Fig. 5 -- STOP 2. Location: SE SE Sec. 21, T. 55 N., R. 4 W., Hannibal Quadrangle, Ralls County, Missouri.

Fig. 6 -- STOP 2. Plattin formation exposed in roadcut on U. S. Hwy. 61 just north of Spencer Creek bridge; SE SE Sec. 21, T. 55 N., R. 4 W., Ralls County, Missouri.

feet for the area with the thicker sections on the eastern flank of the fold.

The name "Auburn Chert" was proposed by Rowley (1907, p. 14) for the cherty limestone beds beneath the Kimmswick in Pike County. In 1928 Weller (Weller and St. Clair, 1928, p. 110) introduced the name Decorah in Missouri, and it has been used in most subsequent publications by the Missouri Geological Survey. The Plattin-Decorah contact has never been clearly defined in the state, and the Decorah is frequently included with the Plattin in surface mapping, General practise has been to place the base of the Decorah, where it is separated from the Plattin, at the top of the Castlewood member of the Spechts Ferry formation (Fig. 7). The Decorah is a very fossiliferous, cherty limestone with interbedded shales and thin bentonites. Common fossils in the unit are the brachiopod genera Pionodema, Strophomena, Sowerbyella, and Rafinesquina, as well as fenestrate and ramose Bryozoa, and gastropods. The Decorah averages from 20 to 40 feet in thickness.

Subdivisions of the Plattin by Grohskopf (1948), based on well cuttings and insoluble residues, consist of an "Upper Chert zone" and "Upper Shale zone", a "Lower Chert zone" and a basal "Oolite and Conglomerate zone". Figure 7 illustrates the subdivisions of the Plattin at this stop by Templeton and Willman and by Larson (1951). The base of the Plattin shown on Figure 5 does not conform with the base of the Plattin Subgroup of Templeton and Willman. They select a base which is several feet lower in order to include limestone below the oolite and pebble conglomerate bed. Although the Templeton and Willman break more nearly fits with the original definition of the Plattin-Joachim boundary, the oolite and conglomerate zone has been used fairly consistently by the Missouri Geological Survey in recent years in both well logs and field mapping. The difference in boundaries is only a matter of a few feet in this area.

The Plattin is almost entirely an evenly bedded, fine-grained to sublithographic limestone. Shales are interbedded with the limestone, particularly in the lower and upper units. Scattered quartz sand grains are present in the limestone 8 to 15 feet above the oolite and pebble conglomerate bed. Insoluble residues of these beds show a percentage of from 5 to 20 percent fine- to medium-grained, rounded and frosted quartz sand. The upper part of the formation is characterized by irregular masses or mottles of coarse-grained dolomite or limestone which weather more readily than the surrounding rock giving the weathered surface an appearance similar to the Kimmswick. A fucoidal structure is suggested by small rod shaped concentrations of dolomitic material which either weather to tubular openings or stand out in relief.

The Plattin formation thins northward from the Cape Girardeau area where it is 400 feet thick to a thickness of 50 to 70 feet in this general area. Thinning continues to the north and northwest.

In Clark County in extreme northeastern Missouri, 25 feet of dolomite were logged as Plattin. North and west of Knox County the Plattin apparently is absent.

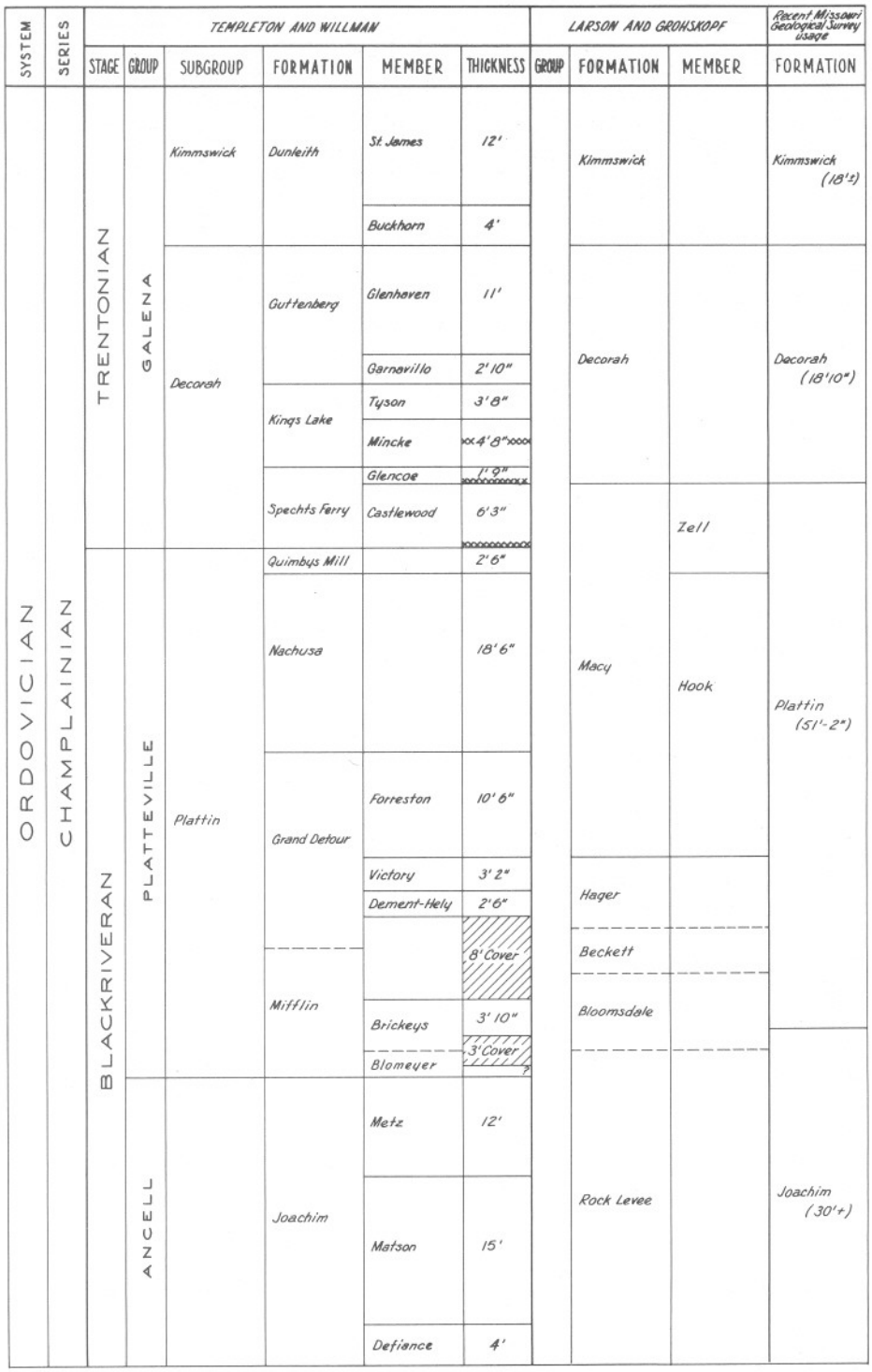


Fig. 7 -- Classification of post-St. Peter, Champlainian formations of the Ordovician System in Missouri and Illinois, by H. B. Willman, Illinois Geological Survey. Thicknesses refer to section at STOP 2, SE SE sec. 21, T. 55 N., R. 4 W.

Grohskopf (1948), in redefining the Joachim and Plattin formations, placed the base of the Plattin at a persistent oolite and pebble conglomerate zone and restricted the name Joachim to the lower dolomitic part of that formation below a chert zone found in well cuttings and at a number of outcrops. The dolomite and limestone above the chert zone and beneath the oolite and conglomerate zone he named Rock Levee. The chert zone is rather spotty and is not believed to be present at a consistent horizon. For this reason the two units are still generally mapped and logged as Joachim.

The Joachim is principally a light tan to brown argillaceous to pure dolomite containing shaly partings. Shale beds are present in the lower part. Several thin limestones are interbedded with the dolomite in the upper part of the formation. These beds are placed in the Plattin Subgroup by Templeton and Willman (Fig. 7). Fossils are rare in the Joachim.

The formation which averages 50± feet thick in this area thins northward and is probably absent north of Knox County, Missouri. The Joachim thickens southward reaching a thickness of 450± feet in Cape Girardeau County, Missouri.

The Atlas Portland Cement Company, No. 1 Jones oil test, was drilled in the Spencer Creek bottoms 3 to 4 tenths of a mile west of this outcrop. The log of this well which completes this section to the Precambrian follows:

Atlas Portland Cement Co. - Well #1 Jones
NE NE Sec. 28, T. 55 N., R. 4 W., Ralls Co.
Elevation 502 ft.

	No samples	0	-	10
Ordovician				
	Joachim	10	-	50
	St. Peter.....	50	-	145
	Everton?	145	-	190
	Cotter	190	-	390
	Jefferson City	390	-	550
	Roubidoux	550	-	675
	Upper Gasconade	675	-	710
	Lower Gasconade	710	-	910
	Gunter	910	-	945
Cambrian				
	Eminence	945	-	1030
	Potosi	1030	-	1125
	Derby-Doerun	1125	-	1310
	Davis	1310	-	1610
	Bonneterre	1610	-	1845
	Lamotte	1845	-	2180
	Arkose	2180	-	2190
	Precambrian, granite	2190	-	2205 T.D.

16.6 0.2 Spencer Creek bridge.

16.8 0.2 Entering Pike County.

Pike County, settled about 1808 and organized in 1818, was named for Brigadier General Zebulon Montgomery Pike, discoverer of Pike's Peak. The slang terms "Pike" or "Piker" derives from this place. The term was originally applied to Missourians from Pike County, but afterwards was used to designate individuals presenting a happy compound of verdancy and ruffianism.

17.9 0.9 Kimmswick limestone in roadcut.

18.6 0.9 Junction of State Rd. C with U. S. Hwy. 61. Galloway Quarry ahead on left, excavation in Kimmswick and Plattin.
Bear right on State Rd. C.

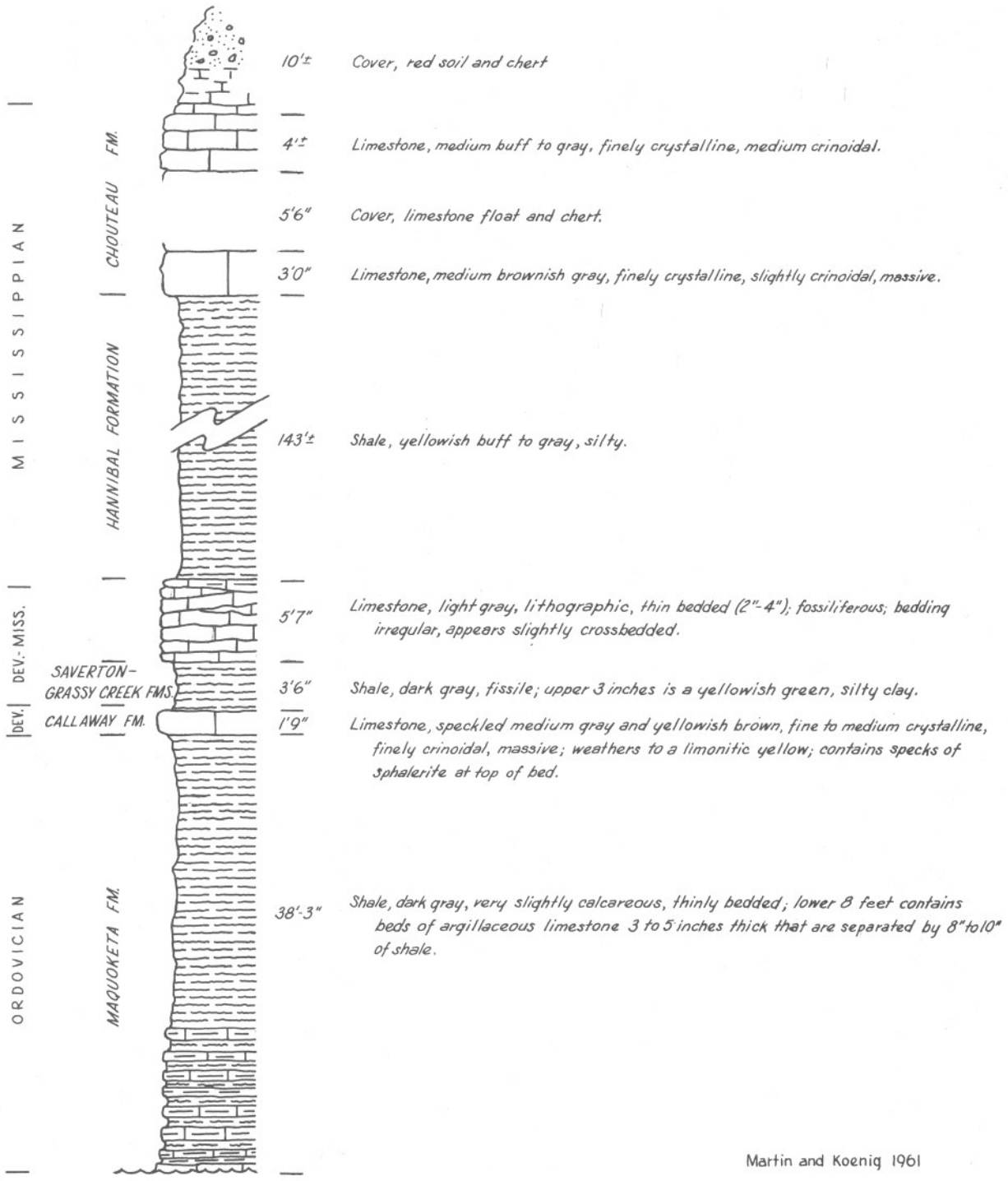


Fig. 8 -- STOP 3. Location: SE NW Sec. 13, T. 54 N., R. 5 W., Vandalia Quadrangle, Pike County, Missouri.

Fig. 9 -- STOP 3. Maquoketa shale and Callaway limestone exposed in roadcut on State Rd. C just east of Spencer Creek bridge, SE NW Sec. 13, T. 54 N., R. 5 W., Pike County.

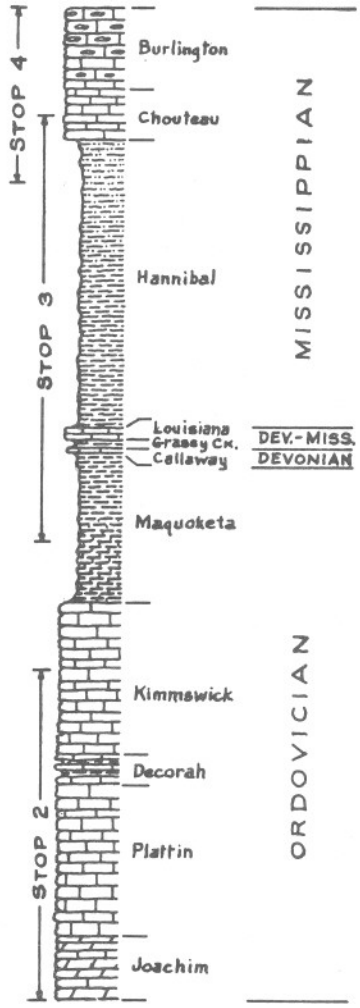


Fig. 10 -- Generalized composite section of formations at STOPS 2 to 4 on southwest flank of Lincoln fold.

18.7	0.1	Kimmswick limestone on left.
18.8	0.1	Junction of State Rds. B and C.
18.9	0.1	Frankford city limits.
19.2	0.3	STOP! Turn right (west) on main street of Frankford.
19.7	0.5	Frankford city limits.
20.9	1.2	Junction of State Rds. E and C. Bear right on State Rd. C.
20.6	0.7	Hannibal shale on right.
21.9	0.3	Louisiana limestone in gully beneath the culvert.
23.5	1.6	Crooked Creek bridge.
23.7	0.2	Hannibal shale on left.
24.0	0.3	End of paved road.
24.2	0.2	Hannibal shale and Chouteau limestone on right.
24.6	0.4	Microwave relay tower on right.
25.1	0.5	Hannibal shale and Chouteau limestone on right.
25.5	0.4	Hannibal shale on right.
25.7	0.2	STOP 3 - (20 minutes) - John W. Koenig.

SE NW Sec. 13, T 54 N., R. 5 W., Pike County. This particular exposure portrays in an unbroken sequence the stratigraphic succession that lies on the southwest flank of the Lincoln fold between the Ordovician formations which were seen at the last stop (STOP 2) and the Mississippian formations which will be seen at the next stop (STOP 4) as indicated in the accompanying sketch (Fig. 10).

It also permits us to see another type of Devonian lithology which is distinctly different from the white stromatolitic limestones seen at the first stop. It is well to point out here that on the opposite flank of the Lincoln fold the interval between the Maquoketa and Grassy Creek which is here occupied by the Callaway formation (Devonian) is occupied by the Edgewood formation (Silurian).

The Louisiana limestone at this locality is not regarded as typical, that is a "masonry-wall" type of blocky, lithographic limestone. In many respects it resembles the unevenly bedded limestone that will be seen in the upper part of the Louisiana.

The aspect and thicknesses of both the Maquoketa and Hannibal shales at this locality is considered typical and widely characteristic throughout the area on both flanks of the Lincoln fold.

The Grassy Creek and Saverton shales, as they are exposed here, illustrate some of the reasons for much of the controversy that has been incited by these units in years past. It will be noted that about the upper 3 inches of the 3- to 4- foot shale succession beneath the Louisiana formation at this outcrop consists of a yellowish-green, somewhat silty clay. This particular clay is regarded by some geologists as representative of the Saverton formation and the dark gray shale below as the Grassy Creek. Other geologists would state that there is little to distinguish the one unit from the other either mineralogically or faunally, therefore they claim that the shales should be regarded as belonging to one formation. To add to the problem, is the fact that in many places in the Lincoln fold area the shales of the Grassy Creek and Saverton formations lie directly on the shale of the Maquoketa formation, as will be seen at STOP 10 in the Universal Atlas Cement Company quarry late this afternoon, and in some instances they are directly overlain by the Hannibal formation. In most places because of the grass cover and forest litter on these rapidly weathering shales, it is very difficult to identify the formations in the field, not to mention the problem of ascertaining their contacts. A similar difficulty in differentiation is encountered in studying well cuttings from a continuous succession of the shale units in the subsurface.

The resulting proposals for solution of the terminology problems arising from the various viewpoints of different geologists who have studied the relations of the three lower formations have been almost as numerous as the geologists. Keyes (1898, p. 63) proposed the name Grassy Creek for the 6 feet of shale that lies beneath the Louisiana formation in the vicinity of Louisiana - at STOP 8 at Clinton Springs just south of Louisiana, this unit is about 4 feet thick - and stated that it thickened to 30 feet "ten miles west of Grassy Creek. This quoted statement of course led to some confusion concerning the location of the type section, which is actually about 6 1/2 miles west of Louisiana on Grassy Creek. Later, Rowley (1907, p. 24) stated that the shale sequence on Grassy Creek "five or six miles due west of Louisiana" was 40 to 60 feet thick, and he referred to it as the Hamilton shale. Actually, he had included some 30 feet of Maquoketa in his estimate because at this locality the three shale formations occur together. Keyes (1912, p. 153) separated the blue or green shale from the black shale below and named it the Saverton shale. Krey (1924, pp. 33-34) thought the shales represented a single formation which he referred to as the Sweetland Creek (Grassy Creek) shales. Moore (1928, p. 37) and James Steele Williams (1943, pp. 4-5) differentiated the Saverton from the Grassy Creek on the basis of lithology. Branson and Mehl, (1933, p. 174) regarded the shales as a single unit and used the name Grassy Creek. J. M. Weller (1935, pp. 191-192) suggested that use of the name Grassy Creek be discontinued or restricted to the "dark shale member in the upper part of the Maquoketa" and that the name Saverton be used to include both the black and green shales that are exposed near Louisiana. J. M. Weller and Sutton (1940, p. 779) thought that the two shales did not deserve recognition as separate formations. They therefore tentatively employed the term Grassy-Saverton shale for what they considered to be a single unit. In 1948, Weller, et al., accepted both Grassy Creek and Saverton as separate formations, and to date there is a tendency to continue to follow this acceptance.

When R. R. Rowley was working in this area around 1900, a natural mineral spring, health resort was situated just west of the present bridge. The spa was called Elk Lick Springs and according to Rowley's account, it was "somewhat of a health resort where accomodations are offered at a quiet rural inn to those 'run-down' in health and wishing to recuperate," (Rowley, 1907, p. 10). There are a number of sulpho-saline springs and wells through the Lincoln fold area, and this condition points up a real ground-water problem because all wells of any depth throughout the area yield mineralized water. Potable ground-water is obtainable only from shallow wells in glacial drift or river alluvium or from the bed rock

immediately beneath which is usually the upper part of the Burlington formation.

27.1	1.4	T-road o.1 mile east of microwave tower. Turn right (south) on T-road.
27.5	0.4	Chouteau limestone in gully on left. The Hannibal-Chouteau contact is about 25 feet below the level of the road in the gully.
29.1	1.6	Hannibal-Chouteau contact on right.
30.9	1.8	Chouteau limestone in stream bed on right. The Hannibal-Chouteau contact is about 25 feet below the level of the road in the stream bed.
31.1	0.2	Chouteau limestone on right.
31.3	0.2	Cemetery and School No. 16 on right.
31.5	0.2	Spencerberg and junction of State Rd. MM. Turn left (south) on State Rd. MM.
31.6	0.1	Chouteau limestone in gully on right.
32.5	0.9	Junction of T-road south and State Rd. MM. Turn right (south) on T-road.
33.5	1.0	Turn right (west) at end of T-road.
33.9	0.4	STOP 4 - (60 minutes) - Coffee break - T. R. Beveridge.

NE SW NW Sec. 5, T. 53 N., R. 4 W., Pike County. This is the only locality on this part of the trip where we will have an opportunity of observing the "Chouteau limestone" or Chouteau group undifferentiated as the unit is now regarded by the Missouri Geological Survey.

The Chouteau group, as it is defined at its type locality in central Missouri, is composed of three formations which are from the base upward, the Compton, Sedalia, and Northview. The Compton is characteristically a bluish-gray, fine-grained to sublithographic limestone, the Sedalia a yellowish brown, earthy, fine-grained dolomitic limestone, and the Northview a gray to brown, silty shale and siltstone. Eastward from the type area, the Northview thins and is absent east of Howard and Cooper Counties in central Missouri, and the lithologies of the Compton and Sedalia interfinger and merge to such a degree that it is not practicable to distinguish the two formations in east-central or northeastern Missouri.

The limestones which compose this undifferentiated unit at this locality are present along the entire southwest flank of the Lincoln fold, as they can be traced northwestward along the fold from a point on the Cuivre River a few miles east of Troy in the vicinity of the Cap au Gres fault to a point on the South Fabius River near Newark in Knox County where the nose of the fold plunges northwestward into the subsurface. Throughout most of this distance the unit, as it is here, is between 20 and 30 feet thick, but it is absent a short distance northeastward toward the crest of the fold where it has been removed by erosion. A few isolated exposures of the unit are present in southern Pike County in the bluffs along the Mississippi River indicating its presence in Missouri on the east flank of the fold. The same unit is observed east of the Mississippi in Calhoun and Jersey Counties, Illinois.

The unit at this locality is fairly fossiliferous, but no attempt has been made here to collect and identify this particular fauna. Extensive faunal lists are given by R. C. Moore in his excellent work on the"Early Mississippian formations in Missouri", Missouri Bur. Geology and Mines, 2nd Ser., vol. 21,

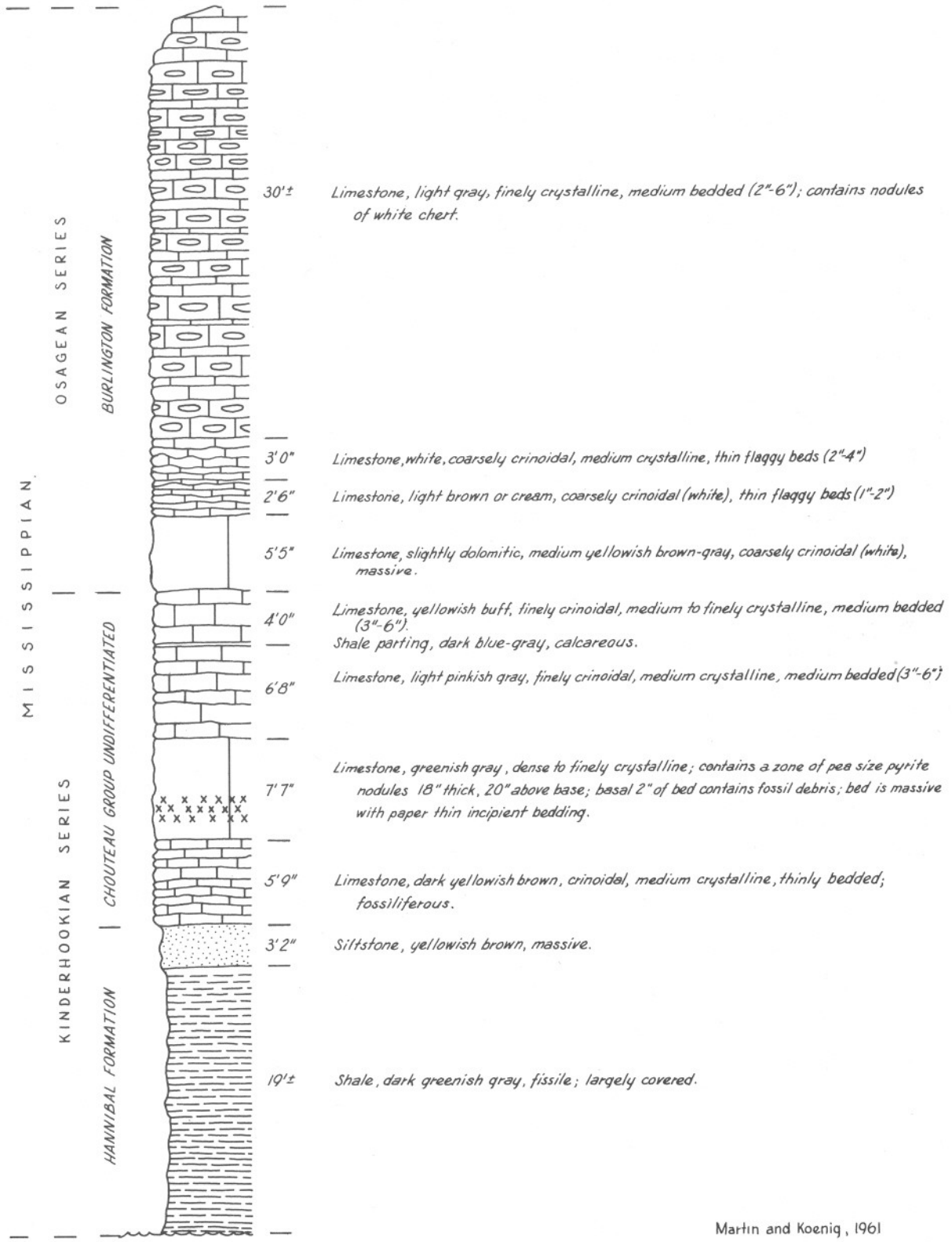


Fig. 11 --STOP 4. Location: NE SW NW Sec. 5, T. 53 N., R. 4 W., Vandalia Quadrangle, Pike County, Missouri.

and interested persons are referred to pages 63 to 68 of that volume for the names of most of the species that may be found here.

There are two caves at this locality. One cave, Stillhouse Cave, has a nearly cylindrical tunnel-like entrance 8 feet in diameter, and the other, Buzzard Cave, has a fracture-outline entrance which is filled by the fall of ceiling and wall rock (Fig. 12). Neither cave can be penetrated for any great distance. Stillhouse Cave is blocked a short distance from the entrance by a deep pool on the floor and the passage beyond narrows to an impassable slot. The entrance to Buzzard Cave is exceedingly unsafe, and the passage beyond is only a narrow crawlway. Bretz (1956, p. 385) states that Stillhouse Cave is "almost wholly vadose in origin" and that "the only relics of earlier phreatic solution are in the termini of two or three tubes truncated by the fracture wall." One of these tubes, just inside the entrance, normally discharges a clear stream of water. Because of the collapsed condition of Buzzard Cave, Bretz (1956, p. 385) states that "It is impossible to determine if the cave had a phreatic beginning or was entirely vadose in origin. A suggestion that it was wholly vadose is in the outcrop of a greenish-gray shale at the bottom of the ravine just outside the foot of the cave mouth talus. Vadose caves are most likely to develop just above such an impervious layer."

34.3 0.4 Turn left (north) on T-road.

35.3 1.0 Junction of T-road south and State Rd. MM. Turn right (east) on State Rd. MM.

36.0 0.7 Ralph Epperson farm on right.
Morris and Biernbaum - Well #1
NW NW Sec. 33, T. 54 N., R. 4 W.,
Pike Co.
Elevation 797 ft.

Soil and residuum.....	0 -	30	
Mississippian			
Burlington	30 -	65	
Chouteau	65 -	80	
Hannibal	80 -	170	
Devonian-Mississippian			
Grassy Creek	170 -	175	
Sandstone	175 -	177	
Silurian			
Edgewood?	177 -	200	
Ordovocian			
Maquoketa	200 -	295	
Kimmswick	295 -	415	
Decorah	415 -	450	
Plattin	450 -	495	
Joachim	495 -	545	T.D.

Fig. 12 -- STOP 4. Chouteau and Burlington formations exposed in bluff at entrance to Buzzard Cave, NE SW NW Sec. 5, T. 53 N., R. 4 W., Pike County, Missouri.

36.4 0.4 Junction of State Rds. E and MM.
Turn right (south) on State Rd. E.

37.4 1.0 Junction of crossroad and State Road E.

38.1 0.7 Road turns south.

38.3 0.2 T-road east.
Turn left (east) on T-road east.

40.5 2.2 Road turns south.

40.8 0.3 Junction of State Rd. U.
Proceed south on State Rd. U.

41.6 0.8 Road turns east for a distance of 0.2 miles then turns south.

41.9 0.3 STOP 5 - (20 minutes) - W. V. Searight.

SW SE SE Sec. 1, T. 53 N., R. 4 W., Pike County. This significant outcrop of Pennsylvanian beds lies high on the southwest flank of the Lincoln fold, probably 10 miles or less from the crop-line of the Devonian.

The Excello formation at the top of the Cabaniss Subgroup of the Cherokee Group separates the Mulky coal bed from Basal Marmaton in the northern Mid-Continent and its equivalent in western Illinois lies between the Springfield

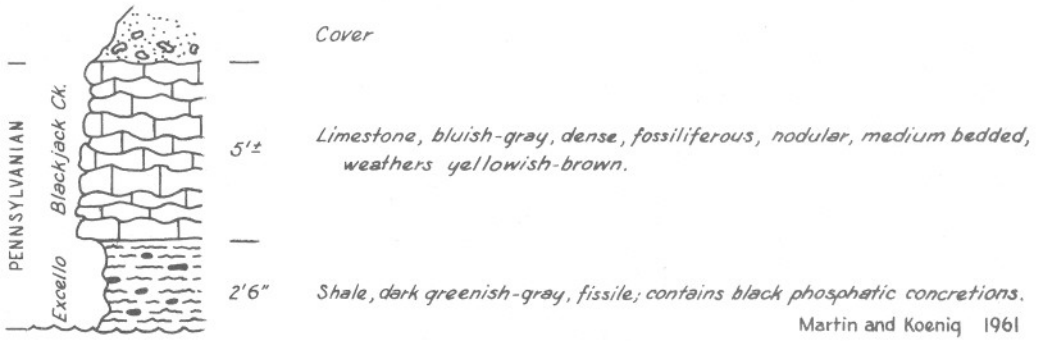


Fig. 13 -- STOP 5. Location: SW SE SE Sec. 1, T. 53 N., R. 4 W., Vandalia Quadrangle, Pike County, Missouri.

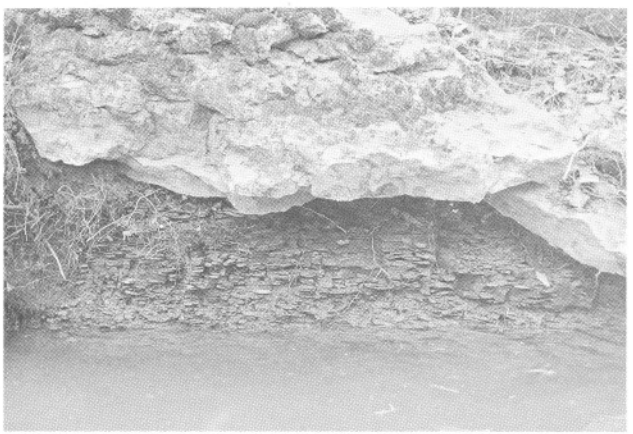


Fig. 14 -- STOP 5. Excello shale and Blackjack Creek limestone exposed in stream bank of a northwest tributary of Weatherly Branch, one-half mile north of Hickory Grove School; SW SE SE Sec. 1, T. 53 N., R. 4 W., Pike County, Missouri.

coal and the Hanover limestone. It is one of the most widely distributed Des-moinesian units, having been identified at the surface and in the subsurface from this point southwestward into northeastern Oklahoma. In most areas, particularly where the Cabaniss below is well developed, the Excello consists of black, fine-grained, marly fissile shale in which flattened phosphatic concretions are abun-dant. Near mildly positive areas where the Cabaniss is thin, the shale is green-ish gray and is less fissile or it becomes claylike. Phosphatic concretions are common, however.

The Blackjack Creek formation of the Fort Scott Subgroup of the Marmaton is likewise well known over the northern Mid-Continent. Between the Lincoln fold and the Saline County arch to the southwest, a distance of 70 to 75 miles, the Blackjack Creek exhibits three rather distinct facies (Searight, T. K., 1959).

The facies developed here resembles that of the Blackjack Creek in the Wellsville area approximately 25 miles southwest of this point and that on the northern flank of the Ozarks approximately 45 miles south. It is suggested that the nodular facies observed here is that developed near mildly positive areas whereas more evenly bedded facies are present in somewhat less positive areas.

The thickness here, high on the Lincoln fold, as well as that elsewhere near the fold, is evidence that the Blackjack Creek was deposited continuously across the fold.

42.5 0.6 Hickory Grove School on left.

45.2 2.7 STOP! Junction of U. S. Hwy. 54 and State Rd. U.
Turn left (east) on U. S. Hwy. 54.

49.3 4.1 Sewage lagoon on right.

49.9 0.6 Bowling Green city limits.

Bowling Green, the county seat of Pike County, was platted in 1826 and named for the Kentucky home of many of the town's early residents. James Beauchamp Clark (1850-1921), nationally known as "Champ" made his home here, coming from Kentucky in 1876. From 1893 until his death in 1921, with the exception of the term 1895-97, he was a member of the House of Representatives. He served as Speaker of the House for eight years and in 1912 was a serious contender for the Democratic Presidential nomination.

50.4 0.5 STOP! Junction of U. S. Hwys. 61 and 54.

LUNCH STOP - (60 minutes). The city of Bowling Green is located immediately southeast of the highway junction.

City of Bowling Green - Well #1
SE SW NW Sec. 25, T. 53 N., R. 3 W., Pike Co.
Elevation 878 ft.

Clay and gravel	0	-	65
Mississippian			
Burlington	65	-	115
Chouteau?	115	-	130
Hannibal	130	-	225
Devonian-Mississippian			
Louisiana and Grassy Creek	225	-	230
Sandstone	230	-	235

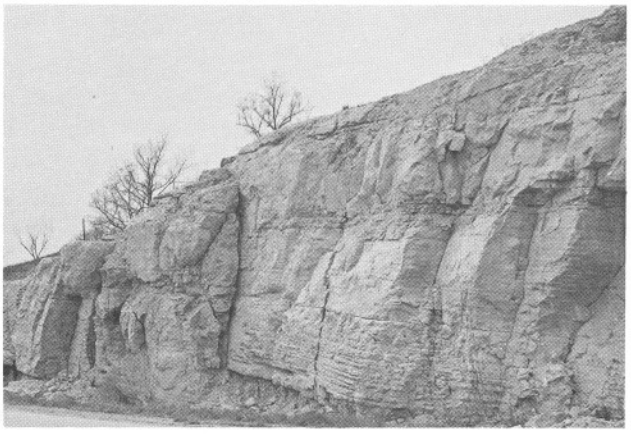


Fig. 15 -- Bowling Green dolomite member of the Edgewood formation exposed in roadcut on U.S. Hwy. 54 about one mile east of junction of U. S. Hwys. 61 and 54; NW NW Sec. 24, T. 53 N., R. 3 W., Pike County, Missouri.

Silurian
  Edgewood
    Bowling Green mem ..... 235 - 275
    Cyrene mem. (Noix oolite
      at top)..... 275 - 300
Ordovician
  Maquoketa ..... 300 - 400

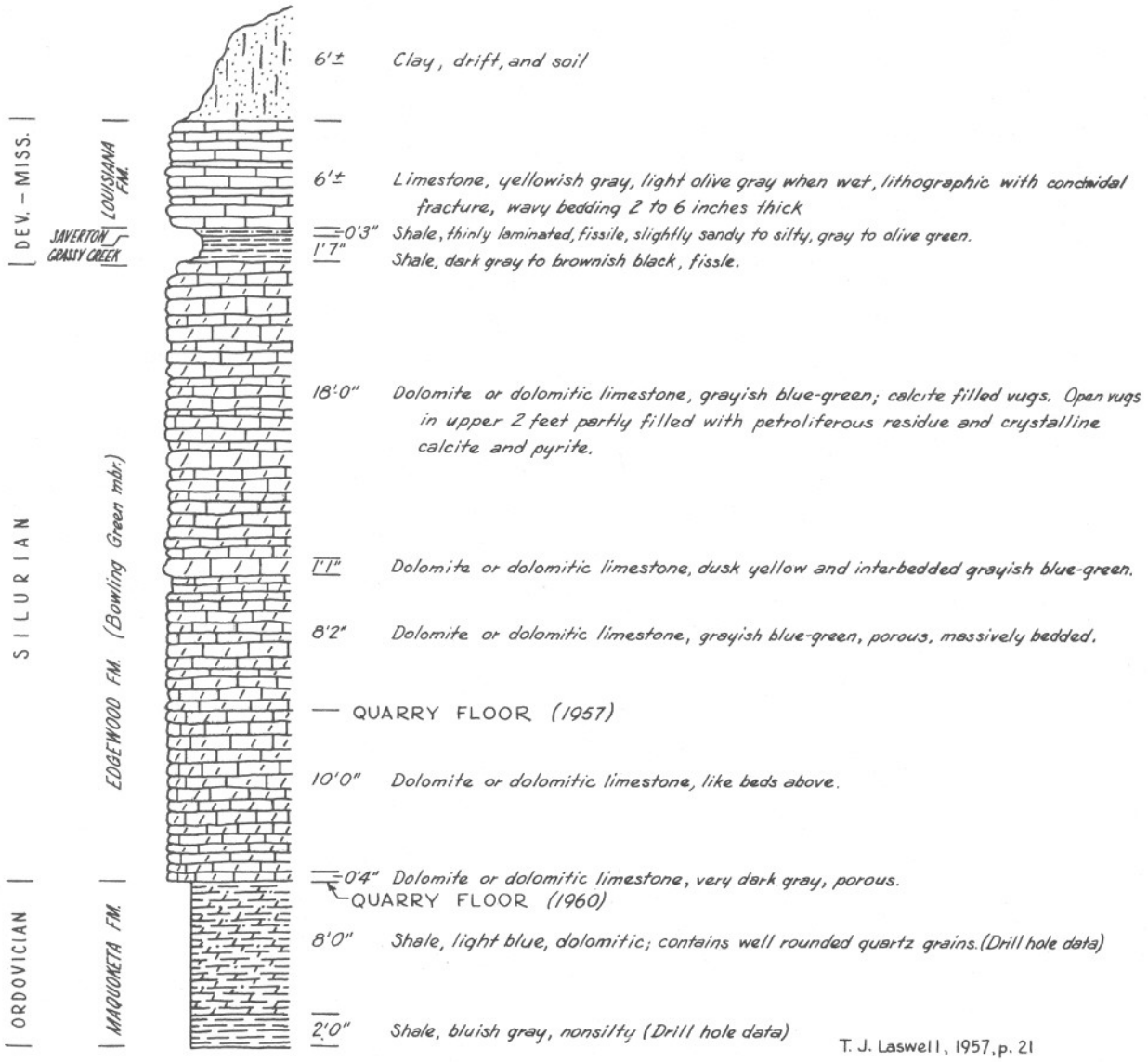


Fig. 16 -- STOP 6. Location: NE NE Sec. 14, T. 53 N., R. 3 W., Bowling Green Quadrangle, Pike County, Missouri.

Kimmswick ..... 400 - 520
Decorah ..... 520 - 560
Plattin ..... 560 - 625
Joachim ..... 625 - 680
St. Peter..... 680 - 760
Cotter..... 760 - 771 T.D.

51.0 0.6 Maquoketa formation on right; interbedded limestone and shale.

51.5 0.5 Bowling Green member of Edgewood formation on right, dips approximately 4 degrees east (Fig. 15).

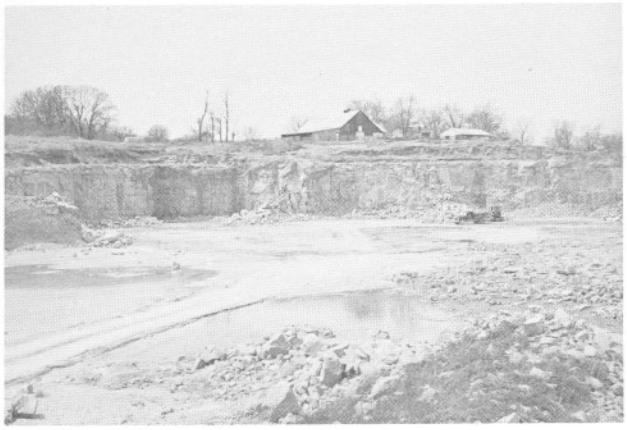


Fig. 17 -- STOP 6. Bowling Green dolomite member of the Edgewood formation, Saverton and Grassy Creek shales, and Louisiana limestone exposed in Magnesium Mining Company Quarry; NE NE Sec. 14, T. 53 N., R. 3 W., Pike County, Missouri.

51.8 0.3 Junction of T-road north and U. S. Hwy. 54
Turn left (north) on T-road north.

52.8 1.0 STOP 6 - (20 minutes) - James H. Williams.

NE NE Sec. 14, T. 53 N., R. 3 W., Pike County. The Edgewood formation in Lincoln fold area is composed of two members. Here we can observe the upper or Bowling Green member of the formation. The lower or Cyrene member which contains a distinctive oolitic phase named the Noix oolite will be seen at STOP 8.

The Bowling Green member is typically a brown to yellowish-brown dolomitic limestone and dolomite. When the rock is freshly broken, it has a bluish gray color, but it quickly weathers to brown and yellow. In some places, as in the upper part of the member here in the quarry, the dolomite contains small vugs and veinlets which are filled with crystalline calcite, pyrite, and sphalerite, and many of the vugs contain petroliferous residues. Some of these vugs are as much as 3 inches in diameter and contain small amounts of viscous, low gravity petroleum.

The present floor of the quarry is just about at the top of the Maquoketa shale, and the top of the Bowling Green member can be seen at the upper part of the quarry face where it is overlain by about 2 feet of shale which represents the Grassy Creek and Saverton formations. You will note that this interval between the Maquoketa and the Grassy Creek is the same interval that is occupied by the Callaway formation (Devonian) at STOP 3.

The Silurian rocks in the Missouri portion of the fold area are exposed along the crest and high flanks of the fold southeast of a north-south line that is situated just east of Frankford southeastward to the central part of Lincoln County. With few exceptions, the Devonian limestones of the Callaway formation are absent throughout most of this area. However, on the flanks of the fold, as has already been pointed out, much of the conglomerate in the Devonian beds is composed of Silurian rock, the most noticeable being that of the Noix oolite of the Cyrene member.

The Bowling Green member is being quarried here by the Magnesium Mining Company for agricultural limestone and for local construction work. Analyses of the rock show that it contains about 48 percent $CaCO_3$, 30 percent $MgCO_3$, and 12.5 percent SiO_2.

The following log shows the balance of the post-St. Peter section that lies beneath the quarry floor.

Magnesium Mining Company - Well #1
NW NW NW Sec. 13, T. 53 N., R. 3 W., Pike Co.
Elevation 723 ft.

No samples (probably Maquoketa)..... 0 - 110
Ordovician
Kimmswick .....110 - 235
Decorah .....235 - 265
Plattin .....265 - 335
Joachim .....335 - 380
St. Peter.....380 - 385 T.D.

53.9 1.1 Junction of T-road north and U. S. Hwy. 54.
Turn left (east) on U. S. Hwy. 54.

54.3 0.4 Hannibal shale and Louisiana limestone on left.
The Bowling Green member of Edgewood formation
is exposed in the south bank of Noix Creek across
the valley on the right.

54.6 0.3 Junction of Missouri Hwy. 161 and U. S. Hwy. 54.

56.2 1.6 Glacial till in roadcut.

56.7 0.5 Noix Creek bridge.

59.7 2.8 Hills ahead on both sides of road are capped with
Burlington limestone.

60.0 0.3 Noix Creek bridge.

61.3 1.3 Little Noix Creek bridge.

63.0 1.3 Junction of State Rd. NN and U. S. Hwy. 54.
The main office of Stark Nurseries is located
north of the junction.
Turn right (south) on State Rd. NN.

Stark Nursery.. The log cabin which can be seen to the
left as we turn off the highway was moved here from nearby,
restored, and opened as a museum in 1952 to honor James Hart
Stark who built the cabin. The orchard which he planted in
1816 with grafted scions brought from the family's orchard,
considered the first of grafted apple trees west of the
Alleghenies, has become known under his descendents as one of
the oldest and largest commercial nurseries in the world.
Here are carried on many of Luther Burbank's experiments.
The Stark Nursery obtained the first patent granted a fruit in 1934.

63.1 0.1 STOP! Alton Railroad crossing.

63.4 0.3 STOP 7 - (30 minutes) - M. G. Mehl.

SE NE SW Sec. 25, T. 54 N., R. 2 W., Pike County. This locality is unique for Missouri, because it is the first outcrop in the state where an oolite has been observed in the upper part of what is here considered to be the Louisiana formation. In many respects, this outcrop of the Louisiana resembles the one that will be seen at the first stop in Illinois tomorrow at the town of Hamburg in Calhoun County except for the fact that the Louisiana at this outcrop is better exposed and a good deal thicker.

The oolitic limestone at Hamburg, Illinois, was informally designated as the Hamburg oolite by Stuart Weller in 1906 (p. 464) who considered it to be slightly younger than the Glen Park oolitic limestone of Missouri which it resembles. Because the name Hamburg was pre-empted and because R. C. Moore (1928, p. 138) regarded the fauna from the oolitic beds at Hamburg "as contemporaneous with that of the Glen Park limestone", he stated that "The Glen Park limestone unconformably overlies the Louisiana limestone in Calhoun County, Illinois,"

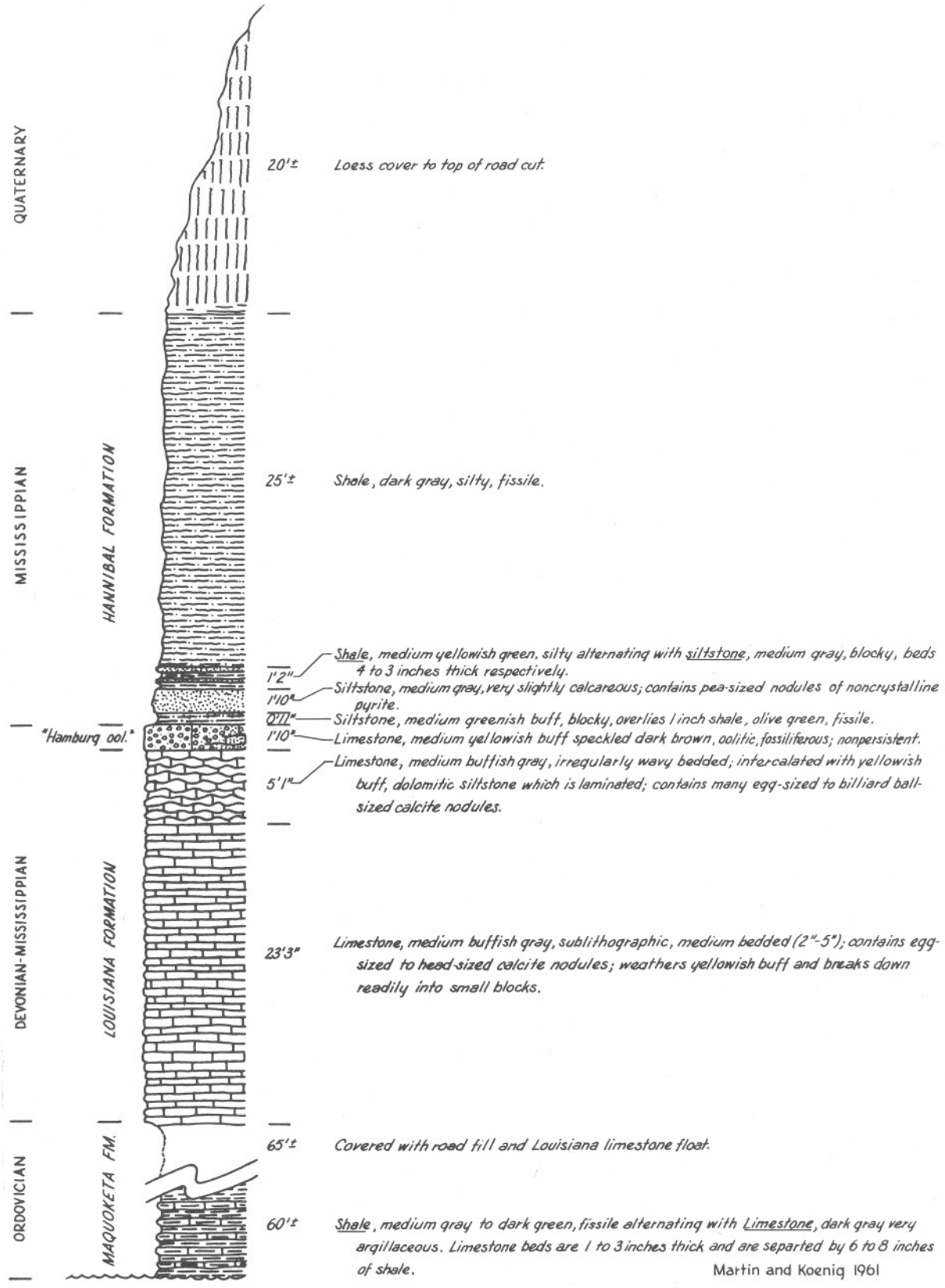


Fig. 18 -- STOP 7. Location: SE NE SW Sec. 25, T. 54 N., R. 2 W., Bowling Green Quadrangle, Pike County, Missouri.

(Moore, 1928, p. 140). In this manner, the Missouri name was transferred to Illinois. In 1956 (p. 21), Workman and Gillette - as did Moore (1928, p. 138; 1935, p. 240), J. S. Williams (1943, p. 25), and Rubey (1952, p. 35) - defined the Glen Park of Calhoun County, Illinois, so that the formation includes the unevenly bedded siltstone and lenticular lithographic limestone that lie beneath the oolitic limestone beds at the Hamburg locality in Illinois. According to Moore's interpretation (1928, p. 138; 1935, p. 240), the upper 7 feet of this particular outcrop, here in the roadcut, would be regarded as the Glen Park formation by some geologists, although recent conodont studies by Collinson have verified what Weller suspected in 1906-that the formation now called Glen Park in Illinois is significantly younger than the type Glen Park of Jefferson County, Missouri. This situation has led Collinson to use the name Glen Park in quotation marks as an expediency in this guidebook, although a manuscript proposing a new name for the "Glen Park" of Illinois is now in press. This cannot be done in Missouri because here the name is in good standing and the formation which it does designate is older than the rock units which are present in the upper 7 feet of this outcrop. The name Glen Park therefore cannot be applied here. This creates a paradoxical situation because for the want of a new authoratively established name, we must, for the time being, transfer the Illinois term "Hamburg oolite" to Missouri.

Lithologically, the Louisiana here is composed entirely of buffish gray, lithographic limestone except for the upper 5 feet below the oolite. This upper part is slightly dolomitic and is interbedded with yellowish-buff, dolomitic siltstone. Northward, the upper dolomitized part of the formation thickens at the expense of the lower limestone, and in northern Ralls and in Marion Counties the middle part of the formation is composed of interbedded dolomitic limestone and dolomite and the upper part is almost entirely composed of dolomite.

Fig. 19 -- STOP 7. Louisiana formation, containing a 1-foot 10-inch bed of oolitic limestone at the top, exposed in roadcut on State Rd. NN about one-half mile south of the Stark Nursery; SE SE SW Sec. 25, T. 54 N., R. 2 W., Pike County, Missouri.

This outcrop is unique in other respects in that here the lower 6 feet of the Hannibal formation is regarded on the basis of M. G. Mehl's conodont studies as being the oldest Hannibal known in the state. He regards this unit as a formation and has applied the name Cuivre to it in a recent publication (Mehl, 1960).

A log of the well of F. D. Wilkins farm, which is located on the other side of the hill west of the roadcut indicates that the Silurian limestones of the Edgewood formation may be absent in the immediate vicinity.

F. D. Wilkins Well
NE SE SW Sec. 25, T. 54 N., R. 2 W., Pike Co.
Elevation 578 ft.

No samples 0 - 30

Ordovician

Maquoketa	30	-	160
Kimmswick	160	-	280
Decorah	280	-	315
Plattin	315	-	385
Joachim	385	-	440
St. Peter	440	-	525 T.D.

63.7 0.3 STOP! Alton Railroad crossing.

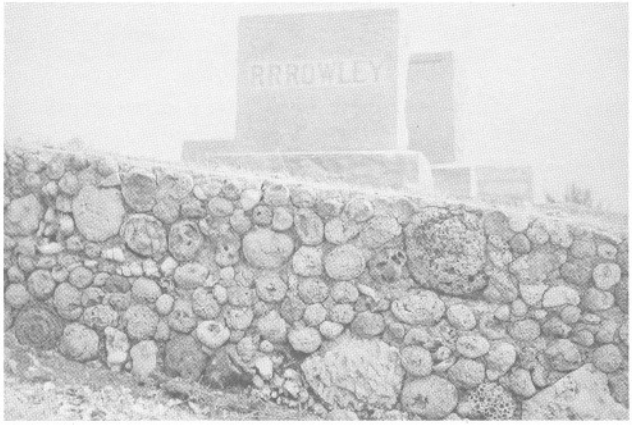
63.8 0.1 Junction of State Rd. NN and U. S. Hwy. 54.
Turn right (east) on U. S. Hwy. 54.

64.7 0.9 Louisiana city limits.

Louisiana is a one-time river port which has turned to agriculture and industry. Like other Mississippi River towns, Louisiana began on the bank of the river in 1817 and developed inland, leaving the older sections along Water and Main Streets to be taken over by industries and wholesale business houses. Laid out by Samuel K. Caldwell and Joel Shaw in 1818, and named for the State of Louisiana, the town served as the seat of Pike County until succeeded by Bowling Green in 1823.

Robert Roswell Rowley, a naturalist whose interests ranged widely in biological fields, made his home here in Louisiana. His publications on the stratigraphy and paleontology of Missouri are widely known, and his collection of lower Mississippian fossils from the Mississippi Valley region was and probably still is one of the most complete. In addition, the collection contains many Ordovician, Silurian, and Devonian species, and in all has some 220 types, many of which were named by Rowley. It is believed that most of the collection is now at the University of Illinois, but at least enough of it was left here in Louisiana to build a retaining wall around Rowley's family plot in Riverivew Cemetery on the northern edge of town where Rowley is now buried (Fig. 20).

Rowley, who died on January 26, 1935, was born in Louisiana on January 4, 1854. He spent most of his life here as a high school teacher and as Superintendent of Schools. He graduated in 1875 from the Louisiana High School and then went to the University of Missouri where he studied geology and paleontology under Professor G. C. Swallow.



After two years at the University he taught school in Missouri and Arkansas and then returned to Louisiana in 1894 as principal to the high school from which he graduated. In 1911, he was made Superintendent of Schools, and in various capacities he maintained his connection with the Louisiana Public Schools until his death at the age of 81.

Fig. 20 -- Retaining wall around the family plot of R. R. Rowley in Riverview Cemetery, Louisiana, Missouri, is composed entirely of fossil specimens from his collection.

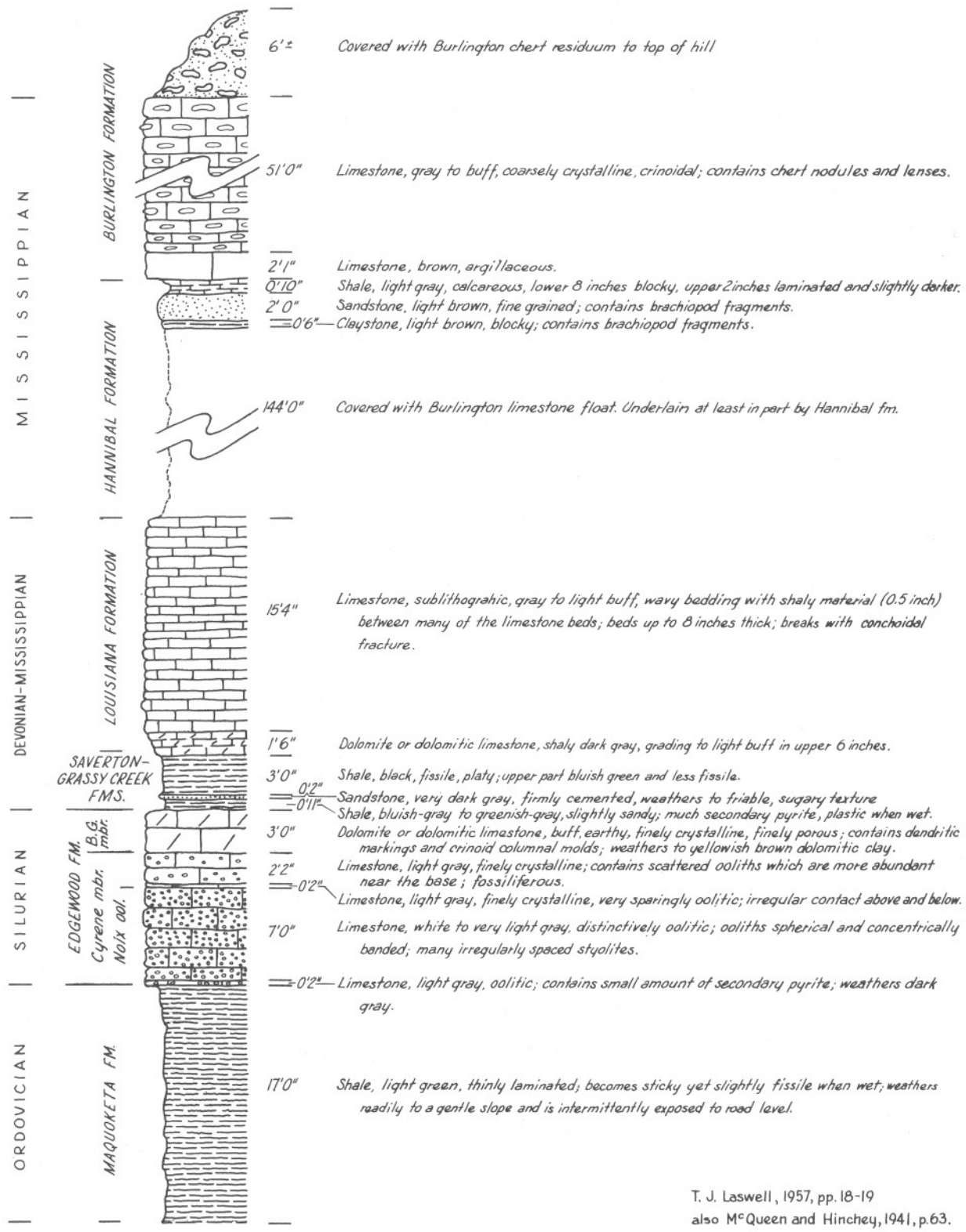


Fig. 21 -- STOP 8. Location: NE NW Sec. 20, T. 54 N., R. 1 W., Bowling Green Quadrangle, Pike County, Missouri.

66.2 1.5 STOP! Junction of Missouri Hwy. 79
and U. S. Hwy. 54.
Turn right (south) on Missouri Hwy. 79.

66.6 0.4 STOP! Railroad crossing.

66.7 0.1 Noix Creek bridge.

67.0 0.3 STOP! Railroad crossing. Cross tracks and stop in roadside park.

STOP 8 - (20 minutes) - James A. Martin.

NE NW Sec. 20, T. 54 N., R. 1 W., Pike County. The Noix oolite facies of the Cyrene member of the Edgewood formation is excellently exposed at this locality. The facies is a white to very light gray, massively bedded oolitic limestone. According to T. J. Laswell's (1957, p. 18) description "The closely packed oolites are spherical, concentrically banded, and from 0.8 mm to 1.1 mm in diameter. They constitute 80 percent or more of the rock and are embedded in a matrix of finely crystalline calcite."

Keyes named this lithologic unit as the Noix oolite in 1898 (p. 62), and later Savage (1913, p. 376) recognized the oolite as part of the Cyrene member as equivalent to the upper one-half or two-thirds of the member Laswell (1957, p. 17) demonstrated that the "Cyrene limestone member contains interfingering facies of oolitic and non-oolitic limestone, and that the Noix oolite is only one of these oolitic facies which is equivalent to the lower part and not to the upper one-half or two-thirds of the member as proposed by Savage."

Buffalo Fort. About 2 miles south of Clinton Springs on State Rd. D, there is a granite boulder which marks the site of Buffalo Fort which was erected about 1811 to protect 25 pioneer families who lived in the vicinity. Trouble with the Sauk and Fox Indians began about 1811 and continued until the Treaty of 1815 removed the Indians to lands farther west. During the War of 1812, especially, the Indians abetted by the British waged war against the settlers of the Buffalo and Noix Creek valleys.

67.3 0.3 Noix Creek bridge.

67.4 0.1 STOP! Railroad crossing.

Fig. 22 - STOP 8. Noix oolite facies, Cyrene member of the Edgewood formation exposed in bluff above Clinton Springs Roadside Park, Louisiana, Missouri; NE NW Sec. 20, T. 54 N., R. 1 W., Pike County, Missouri.

67.8	0.4	STOP! Junction of Missouri Hwy. 79 and U. S. Highway 54. Proceed straight ahead (north) on Hwys. 79 and 54.
68.3	0.5	STOP! Junction of Missouri Hwy. 79 and U. S. Hwy. 54. Turn left (west) on Missouri Hwy. 79. Champ Clark Highway Bridge which spans the Mississippi River at this point was completed in 1928 at a cost of $1,000,000.
68.8	0.5	Burlington limestone at top of hill on right.
69.1	0.3	Burlington limestone on left and in Dug Hill Quarry on far right. This quarry is now used as a residential site.
69.9	0.8	Loess on right.
70.2	0.3	Tanyard Branch bridge; Salt River Flood plain on right.
70.6	0.4	Maquoketa shale, Noix oolite of Cyrene limestone, and Grassy Creek shale exposed at spring in hill on left.
71.1	0.5	Grassy Creek bridge.
71.5	0.4	Maquoketa shale in bluff of Grassy Creek on far left.
72.2	0.7	Junction of State Rd. YY and Missouri Hwy. 79. Turn right (north) on Missouri Hwy. 79.
72.5	0.3	Hannibal shale on right with Louisiana limestone float in gully.
73.7	1.2	Missouri Hwy. 79 curves sharp left (west).
74.3	0.6	Grassy Creek shale on left.
76.7	2.4	Sugar Creek bridge.
76.8	0.1	Junction of State Rd. B and Missouri Hwy. 79. Turn right (north) on Missouri Hwy. 79.
77.7	0.9	Salt River bridge. Burlington limestone caps hills ahead.
78.8	1.1	Grassy Creek and Saverton shales on right with Louisiana limestone float on hillside.
79.6	0.8	Grassy Creek and Saverton shales on right.
79.7	0.1	Junction of State Rd. TT and Missouri Hwy. 79.
80.3	0.6	STOP 9 - (30 minutes) - Alfred C. Spreng.

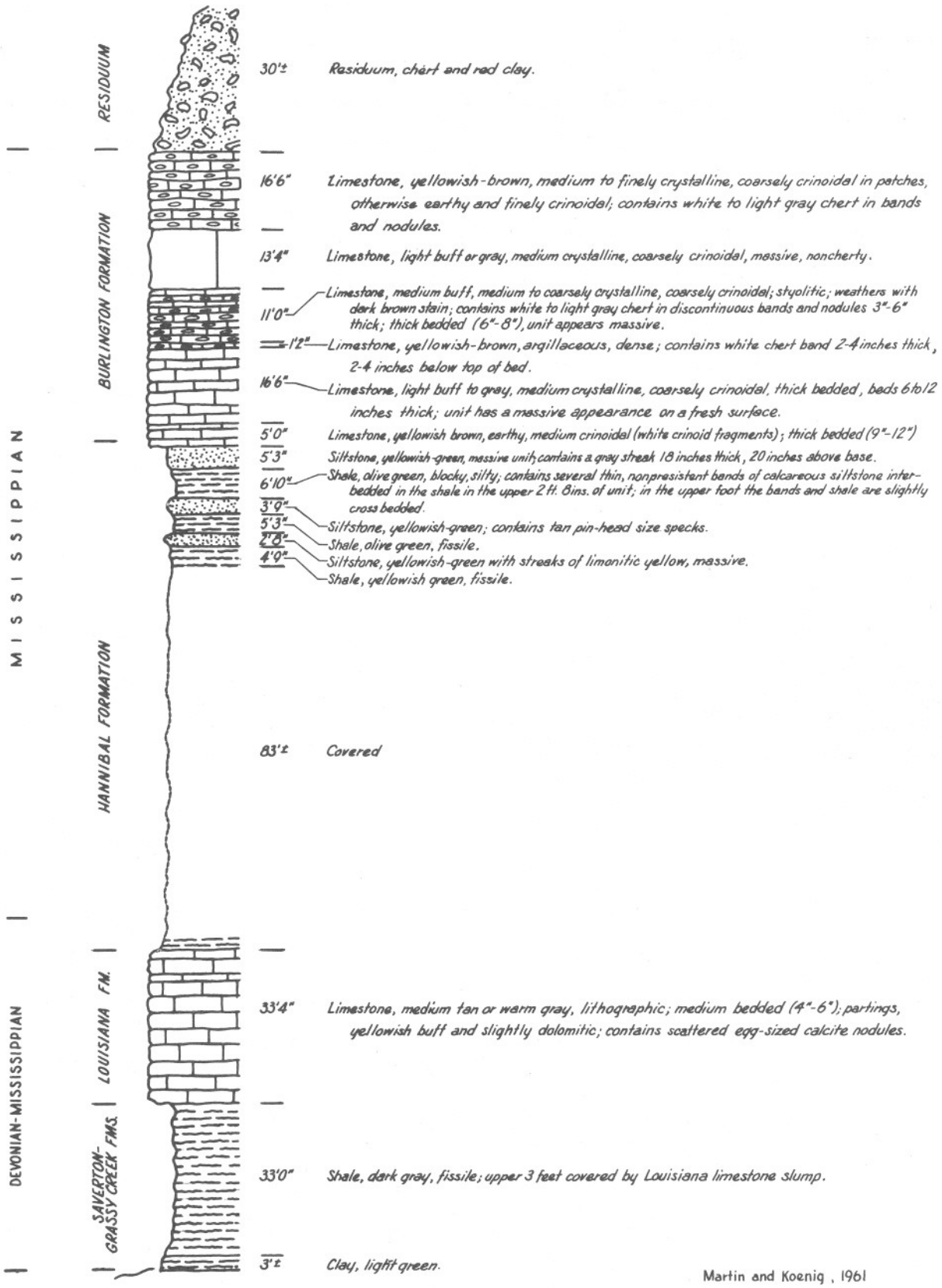


Fig. 23 -- STOP 9. Location: NE SW Sec. 12, T. 55 N., R. 3 W., Barry Quadrangle, Pike County, Missouri.

NE SW Sec. 12, T. 55 N., R. 3 W., Pike County. The formation of interest at this outcrop is the Burlington which is well exposed in this newly completed highway roadcut. In searching for material which could be used for a discussion of this particular exposure, we could find none better than the statements made by R. R. Rowley in 1907 (pp. 36-37) which are as follows:

> "The line of separation between the Lower and Upper Burlington is well marked at Louisiana and it is convenient to separate the Lower Burlington into the following beds: Basal division from five to eight feet, resting on the vermicular sandstone at Louisiana, rust brown, weathering soft. The stone is poor and seldom quarried. This division usually forms the floor of the various quarries in Louisiana. The fossils are peculiar and some of them as Batocrinus calvini, B. bulbosus, and Dorycrinus inflatus are characteristic of the division. It might be called the Batocrinus calvini horizon.
>
> Above this division is a series of white and brown layers, quite cherty in some quarries and ranging from fifteen to twenty feet in thickness. These beds are near the top of this division where Codonites stelliformis occurs as also Cryptoblastus melo and Amphoracrinus divergens. Lobocrinus longirostris ranges through this entire division and it might be designated the Lobocrinus longirostris horizon.

Fig. 24 -- STOP 9. Hannibal siltstone and Burlington limestone exposed in roadcut on Missouri Hwy. 79 about one-half mile north of Junction of Missouri Hwy. 79 and State Rd. TT; NE SW Sec. 12, T. 55 N., R. 3 W., Pike County, Missouri.

> The third division is the "White Ledge", from ten to fourteen feet thick and without seams and with little or no chert.
>
> There are a great many brachiopods in this layer and but few crinoids, among the latter Agaricocrinus planoconvexus, Steganocrinus, sculptus, Ichthyocrinus burlingtonensis and Cactocrinus expansus. For convenience we would designate this the Cactocrinus expansus horizon.
>
> The "Blue Layer" of four feet overlies the "White Ledge" and is the top of the Lower Burlington limestone. This division contains mainly brachiopods and corals with but few blastoids and crinoids, the latter coming up from the division below. In this layer occur a few upper Burlington fossils such as a small variety of Schizoblastus sayi, Physetocrinus ventricosus, Actinocrinus scitulus. This might be called the Coral horizon.
>
> There is no persistency in the character of the Upper Burlington and it is almost impossible to separate it into divisions. It is made up of thin bands of brown and yellow limestone and chert. The stone is of little value."

For those who are interested in the fauna of the Burlington

limestone, they will find extensive faunal lists in Rowley, 1907, pp. 37-42; Moore, 1928, pp. 172-190; and Branson, E. B., 1944, pp. 229-234. In 1937, L. R. Laudon (pp. 1158-1167) expanded and refined the faunal zones of the Burlington that were established by Rowley in 1907.

80.6	0.3	Junction of southern Scenic Drive and Missouri Hwy. 79.
81.6	1.0	Burlington limestone on left.
81.7	0.1	Burlington limestone on right.
81.8	0.1	Junction of northern Scenic Drive and Missouri Hwy. 79. Turn right (east) on to scenic drive.
82.1	0.3	RECREATION STOP - (30 minutes)
82.4	0.3	Junction of northern Scenie Drive and Missouri Hwy. 79. Turn right (north) on Missouri Hwy. 79.
82.6	0.2	Hannibal shale and Burlington limestone contact on right.
83.5	0.9	Junction of Busch city route.
84.0	0.5	Missouri Hwy. 79 curves sharp left (west).
85.0	1.0	Grassy Creek shale on right in gully.
85.4	0.4	Entering Ralls County.
85.6	0.2	Grassy Creek shale beneath culvert in gully.
86.5	0.9	Louisiana limestone on left.
86.7	0.2	Grassy Creek shale on right.
88.2	1.5	Maquoketa shale on left.
88.5	0.3	Kimmswick limestone on left.
88.7	0.2	Junction of Saverton Road and Missouri Hwy. 79. Turn right (north) on Saverton Road.
91.2	2.5	Louisiana limestone on left.
91.9	0.7	Saverton shale and Louisiana limestone contact in Malaruni Creek on right.
92.6	0.7	T-road east, bear left (North).
93.2	0.6	The gully behind the farm house to the right contains exposures of the Maquoketa, Edgewood (Noix oolite of the Cyrene mem.), Grassy Creek, Saverton, and Louisiana formations. In the gully, these formations have an approximate dip of 4 degrees to the south-southwest indicating the presence of a minor structure in this area.
93.3	0.1	Ilasco Creek bridge.

The shale that is exposed in the bluff to the right is Maquoketa, and the large blocks of slump are composed of oolitic limestone from the Noix oolitic facies of the Cyrene member of the Edgewood.

This area is considered to be the type area of the Saverton formation which was named by Keyes in 1912. J. S. Williams (1943, p. 4) points out that Keyes suggested in his original description that the Saverton shale "probably attains a maximum thickness of at least 75 feet and others have said that it was 70 feet at the type locality". Moore (1928, p. 37, and 75) states that "In Ralls County, where the type locality is located the formation (Saverton) attains its maximum observed thickness, about 100 feet," and that "In Ralls County the Saverton has a thickness ranging from 50 to nearly 100 feet (Buehler, 1907, p. 192). [In Buehler's reference the term Hamilton is used, and as used by Rowley the Hamilton included both the Grassy Creek and the Saverton and in some cases the Maquoketa as well.] West of the station at Saverton the shale is 80 feet thick, and at Ilasco, three miles farther north, it is 60 feet," (Moore, 1928, p. 38). The latter two thicknesses given by Moore also appear to have been derived from Buehler's information (Buehler, 1907, p. 193). J. S. Williams (1943, p. 4) states that "only 36 feet of mudstones and shales occur beneath the Louisiana and above the Silurian in the good exposures about 1 mile south of the type locality", and that "the type locality affords no satisfactory contact between it [Saverton] and the Grassy Creek shale as restricted by Keyes and... it is not evident just what beds Keyes meant to include in his Saverton."

From the above statements and from the presence of thick sections of Maquoketa shale that are exposed in the bluffs of Ilasco Creek in what is considered to be the type area of the Saverton formation, it is possible that Keyes and others have included the Maquoketa in their estimate of the thickness of the Saverton formation in this area.

J. H. Williams (1955) in his report on the Hannibal Quadrangle states that "A thickness of 21 feet [of Saverton shale] is recorded in an Atlas Cement Company churn drillhole near Ilasco in W 1/2 NW NW NW Sec. 11, T. 56 N., R. 4 W.," and that "In the Atlas Cement Company shale quarry west of Ilasco [STOP 10] in the SW NW NW Sec. 11, T. 56 N., R. 4 W., the maximum exposed thickness is 14 feet." He also reports that, for an approximate 12 mile distance along a line subparallel with U. S. Hwy. 61 between Bear Creek and Spencer Creek, thicknesses for the Saverton are not in excess of 3 feet.

J. H. Williams describes the Saverton as consisting of lower and upper units as follows:

> In the western part of the Hannibal Quadrangle, the lower unit is a soft, silty, and sandy, bluish-gray slightly calcareous shale that weathers readily to flaky particles...eastward toward the Mississippi River bluffs ... the shale becomes distinctly blue and flaky on fresh surfaces and contains clear, rounded, sand-size quartz grains. The upper portion of the Saverton in the western part of the Hannibal Quadrangle is a silty, yellowish-gray, slightly calcareous claystone. Eastward, it is an argillaceous siltstone that is slightly calcareous, soft, massive, bluish-gray, and exhibits a conchoidal fracture.

93.4	0.1	Junction of State Rd. N and Saverton Road. Turn right (east) on State Rd. N.
93.6	0.2	Maquoketa shale on right.
94.1	0.5	STOP! Saverton City limits. Turn left (north) on State Rd. N.
95.4	1.3	Louisiana limestone on left.

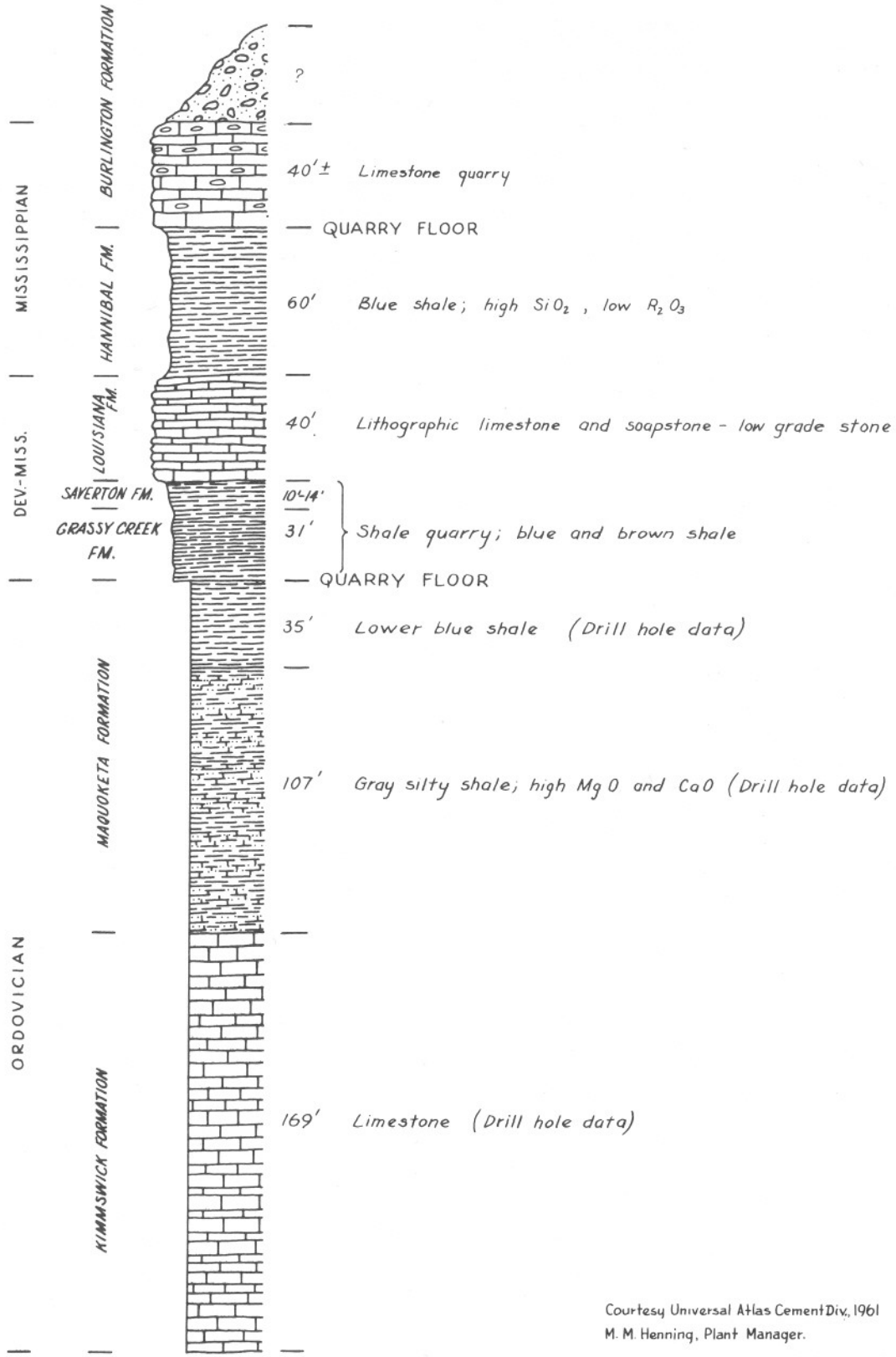


Fig. 25 -- STOP 10. Location: NW NW NW Sec. 11, T. 56 N., R. 4 W., Hannibal Quadrangle, Ralls County, Missouri.

Fig. 26 -- STOP 10. Grassy Creek and Saverton shales, Louisiana limestone, and Hannibal shale exposed in Shale Quarry of Universal Atlas Cement Division, west of Ilasco, Missouri; NW NW NW Sec. 11, T. 56 N., R 4 W., Ralls County, Missouri.

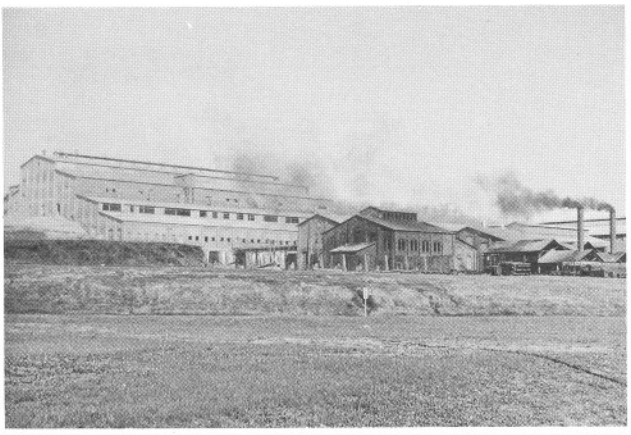


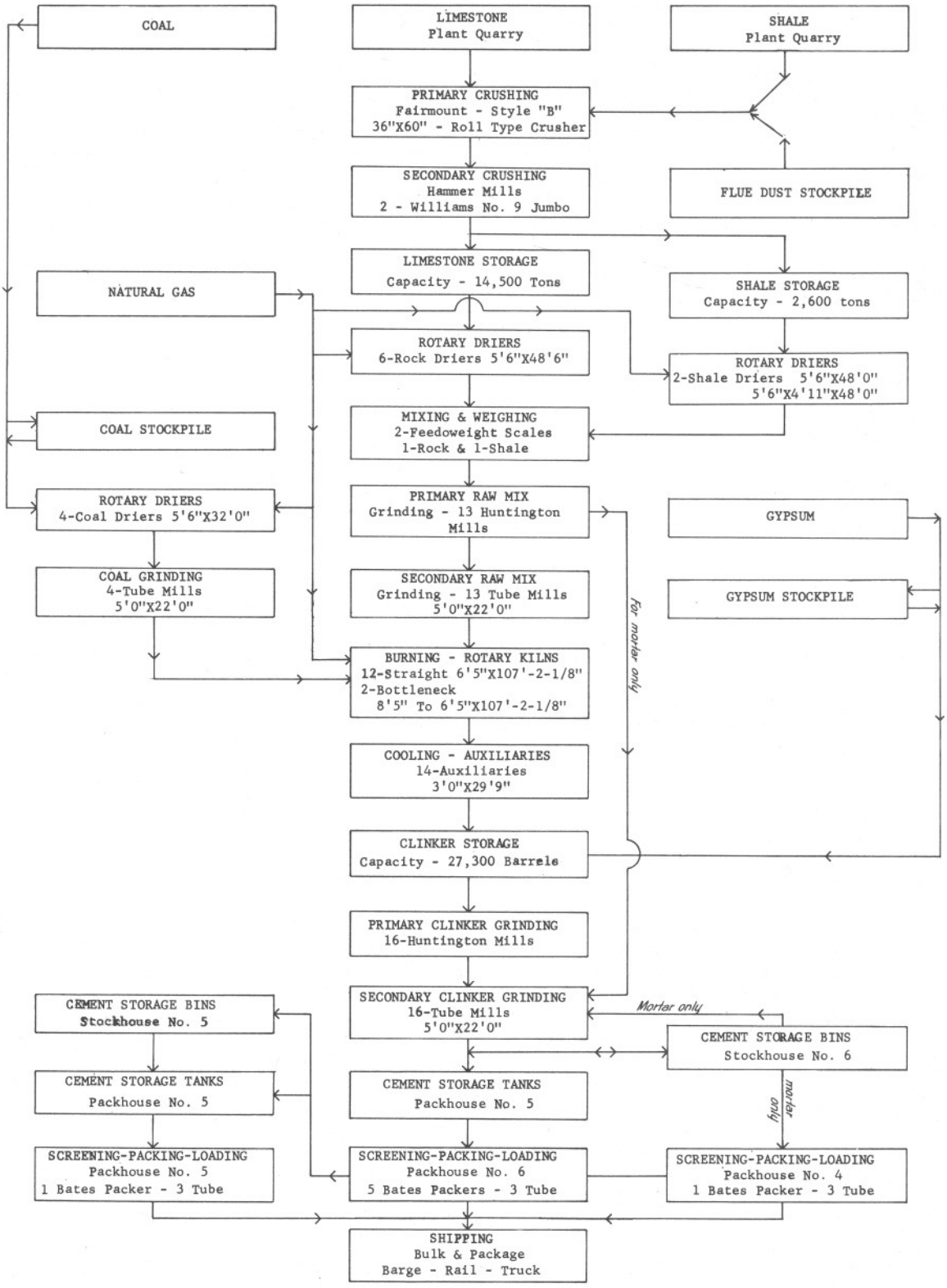
Fig. 27 -- STOP 10. Hannibal Plant, Universal Atlas Cement Division of the United States Steel Corporation, Ilasco, Missouri.

95.7	0.3	Saverton shale and Louisiana limestone contact on left.
97.0	1.3	Ilasco city limits.
97.2	0.2	Louisiana limestone on left.
97.4	0.2	Saverton shale and Louisiana limestone contact on left.
97.6	0.2	Marble Creek bridge. Turn left (west) just beyond the bridge on road leading to Ilasco.
97.8	0.2	Bear right at church.
98.2	0.2	Bear left at junction.
98.3	0.3	STOP 10 - (30 minutes) - Anthony C. Tennissen.

NW NW NW Sec. 11, T. 56 N., R. 4 W., Ralls County. The Hannibal plant of the Universal Atlas Cement Division, United States Steel Corporation, was the first cement plant built west of the Mississippi River. It initially consisted of two manufacturing units. Construction was started on the oldest unit in 1901 and completed in 1903. This plant was dismantled in the early thirties. Construction of the second unit, which is the present plant (Fig. 27), was initiated in 1903 and completed in 1905. Its physical appearance is nearly the same today as when built. However, various improvements in equipment and methods have occurred.

The quarry has experienced the greatest change. Originally, stone and shale were mined from underground tunnels by hand labor and horse power. Now, modern electric and diesel-powered equipment recovers the stone and shale from exposed quarry faces.

The plant proper has undergone considerable change but less outstanding than that of the quarry because the original type of basic equipment, such as kilns and tube mills, is still being used. Large steam engines furnished the power for the early operation. Today, machinery is powered by electric motors energized with electricity obtained from out-plant sources. The original primary crushing system consisted of several small crushers. These have been replaced by a 36" x 60" Fairmount crusher and two Williams hammer mills. Natural gas has replaced



Fkg. 28 -- Flow chart of the Hannibal Plant, Universal Atlas Cement Division, United States Steel Corporation.

coal as the fuel for drying. Trucks, payloaders, tractors, and other miscellaneous improvements have provided the means necessary for modern efficiency. And now, this year, for the first time, truck shipments of cement have been made available to the customer. This is in addition to rail and barge services which have been the standard means of shipping cement for many years. (Fig. 28).

The present plant, which occupies approximately 2,000 acres of land including shale and limestone quarries, his twelve 6' 5" diameter kilns and two bottleneck kilns each 8' 5" in diameter at the discharge end. All kilns are 107' in length. Annual capacities at the 14-kiln level of operation are over 2,000,000 barrels of cement, some 500,000 tons of limestone, and more than 100,000 tons of shale.

Typical chemical analyses of limestone and shale quarries at the Hannibal plant are as follows:

	Limestone	Shale
SiO_2	8.4%	48.2%
Al_2O_3	0.4%	20.2%
Fe_2O_3	0.6%	4.4%
CaO	49.0%	1.4%
K_2O	0.1%	4.7%
Na_2O_3	0.1%	0.2%
Loss	40.2%	7.9%

The above account provided by M. M. Henning, Plant Manager, Universal Atlas Cement Division.

99.0 0.7 Junction of State Rd. NN and Ilasco Rd.
Turn left (north) on State road NN.

99.3 0.3 Junction of State Rds. N and AA.
Continue straight ahead (north) on State Rd. AA.

99.9 0.6 Louisiana limestone on left.

100.2 0.3 Louisiana limestone on left.

101.2 1.0 Entrance road to Mark Twain and Cameron Caves.

Mark Twain Cave was discovered in the winter of 1819-20 by Jack Sims, a hunter. At first it was called Big Saltpetre Cave, because a large quantity of saltpetre was manufactured from the bat guano found in it. Later it was called McDowell's Cave for Dr. E. D. McDowell of St. Louis, who unsuccessfully experimented with placing the body of a child in the cave to see if it would petrify.

The labyrinthine pattern of Mark Twain Cave, as well as Cameron Cave which is situated in the opposite side of Cave Hollow, is completely joint controlled by three or more intersecting sets of joints in the Louisiana formation. Mark Twain Cave has 23 hillside openings, 20 of which are now blocked by fallen rock and flowstone. Cameron Cave has about two dozen blockaded openings. It is believed that the two caves are severed parts of a once-continuous cave system. Bretz (1956) who describes both of these caves in detail (Cameron Cave, pp. 55-61, figs. 20-23; Mark Twain Cave, pp. 151-156, figs. 72-75) ascribes their origin entirely to phreatic conditions.

101.4 0.2 Louisiana limestone on left.

101.8 0.4 Hannibal city limits.

Hannibal is Missouri's fourth industrial city, and aside from being renowned as the home town of Mark Twain, it is equally known for its various industries. Although Hannibal owes its early growth to river trade, the lumber industry, and flour milling, it assumed its contemporary character with the advent of railroads in the Midwest shortly after the Civil War. Hannibal's position on the western shore of the Mississippi suggested it as a logical terminus for a railroad to the West at a time when the railroads from the East stopped short at the river. In 1856, the first train of the Hannibal and St. Joseph Railroad (now the C. B. and Q.) was run westward as far as Palmyra, the county seat of Marion County. Three years later, the road was completed across the state to St. Joseph. Shops for the road were established in Hannibal, and in them, in 1862, was built the world's first railroad mail car. Here, too, was constructed the General Grant, the first locomotive built west of the Mississippi, which made its initial run in March, 1865.

In 1871, the Hannibal (now Wabash) Bridge was completed. Of draw-span design, it was the second bridge across the Mississippi to touch Missouri's shores. In 1886, the town built the state's first city-owned light and power plant, and in 1889 it established the first tax-supported library in Missouri. Hannibal-LaGrange College, a Baptist coeducational institution, moved to Hannibal from LaGrange, Missouri, in 1929, and in 1935, the $1,000,000 Mark Twain Memorial Bridge across the Mississippi River was completed.

Hannibal now has a population of about 20,444 people and is a thriving industrial city which has the added support of rich farm lands in the immediate vicinity. The number of products manufactured in Hannibal is large and varied and it is strategically located close to one of the best cement producing localities in the Midwest, being just three miles north of the Universal Atlas Cement Company plant, which is considered to be one of the largest such plants in the country.

102.0 0.2 Louisiana limestone on left; C. B. & Q. Railroad yard on right.

102.2 0.2 STOP 11 - (20 minutes) - Charles W. Collinson.

SE SE Sec. 28, T. 57 N., R. 4 W., Marion County. At this stop we are in the type area of the Hannibal formation, and although Keyes who named the Hannibal in 1892 (p. 289) did not designate a particular type locality, it can be assumed with reasonable assurance that he may have considered this locality as his type. The thickness of the Hannibal ranges between 60 and 100 feet, and it is exposed throughout the extent of the eroded portion of the Lincoln fold in Missouri and Illinois. West of the area it thins rapidly and is not known to be present in central Missouri. Throughout its known extent, its lithologic character is fairly uniform. It is essentially a very fine-grained sandy shale which contains interbedded claystone and siltstone. Fairly thick beds of very fine-grained calcareous sandstone or siltstone are present in the upper part of the formation. These siltstones are normally marked by an abundance of irregular tabular markings which because of their resemblance to the worm borings suggested the name "vermicular" to early Missouri geologists. Another common marking is that of Taonuris caudigalli which resembles the curved sweep of a "cock's tail."

Concerning this locality, J. S. Williams (1943, p. 6) makes the following statements regarding the unconformable relationship of the Louisiana and the overlying Hannibal:

> "The existence of an unconformity in Missouri is, however, well shown in the east face of Lovers Leap at Hannibal, Missouri. There a bed of dolomite about 22 inches thick is the uppermost bed in the Louisiana. It is underlain

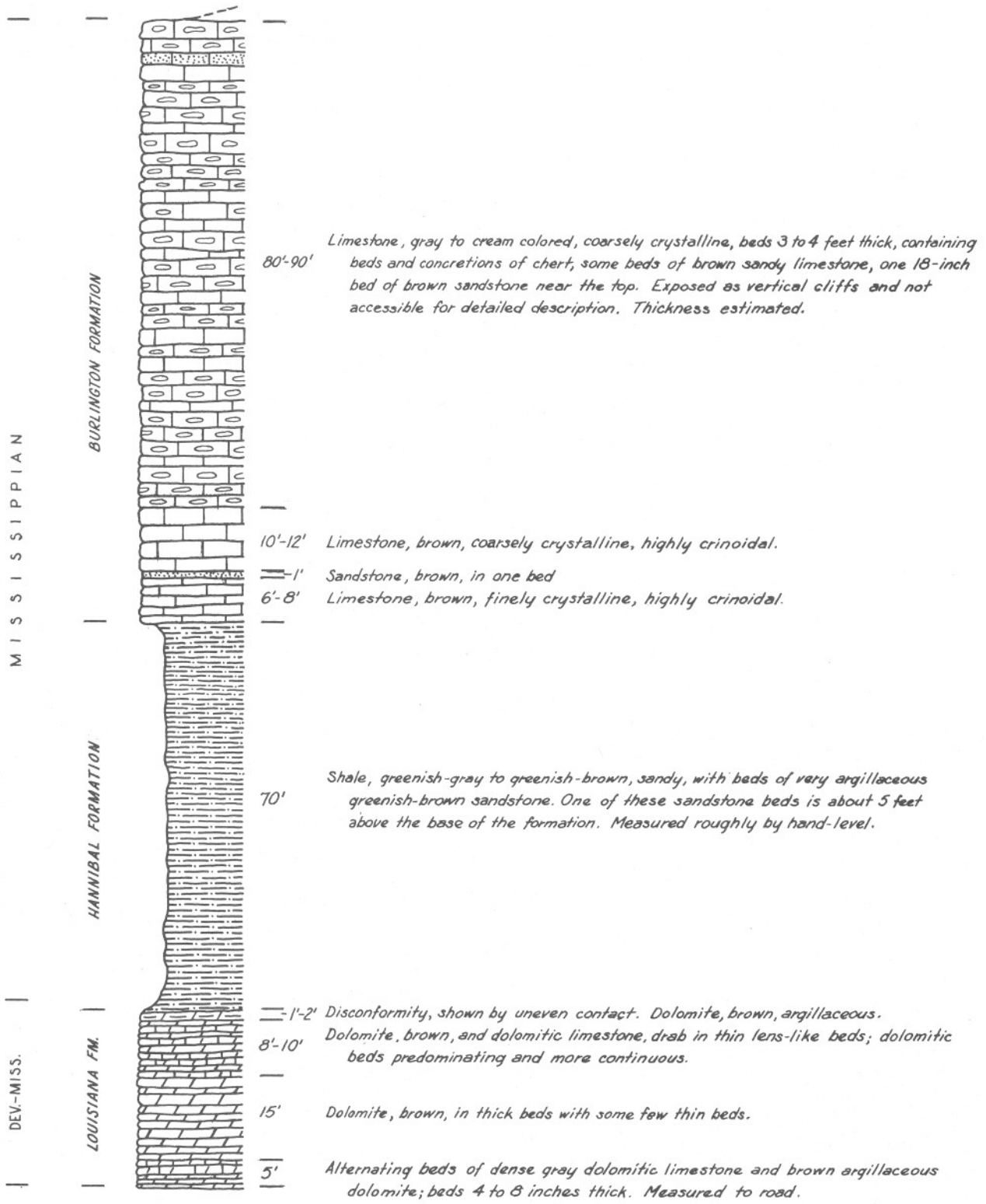


Fig. 29 -- STOP 11. Location: SE SE Sec. 28, T. 57 N., R. 4 W., Hannibal Quadrangle, Marion County, Missouri.

by eight or ten feet of brown and white lenslike beds of dolomite and dolomitic limestone. At several places along the cliffs at the base of Lovers Leap, erosion has cut channels through the massive layer and into the thinner dolomites. These channels are filled with green and brown shales of the Hannibal. Some of the larger channels are as much as five feet deep and eight to ten feet across the top."

Although some shallow channeling can be seen in the upper dolomite bed of the Louisiana formation, subsequent observers have been unable to see as deep a channeling in the formation along this bluff as described by Williams.

Lovers Leap rises 230 feet above the road. The usual legend of the Indian lovers who flung themselves from its heights is told of this bluff. More authentic, however, is the story of its use by a religious group as a gathering place in anticipation of ascending to Heaven. In the early 1840's, William Miller, a New York City deist, decided that this world was coming to an end in 1843. Protestant churches throughout the country were thrown open to his preaching, and he gained a great following among a group of Hannibal and Marion County citizens. Disappointed in their expectation in 1843, the "Millerites", as the sect was called, again looked for Christ on October 22, 1844. Crops and jobs were left unattended, stores were closed, and positions were resigned, as the people prepared, as though on their death beds, to meet their God. Dressed in long white robes, the group ascended to the crest of Lovers Leap, where they waited to be snatched to Heaven when the world was destroyed. Actually Miller was just about 116 years, 8 months, and 22 days too early. The event that he had anticipated is going to occur in the morning.

102.5 0.3 Junction of Missouri Hwy. 79 and State Rd. AA. Turn right (north) on Missouri Hwy. 79 and proceed to hotel.

END OF FIRST DAY.

Fig. 30 -- STOP 11. Louisiana, Hannibal, and Burlington formations exposed in the bluff at Lovers Leap, Hannibal, Missouri; SE SE Sec. 28, T. 57 N., R. 4 W., Marion County, Missouri.

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SECOND DAY OF FIELD CONFERENCE

Saturday, September 16, 1961

Hannibal to Hamburg, Illinois, and return

Driving distance: 119 miles

Departure time, 7:00 A.M., C.S.T. Place, Mark Twain Hotel

Log prepared by Charles W. Collinson, Illinois State Geological Survey

1. Mark Twain Hotel
2. Parking Lot
3. Windsor Hotel
4. Mark Twain Boyhood Home
5. Becky Thatcher Home
6. Cardiff Hill

Fig. 1 - Hannibal Business District

Directions from Mark Twain Hotel to Starting Point.

To reach mile 00 of road log, leave Mark Twain parking lot by turning left onto Church Street. At stop sign on Main Street turn right and continue ahead beyond stop light on Broadway to Hill Street. Turn left on Hill Street. Turn right at stop sign on Third Street and continue to stop light where Third Street intersects U. S. 36. Turn right and proceed to mile 00 at west end of Champ Clark bridge.

STARTING POINT: West end of Champ Clark bridge on U. S. Hwy. 36.

Cum.
Mileage

0.0 West end of Champ Clark bridge. The river is about four-fifths of a mile wide at this point. River stage is closely controlled by Lock and Dam 21 at Quincy, 20 miles above Hannibal, and Lock and Dam 22 at Clarksville, about 30 miles down river. The dams are designed to maintain water levels during periods of low water so that a minimum depth of 9 feet will be available for navigation.

0.1 Enter Pike County, Illinois; organized in 1821 and named for Zebulon M. Pike, a general in the War of 1812.

1.2 East Hannibal - look quickly! We are crossing the 6 mile wide, flat and fertile flood plain of the Mississippi. Levee drainage districts protect the fields with levees and ditches that will be seen all along the field trip route. Here the river valley trends northwest-southeast, and we are crossing it in an easterly direction.

Actually we are crossing a magnificent gorge 150 to 180 feet above its floor. The sediments that fill it consist of Pleistocene outwash sand and gravel

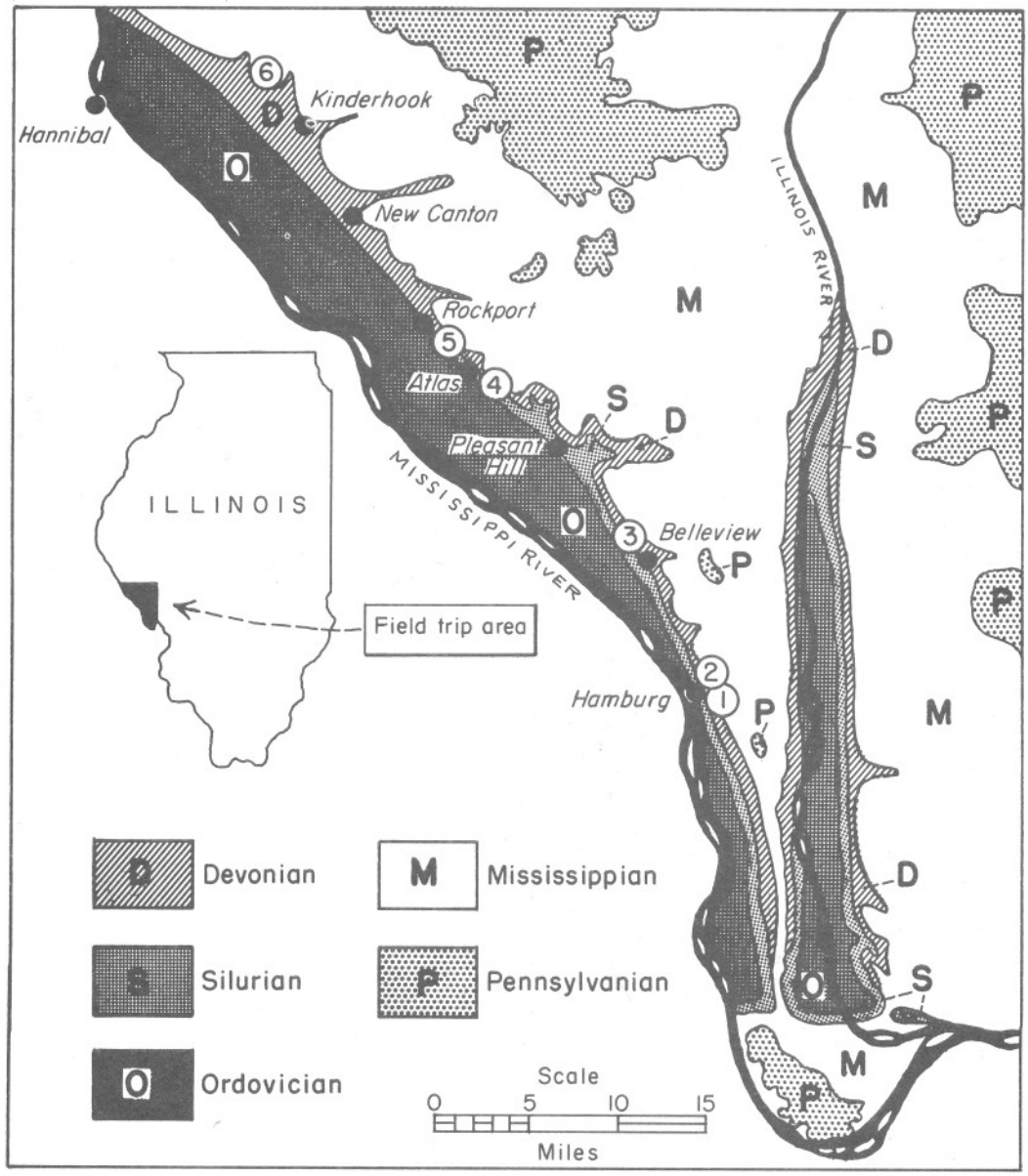
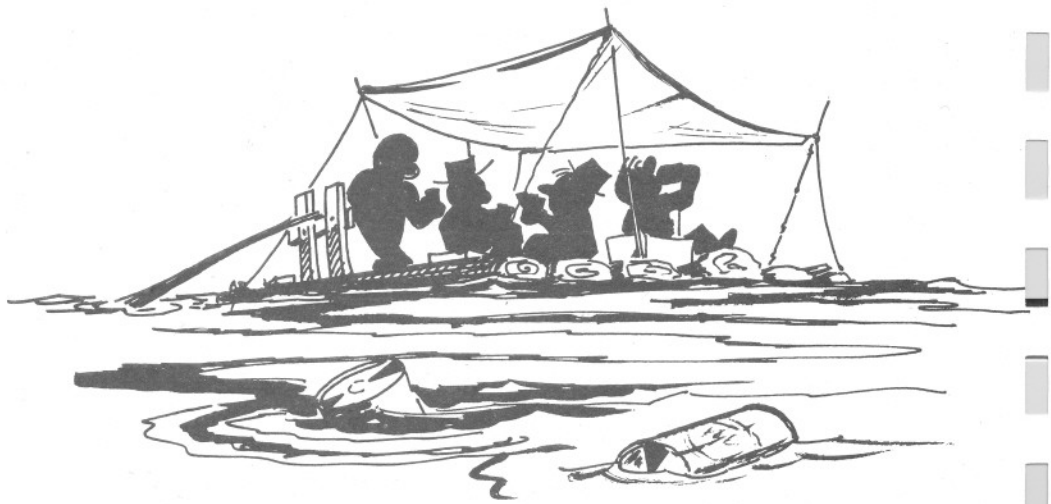


Fig. 2-- Generalized geologic map of field trip area.



that form excellent ground-water reservoirs supplying the villages in the valley as well as some on the bluff.

5.6 Bridge over the Sny. For 50 miles along the Mississippi, none of the streams on the Illinois side flow directly into the main river but join the Sny which lies east of and parallel to the Mississippi River. The channel is kept open by dredging.

8.8 Enter Hull, Illinois; a grain elevator village on the Chicago, Burlington, and Quincy R.R.

11.2 Junction of Route 36 with 96. Turn right. Directly ahead is the mouth of McCraney Creek. The hill to the left, just off the curve, is the south bluff that R. C. Moore described in 1929. Just before we reach the white brick house on the left, we will be able to see, high in the bluff, 7 feet of mottled limestone of the McCraney formation underlying massive overhanging ledges of limestone of the Burlington formation. A few feet of buff siltstone belonging to the Hannibal formation can be seen beneath the McCraney.

Moore named the McCraney from the ravine behind the house. It is the same section from which Meek and Worthen (1861, p. 288) derived the name Kinderhook and applied it to the group defined "to include the beds lying btw. Black sl. below, and Burlington ls. above" [sic]. The black shale was later included in the Kinderhook but is here considered a formation in the Upper Devonian Series.

Just beyond the white house, the McCraney is well exposed in the bluff for a quarter of a mile, although it is partly obscured by trees.

11.9 Lower part of Hannibal and upper part of Saverton formations exposed on left in gully north of red barn. This is considered the southern end of the type McCraney section.

12.4 City limits of the village of Kinderhook, pop. 300.

12.8 Junction of Routes 36 and 96. Turn right on Route 96.

13.4 Hadley Creek Valley. This is the first of many small streams flowing in outsize valleys that we will see. In most such valleys, remnants of high level terraces stand 40 to 50 feet above the valley floor.

Neither Illinoian nor Kansan ice sheets completely covered the river bluffs of the field trip area. The western lobe of the Kansan ice sheet, moving from the northwest, crossed the Mississippi and covered the area north of Pleasant Hill, but south of there it halted west of the river.

The eastern lobe of the Kansan sheet, advancing from the northeast, reached only as far west as the Illinois River, and Illinoian ice approaching from the same direction did not extend much farther west. The latter did cross the Illinois River, but it stopped several miles short of the Mississippi except for one small area; between New Canton and Rockport, it reached the Mississippi River bluffs.

None of the ice sheets entered Calhoun County which today stands as a strongly dissected, upland, driftless area.

The outsize valleys of present day, Mississippi River, tributaries in the area are old proglacial drainage channels but most were in existence before the glacial epochs. Whether the terraces in them are aggraded material left by the glacial streams, or deposits associated with ponding of meltwater by damming of the lower Mississippi is conjectural. However, many of the terraces occur at the same elevation as the prominent Brussels terrace of southern Calhoun County which has been attributed to ponding of Illinoian meltwater.

13.7 Abandoned high level quarry in the limestone of the lower Burlington. The coarse crinoidal Burlington is the most prominent formation in this area; it forms the brow of the cliffs for more than 60 miles from north of Quincy to south of Hamburg. In Calhoun County it also forms the divide between the Illinois and Mississippi Rivers. Its prominence is partly attributable to the fact that the middle part of the Burlington is very cherty, and, as weathering proceeds, residual chert accumulates to form a resistant cap. The lower Burlington is 10 to 20 feet thick and is relatively chert free.

Perhaps nowhere else can the regional unconformity at the base of the Burlington and the relationships of the Kinderhook formations beneath it be better demonstrated than in the field trip area. Several miles north of Kinderhook, the Prospect Hill formation wedges out beneath the unconformity, and, as we go southward, the McCraney and most of the Hannibal will successively disappear. As we approach Hamburg, some 40 miles farther south, the Chouteau formation comes into the section at the base of the Burlington and thickens rapidly to more than 50 feet in central Calhoun County.

The broad pre-Burlington arch accounting for these relationships trends in a NE-SW direction and has been referred to as the Schuyler Arch (Workman & Gillette, 1956, p. 12).

14.9 Bluffs on left capped by limestone of the Burlington.

15.3 Grubb School on the left. Hannibal, Saverton, and Burlington formations are exposed in stream cuts east of the school.

15.45 Prominent cliff on left ahead. The cliff exposes 6 to 8 feet of the middle Burlington underlain by 15 to 20 feet of pure lower Burlington.

16.00 Well developed hill prairie above Burlington limestone cliffs mantled with thick Wisconsinan loess. Such loess mounds served as lookout, burial, and flint chipping sites for the Indian tribes that lived in the Mississippi Valley.

16.8 Burlington cliff.

17.6 The southernmost outcrop of McCraney formation occurs at the tip of the bluff on the left. Here the formation is only 38 inches thick and is overlain by lower and middle Burlington. Beneath the McCraney, more than 30 feet of bluff siltstone referable to the Hannibal is exposed.

18.1 McCraney is absent from this spur and there is no sign of its nearby occurrence.

18.3 Pleistocene terrace in valley mouth to left.

18.5 North limits of New Canton, pop. 450. In the early 1800's this community had a significant Mormon population that later moved to Nauvoo.

19.0 Zones in the Hannibal recognizable north of the valley are identifiable here and show that the formation continues to thin southward.

19.6 Saverton formation exposed on left.

20.25 Burlington cliff.

21.0 Brewster Branch. Dark gray fissile shale of the Grassy Creek formation is exposed near road level and is successively overlain by 45 to 50 feet of Saverton, 20 feet of Hannibal, and 10 feet of Burlington.

21.7 Stillhouse Branch section behind white barn shows one of the northernmost exposures of the "Glen Park" formation.

22.0 Brown's Branch. Excellent exposure of "Glen Park" with abundant brachiopod and conodont fauna.

22.1 Stark Brothers Nursery plantings on right.

22.6 Burlington forms cliff on left.

23.5 Across the river valley to the west the large gap in the bluffs represents the Salt River Valley north of Louisiana, Missouri.

23.8 Middle and lower Burlington well exposed in cliff.

24.9 Horton Creek. Nearly the entire section from Grassy Creek to Burlington is exposed up this valley.

25.6 Dutch Creek. Near the cemetery visible on the left, the Grassy Creek formation is exposed. The "Glen Park" formation is represented by 7 feet of limestone, conglomerate, and claystone overlain by 60 feet of Hannibal all exposed farther up the valley.

26.8 North limits of Rockport. The Grassy Creek is now above road level.

28.1 Silurian limestone in ditch to left.

28.6 Jimtown Branch. Excellent outcrop of conglomeratic oolitic limestone belonging to the "Glen Park" formation is exposed up the creek.

30.3 Atlas, Illinois. Atlas is the oldest community in Pike County. It was first settled by Ebenezer Franklin in 1820. William Clarendon and Leonard Ross settled nearby later in the year, and the place was named "At Last" by them. The name has since been corrupted to Atlas. In 1821, malaria killed half the population. The same year the first brick house, general store and hotel were constructed and in 1824 a jail and courthouse were built. In 1826 a Pennsylvania Dutchman set up the first whiskey still and the First Baptist Church was built.

From 1823 to 1833 Atlas was the county seat of Pike County which then included all the territory north of the Illinois and Kankakee Rivers. The city was growing so rapidly that it bragged that Quincy would never amount to much because it was too close to Atlas.

After the county seat was moved to Pittsfield, however, the city declined and today is little more than a crossroads. A contributing factor may have been a competitive whiskey still at Kinderhook set up in 1828. The church wasn't set up there until 1859.

30.5 Stop sign and flashing light. Junction with Route 54. Louisiana, Missouri, 7 miles to west. Continue straight ahead. One-half mile up Atlas Hollow to the left, the oolite of the "Glen Park" is well exposed.

30.6 Stark Brothers Warehouse on right.

32.6 Hannibal overlain by Burlington. Stop 4 will be near here.

33.1 High level quarry in Burlington. This type of quarry commonly offers excellent crinoid collecting. Across the valley, Clinton Hill south of Louisiana and Buffalo Hill a mile and a half still farther south can be seen.

34.7 Pleasant Hill pumping station, Panhandle Eastern Pipeline Company.

35.5 Silurian Kankakee limestone at road level on left.

37.2 Pleasant Hill, pop. 850. The village is located on a broad gentle post-Burlington anticline that brings the lower Silurian Alexandrian Series to

the surface. The Burlington is exposed 2 to 3 miles to the east.

37.7 Kankakee limestone exposed along main street north of business district. 1 to 2 inches of the Sylamore sandstone overlie the limestone. The Devonian Cedar Valley limestone is absent.

38.6 Looking across the valley, we can see the well-known Pinnacle Hill north of Clarksville as well as the knob topography so well developed south of there.

39.1 Nebo Road. Chicago and Alton R. R. overpass ahead.

39.7 Bay Creek. Pleistocene terraces on the left.

43.0 Hill prairies well developed on top of bluffs ahead on left. These high level grass lands are the last of the original prairie in Illinois and represent a very special ecologic unit with characteristic fauna and flora. Across the valley Salt Peter Bluff near Annada is in view.

43.0 Howell Hollow. Northernmost exposure of Louisiana formation.

44.65 North edge of Wildcat Hollow. The Louisiana has thickened to 35 feet at this place. Grassy Creek at road level.

45.2 Wildcat Creek. Note how the cemeteries are commonly on loess terraces where drainage is good and the digging easy.

46.2 Kankakee limestone at road level.

46.5 Village of Belleview on left. This village is still much as it was in 1840, a few years after it was founded.

47.0 Excellent exposures of Silurian and Devonian along road. The Silurian is well exposed in cliffs above road level for the next 4 or 5 miles.

49.2 Infidel Hollow. Note the presence of the Sny Drainage to our right in the valley.

51.0 Mozier village limits.

52.1 Continue straight ahead. Route 96 turns to Kampsville on the Illinois River 8 miles to the east.

52.4 Fox Creek.

53.6 Apple Orchard to left. This is the northernmost edge of a large fruit growing district for which Calhoun County is well known.

53.9 Pancake Hollow to left.

54.4 Lower Burlington and Chouteau in the bluff.

55.2 High bluff on left is capped by limestone belonging to the lower and middle Burlington. The Chouteau is poorly exposed beneath the Burlington.

56.00 Hamburg, pop. 300. Fishing village on main channel of Mississippi. All the land upon which Hamburg is now located was once owned by John Shaw, Calhoun County's most prominent citizen of pre-Civil War days. Shaw first visited the land in 1821 after participating in the Indian wars along the river. He was an astute business man. In the 40's when Hamburg was a flourishing lumber town, Shaw built a steamboat here and persuaded citizens for miles around to bring their surplus produce for shipment to New Orleans. When a full cargo was aboard, the steamboat and Shaw disappeared down the river never to return.

56.2 Hamburg Ferry. Bell rings when ferry is ready to load. The Hamburg Ferry began service in 1847 when Augustus Bartell was granted the first license to operate it.

56.4 Road turns left.

56.5 STOP 1. HAMBURG SOUTH.

Buses park on right-hand side of road just short of bridge. The

Fig. 4 -- Stop 1. Joliet, Cedar Valley and Sylamore formations along creek south of Methodist Church, Newburg, Illinois.

lowest part of the section is beneath the Bluff Road bridge. The outcrop extends about 0.2 mile upstream. The Silurian outcrop extends just around the bend. Middle Silurian and Middle Devonian rocks are best exposed on the south side of the creek just below the bend. Upper Devonian and Mississippian rocks occur in a vertical bank behind the Methodist Church. The uppermost part of the section exposes the "Hamburg oolite" where the stream flows next to Irish Hollow Road.

Although not as well exposed as countless other sections, this is one of the best known in western Illinois. It probably is the only one that clearly demonstrates the unconformable relationship of the Louisiana limestone to the overlying "Glen Park" formation and has been successively studied in detail by A. H. Worthen (1870), Stuart Weller (1906), T. E. Savage (1913), Frank Krey (1924), R. C. Moore (1929), W. W. Rubey (1952), James Steele Williams (1943), and Merrill Stainbrook (1950).

The oldest rocks in the section are those of the Alexandrian (Lower Silurian) Kankakee formation which is at times exposed below the bridge. It is a hard massive finely crystalline to dense, pure buffish gray limestone mottled with green stains. Irregular bedding surfaces are common and a peculiar weathering surface marked by pits is characteristic.

The Kankakee is overlain by the Joliet formation of Middle Silurian age. A prominent but very smooth bedding plane marks the contact. The contact is well exposed in Gresham Hollow a half mile to the southeast.

The Joliet formation is of very restricted occurrence in Calhoun

County in that it extends in a narrow belt from this outcrop, its northernmost exposure, only 3 miles southward. The Joliet can be distinguished from the underlying limestone with confidence only by comparison of fossils. It is a hard, massive- to thin-bedded, finely crystalline limestone, light gray with pink mottling.

The Joliet is overlain by the Middle Devonian Cedar Valley formation which consists mainly of brown to buff crystalline limestone that is sandy both at top and bottom. In this section the Joliet is immediately overlain by a brown sandstone exposed in the south bank of the creek not far above the bridge. This sandstone, here considered the Hoing sandstone member of the Cedar Valley formation, is of special interest becuase it is an oil-producing zone in the Colmar-Plymouth field some 70 miles to the north. In many other places, the Hoing is overlain by sandy calcareous gray shale or claystone and contains light brown to gray siliceous nodules.

Over much of this area, the Cedar Valley is capped by a prominent ledge of hard crystalline limestone that is very sandy in the upper

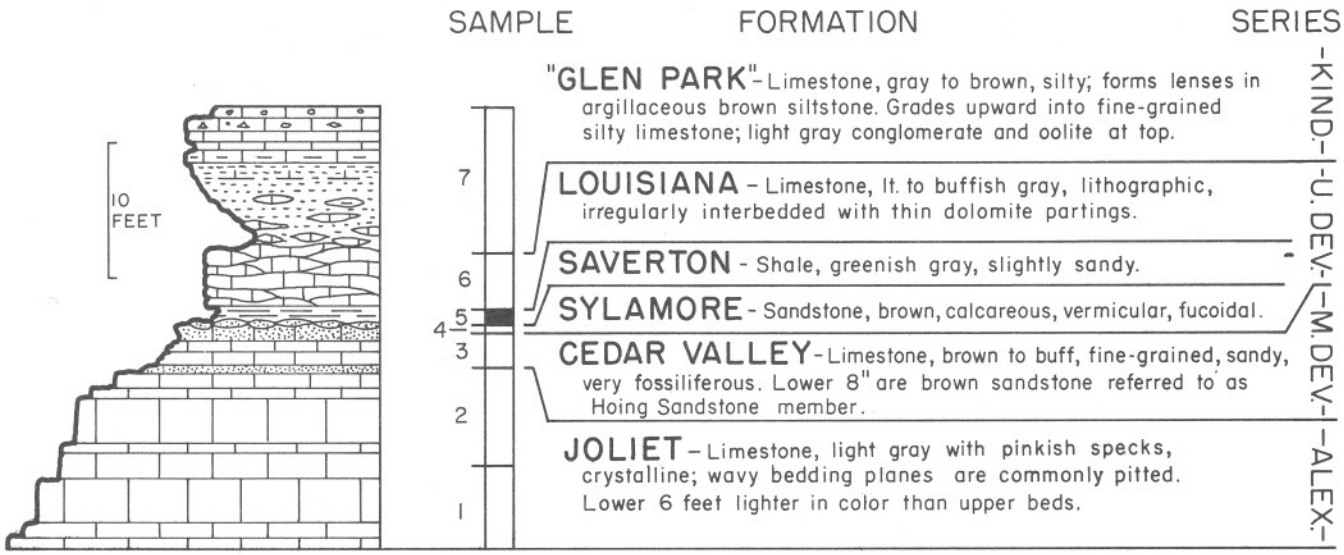


Fig. 5 -- Stop 1. Hamburg South. Section along creek in south part of Hamburg, SW NE Sec. 35, T. 9 S., R. 3 W., Calhoun County, Illinois.

2 or 3 inches. Although not well developed here, the upper zone is commonly a pure sparkling noncalcareous sandstone.

The Cedar Valley is the most fossiliferous formation in the field trip area, and the upper beds in this section contain numerous brachiopods, crinoids, bryozoans, and corals represented by the following species:

SPONGES

Astreospongia hamiltonensis, saucer-shaped, indistinguishable from A. meniscus, the Niagaran guide

CORALS

Hexagonaria (Acervularia or Prismatophyllum), compound tetracoral
Favosites alpenensis, honeycomb tabulate, 1 mm. cells
Alveolites, fine-tubed, slanting honeycomb tabulate
Striatopora, twig-like tabulate

Cystiphyllum, solitary tetracoral, vesicular structure
Tabulophyllum, small, solitary tetracoral, strong horizontal tabulae
"Cyathophyllum", unidentified solitary tetracorals

CRINOIDS

Numerous stems and isolated plates

BRYOZOANS

Fenestella, the lace-like cryptostome
Sulcoretapora, a strap-like branching cryptostome

BRACHIOPODS

Athyris fultonensis, subcircular, biconvex, low fold, weak concentric lamellae
Atrypa reticularis, flat ventral overlapping strongly convex dorsal; numerous costellae and lamellae reticulate
A. (Hystricina) hystrix, few strong costae
Chonetes, semi-elliptical, concavo-convex; spines on straight hinge
Cranaena, smooth ovoid, curved beak, small to medium
Elytha subundifera, large narrow spiriferoid; few low costae, extremities rounded
Megastrophia, large, deeply concave stropheodontid
Pentamerella, small subcircular costate pentameroid, ventral sulcus
Pholidostrophia, small, smooth, semi-elliptical
Platyrachella iowensis, very large, wide, acute spirifer
P. euryteines, large, acute, sharper costae than P. iowensis
Schizophoria iowensis, transversely elliptical; very low, broad sinus; finely striate
Schuchertella, semi-elliptical, often asymmetrical, finely costellate; prominent rounded deltidium
Stropheodonta, semi-circular to subrectangular, concavo-convex, costate; denticulate hinge; several species
Strophonelloides, reversed convexo-concave stropheodontid
Syringospira, medium spiriferoid; very high triangular cardinal area
Tylothyris, medium spiriferoid; strong plication on sinus and groove on fold

TRILOBITES

Phacops, compound eye, swollen nose
Proetus, smooth eye, large rims on head and tail

FISH

Helodus, small corrugated crushing teeth
Dinichthys and Ptyctodus, large worn plate fragments, commonly black

At this section we are only ten miles south of the erosional edge of the Cedar Valley formation. South and southeastward the formation thickens gradually to about 15 feet in 6 miles then abruptly thickens to 40 feet in the next 4 miles. From its thickest occurrence, it then thins and is absent in the southern part of Calhoun County.

The Cedar Valley is here overlain unconformably by the Sylamore sandstone, an oxidized brown sandstone up to 3 inches thick lying in pockets on and infiltrating cracks in the underlying Cedar Valley. Because the Cedar Valley is exceedingly sandy in its upper part here, it is very difficult to distinguish from the Sylamore. To make differentiation more difficult, Cedar Valley fossils are mixed into the overlying beds.

The Sylamore differs from the sandstone of the Cedar Valley mainly in that it

is pyritic and darker in color. Furthermore, Cedar Valley sandstone tends to range from fine to medium, whereas Sylamore grains tend to be coarser. There is commonly more secondary enlargement of grains in the Cedar Valley.

The Sylamore is rarely more than a few inches thick in this area but is widespread in occurrence. Throughout much of the area it overlaps both the Cedar Valley and the Joliet and rests directly on the Kankakee.

The Sylamore of Calhoun County correlates with the type Sylamore of Arkansas and the Misener of the northern Mid-Continent. The name, Hardin, taken from sandstone underlying the Chattanooga of western Tennessee has in the past been applied to the Sylamore here.

Overlying the Sylamore but much restricted in its exposure is the greenish-gray Saverton shale which is 10 inches thick. The formation has overlapped the Grassy Creek to the north and is overlapped in turn by the Louisiana within a few miles to the south. Dark shale in the lower part indicates the nearness of the Grassy Creek. There is some sandstone in the upper part of the formation here. The contact with the overlying Louisiana is sharp and regular.

This outcrop of Louisiana limestone is characteristic of the lower part of the formation and consists mainly of 2- to 7-inch beds of light gray lithographic limestone separated by very thin dolomitic shale partings. In this exposure the formation ranges from 3 to 4½ feet thick. In placed the upper part is channeled as much as 2½ feet and the channels are filled with alluvium. Beneath the overhanging ledges of "Glen Park" at the north end of the outcrop, the irregular pre-"Glen Park" surface can be seen to have 10 to 12 inches of relief with "Glen Park" beds completely filling the depressions. Nowhere else in the Mississippi Valley are the relationships so clearly shown. Commonly, pebbles of lithographic limestone can be found in the oolite of the "Glen Park" near the top of the section.

The thickness of the Louisiana here is well below its Illinois maximum of 40 feet because we are 4 or 5 miles off the main axis of the Louisiana lens which, northwest of Hamburg, trends nearly due northwest but east of here trends nearly due east-west. Eastward the lens thickens to a maximum of 20 feet in about 16 miles. Northwestward along the bluffs the formation attains a thickness of 35 feet within 30 miles.

The age of the Louisiana has been the subject of heated discussion for many years. Its age is discussed elsewhere in the guidebook but the conclusions of long-pursued studies by Collinson and Scott have, in their opinion, demonstrated the Upper Devonian age of the formation. A few fossils have been found in the Louisiana here. They consist of the genera Orbinaria, Schuchertella, Spirifer, Linqula and Syringothyris. None is conclusive proof for either a Devonian or Mississippian age.

The "Glen Park", which lies on the Louisiana with obvious unconformity, is characteristically developed here. It consists mainly of a lower unit of hard, silty, somewhat sandy limestone in layers of 1 to 4 inches thick interlaminated with thinner beds of soft argillaceous siltstone. The limestone is light to dark gray on fresh surfaces and brownish gray on weathered ones. The limestone is fine-grained and contains scattered crystals of calcite, sphalerite, and pyrite as well as phosphate nodules. The bedding planes between, and within, the layers of limestone are irregular and wavy with the rippled surfaces oriented in nearly every direction. If there is a predominant trend, it is in a north-northwest direction.

Above the lower unit, which is about 6 feet thick here, the siltstone becomes increasingly limy and grades into slabby fine-grained, silty, brownish-gray limestone that weathers brown to buff. In several places in this area, however, this unit consists of brownish-gray shale. The limestone here attains a maximum thickness of 4 or 5 feet and crops out both behind the church and upstream along the west side of the creek.

Near Irish Hollow road, about 75 yards upstream from the Louisiana outcrop,

the well-known "Hamburg oolite" of Stuart Weller (1914) crops out in the south bank. Two and a half to 3½ feet of oolitic limestone and fine-grained, fossiliferous, silty, gray limestone crop out along the south side of the stream bank. Prior to installation of the lock and dam system on the Mississippi, some 15 feet of the oolite were exposed on the river front in the north part of the village.

Both the oolite and the fossiliferous limestone contain rounded pebbles and small particles of fine-grained limestone. The oolites are one-half to two-thirds millimeter in diameter and are in a matrix of clear calcite. The nucleus is commonly a bit of fine-grained limestone.

The fauna of the "Glen Park" has been listed by Weller (1906, 1914) and consists of the following species, some of which can be collected here:

BRACHIOPODS

Schellwienella chemungensis (Conrad)
Chonetes glenparkensis Weller
Camarophorella lenticularis (White & Whitfield)
Rhynchopora hamburgensis Weller
Dielasmella calhounensis Weller
Dielasmella compressa Weller
Hamburgia typa Weller
Delthyris missouriensis Weller

PELECYPODS

Nucula glenparkensis Weller
Parallelodon sulcatus Weller
Schizodus appressus (Conrad)

GASTROPOD

Mourlonia sp.

It is this fauna that Weller (1914) correlated with the fauna from the Glen Park member of the Sulphur Springs formation of Jefferson County, Missouri, and led Moore (1929) to apply the name Glen Park to these beds. Recent comparison of conodont faunas from the "Glen Park" in Illinois with those from the Glen Park of the type section shows the Illinois "Glen Park" to be significantly younger than the type Glen Park beds and indicates that the name Glen Park must be abandoned in Illinois. Pending an official revision of Illinois Geological Survey classification, Glen Park in quotes is being temporarily used. The irony of the situation is that there are many times more exposures of "Glen Park" than Glen Park in the Mississippi Valley.

56.5 Buses turn left (north).

56.65 Irish Hollow road. Turn left and proceed directly toward the river for two blocks. The Irish Hollow road to the right passes through a deep cut in loess and alluvium that forms terraces at the valley mouth. About 20 feet of yellowish-brown Wisconsinan loess here overlie 3 or 4 feet of brown silt and 10 feet of chert shingle alluvium.

56.75 Stop sign. Turn right on main street.

57.00 Beneath the fishing cabins on the left the "Hamburg oolite" may be found along the river bank at low river stages. This is the locality where Bassler (in Weller, 1906, p. 464-465) reported 15 feet of the oolite.

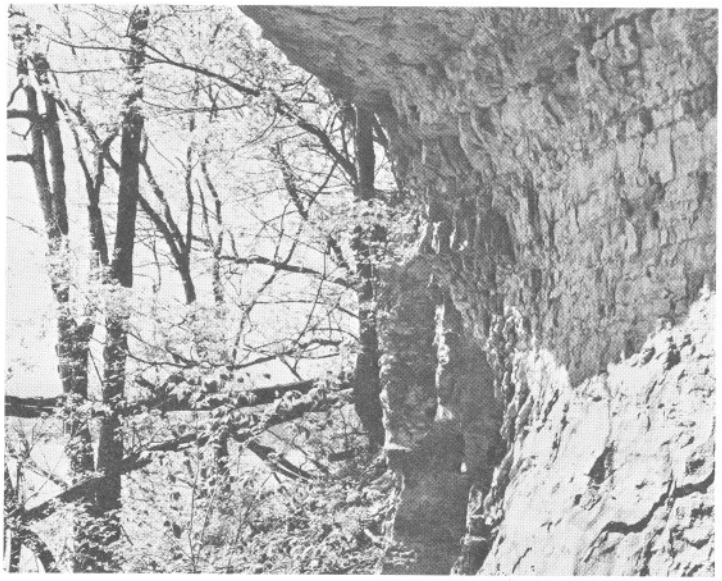


Fig. 6 --View of gray, argillaceous Chouteau limestone overlain by crinoidal Burlington limestone (overhanging ledge) high in bluff north of Hamburg, Illinois.

57.10 STOP 2. North Hamburg.

The south point of the bluff here exposes much of the section above that seen at at Stop 1 and is the best locality in the area from which to see the Chouteau formation, the Nutwood member of the Hannibal formation, and the silty brown shale of the Hannibal that in the subsurface has been called "Glen Park" shale.

The lower part of the section exposes a greenish-gray shale facies in the Hannibal not seen in the Hannibal-Kinderhook area. This facies results from the fact that southward from Kinderhook the clay content of the lower Hannibal increases and silt content decreases. The Hannibal also increases in thickness southward, and most of the increase may be attributed to thickening of the lower part of the formation.

In the lower part of this section the dark gray to black noncalcareous platy shale referred to as the Nutwood member of the Hannibal is exposed. Workman and Gillette (1956, p. 27) named the member from outcrops east of the Illinois River and referred it to the Maple Hill formation, although Collinson considers it to be Hannibal. The Nutwood has a broad distribution and extends northeastward in the subsurface for nearly 160 miles. About 40 miles due east, it attains a thickness of 30 to 40 feet. In many places it bears numerous Tasmanites. The Nutwood is difficult to differentiate from the Grassy Creek in some places, although it generally is lighter in color, is less laminated and contains about twice as much silt as the Grassy Creek. The 5 to 6 feet of buff to brown shaly siltstone overlying the Nutwood here is a good example of the silty shale or shaly siltstone that Workman and Gillette referred to the "Glen Park" in the subsurface east and north of here. In fact, their isopach maps indicate that 40 to 50 feet of "Glen Park" occur at this place. If one places the top of the "Glen Park" at the top of the brown siltstone here, that thickness is accounted for. The silty shale is here considered a distinct facies of the lower part of the Hannibal that may have had the same source and sediment transport directions as the "Glen Park" but is distinguishable lithologically. Normal silty gray shale of the Hannibal overlies the brown silty shale.

Above the shale and siltstone exposure, about 70 feet more of Hannibal are covered. Above this interval, approximately 25 feet of gray argillaceous, finely calcarenitic limestone representing the Chouteau formation are exposed. This, in turn, is overlain by some 30 feet of buff to light gray crinoidal limestone belonging to the Burlington.

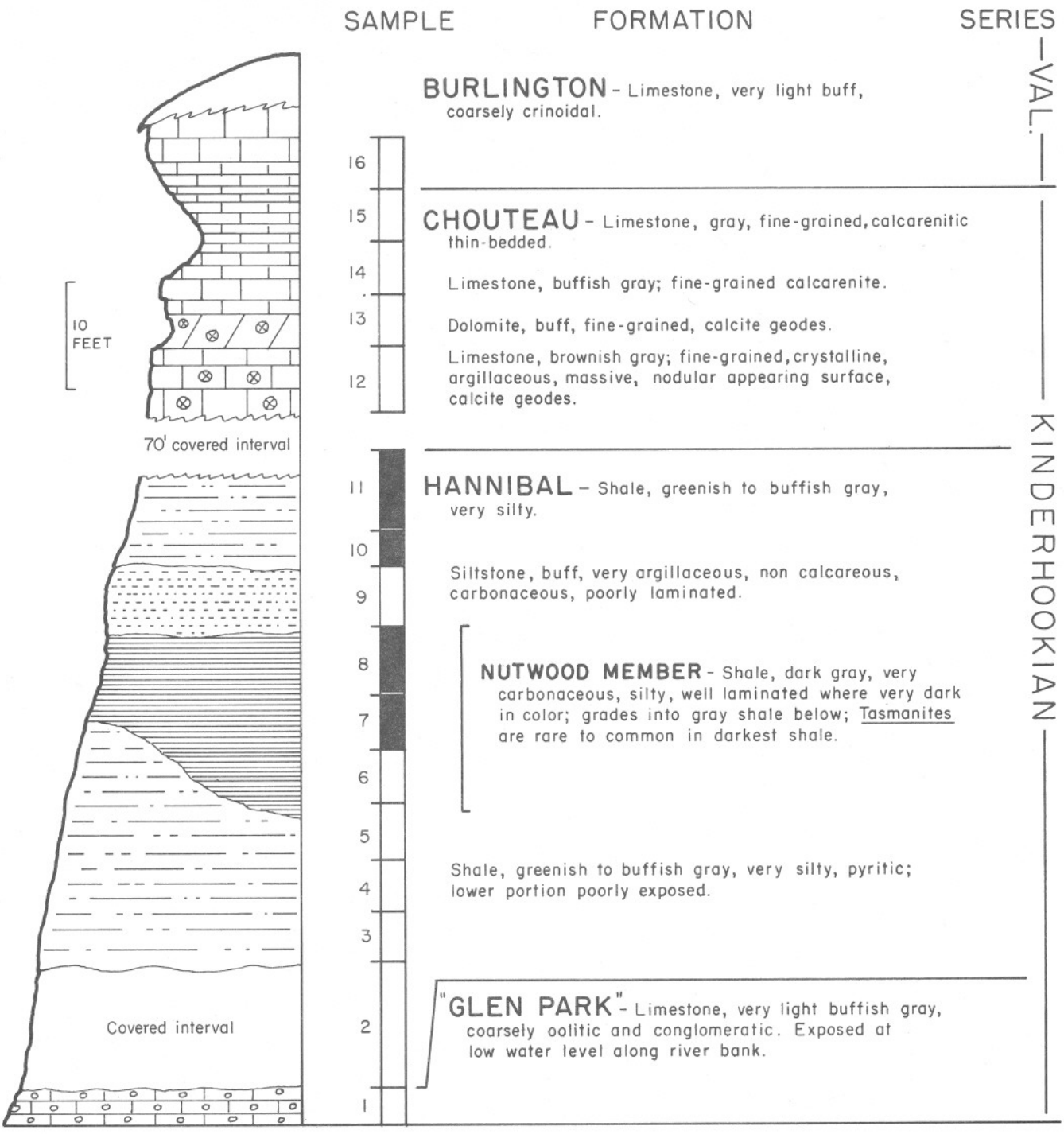


Fig 7. -- Stop 2, Hamburg North. Bluff at north edge of Hamburg, NW NE Sec. 35, T. 9 W., R. 3 W., Calhoun County, Illinois.

The Chouteau is especially interesting because it is near its northernmost extent in this area. The formation is about 25 feet thick in this section, although 10 miles to the southeast it is between 50 and 60 feet thick. From here it thins even more rapidly northward, and, only 4 miles to the north, it is reduced to 3½ feet. Conodont faunas from this area as well as exposures showing interlamination of the upper 10 to 15 feet of the Hannibal with the lower part of the Chouteau suggest that the Hannibal and Chouteau are, in part, time equivalents. The rapid disappearance of the Chouteau is partly attributable to

pre-Burlington erosion.

Some 20 to 30 feet of Burlington overlie the Chouteau here, and unless one carefully checks the lithology of each bed going upward in the section the unconformable contact may be easily overlooked. The Burlington forms a sheer face and is not easily observable.

The bluff is capped by a lone monument to the memory of Capt. Lewis Swarnes, born May 1821, died July 1867. The view of the river below Hamburg is well worth the steep climb.

At this stop, those who do not wish to climb the steep cliff may be interested in checking the riverbank for outcroppings or loose slabs of "Hamburg oolite".

57.10 Buses continue straight ahead. Mozier Island on the left.

59.3 Alexandrian, Kankakee formation at road level.

59.7 Burlington and Chouteau in bluffs on right.

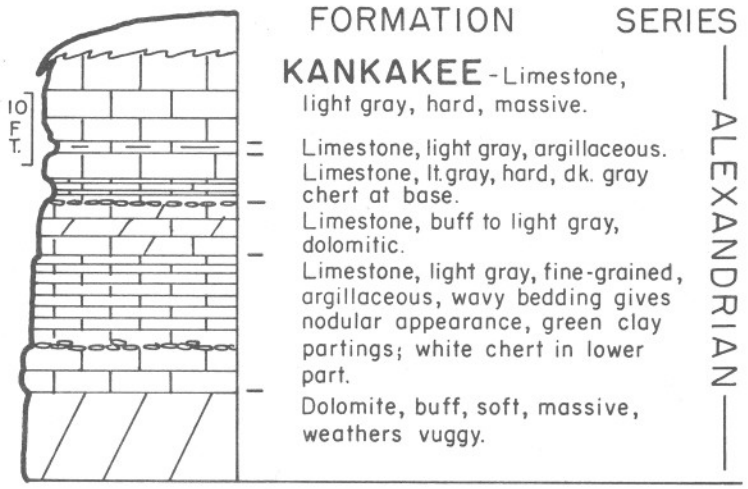


Fig. 8. --Exposure of Lower Silurian Kankakee formation, east side of highway, NE/4 Sec. 15, T. 9 S., R. 3 W., Calhoun County, Illinois.

60.0 Pancake Hollow on right. Mouth of the Sny a quarter of a mile to the left.

60.1 High level Pleistocene terrace with apple orchard on it.

61.75 Stop sign. Junction with Route 96. Continue straight ahead. We are back on the Great River Road. Note the high level terraces on the north side of the valley. Route 96 to Kampsville on the Illinois River crosses the divide of the Calhoun peninsula, 7½ miles to the east.

62.15 Enter Mozier which owes its existence to hunting and fishing.

63.2 Limestone and dolomite of the Kankakee formation exposed on right for next 2 miles; maximum exposure is about 30 feet.

64.6 Panther Hollow.

65.3 Kankakee capped by thin Cedar Valley limestone on right.

66.9 Abandoned quarry, hidden by trees but marked by fallen blocks near road, exposes about 11 inches of the Cedar Valley formation underlain by 20+ feet of Kankakee and overlain by 0 to 3 inches of Sylamore sandstone and 8 feet of very dark gray fissile shale referable to the Grassy Creek formation. The Grassy Creek and the Saverton are thickening rapidly as we go northward. The Chouteau has disappeared and the Hannibal is thinning.

67.3 Belleview Creek.

67.35 Village of Belleview on right. Northernmost exposures of the Cedar Valley formation in the area are just ahead.

68.7 Wildcat Creek.

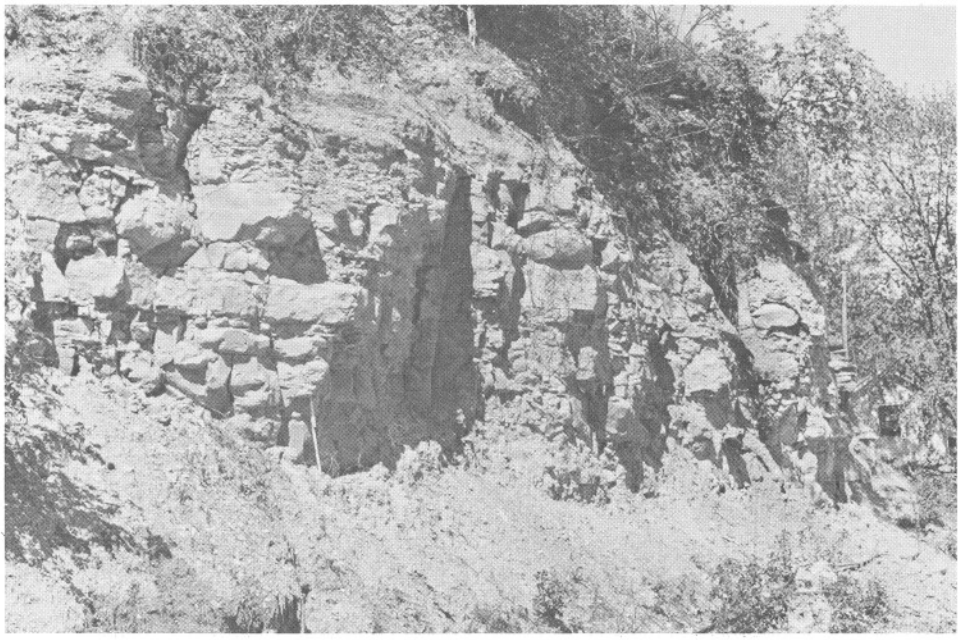


Fig. 9. --Silty facies of Saverton formation at base of bluff at Stop 3, Wildcat North.

69.3 STOP 3 - WILDCAT HOLLOW NORTH.

Buses stop on shoulder. The lower part of the section is along the farm lane. The remainder is in the bluff north of the lane. The importance of this section is threefold. First, it shows the Louisiana near its maximum thickness in Illinois. Second, it shows the "Glen Park" to be absent, without a trace, even though at least two authors have indicated that in Illinois it occurs everywhere with the Louisiana. Third, this section very nearly duplicates the sections at Hannibal and Saverton and gives us a reference for comparison of the other sections seen today. In addition this is the southernmost occurrence of a limestone bed in the Saverton. From here northward such beds are of considerable use in matching sections from gully to gully, especially where both "Glen Park" and Louisiana are missing.

At the top of the section the Burlington is underlain by a weak, buff, silty dolomite that contains geodes. Moore (1929, p. 71) has used, with question, the term "Sedalia" for such a unit at Clarksville and Hannibal in Missouri. Detailed examination of beds at this position up and down these bluffs as well as those of the Illinois River has shown that there is a closely similar buff

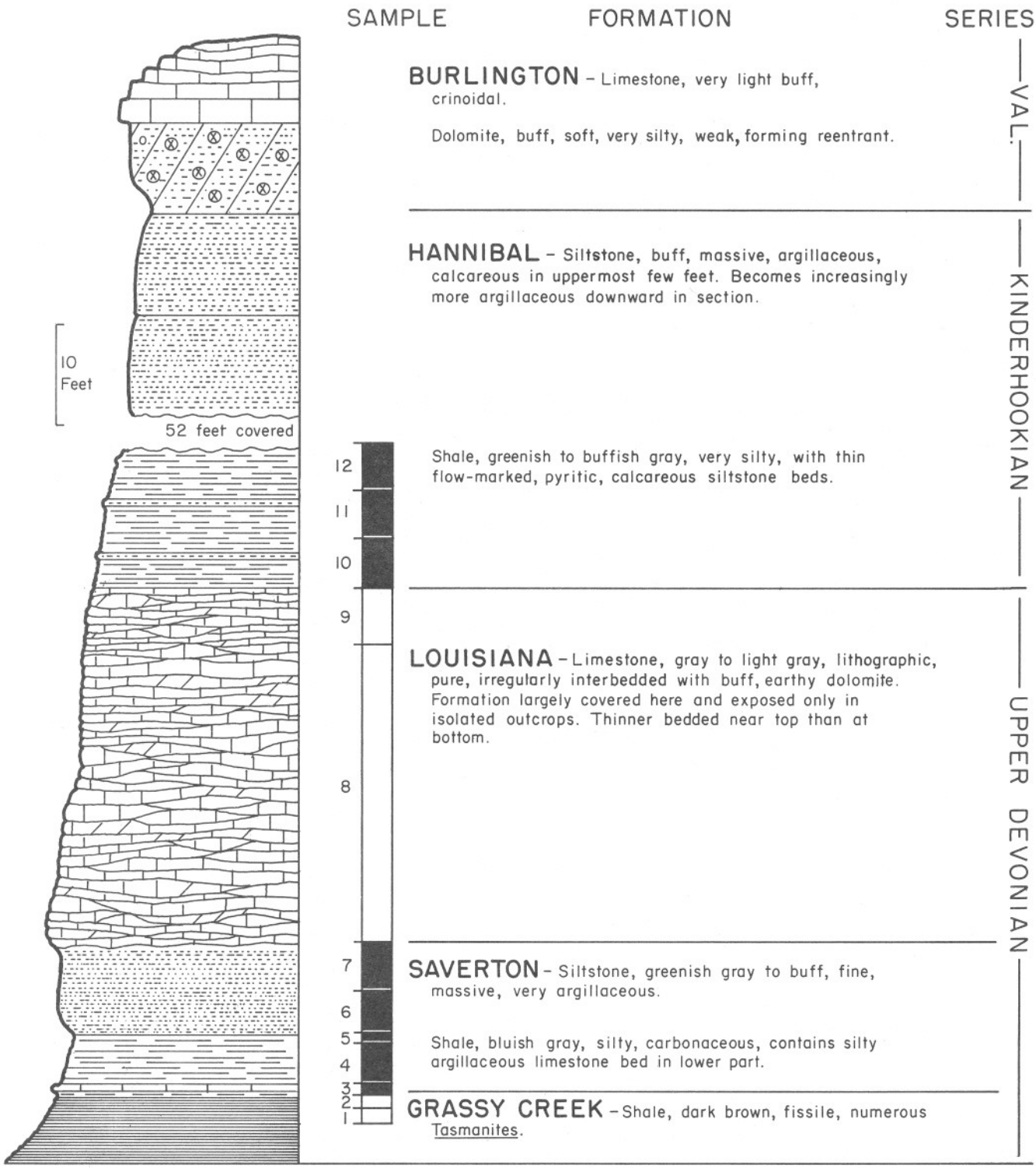


Fig. 10. --Stop 3, Wildcat North. East side of highway SW/4 NW/4 Sec. 7, T. 8 S., R. 3 W., Calhoun County, Illinois.

dolomitic limestone or calcareous dolomite unit exposed in southern Calhoun and Jersey Counties, but the unit carries a post-Kinderhookian conodont fauna and, therefore, cannot be a correlative of the Sedalia formation of Missouri. The dolomite seen here seems to be a calcareous silty unit that occurs discontinuously

along the bluffs at the Hannibal-Burlington contact and is not actually a mappable stratigraphic unit.

Conodont faunas from this outcrop clearly place the Mississippian-Devonian contact between the base of the Hannibal and the top of the Saverton.

69.3 Buses continue straight ahead.

70.9 Howell Hollow. On the south side of this hollow the Louisiana can be seen to have decreased to less than 20 feet in a distance of less than a mile and a half. This is the northernmost exposure of the Louisiana in the bluff. The five small gullies in the bluff between here and the large Bay Creek valley 2½ miles ahead have been explored in detail with no sign of the Louisiana. As is to be expected in such an elongate lens-shaped body, the formation thins very rapidly laterally.

72.35 Kankakee in ditch on right.

73.8 Bay Creek valley. The village of Nebo is situated 3 miles up the valley. The valley lies along the axis of a broad anticline that breeches the Burlington limestone cap of the bluff. Accordingly, from here to beyond Pleasant Hill the Silurian strata will be 10 to 20 feet above road level and the bluffs will be very low.

74.3 Bay Creek.

74.6 Chicago and Alton Railroad overpass.

74.8 Junction with Nebo Road. Two and a half miles northeast on this road the Grassy Creek is well exposed, and far above it in a southeast facing bluff a considerable thickness of the brown, shaly siltstone, referred by Workman and Gillette to the "Glen Park," is exposed.

75.0 West across the Mississippi Valley the Missouri town of Clarksville can be seen. Pinnacle Hill is the tall bluff rising to the north of the town.

75.6 Enter Pleasant Hill.

76.0 Limestone and dolomite of the Kankakee formation are exposed behind the ice cream parlor on the right. From here north beyond the village limits, Lower Silurian rocks are above road level.

77.4 Sixmile Creek.

78.85 We are now off the anticline. The Saverton and Hannibal shales are well exposed in the bluffs for the next 3 miles.

79.2 Pleasant Hill Station for the Panhandle Eastern Pipeline Company.

79.9 Active high level quarry in the Burlington limestone. Buffalo Creek Valley can be seen across the river.

80.3 Saverton and Hannibal exposed.

81.35 STOP 4 - ATLAS SOUTH

This section probably represents the most accessible and continuous section of Hannibal and Saverton. Because the sections north from here are so critical in determining the physical relations of the McCraney and Louisiana, it is important to understand this section. The "Glen Park" is present as a single brown dolomitic limestone unit with both macrofauna and microfauna. Excellent conodont faunas have been taken from the lower Hannibal, "Glen Park", and the entire Saverton. The faunas clearly indicate that the Mississippian-Devonian boundary occurs between the uppermost Saverton and the lowermost

Fig. 11 --Fossiliferous dolomitic "Glen Park" limestone at Stop 4, Atlas South.

Hannibal, a situation not so clear in many sections to the north.

The Burlington may be easily examined here. The Hannibal and "Glen Park" have decreased in thickness from our last stop while both the Saverton and Grassy Creek have greatly increased in thickness.

This outcrop will be of special interest to those interested in microfossils, because Sample 8 of this section contains an exceedingly abundant and apparently unsorted conodont fauna of Upper Devonian age. Collections from this sample and those immediately overlying it have been subjected to a variety of statistical studies by Scott & Collison (1959, 1960). In this section, the Saverton is easily divisible into several faunal zones directly correlatable with the Upper Devonian sections of the Rhenish Schiefergebirge in western Germany.

The bluff is capped by several conical mounds of loess that are typical of the bluffs in this area. The mounds served as lookout points for Indians in the area and commonly are burial sites. In the past, many flint scrapers, hunting points, and flint chips have been collected from the surfaces of such mounds. From the bluff, one has an excellent view of Clinton Springs Hill south of Louisiana, Missouri, as well as Buffalo Creek and Noix Creek valleys.

81.35 Buses continue straight ahead.

81.8 Twomile Creek.

82.4 Kankakee in ditch on right.

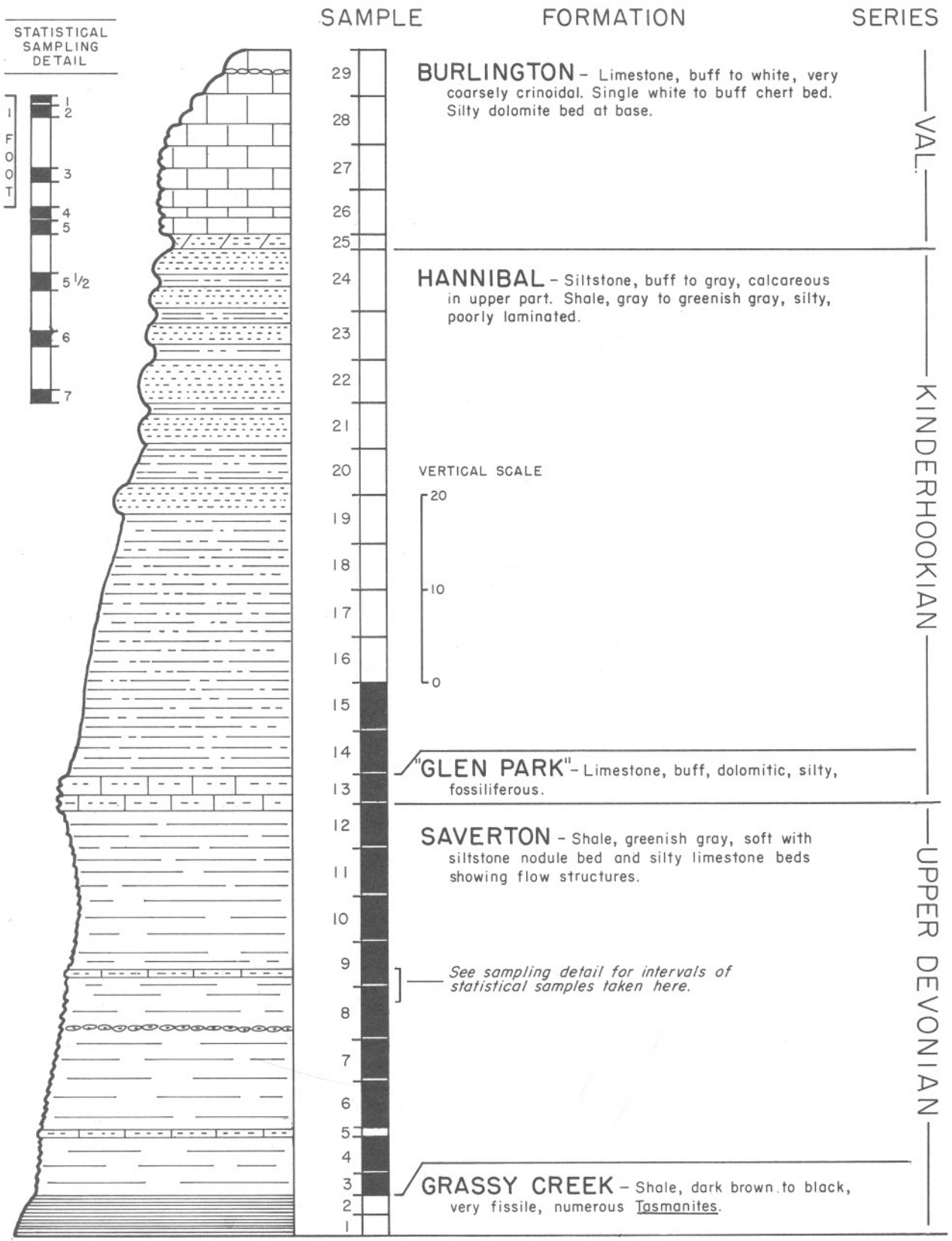


Fig. 12. -- Stop 4, Atlas South, Section in east bluff of Mississippi River Valley, near center of SE/4 Sec. 35, T. 6 S., R. 4 W., Pike County, Illinois.

Fig. 13. -Cross bedded conglomeratic oolitic limestone along Jimtown Branch, Stop 5.

83.2 Village limits of Atlas.

83.5 Stop sign and flashing light. Junction with U. S. Highway 54; continue straight ahead. Road to right goes to Pittsfield. Good exposure of "Hamburg oolite" quarter of a mile up Atlas Hollow.

83.7 Grassy Creek at road level.

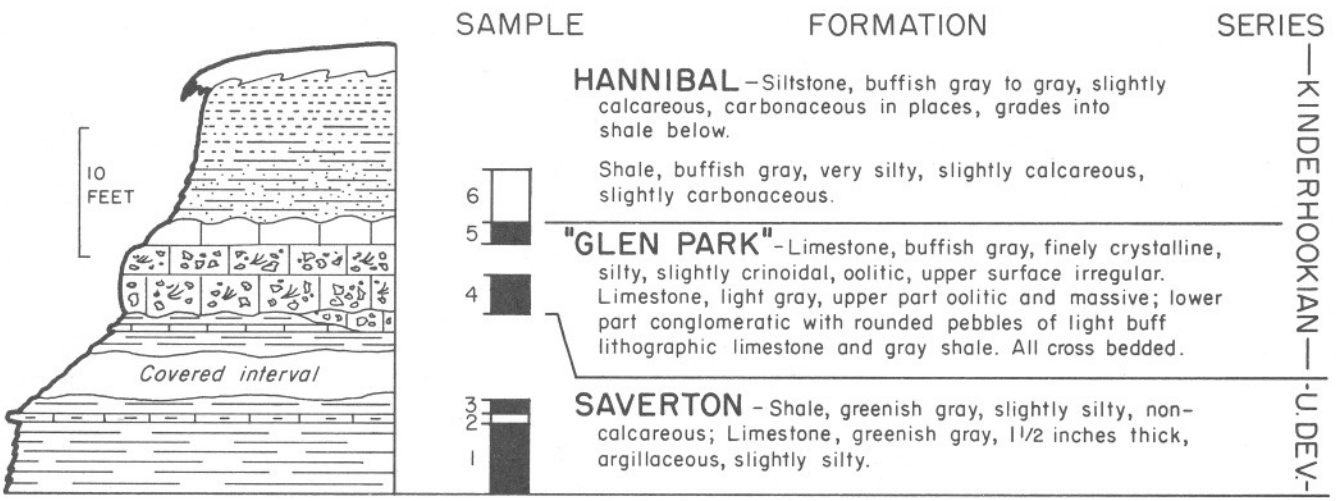


Fig. 14 -- Stop 5, Jimtown Branch. Section along creek extending from SW/4 SW/4 Sec. 16, to NE/4 NE/4 Sec. 20, T. 6 S., R. 5 W., Pike County, Illinois.

84.6 Jimtown Branch. Turn right on gravel road just beyond bridge.

85.2 STOP 5. JIMTOWN BRANCH.

Stop 5 is exposed along Jimtown Branch both upstream and downstream from the

concrete bridge over the small north tributary. The section is the most extensive exposure of "Hamburg oolite".

The oolite is exposed for about 75 yards along the creek. It is strongly cross-bedded with beds inclined at angles up to 40 degrees. The predominant direction of inclination is toward the northwest. The conglomerate associated with the oolite generally consists of coarse pebbles and small cobbles of sub-lithographic to lithographic limestone in a matrix of clear calcite and coarse oolites.

The Saverton formation is exposed in a cut-bank about 50 yards downstream and the siltstone of the Hannibal can be seen lying unconformably on the "Glen Park" at the upper end of the section. Heavy spring rains unearthed the "Glen Park"-Saverton contact at the downstream end of the section and the irregular contact can be observed.

85.8 Stop sign. Turn right on Route 96.

86.45 Excellent exposures are found along the creek in Rockport. The section very nearly duplicates that at Stop 4, Atlas South, except that the brown-fine grained limestone of the "Glen Park" is about 6 feet thick. The Grassy Creek is well exposed adjacent to the highway.

88.5 Dutch Creek Hollow. On the south side of this hollow, 6 feet of Saverton are overlain by 2 feet of sandy conglomerate, 3 feet of buff claystone, and 2 feet of buffish-gray, fine limestone. All belong in the "Glen Park". Seventy feet of Hannibal formation overlie the limestone.

89.4 Horton Creek.

90.0 Horton Hollow. Section very similar to Dutch Creek but shows oolite in lower part of "Glen Park". The Hannibal is 60 feet thick here but thins rapidly northward as we approach a pre-Burlington anticline.

90.3 Burlington cliffs on right.

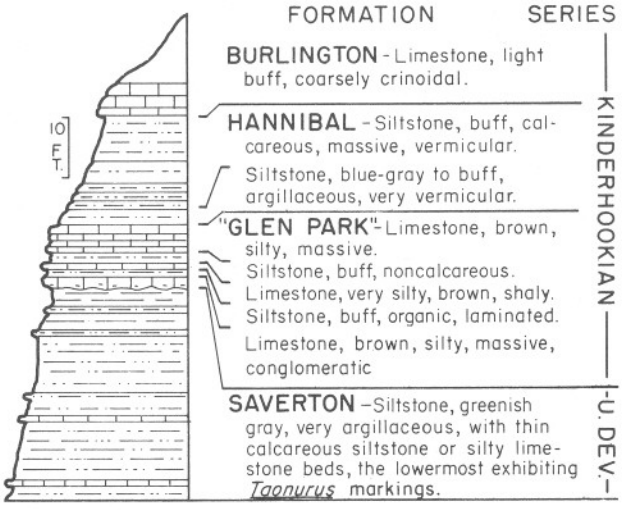


Fig. 15 - Section along west bank of Brown Branch, SE/4 NW/4 SW/4 Sec. 26, T. 5 S., R. 8 W., Pike County, Illinois. This exposure shows a very short Hannibal section. The "Glen Park" here yields abundant brachiopods and pelecypods as well as conodonts. The Saverton yields rich conodont faunas.

92.3 Brown Branch. A well exposed section on the south side of the mouth of this hollow is similar to that in Horton Hollow and Dutch Creek except that it carries excellent faunas, both visibly large and microscopic. The conodont fauna here is abundant in the fine-grained, brown limestone at the top of the "Glen Park". This is the northernmost exposure of the conglomeratic lower part of the "Glen Park". Within the next mile and a half the "Glen Park" is represented only by the fine-grained, brown limestone, and, beyond that is absent. Thus, it is

exceedingly important to trace beds above and below the "Glen Park" in order to establish the horizon of the "Glen Park" to the north where the limestone is absent.

92.7 In the small gully to the right, 6 feet of "Glen Park" are well exposed but the thickness of the overlying Hannibal has been reduced to 21 feet because of a pre-Burlington anticline whose axis closely parallels Kiser Creek 2½ miles ahead.

93.0 Section in small gully to right shows 2 feet of "Glen Park".

93.4 Brewster Ranch. A nearly complete section consisting of 20 feet of Grassy Creek, 55 feet of Saverton, 15 feet of Hannibal and 10 feet of Burlington may be seen along this creek stretching nearly a mile upstream. The "Glen Park" is absent.

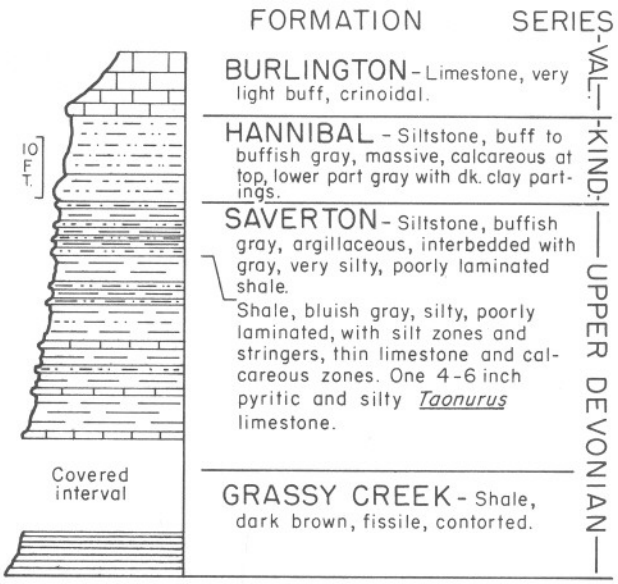


Fig. 16 - Composite section along Brewster Ranch, E/2 Sec. 22 and NW/4 Sec. 23, T. 5 S., R. 6 W., Pike County, Ill. The Hannibal section is very short and the Hannibal-Saverton contact gradational and indistinct.

94.9 A quarter of a mile up this gully to the northeast 10 feet of Saverton overlain by 8 inches of brown limestone, referable to the "Glen Park" can be seen. Fifteen feet of Hannibal overlain by 8 feet of Burlington overlie the "Glen Park". A fossil zone in the Hannibal here is apparently traceable across the valley ahead.

95.4 New Canton village limits.

98.7 Siltstone of Hannibal formation underlies Burlington in point of bluff.

98.2 The McCraney formation, missing at last bluff, is 3½ feet thick here. The underlying Hannibal is 27 feet thick, indicating that we are going down the north limb of the anticline. There is no sign of the "Glen Park" in this section but the fossil zone recognizable in the sections on the south side of the valley is recognizable here. The zone indicates that the "Glen Park" horizon should be about 45 feet below the base of the Burlington. From here northward the McCraney thickens gradually.

99.4 Grubb School section, just beyond the school, shows 50 feet of Saverton overlain by 25 feet of Hannibal. Lithologically, there is nearly complete gradation from one to the other and it is difficult to pick a boundary.

100.7 Hadley Creek.

101.3 City limits of Kinderhook.

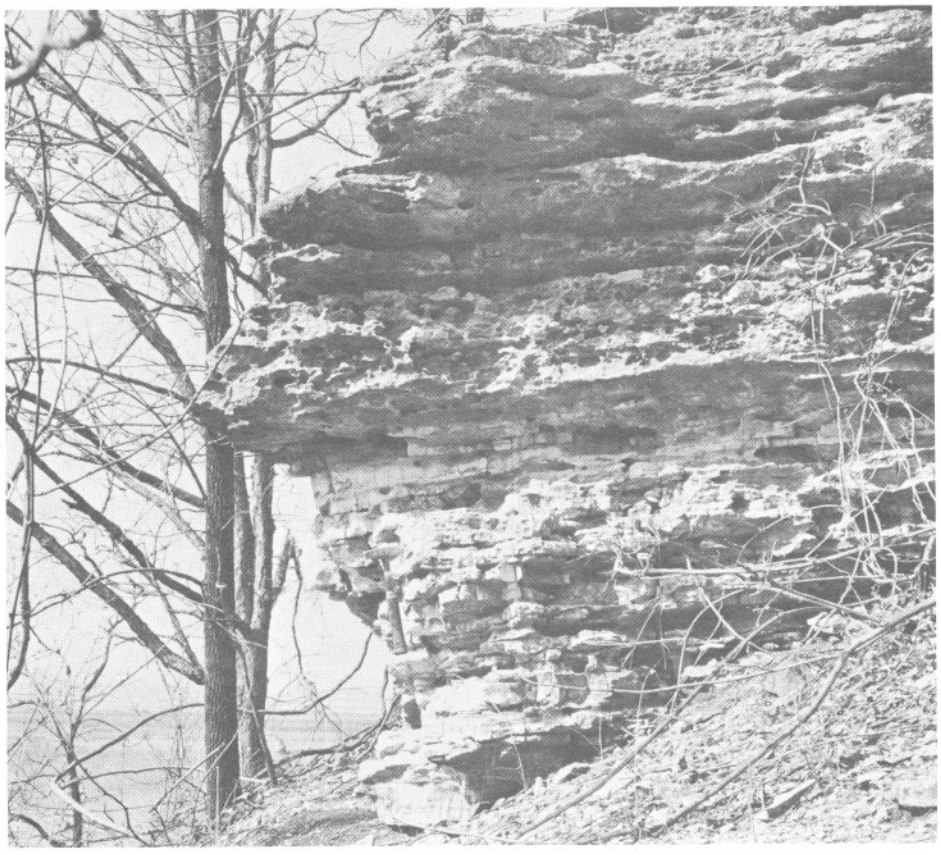


Fig. 17 - View of southernmost outcrop of McCraney limestone beneath the prominent overhanging ledge of Burlington, north of New Canton, SW/4 NE/4 Sec. 8, T. 5 S., R 6 W., Pike County, Illinois.

101.45 Stop sign. Junction with U. S. Highway 36. Turn left.

102.4 South end of type Kinderhook section, referred to as McCraney South. This section is described in the discussion at Stop 6, McCraney North.

102.7 The Kinderhook section, described by Moore, is behind the white brick farmhouse on the right.

103.5 McCraney Creek, Route 36, goes left at Y. Continue straight ahead.

103.6 STOP 6. McCRANEY NORTH.

One of the principal reasons for general disagreement among stratigraphers concerning the correlation of the Louisiana and McCraney formations is the close proximity of this section to the one at Lovers Leap in Hannibal, Missouri, 8½ miles across the valley. In each area there is a single, mottled, seemingly unique, lithographic limestone formation underlain by silty shale and overlain by siltstone. (The siltstone that overlies the McCraney, the Prospect Hill formation, is absent here but crops out less than 3 miles to the north.) The two limestones have never been found in the same outcrop section. It seems logical upon first examination, therefore, to correlate the two limestones, which S. Weller (1900), Harris (1947) and Stainbrook (1950) have done. J. M. Weller and A. H. Sutton (1940), R. C. Moore (1929) and Workman and Gillette (1956), however, have considered the two formations separate and of different ages.

Actually, this outcrop is only the north end and top part of what is considered the type McCraney section. The south and lower part is exposed in the

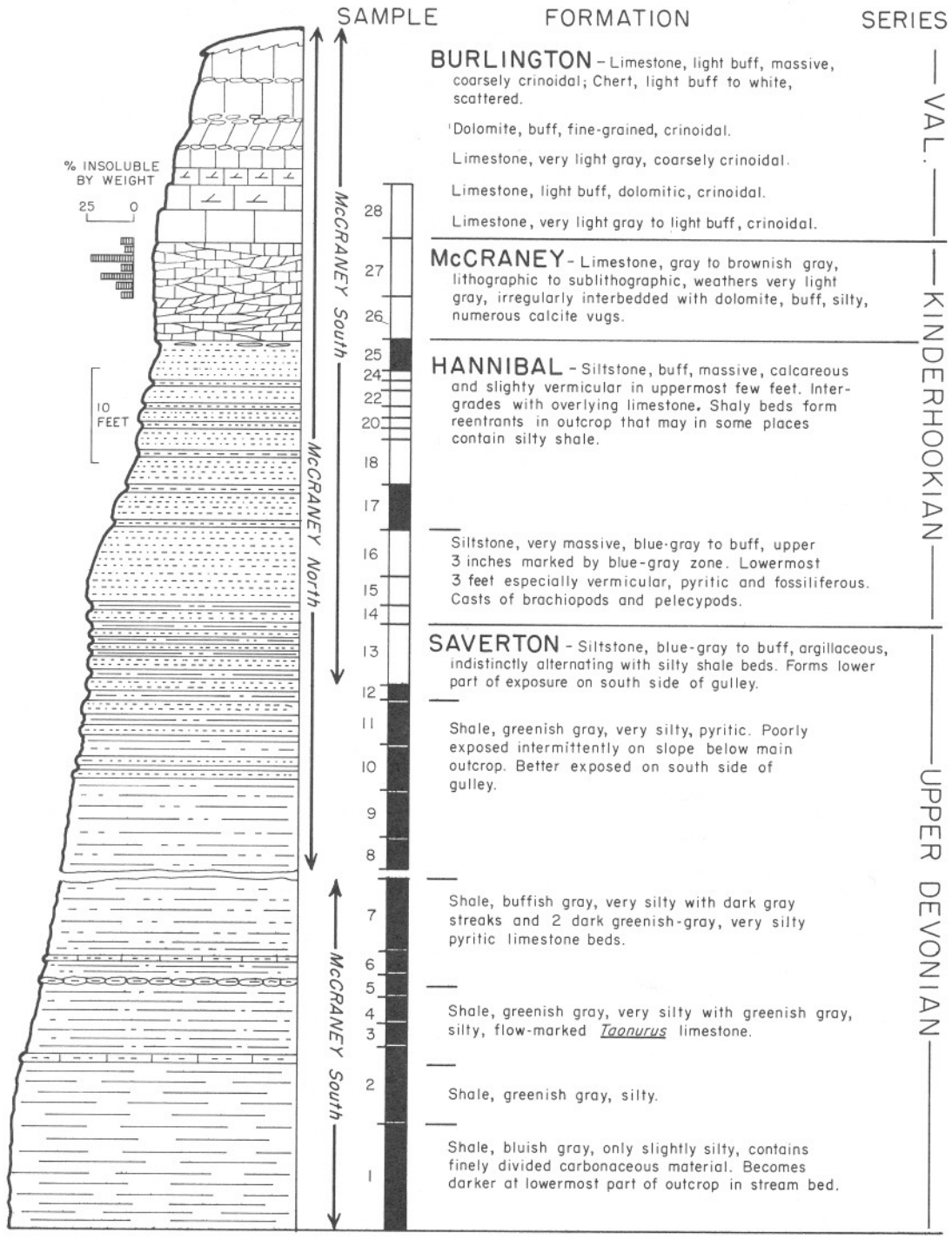


Fig. 18.—Stop 6, McCraney North. Section showing sections exposed in Mississippi River bluffs both north and south of McCraney Creek NE NE Sec. 15, SE SE Sec. 14, and NW NW Sec. 24, T. 4 S., R 7 W., Pike County, Illinois.

bluff south of McCraney Creek. The stratigraphic extent of the two exposures is indicated on the outcrop diagram (Fig. 18).

The lower end of the section consists of greenish-gray shale referred to by Moore (1929) and Workman and Gillette (1956) as Maple Mill but here referred to as Saverton. The shale of the Saverton becomes increasingly silty upward and grades into what Moore called the English River (?) sandstone member of the Hannibal. The siltstone is buff, massive and vermicular. Approximately 28 feet below the top of the unit, molds of brachiopods and pelecypods are locally abundant. Among the fossils most common are:

Schellwienella chemungensis (Conrad)
Chonetes geniculatus White
Chonetes ornatus Shumard
Chonetes cf. C. illinoisensis Worthen
Productella ? sp.
Productus curtirostris Winchell
Spirifer marionensis Shumard
Syringothyris extenuatus Hall
Pterinopectin cf. P. laetus Hall
Goniophora jennae Winchell

Spirifer marionensis and the chonetids are by far the most common.

Three-fourths of the species in this fauna are associated with the English River formation in the Burlington, Iowa area, and even though the name-giver brachiopod Chonopectus fisheri is not present, both Weller (1905) and Moore (1929) correlated the siltstone here with the English River "Chonopectus" sandstone at Burlington.

Discussion of the correlation of this section with the famous Kinderhookian sections at Burlington, Iowa are discussed elsewhere in the guidebook, but it is enough to say here that conodont faunas from the siltstone at Burlington show it to be entirely Devonian in age, whereas the conodont faunas from the siltstone here seem to show at least the upper part to be lowermost Mississippian. Because of this difference in age and because Hannibal is available for use, the name English River is not used here.

Overlying the Hannibal, the McCraney is 10½ feet thick. It is typically developed and is virtually nonfossiliferous except for a fairly abundant arenaceous foraminifera fauna. The formation consists of gray to brownish-gray, lithographic to sublithographic limestone interbedded with buff dolomite. The formation intergrades somewhat with the underlying siltstone as shown by a wavy bedded silty zone at the base. Although apparently identical in lithology to the Louisiana, the McCraney is measurably siltier. Insoluble residues from the McCraney range from 5 to 25 percent by weight and average 11 percent. Residues from the Louisiana average only 3 percent and range from a trace to 5 percent.

Northward from this outcrop, the McCraney increases in thickness to a maximum of more than 40 feet in the vicinity of Fort Madison, Iowa. Three miles north of here, the McCraney is overlain by 3 feet of siltstone referable to the Prospect Hill formation, which is indistinguishable lithologically from the siltstone of the Hannibal.

The pure, coarsely crinoidal beds of the lower part of the Burlington limestone overlie the McCraney unconformably and are relatively accessible here. Buses continue straight ahead and turn around at junction of routes 96 and 57. Return to Stop 6.

107.25 McCraney North.

108.0 Turn right at Y making junction with Route 36. Stop sign. Continue toward Hannibal.

109.9 Hull, Illinois.

118.9 Mississippi River.

119.1 Hannibal, Missouri.

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THE LINCOLN FOLD OF NORTHEASTERN MISSOURI

by
John W. Koenig

Introduction

The Lincoln fold is a feature of major importance in the tectonic structure of the interior region of North America. It, together with the Mississippi River arch, separates the Illinois basin to the east from the Forest City basin to the west. It also, with the Mississippi and Wisconsin arches, forms a discontinuous arcuate succession of highs between the Wisconsin uplift to the north and the Ozark uplift to the south. The axis of the fold strikes approximately northwest-southeast. Southeastward the fold is truncated by the Cap au Gres fault and northwestward it plunges into the subsurface toward Iowa (Fig. 1).

The early Paleozoic tectonic history of the fold is obscure because of a lack of deep drillhole information, but it is generally believed that its original inception was related to the initial uplift of the Ozark dome in post-Canadian time. Prior to this time, a thick succession of upper Cambrian and lower Ordovician sediments had been deposited in a deep syncline that extended "north from the central Ozark region into northeastern Missouri and eastern Iowa" (Lee, 1946, sheet 1).

Following subsequent areal exposure and the development of the pre-St. Peter erosion surface in the Ozark area, it is surmised that during the period of deposition of the balance of the Ordovician and lower Silurian sediments, the Ozark dome and a broad northward-trending arch in northeastern Missouri were being intermittently uplifted while basins of regional extent were being formed to the northwest in northeastern Kansas and eastern Nebraska, and to the southeast in Illinois.

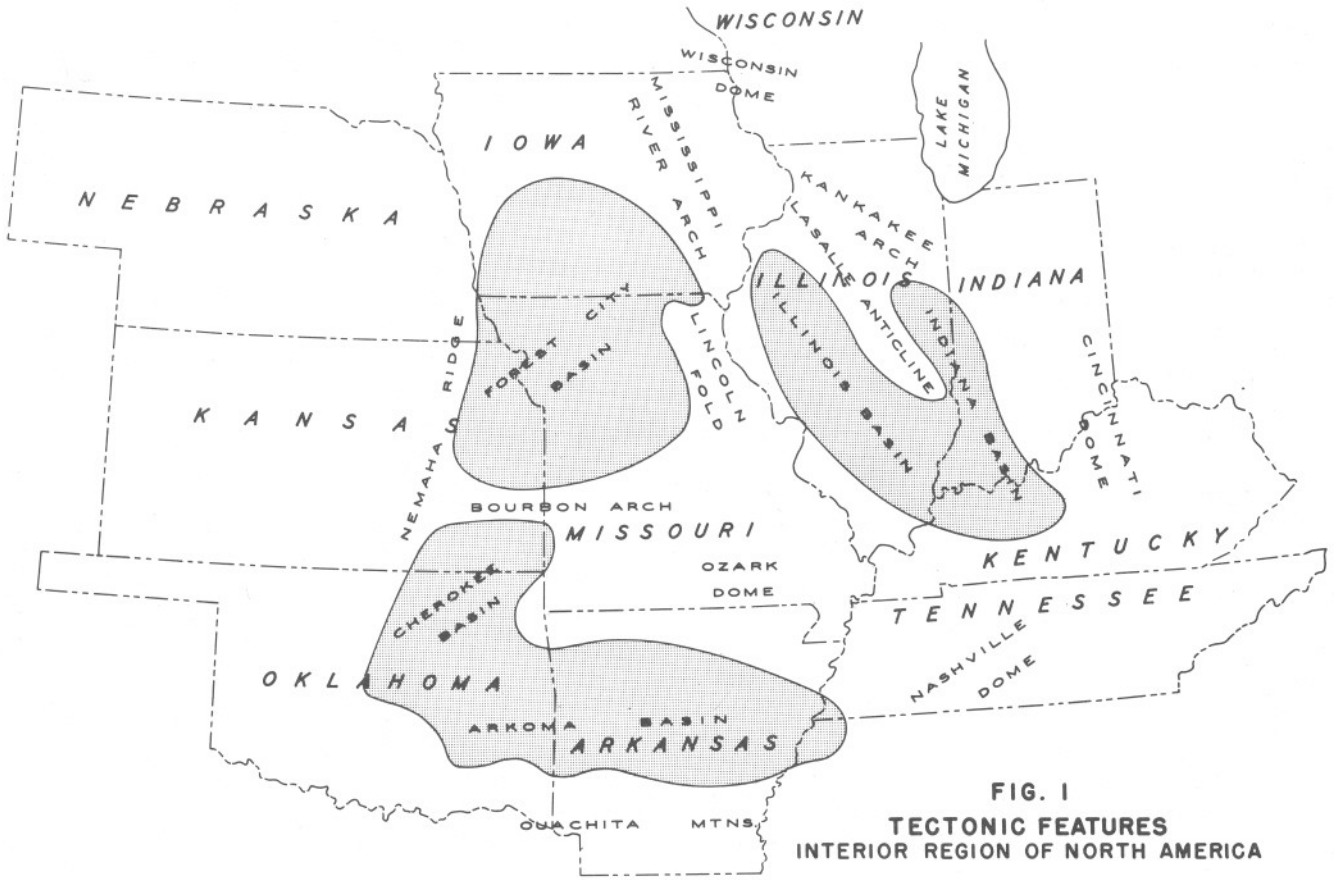

FIG. 1
TECTONIC FEATURES
INTERIOR REGION OF NORTH AMERICA

Possibly during the late part of the Silurian or the early part of the Devonian Period, the Lincoln fold began to develop as a unique structural feature. Subsequent stages of the fold's development involved recurrent episodes of erosion and deposition throughout Devonian and Mississippian time. This set of conditions culminated at the end of the Mississippian in further folding and faulting and was followed by a period of prolonged exposure when most of the Mississippian rocks were stripped from the fold. The structure was then buried beneath Pennsylvanian deposits. The balance of the fold's history has been obscured by the removal of most of the Pennsylvanian rocks from the fold following the major disturbances of the Appalachian revolution. It is assumed, however, that the area was never again inundated by a marine invasion and that the fold as well as the Ozark dome has been a prominent land-mass feature throughout the balance of geologic history.

Stratigraphy

The sedimentary rocks that are exposed in the fold area range in age from early Ordovician (Canadian) to middle Pennsylvanian (Desmoinesian). The accompanying chart (Fig. 2) shows only the formations of this sequence that will be seen during this field conference.

ILLINOIS			MISSOURI			KANSAS			
PENN.			PENN.	DESMOINESIAN SERIES	Blackjack Creek	PENN.	M. PENN.	DESMOINESIAN STAGE	Blackjack Creek
					Excello				Excello
		Cheltenham		ATOKAN SER.	Cheltenham				
MISSISSIPPIAN	VALMEYERAN SERIES	Burlington	MISSISSIPPIAN	OSAGEAN SERIES	Burlington	MISSISSIPPIAN	LOWER MISSISSIPPIAN	OSAGIAN STAGE	Burlington
		"Sedalia"			Pierson ?				
	KINDERHOOKIAN SERIES	Starrs Cave (Chouteau)		KINDERHOOKIAN SERIES	Chouteau gp. undif.			KINDERHOOKIAN STAGE	Gilmore City
		Prospect Hill (Chouteau)							Sedalia
		Mc Craney (Chouteau)							Chouteau
		Hannibal Nutwood Mbr.			Hannibal				Boice
		"Glen Park"	DEV. OR MISS.		"Hamburg oolite"				
DEVONIAN	UPPER DEVONIAN SERIES	Louisiana			Louisiana	DEV. OR MISS			Chattanooga
		Saverton			Saverton				
		Grassy Creek			Grassy Creek				
		Sylamore							
	M. DEVONIAN SERIES	Cedar Valley	DEV.	M. DEVONIAN SERIES	Callaway	DEV.	M. DEV.		
SILURIAN	NIAGARAN SERIES	Joliet	SILURIAN			SILURIAN	L. SIL.		"Hunton" Gp.
	ALEXANDRIAN SERIES	Kankakee		ALEXANDRIAN SERIES	Sexton Creek				
		Edgewood			Bowling Green mbr. Edgewood Cyrene mbr. (Noix oolite)				
ORDOVICIAN	CINCINNATIAN SERIES	Maquoketa	ORDOVICIAN	CINCINNATIAN SERIES	Maquoketa	ORDOVICIAN	U. ORD.		Maquoketa (Sylvan)
	CHAMPLAINIAN SERIES	Kimmswick Subgp.		CHAMPLAINIAN SERIES	Kimmswick		M. ORDOVICIAN		Viola (Kimmswick)
		Decorah Subgp.			Decorah				Simpson Gp.
		Plattin Subgp.			Plattin				
		Joachim			Joachim				

FIG. 2
GENERALIZED STRATIGRAPHIC SECTION
LINCOLN FOLD AREA AND KANSAS COUNTERPART

The oldest exposed rocks of the Lincoln fold belong to the Cotter formation which crops out along the Mississippi River bluffs in southeastern Lincoln County. They are situated at the crest of the fold immediately north of the Cap au Gres fault. The Cotter consists of light gray to brown, fine- to medium-grained, cherty dolomite. Oolitic chert in the form of thin discontinuous beds and nodules, and sandstone and green shale in thin beds are constituents of secondary prominence.

The St. Peter formation crops out at several places along the crest of the fold in Lincoln County north of the Cap au Gres fault between the towns of Winfield and Foley. It is characteristically a massive quartzose sandstone which is white to light gray on fresh surfaces but which weathers to a dirty gray or brown. The sand grains are fine to medium grained in size, are rounded and frosted, and well sorted.

The Joachim formation is the oldest rock unit of the fold area that will be seen on this trip. It consists of a yellowish-brown, argillaceous dolomite and contains interbedded limestone and shale in its lower part. It crops out at various places on the crest of the fold in Lincoln County, and its northernmost exposure is on Spencer Creek just north of the Pike-Ralls County line in the vicinity of U. S. Hwy. 61.

The overlying Plattin formation, an evenly bedded dark gray, fine-grained to sublithographic, fossiliferous limestone, is exposed in a few places in northeastern Lincoln County and in northeastern Pike and Ralls Counties. In some places the weathered fucoidal limestone in the upper part of the formation bears a strong resemblance to the weathered "honey-comb" structure of the younger Kimmswick.

The Decorah formation, which intervenes between the Plattin and Kimmswick, is a very fossiliferous unit of interbedded greenish-brown shale and gray to browm limestone. The basal part of the formation contains one or two thin beds of metabentonite. The Decorah in the fold area is usually found in or near areas where the Plattin is exposed.

The Kimmswick formation is a distinctive light gray to grayish-white, coarse-grained limestone that is prominently exposed along the crest of the fold in a number of places in Pike and Ralls Counties. Its most characteristic feature is that the weathered surfaces of the limestone are profusely pitted, so much so that the descriptive phrase "honey-comb structure" is very apt.

The Maquoketa formation, overlying the Kimmswick and completing the Ordovician succession, is exposed over most of the fold area, but it is absent in northern Ralls County where Devonian rocks lie on the Kimmswick. The Maquoketa is a thinly bedded, silty, slightly calcareous, dark greenish-gray to brown shale. In the lower part, the formation is interbedded with thin beds of gray to brown argillaceous limestone.

The Silurian rocks in the Lincoln fold area are represented in Missouri largely by the Edgewood formation which consists of the lower Cyrene member and the upper Bowling Green member. The Cyrene member of the Edgewood is a light gray, medium- to coarse-grained limestone which contains an oolitic facies that is referred to as the Noix oolite. The Bowling Green member is a yellowish-brown, fine- to medium-grained dolomite and is usually thickly bedded.

A few scattered outliers of the overlying Sexton Creek formation complete the Silurian section in northeastern Missouri. These outliers are present on the east flank of the fold near the Lincoln-Pike county line. Here the formation is a white to light gray fine-grained, siliceous limestone which contains a small amount of slabby, milk-white chert. In Illinois, the Kankakee formation which is regarded as the equivalent of the Sexton Creek, is partially exposed near the town of Hamburg in Calhoun County where it is a hard, massive, fine-grained to dense, buffish-gray limestone.

In west-central Illinois, the Kankakee is overlain by the middle Silurian Joliet formation, exposures of which are restricted to Calhoun County. It is hard, massive, fine-grained, light gray limestone that is difficult to distinguish from the Kankakee formation. The Joliet or rock of equivalent age is apparently absent in Missouri.

The middle Devonian Period in the Lincoln fold area of Missouri and Illinois is represented by two formations of varied lithologies but of equivalent age. The Missouri Devonian formation is named the Callaway, and that of Illinois, the Cedar Valley. The Callaway in the

vicinity of the fold in Missouri is in many areas composed of light gray, fine-grained to lithographic, conglomeratic limestone. In some of these areas, the formation also contains thick beds of sandstone, siltstone, shale and limestone which is almost completely composed of masses of Stromatopora. In Illinois, the Cedar Valley formation consists mainly of a very fossiliferous brown to buff limestone that is sandy both at top and bottom. Some of the sandstone in the upper part of the Cedar Valley of Illinois produces oil in the Colmar-Plymouth oil field.

Overlying the Devonian Callaway and Cedar Valley formations and underlying the Mississippian Hannibal formation, both in Missouri and Illinois within the area of the Lincoln fold, there is a succession of rock units which has been the subject of much debate for a number of years. Geologists of the Illinois Survey are currently inclined to believe that this succession, with the exception of the formation which they designate as "Glen Park", is Upper Devonian in age. Geologists of the Missouri Survey currently refrain from making a definite age assignment for this same succession including the "Glen Park" of Illinois and prefer to regard it as assignable to either the Devonian or Mississippian. In ascending order, the formations of the succession are named the Sylamore, Grassy Creek, Saverton, Louisiana, and "Glen Park"-"Hamburg".

In Illinois the Sylamore is composed of a thin, widespread bed of oxidized, brown sandstone which throughout much of the area overlaps both the Cedar Valley and Joliet formations and rests on the Kankakee. The presence of sandstone of a similar character and stratigraphic position has been reported in the Lincoln fold area of northeastern Missouri at several localities but no formal assignment of the unit has been made in this area other than to include the unit in the lower part of the Grassy Creek formation which also contains other thin sandstone beds higher up in the formation.

The Grassy Creek is a dark, olive-gray to brownish-black, hard, fissile, carbonaceous shale which is somewhat sandy at the base within the fold area of Missouri. It is exposed at a number of places on the flanks of the fold both in Missouri and in Illinois. Conodonts and spores are commonly present in the formation.

The Grassy Creek is overlain by the Saverton formation in most of its exposures in the fold area. The Saverton is a greenish-gray or bluish-gray silty to sandy, fissile shale. The upper part of the unit in most places is a bluish-gray, calcareous mudstone, and in a few outcrops the upper half of the formation contains a bed of light gray to reddish-brown friable sandstone.

The Louisiana formation is unique because of the amount of conversation which it engenders among geologists in this part of the country. Its age has been debated for years, but to date complete agreement has not been reached. Another interesting topic for discussion which arises over the Louisiana is its relation to or with the McCraney formation of Illinois. Complete agreement has also not been reached on this issue. The Louisiana and the McCraney are almost lithologically identical. Both formations are composed of dense to lithographic, bluish-gray hard, brittle limestone which breaks with subconchoidal fracture. The beds of limestone are about 3 to 6 inches thick and are separated by yellowish-brown, dolomitic partings. The Louisiana is exposed at numerous places on the flanks of the fold in Missouri, but exposures of the McCraney are limited within the fold area to a small area of northern Pike County in Illinois.

In northern Calhoun and in southern Pike Counties, Illinois, just east of the Mississippi River, as well as in Jersey, Greene, Macoupin, Montgomery, and Bond Counties, Illinois, and at one locality in Pike County, Missouri, a rock unit of oolitic conglomerate and limestone occurs at the top of the Louisiana formation. In the single Missouri outcrop near Starks Nursery west of Louisiana, the oolitic limestone is temporarily regarded by Missouri geologists as being the correlative of the "Hamburg oolite" of Illinois. However, many geologists would consider this unit to be part of the "Glen Park" formation of Illinois, which is well exposed near the south edge of the town of Hamburg, Illinois. Here, the Glen Park" consists of a lower unit of interbedded silty, somewhat sandy, dark gray limestone and soft, yellowish-brown, argillaceous siltstone, and an upper unit of calcareous siltstone which grades into slabby brownish-gray limestone the upper part of which is oolitic and conglomeratic.

Throughout the fold area both in Illinois and Missouri, the overlying Hannibal formation of the Mississippian System is widely exposed. The Hannibal is a gray to bluish-green, silty

shale that contains beds of very fine-grained sandstone in its upper part. In Illinois, a dark gray to black, noncalcareous, platy shale in the lower part of the Hannibal has recently been designated as the Nutwood member. This subdivision has not been recognized in Missouri.

On the southwest flank of the fold in Missouri and in Calhoun County, Illinois, on the northeast flank, there are numerous exposures of gray, fine-grained, slightly argillaceous limestone. In eastern and southern Illinois, this unit is referred to as the Chouteau formation. In northeastern Missouri, it is regarded as an undifferentiated part of the Chouteau group which in central Missouri consists of three formations, the Compton, Sedalia, and Northview. In Illinois, it is believed that the McCraney, Prospect Hill, and Starrs Cave formations in the northeastern part of the state are equivalent to the Chouteau formation of the southern and eastern parts.

Another formation in the Illinois-Missouri area of the Lincoln fold which has given rise to a good bit of lively discussion in years past is the Sedalia formation. In central Missouri where the formation was originally defined, the formation is a brown to buff dolomitic limestone and it underlies the Northview formation which is a silty shale. The age of the Sedalia, as well as that of the Northview, is now considered by Missouri geologists to be Kinderhookian, but when it was defined by Moore in 1928 (p. 149) the Sedalia was thought to be Osagean in age. Overlying the Northview in central Missouri, there is a thin unit of yellowish-buff dolomitic limestone which can be traced into southwestern Missouri where it thickens and is named the Pierson formation which faunally has proven to be Osagean in age. It is believed that this same thin unit of central Missouri extends eastward and northward into the Lincoln fold area where it is tentatively recognized as the brown dolomitic limestone bed at the base of the Burlington formation. It is possible, therefore, that the unit, which is designated as "Sedalia" in Illinois, may be the equivalent of what is thought to be an extension of the Pierson into northeastern Missouri.

The Burlington formation is the most widely exposed formation in the Lincoln fold area both in Missouri and Illinois. It lies on all flanks of the fold and even cuts across the crest of the fold in a wide belt between Louisiana and Bowling Green in Pike County, Missouri, thereby giving a hint to a minor structure in that area which has not been investigated but which may be significant in the solution of many of the area's unresolved stratigraphic problems. The Burlington consists of white to light buff, very coarse-grained, fossiliferous, crinoidal limestone in which layers and nodules of white to light gray chert are common, especially in the upper part. Throughout most of Missouri it is difficult to determine the thickness of the Burlington because of its close similarity and conformable relations with the overlying Keokuk formation. It is believed, however, that in the northeastern part of Missouri the Burlington is from 70 to 100 feet thick and that the Keokuk is from 60 to 70 feet thick.

The Pennsylvanian System in the fold area is represented by isolated remnants of rock that have been identified as belonging variously to the Cheltenham, Excello, and Blackjack Creek formations. Because these units are fully described elsewhere in this guidebook by W. V. Searight and T. K. Searight, the reader is referred to their article for a discussion of the relation of the Pennsylvanian units to the fold.

Oil and Gas Possiblities

Although Missouri is considered to be a dry state insofar as its oil and gas potential is concerned, it would be an oversight not to mention here the exploration possibilities that are present within the fold area.

In 1952, the Laclede Gas Company of St. Louis, in the process of drilling some reconnaissance wells in the Florissant area south of the Cap au Gres fault in northern St. Louis County for the development of an underground gas-storage structure, encountered oil in the Kimmswick formation immediately beneath the Maquoketa shale. By 1954, approximately 75,000 barrels of oil had been produced from the field. Even though the production was small and short lived, it did indicate that similar oil-producing structures might be present elsewhere in the vicinity of the Lincoln fold farther to the northwest. A short article was published in the January 3, 1955 edition of the Oil and Gas Journal by the late Earl McCracken of the Missouri Survey staff drawing attention to the oil possibilities that exist along the axis of the Lincoln fold, and from his statements it is quite clear that the Lincoln fold can not be ruled out of future explorations plans.

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THE LINCOLN FOLD IN LINCOLN, PIKE, AND RALLS COUNTIES, NORTHEASTERN MISSOURI.*

by

Henry S. McQueen, Norman S. Hinchey, and Kenneth Aid

Structure of the Lincoln Fold

The Lincoln fold is a structural feature of regional proportions. Insofar as the available evidence is concerned, it is the largest structural feature as to length and structural relief between the Nemaha granite ridge and the associated Forest City basin on the west, and the Illinois basin on the east. In addition to its size, the fold is characterized by structural and stratigraphic complexity, and probably by a long and interesting geologic history.

The Lincoln fold may be described as an asymmetrical anticline, with a general regional axial strike of N. 45° W. The southwest side of the fold is marked by steep dips, and in some localities by faulting. The northeast flank of the fold is marked by comparatively gentle dips, and faulting is not known to occur on that flank.

The Lincoln fold is not a simple anticlinal structure, but rather is a regional uplift upon which are superimposed anticlines, domes, synclines and faults. The length of the fold within Missouri, from the point at Winfield, Lincoln County, where the structure can first be observed in eastern Missouri, to the point where it crosses the Iowa state line, measures approximately 165 miles. The width of the fold varies, but the area involved may measure as much as 15 miles in a direction transverse to the axis.

The fold has a maximum structural relief of approximately 1000 feet. This figure is obtained by using outcrops and well logs in eastern Lincoln County and represents a difference in the estimated elevation of the top of the St. Peter sandstone at points approximately one mile, or less, apart. The total closure is not definitely known, but it certainly measures as much as 300 feet at places.

The fold has a marked influence upon the distribution of the geologic formations in the area which it underlies.

At the point near where it enters Lincoln County, U. S. Survey 736, T. 49 N., R. 2 E., 1 mile north of Winfield, the lower Ordovician (Cotter dolomite) is exposed along the crest of a local anticline superimposed upon the Lincoln fold. It is overlain by the St. Peter sandstone which is in turn succeeded by the normal Ordovician sequence.

The southwest side of the structure in this locality is marked by faulting which brings the upper part of the Plattin limestone into approximate contact with the Cotter dolomite. This point is perhaps one of the best for a study of the structure, and splendid exposures may be seen in the bluff in the rear of the Tiller farm house in U. S. Survey No. 736. This point also attracted the attention of the earlier geologists and it was here that Keyes applied the name Cap au Gris [sic] fault. The structure at this point has been shown in cross sections by Krey, and that seccion is reproduced in this report (Figure 57) [Figure not reproduced in present publication].

The axis of the fold appears to plunge northwest from this point and strikes in a general direction of N. 70° W. into the southwest portion of T. 50 N., R 1 E. Here a change in strike

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*This excellent article by McQueen, Hinchey, and Aid was originally published in the Fifteenth Annual Field Conference of the Kansas Geological Society in 1941 (pp. 99-110, figs. 57-59). The major portion of the article on the structure of the Lincoln fold is republished here because of its appropriateness to the present conference and because the compilers of this guidebook feel that it excels any other description that could be written at this time. The compilers, however, have taken the liberty of adding a structure map of the Lincoln fold that has been drawn on the surface of the Devonian limestone succession to illustrate the northwestern aspect of the fold in the subsurface of northeastern Missouri (Fig. 2).

occurs and the axis trends in a direction of approximately N. 10° to 20° W. through the northeast corner of T. 50 N., R. 1 W., through the east part of T. 51 N., R 1 W., and into the south part of T. 52 N., R 1 W., Pike County.

In the northeast part of T. 50 N., R 1 W., and through T. 51 N., R. 1 W., there are a series of local domes or anticlines which bring the older beds to the surface. In these areas the St. Peter sandstone is exposed. One of the stops of the conference [1941] (Number 28, SE/4 Sec. 4, T. 50 N., R 1 W.) is in this general area. The strike of the fold across Pike County is approximately N. 20° W. Local folding is also present, and faulting may have occurred in the general vicinity of Bowling Green, T. 53 N., R 3 W., Pike County. Much of the area in this locality is upland country and details are lacking due to poor exposures.

The axis of the fold continues into Ralls County in a direction of N. 20° W. to a point near New London, T. 55 N., R. 4 W., where the strike changes to approximately N. 70° W. and continues in this direction to the vicinity of Spalding, T. 56 N., R. 6 W., where the strike changes to N. 30° to 50° W. This trend, with changes similar to those previously described, is followed to the southwest part of T. 67 N., R. 19 W., Putnam County, where the fold crosses the Iowa state line.

Local doming is known to occur in Ralls County, in Sec. 28, T. 55 N., R. 4 W., where the Joachim formation, which overlies the St. Peter sandstone, is at the surface. This is the last and northernmost known outcrop of this formation in the upper Mississippi Valley. Local folding, or doming, is also known to occur near Spalding, T. 56 N., R. 7 W., Ralls County. Inliers of Devonian limestone occur in T. 57 N., R. 7 W., and their occurrence may be due to local uplifts upon the Lincoln fold.

The presence of Hannibal shale, NE/4 NW/4 Sec. 26, T. 60 N., R. 10 W., near Newark, Knox County, has been reported by Moore. This occurrence also may be due to local doming, although the Hannibal crops out to the southeast. Other areas of local folding on the regional Lincoln fold have been indicated in other parts of Knox County by subsurface studies.

The faulting associated with the Lincoln fold is of the normal high-angle type. Locally, small blocks and slivers within the faulted zones may be slightly overturned, but this would be reasonably expected, the size and complexity of the fold being considered.

In the areas marked by faulting, steep dips are common. In the U. S. Survey 736, T. 49 N., R. 2 E., on the Tiller farm, one mile north of Winfield, the Cotter dolomite on the upthrown side shows gentle dips into the fault plane. The beds on the downthrown side, ranging in age from Plattin (Ordovician) to St. Louis (Mississippian), show high dips.

The situation is reversed, however, on the Kimler farm, center SE/4 Sec. 4, T. 50 N., R. 1 W. On the upthrown side the dip increases as the plane of the fault is approached, and in contact with that plane dips of 65° and more may be observed. A few yards from the plane of the fault on the downthrown side, the beds are horizontal and show little or no disturbance.

Additional detailed geologic work, with specific reference to the structure, is needed before a complete description of the Lincoln fold can be written. The foregoing brief summary, however, may serve to present a few facts regarding the size and complex nature of this regional feature.

Geologic History

In presenting this brief geologic history of the Lincoln fold, it should be kept in mind that no complete, detailed geological survey of the Lincoln fold in its entirety has been made. Information is lacking in large areas of poor or no outcrops. Unfortunately these areas have not been drilled.

The early geologic history of the Lincoln fold is obscure. The oldest formation exposed is the Cotter dolomite which, in the area, is overlain by the St. Peter sandstone. The Cotter formation is best exposed on the Tiller farm, and in the bluffs to the north in U. S. Survey 736, T. 49 N., R. 2 E. Only a very limited number of deep wells have been drilled in this area into the pre-St. Peter section. As a result there is but little evidence pertaining to the age of the earliest movement of the Lincoln fold. A number of wells have been completed in the top of the St. Peter, however, and the history can be sketchily traced since that time.

An Ordovician limestone (Kimmswick, Decorah, Plattin, Joachim) isopach map does not suggest any continuous, or definite, axial trend which corresponds in direction and magnitude to the structural axis of the Lincoln fold as it is known at present, but there appears to have been doming in Pike, Ralls, and possibly Lincoln counties at the end of Kimmswick (Trenton) time and prior to the deposition of the Maquoketa (Richmond) shale. Although adequate control is lacking, there is a suggestion that the top of these domes might reasonably have, if connected, a northwest-southeast trend aligned with that of the present structure. There is also a suggestion of northeast-southwest folding, or elongation, of some of these domal structures. At the close of Maquoketa (Richmond) time there appears to have been gentle eastward tilting, but there is no evidence of pronounced regional folding.

Deposition of the Silurian rocks followed. Whether or not deposition was affected by structural movements, however slight, is a matter of conjecture. Along the present axis of the fold, however, the Edgewood formation probably reached its maximum thickness near Bowling Green, Pike County. At the end of Silurian time, there was probably regional movement in the present area of the fold and the rocks were tilted to the east and southeast. The pattern of the present distribution of the Silurian may have been partly established at this time.

As the Silurian, which is present in this area, is followed by late Middle to Upper Devonian limestone, a long hiatus occurs in the record of the geologic history. In Ste. Genevieve County, southeastern Missouri, Weller has described "faulting that doubtless took place early in Upper Devonian time and probably immediately after the close of the Hamilton epoch". Movement of the Lincoln fold probably occurred at this time, also.

A long period of erosion followed and the early Devonian rocks, if ever deposited, were eroded. The period of erosion which followed resulted in the removal of the Silurian rocks and also the Maquoketa shale in the area of the fold north of T. 56 N., Ralls County; and in this area, and north to the Iowa line, the available evidence shows the Devonian rocks are in contact with various members of the Kimmswick formation of Ordovician age.

Devonian rocks were deposited in the area, but at the close of the period of deposition of the Devonian (Callaway) limestone, the area was again subjected to uplift and erosion and the axis of the fold was probably rejuvenated along the line of its present trend. There also may have been regional tilting of the structure to the northwest and the subsequent removal, or thinning, of the Devonian limestones over what is now the higher portions of the Lincoln fold in Pike and Lincoln counties. Erosion was sufficient to also remove some of the Silurian which remained in this area.

Deposition of the Grassy Creek shale over most of the area of the fold followed. This shale rests upon the Maquoketa, the Silurian, and the Devonian limestones. The unconformity at the base of, and the regional overlap of the Grassy Creek upon older formations may be of significance in considering the problem of the boundary of the Devonian and Mississippian. The Grassy Creek shale was followed by the Saverton shale, which is overlain in turn by the Louisiana limestone. The latter may have been tilted eastward following its deposition.

The Hannibal shale and Mississippian limestones ranging from the Chouteau to the Ste. Genevieve were then laid down.

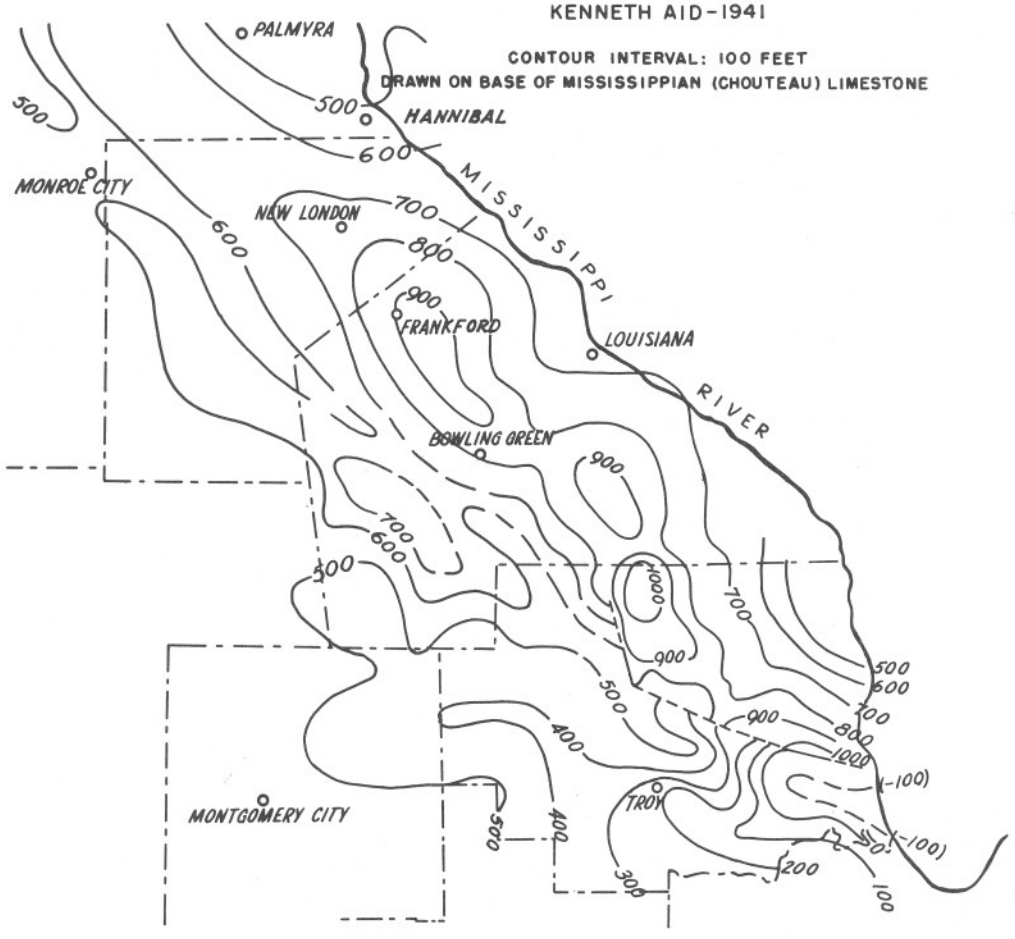
At, or near, the close of Mississippian time, the fold reached its maximum structural development and attacined much of its present configuration. The precise time of folding cannot be determined accurately due to the absence of the Upper Mississippian (Chester beds). The folding, however, may have occurred at the end of Chester time and, if so, is probably related to that interval between the Mississippian and Pennsylvanian, to which the term "Bendian" is often applied. From the available evidence, the faulting so nicely displayed between Winfield and Foley, T. 49 N., R. 2 E., Lincoln County, occurred during this period. To this fault the name Cap au Gris was given by Keyes. Faulting has also been noted in T. 50 and 51 N., R. 1 E., Lincoln County. Stop Number 28 of the fourth day [1941] will afford an opportunity to observe the faulting in this locality. Northwestward tilting of the fold took place, and what is now the highest point on the fold was probably defined. A long period of erosion followed this major period of movement. The Mississippian limestones were eroded and, at the beginning of Pennsylvanian deposition, formations ranging from possibly the Hannibal, and certainly the Burlington, to the Ste. Genevieve were exposed. That there was local doming along the axis of the fold at the end of Mississippian time is suggested by the presence of older Mississippian formations in contact with the Pennsylvanian in some areas where younger

Mississippian beds are also in contact with Pennsylvanian beds in the same general locality.

The late history of the fold is obscure, due to absence of the younger Pennsylvanian beds. Rejuvenation of the fold took place, however, as the Cherokee, Henrietta and Pleasanton beds are gently arched over it. No faulting affecting the Pennsylvanian beds is known at present. Due to the lack of deep drilling in the area of the fold underlain by Pennsylvanian sediments, no information is available relative to the amount of folding which involves the Pennsylvanian rocks. The late history, however, is probably not unlike that of similar regional structures in the northern Mid-Continent region which possess the same axial alignment.

A generalized structure contour map of the Lincoln fold in Lincoln, Pike, and Ralls Counties accompanies this paper. This map is drawn on the base of Mississippian (Chouteau) limestone as a datum and has a contour interval of 100 feet (Fig. 58) [Fig. 1 of present publication].

FIG. 1
GENERALIZED STRUCTURE MAP OF THE LINCOLN FOLD
BY
KENNETH AID-1941



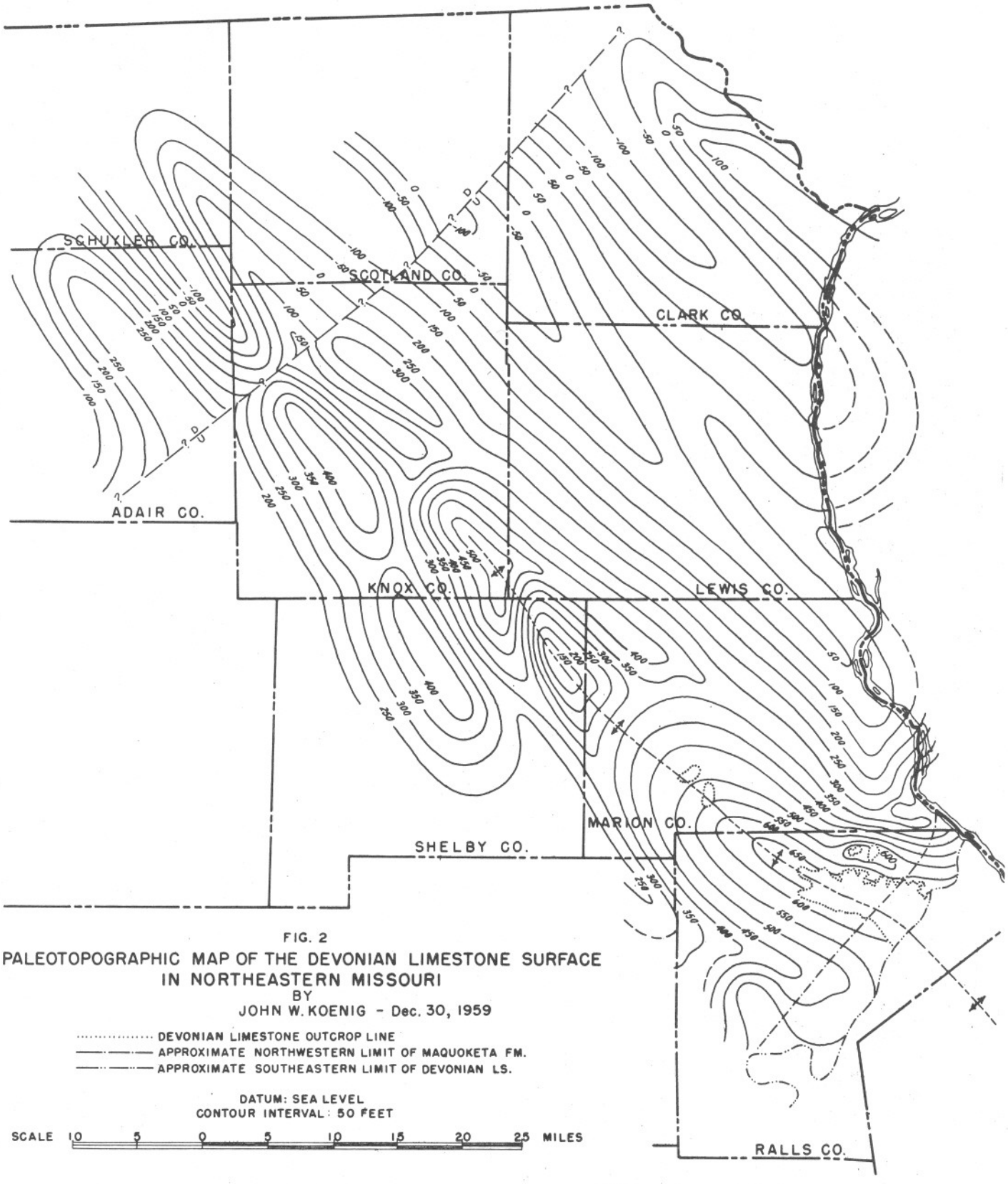


FIG. 2

PALEOTOPOGRAPHIC MAP OF THE DEVONIAN LIMESTONE SURFACE IN NORTHEASTERN MISSOURI

BY

JOHN W. KOENIG - Dec. 30, 1959

..... DEVONIAN LIMESTONE OUTCROP LINE

—·—·— APPROXIMATE NORTHWESTERN LIMIT OF MAQUOKETA FM.

—··—··— APPROXIMATE SOUTHEASTERN LIMIT OF DEVONIAN LS.

DATUM: SEA LEVEL

CONTOUR INTERVAL: 50 FEET

SCALE 10 5 0 5 10 15 20 25 MILES

THE CAP au GRES FAULT

by Virgil B. Cole

The Cap au Gres Fault in west-central Illinois and east-central Missouri is the key to the tectonics of an area characterized by structural and stratigraphic complexity (Fig. 1). Lying between the Ozark Uplift to the south and the Illinois Basin to the northeast, it has relevance to understanding the geologic history of a large region. The generally east-west trending fault is shown on a configuration map on top of the Precambrian basement in relation to axes of the Lincoln Fold and Dupo-Waterloo Anticline, which are structural features of regional proportions and are critical to understanding the genesis of the Cap au Gres Fault.

Geology of the region has been dicussed by Worthen (1870), Keyes (1894), and Weller (1906). The Lincoln Fold, described by McQueen (1941) and by Rubey (1952), is a broad asymmetrical anticline. Rubey concluded that deformation of the fold continued intermittently throughout a long part of geologic time; preliminary movements in middle Paleozoic time culminated in

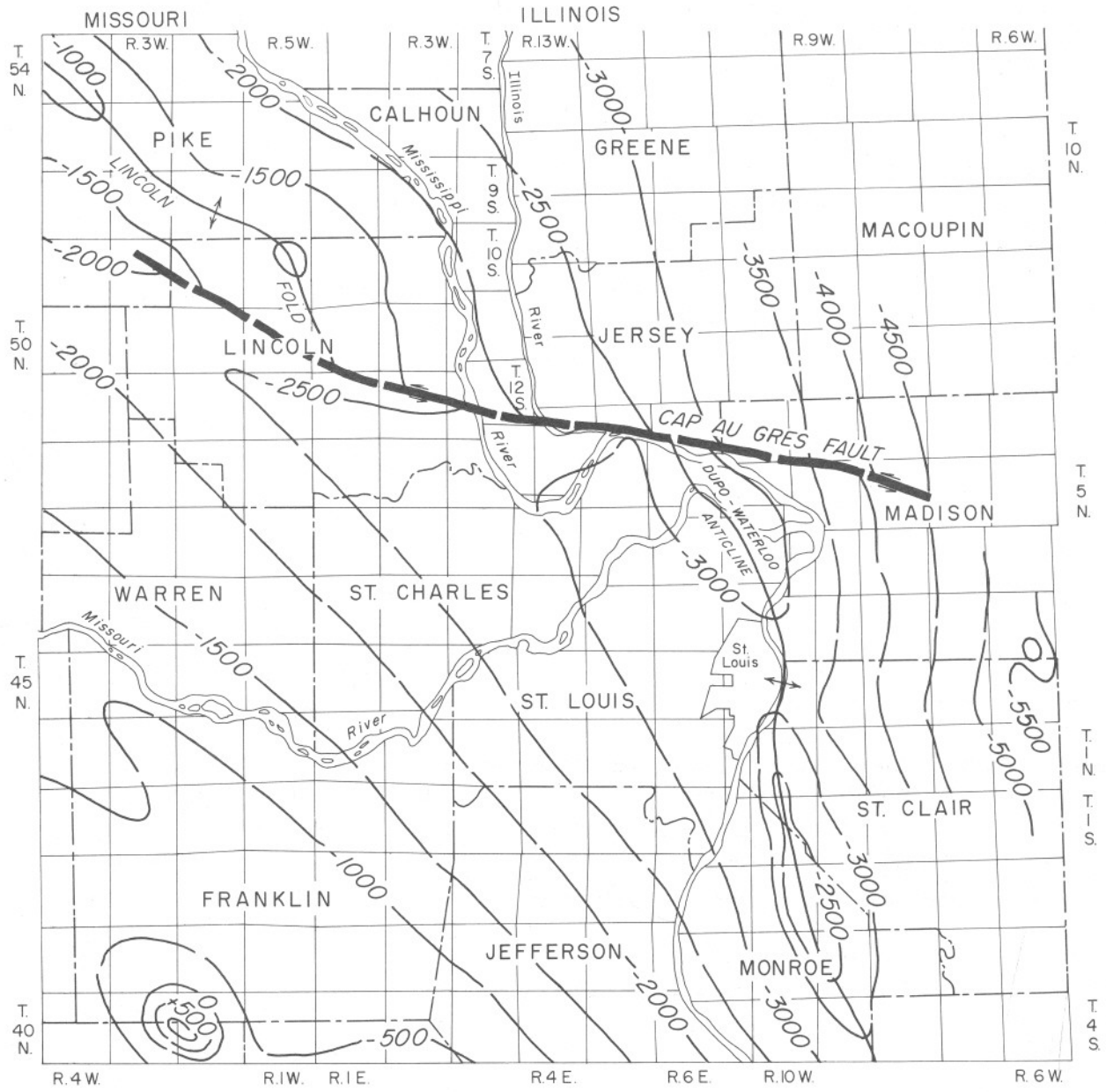


Fig. 1 -- Cap au Gres Fault Area.

a major deformation before Pennsylvanian time and waned with minor uplift continuing to the present. Physiographic evidence shows that later recurrent movements took place before the Pleistocene ice advances, and Heck (1928) suggests that nine earthquakes between October 1857 and May 1920 may have centered in this area.

The Dupo-Waterloo Anticline, mapped by Weller (1911), strikes N. 10° W., and has a steep west flank. Oil was discovered on the structure in about 1920 and as recently as the 1950's additional reserves were discovered at Florissant along the structure. Oil is produced from the Kimmswick limestone at depths from about 400 to 900 feet.

The Cap au Gres Fault derives its name from Cap au Gres Landing just east of Winfield, Missouri, on the Mississippi River (Keyes, 1894). Gres, or sandstone, refers to the St. Peter sandstone, which is exposed at the water's edge on the Illinois side of the river. Rubey (1952) described the east-west Cap au Gres faulted flexure as a narrow band of steeply dipping rocks and discontinuous faults. South of the fault zone, rocks of lower Paleozoic age are steeply upturned whereas north of the zone beds dip gently downward into the fault. Rubey judged that the presence of a long, continuous fault could not be justified by surface work, but recognized that the Cap au Gres Fault was one of the sharpest zones of rock deformation in Illinois. In his regional interpretation, Rubey showed that the fault is related to the Lincoln Fold, and that both the fault and fold are related to the Ozark Uplift. He concluded that steep dips along the Cap au Gres Fault are not the result of drag folding along a normal fault, but are caused by horizontal compression or that the structural features of the area might be accounted for by movements along a deep-seated reverse fault which did not reach the surface.

Rubey's work shows that regardless of the character of the fault, the upthrown side is on the north. In Missouri, Grohskopf (1933, 1941) determined from magnetic data and subsurface information that the upthrown side is to the north and that the throw is approximately 1,100 feet. Mateker (1956) determined vertical displacement of at least 1,000 feet based on gravity investigations and found a gravity low indicating low density material on the upthrown or north side of the fault. In Illinois, Douthit(1959) concluded from magnetic work that the Cap au Gres is a long continuous fault upthrown on the north 1,000 to 1,100 feet. His information indicated that the faulting may extend deep into the basement.

Figure 1, showing configuration on the Precambrian surface, is based on three wells drilled into Precambrian rock (Sec. 7, T. 47 N., R. 7 E. and Sec. 25, T. 45 N., R 6 E. in Missouri; Sec. 35, T. 1 S., R. 10 W. in Illinois) and numerous tests into Ordovician rocks. The Lincoln Fold can be traced readily from the Iowa state line southward where it terminates against the Cap au Gres Fault in Lincoln County, Missouri. The Dupo-Waterloo Anticline can be traced northward from Monroe County to where it terminates against the fault in Jersey County, Illinois.

The Arbuckle is thinner on the Dupo-Waterloo Anticline than in the synclinal area to the west. The Arbuckle, including both Cambrian and Ordovician rocks, increases in thickness from west to east. A recently completed Precambrian test in the Louden field 85 miles northeast of St. Louis substantiates an increased thickness eastward as does another test drilled forty miles south of Chicago that penetrated a thick section of Arbuckle. Seemingly then, the Dupo-Waterloo Anticline is an old feature that was high as early as Lamotte time and had some of the Arbuckle reduced by erosion. The Lincoln Anticline had a similar history.

The structural grain of Missouri is N. 40-45° W. as shown on the Precambrian. Other major structural trends, as well as fractures and faults, parallel this grain. The Camden High is northwest trending as is the Boone or Browns Anticline in Boone and Calloway Counties. The Lincoln Fold also has a northwest alignment to where it intersects the Cap-au-Gres Fault, and the Dupo-Waterloo Anticline exhibits a similar trend south of the fault.

If the Dupo-Waterloo Anticline is an offset southern continuation of the Lincoln Fold, the Cap au Gres may be interpreted as a left-lateral fault. Evidence for this conclusion is: (1) similar early history of the Lincoln Fold and Dupo-Waterloo Anticline; (2) structural gain discontinuity at the fault terminating both the Lincoln and Dupo-Waterloo structures; (3) sudden change in strike of surface features from northwest to east-west along the intensely faulted area; (4) anomalous density and magnetic susceptibility discontinuity at the fault; and (5) the high angle of the fault as observed on the surface which is characteristic of strike-slip faulting in many places. Furthermore, McQueen (1941) shows the Lincoln Fold to be

about fifteen miles in width throughout its length (see Fig. 1), whereas Rubey shows the Cap au Gres Fault only 1,000 to 1,500 feet wide involving nearly vertical beds and only two miles north of the disturbed zone the dip flattens to less than 2 degrees.

It seems possible then from the foregoing evidence to conclude that the Cap au Gres is a left-lateral fault that has experienced movement of approximately 30 miles, offsetting the Lincoln Fold and Dupo-Waterloo Anticline.

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BASAL RELATIONSHIPS OF THE MISSISSIPPIAN IN NORTHEASTERN MISSOURI

by
Maurice G. Mehl

An understanding of the basal relationships of the Mississippian in northeastern Missouri is best gained by comparing the stratigraphy of this province with that to the southwest of the Lincoln fold. A discussion of the relationships in each of these areas involves many localities where the boundary between sediments of Mississippian and Devonian age must be drawn. Among the several boundary formations, the "black" shales (Grassy Creek in northeastern Missouri) are commonly considered the key factor in age assignment. Were the age of these shales agreed upon, other stratigraphic units like the Sylamore, Bushberg, Saverton, Louisiana, Glen Park, and Hamburg could be interpreted and "age-assigned" with some assurance.

The difficulties in fixing the age of the Grassy Creek and similar shales are obvious and to some extent, apply to all of the boundary formations. This shale, very widespread over North America, records an environment hostile to most of the organisms commonly used in making stratigraphic correlations. Most stratigraphers find it impossible to become familiar with the many techniques required in the study of the meager endemic biota afforded, and they are forced to align themselves with the opinion that seems best supported by competent observers. The choice of age assignment of these shales is between Devonian, as presented by Cooper, et al., in 1942, "transitional", as proposed by Campbell in 1946, and Mississippian, as outlined by Weller, et al., in 1956. If there has been any trend in opinion, either before or after these summary statements, it is probably toward transitional, regardless of the multi-million year time gap between the "black shales" and the oldest generally recognized Mississippian, as indicated by recent dating figures.

One of the most promising approaches to the solution of the black shale problem is the study of conodont faunas. Nearly three decades ago, Branson and Mehl (1933a) pointed out that there are several distinct genera abundantly represented in the Grassy Creek and other Devonian formations--genera that are not to be found indigenous to any strata generally agreed upon as Mississippian in age. It was likewise shown that there is an equally large number of genera which are common in rocks generally recognized as Mississippian but which are never found in sediments generally recognized as Devonian.

These authors accepted this distribution of conodont "markers" as good evidence that the time gap between the Mississippian and the Devonian is one of the greatest in the Paleozoic column. I believe that the majority of specialists in conodont studies now recognize this gap, although they may not evaluate its importance to the same degree.

In a "Progress Report" (Mehl, 1960) on investigations of the boundary problem, undertaken at the request of the Missouri Geological Survey, I have presented conodont distribution data in the graphic form herewith reproduced in Figure 1. This is calculated to help in visualizing the "conodont-evidenced gap" in North America by comparison with the standard section of Central Europe.

The obvious interpretation of the data presented is that the Devonian continued appreciably longer in Europe than in North America and that in Europe, Mississippian started slightly later than in North America. The higher range of "Devonian markers" in Europe adds species that are not found on our continent. In evaluating these data, it is well to keep in mind the fact that the upper two zones of the Upper Devonian of Europe have not been satisfactorily identified in North America by any means.

Second only to conodont studies in promise of usefulness is the remarkably abundant and considerably varied megaspores found in the "black" shales. Present studies of these organisms indicate that they too register a sharp break between the two systems, and it is likely that zones within the shales can be correlated with some degree of certainty. The importance of these spore studies justifies more than brief mention, and a progress report on them is included in another section of the publication. It is hoped that with some of the techniques suggested the nonspecialist will find it possible to make use of, and to contribute to, the rapidly accumulating data.

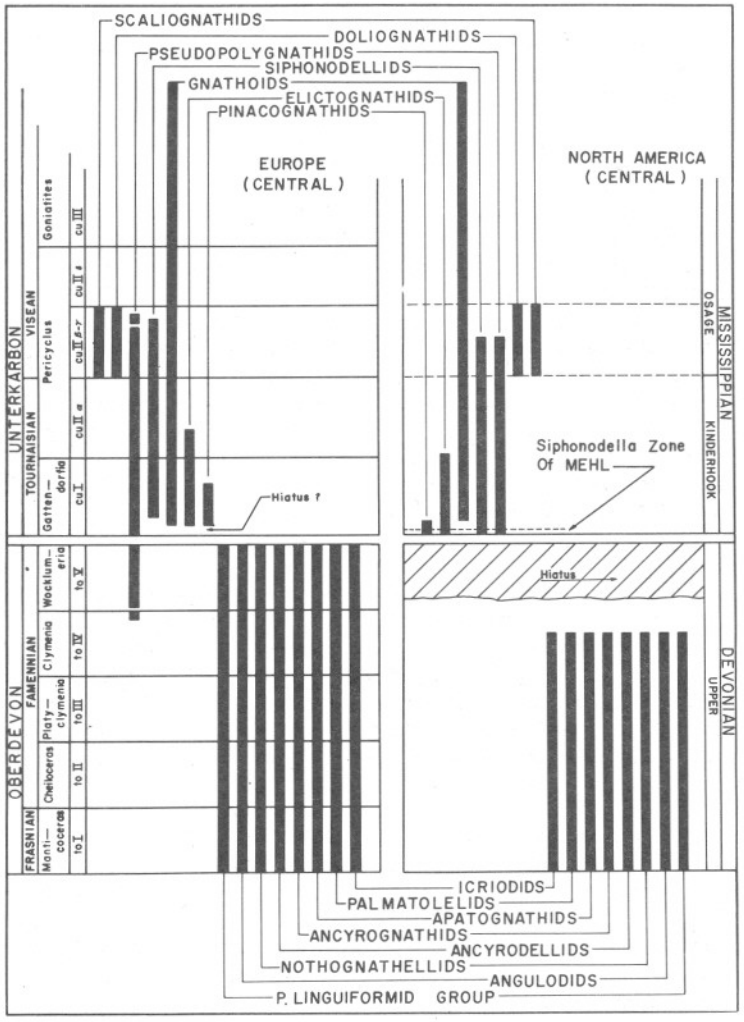

Fig. 1 -- Vertical distribution of key conodont genera in North America and Europe showing Mississippian basal relations. Two genera, Scoliognathus and Doliognathus, are included to illustrate widespread correlation possibilities. The upward vertical extent of Devonian "markers" in North America is not to be interpreted as the exact time of extinction but as an indication of a time gap of considerable magnitude.

Another important factor in placing the Devonian-Mississippian boundary is the interpretation of the very widespread, comparatively thin sandy clay or sandstone zone commonly found immediately beneath the oldest sediments that are generally recognized as Mississippian (the Chouteau and equivalents over much of Missouri).. This is the zone that was commonly called "Sylamore" before Branson and Mehl (1933b) designated it as "Bushberg". In the progress report mentioned above, both of these terms are abandoned for designation of this zone, and it is now called "the Siphonodella zone of the Bachelor sandstone".

On Sylamore Creek, Stone County, Arkansas, in the NW NW Sec. 31, T. 15 N., R. 11 W. (a location considered to be the type for the Sylamore sandstone), the "black shale" totals about 10 feet. At the base of the shale there is a massive sandstone 2 feet thick. Within the shale , there is one or more thin beds of sandstone and a zone of sandstone lenses. At the top of the shale, there is sandstone and sandy shale totaling 12 to 20 inches. All of these sands contain Upper Devonian conodonts as does the shale. Above the highest Devonian sand at this locality is a thickness of 3 to 4 feet of sandstone that contains typical Mississippian

conodont markers--not the oldest Mississippian, but late Kinderhookian or early Osagean in age. It is evident that "Sylamore" was meant to apply to one or all of these sands. Proposals to redefine the Sylamore sandstone in the light of the above evidence have not been followed generally, and it seems best to drop the name from Missouri stratigraphy.

The sandstone at Bushberg in Jefferson County, Missouri, is considered to be the type for the formation by that name. It contains no fossils that are useful in correlation excepting perhaps a fair abundance of spores. This sandstone can be traced with some degree of assurance over limited areas in Jefferson, St. Louis, and Franklin Counties. The evidence of the spores indicates Devonian age. Farther to the west in Warren, Montgomery, Callaway, and Boone Counties, the Massie Creek occupies a similar stratigraphic position and is possibly the time equivalent of the Bushberg, in part at least. The Massie Creek contains a fairly abundant Devonian megafauna. The megafauna described as Bushberg by E. B. Branson (1938) has been duplicated in the general vicinity designated in Branson's paper, but the source sandstone cannot at present be correlated with either Bushberg or Massie Creek. The fauna is unique and may well represent some facies of the Massie Creek. It seems clear that the widespread zone designated as the Siphonodella zone is the oldest Mississippian in North America and not the equivalent of the Bushberg.

The Bachelor sandstone represents initial sedimentation of the Mississippian throughout Missouri. Over its greatest extent by far, it varies little in thickness, averaging less than a foot, and its conodont fauna seems to represent a very short period of time. In limited area, particularly in the east-central part of the state, there was land elevated above the general "invasion plane". As the Mississippian sea encroached upon these areas, the basal sand represents successively later time and lacks the conodont fauna typical of the earliest invasion. This later deposition involves a "time-lag" up to the end of the Kinderhookian. At the type locality, the Bachelor is overlain by a few feet of upper Chouteau limestone, and in places nearby it is directly overlain by Burlington. Not only does the Siphonodella fauna fail to record a "cross over" of the "Devonian markers", but the spore assemblages that are typical of the Upper Devonian are not duplicated in the Mississippian.

The accompanying diagram (Fig. 2) shows the assignment of the several "boundary formations" in Missouri as they are now conceived. Several new names are applied to stratigraphic units as the best alternative to transferring the name of a unit of one province to a unit in another without sufficient evidence of the exact correlation which is implied by the use of a common name.

Some Details of the Mississippian Basal Relationships in Northeastern Missouri

The Hannibal represents the oldest Mississippian sediments to the northeast of the Lincoln fold, except in a few places where it is underlain by comparatively thin, limited patches of Cuivre shale. The Siphonodella zone, characteristic of the base of the Mississippian in most of the area southwest of the fold, is not represented in either the Hannibal or Cuivre, although it is abundantly represented along the down-thrown side of the Cap au gres fault. Here, in a shale beneath the Chouteau, near the Mississippi River bluff a short distance north of Winfield in Lincoln County, the Siphonodella fauna is typically developed.

The concentration of casts of Taonurus caudigalli attachment bulbs--in some places an almost continuous bed--occurs near the base of the Hannibal in many places in Pike, Ralls, Marion, and Monroe Counties.

The Cuivre shale, named from Cuivre Township in Pike County, Missouri (type locality NE SE Sec. 35, T. 54 N., R. 3 W), is dark bluish-gray, blocky to fissile, with thin lenses of pyrite cemented sand. Its distribution is scattered and patchy varying in thickness in a short distance with a maximum of about 12 feet. At the type locality, it is set off from the Hannibal by a sharp color line and lithologic change with stringers of Hannibal penetrating the Cuivre. The indigenous conodont fauna is close to that of the Hannibal but differs in several important details. There is no semblance of a Siphonodella zone. The sandstone lenses contain, in addition to the indigenous fauna, an exceptionally large number of "reworked" Middle Devonian conodonts. The numerous small brachiopods found in the sand lenses are probably derived from earlier sediments. Some may choose to consider that the Cuivre represents a facies or is a member of the Hannibal rather than a formation.

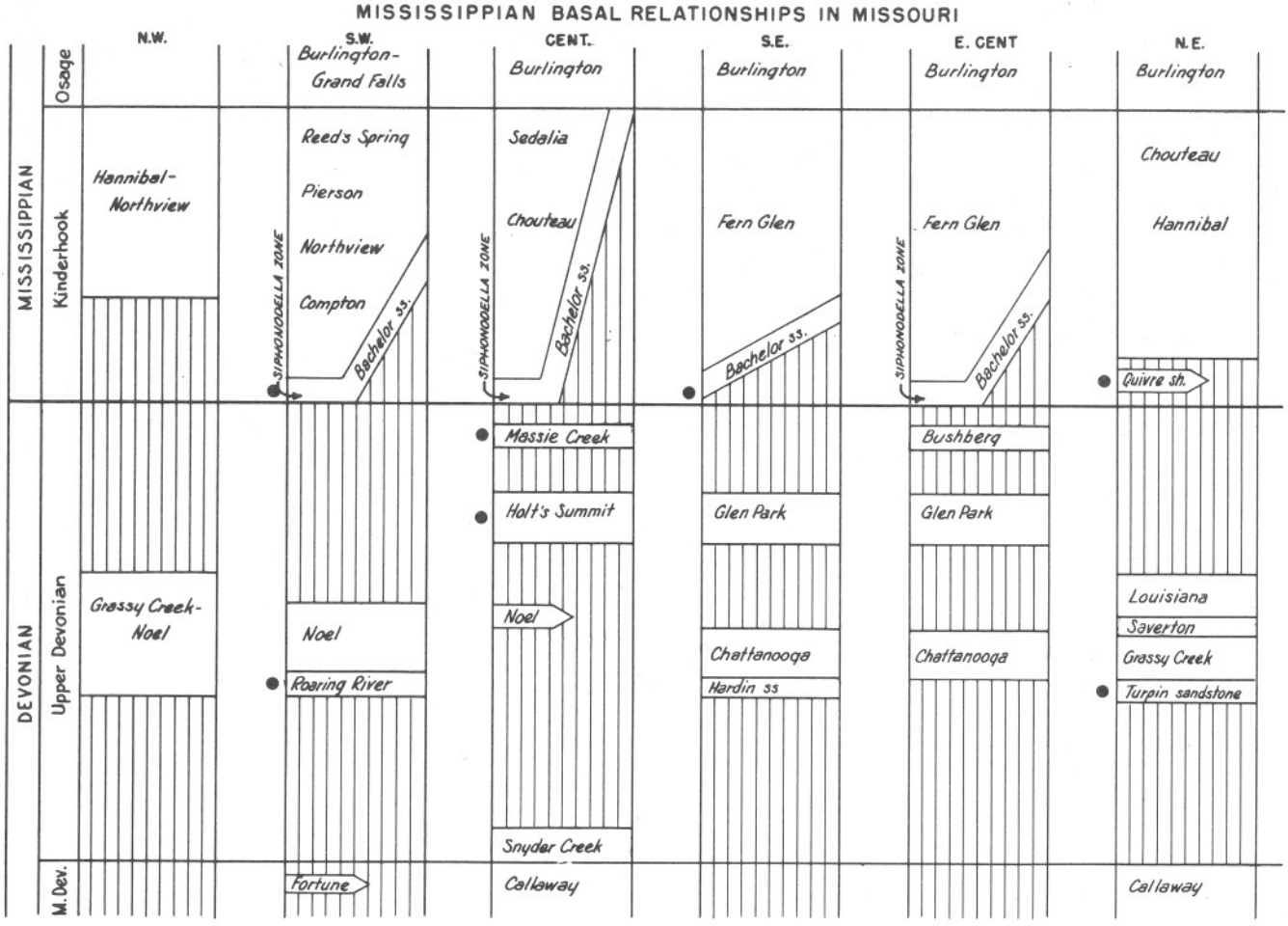

Fig.2 -- Basal relationships of the Mississippian in Missouri. Thickness of units are not drawn proportionately, and corresponding vertical partitions of units in the several columns does not necessarily indicate time equivalence.

The Grassy Creek-Saverton-Louisiana complex leaves many questions unanswered. Even the boundary identification of the units have not been satisfactorily established in the opinion of some, and the age of each is still questioned by many. The fact that the major outcrops on Grassy Creek, about six miles due west of Louisiana (NW SE Sec. 19, T. 54 N., R. 2 W) are Maquoketa shale rather than Grassy Creek has led to the suggestion that another locality be selected as the type of the formation. It has, in fact, been stated that there is no Grassy Creek at the locality named.

There are several places where the Grassy Creek is thicker and better exposed than on Grassy Creek, but all of these exposures change from year to year and even seasonally. The presence of an appreciable thickness of the Grassy Creek shale at the type locality has been verified at the time of the writing. Some excavation is now necessary, as is usually the case. The lower contact is marked by a "micro-conglomerate" in the base of the Grassy Creek. This seems to be the case in every region where the base is exposed. The upper contact is not currently clear on Grassy Creek.

The Saverton-Grassy Creek relationship picture was confused by Branson and Mehl in 1933 through generalizations based on observations in too few, and not sufficiently widely separated localities. They interpreted a zone of limited thickness between the Louisiana and Grassy Creek, correctly in most cases, I believe, as weathered Grassy Creek in part and in part the initial sedimentation of the Louisiana. This led to the conclusion that the Saverton and the

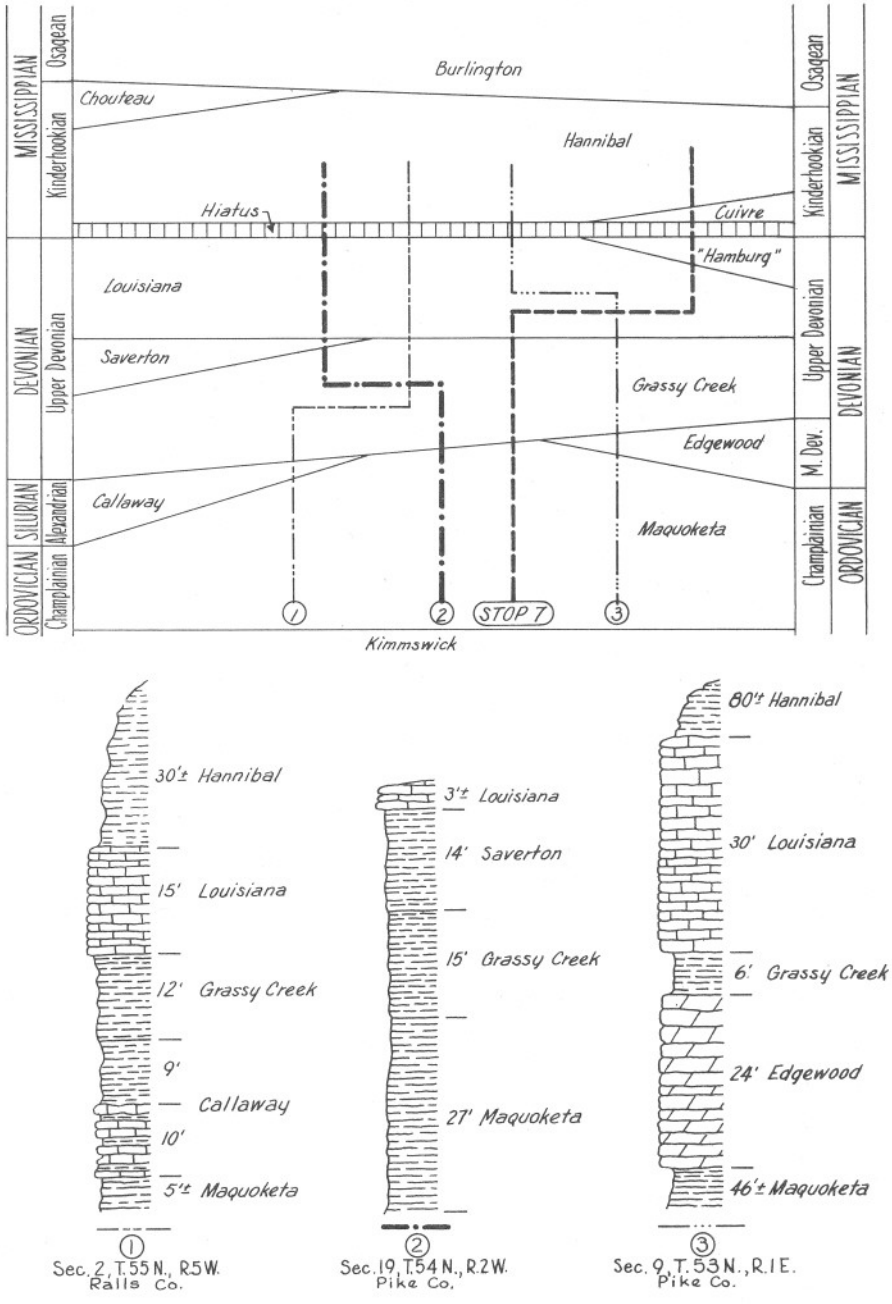

Fig. 3 -- Mississippian-Devonian "boundary" formations in northeastern Missouri. Thicknesses are not proportional, and lateral arrangements of units is a matter of convenience. There is some doubt as to the identification of the Chouteau to the northeast of the Lincoln fold. Coded lines related with the columnar sections show some of the variety in vertical succession of strata.

Grassy Creek were synonymous and ignored the considerable thicknesses of greenish-gray shale and siltstone which do not rest on Grassy Creek shale.

Although all of the important Upper Devonian conodont genera were identified in "the Grassy Creek proper", conodonts are not nearly so abundant in this formation as in the Saverton and are much more difficult to process for description. In reviewing Branson and Mehl's "Grassy Creek conodont localities", it is evident that the great majority of the specimens figured by these authors came from what I now consider Saverton. It follows that many of the details of the faunas of these two stratigraphic units have not been made known.

Although the study of Grassy Creek spores has progressed to the point where some generalizations can be made safely, our work with the spores of the Saverton and the Louisiana have not advanced far enough to permit meaningful comparison of assemblages. That there are differences is already evident.

The megafauna of the Louisiana is neither typically Mississippian nor Devonian, but the limited conodont fauna available is clearly indicative of Devonian age. At several localities where the Louisiana is underlain by a few inches to a foot or more of yellowish-brown clay, calcareous silt and siltstone (Town Branch in Louisiana, for instance) a megafauna similar to that of the Louisiana suggests that the silt is the initial sedimentation of that formation.

There is a great similarity between the megafossils and the spores found in the Glen Park of east-central Missouri and the Hamburg near its type locality in Illinois. The spores strongly indicate Devonian age of both.

The Turpin sandstone, 5 feet or more thick at the type locality (SW SW NE Sec. 3, T. 52 N., R. 1 E.) is reduced to a sand or conglomeratic zone of from one-half inch to somewhat less than a foot at the base of the Grassy Creek in the greater part of its extent.

In the somewhat generalized sections to show varied basal relationships of the Mississippian in the northeastern province (Fig. 3), the "Hamburg oolite" is included. It is known in the single outcrop in Pike County (Stop 7). According to George H. Fraunfelter (personal communication), the crinoids of this outcrop bespeak Devonian age.

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SPORANGITES AS "HORIZON MARKERS"

by

Maurice G. Mehl and Bernard Shaffer

For nearly a century, geologists have been interested in the "yellow, translucent discs, ranging from one one-hundredth to one two-hundredths of an inch in their longest diameter" that are found in the Ohio shale and similar "black" Devonian-Mississippian shales of North America. In general, they have designated these sporelike bodies as Sporangites, following J. W. Dawson who described Sporangites huronensis from the Upper Devonian shale at Kettle Point on Lake Huron in 1871. Although the generic name is considered a nomen ambiguum and Tasmanitis is substituted, there is no reason why stratigraphers should not continue to use the earlier name (without its generic typography) to designate the category without generic or specific identification.

Early in his study of the basal relationships of the Mississippian in Missouri, the senior author was confronted with the problem of identifying and correlating isolated patches of "black shale" in northeastern, centraleastern, southeastern, and southwestern Missouri and, of course, in adjacent states. Recognizing that, of the limited biota in these shales, only the "spores" approached unlimited distribution, a means was sought for their evaluation, in each outcrop, that would have a comparable speed to that involved in collecting and evaluating megafossils in other formations. A rapid extraction procedure was finally evolved which has proven very useful, regardless of its several obvious disadvantages. This is outlined below and is offered as an aid to, rather than as a substitute for, the much slower and more precise techniques of conventional spore study. It is likely that others have found the same or a similar solution for problems of megaspore study but have not yet brought their "short-cut" method to the attention of nonspecialists among "field stratigraphers".

Generous samples, each including a vertical section of 4 to 12 inches, are taken in sufficient number to cross the entire outcrop. To process the samples efficiently, they must be dried either through time-lapse or in an oven at low temperature. Pilot samples from each, weighing 200 grams or less and selected by mixing and dividing the original, are fed through a crusher with the jaws of the crusher set at 2 mm or less. This splits a large percentage of the spores from this matrix with negligible damage to the spores. The coarser product of crushing (plus 40 mesh) is stored for other studies. The fine material is placed in a beaker, covered with a generous amount of carbon tetrachloride, and gently agitated from time to time. When the liquid is poured from the beaker through a cloth filter, it is common experience to find that a few hundred or a few thousand spores have been segregated. These are cleaned in an acetone or other low surface-tension bath by means of an ultrasonic vibrator. Various degrees of bleaching with commercial bleach may be helpful. The total spore collection may be scanned under a microscope at relatively low magnification within a few minutes after the start of processing (Fig.1).

A composite spore collection from a suite of 18 samples representing 12 feet of Grassy Creek shale shows marked differences from zone to zone without specific or even generic identifications. The variations in total numbers are most pronounced, but size proportions from sample to sample are also conspicuous. Varied proportions between thick- and thin-walled specimens, when judged from intensity of color, the varied degrees of bleaching with standard time and bleach, and the nature of the deformation that has resulted from the compaction of the sediments, seem to have meaning. Comparison of the composite spore picture of one outcrop with that of another, even at localities as widely separated as northeastern and centraleastern Missouri, seems to justify the correlation of one or more zones from each.

A check of the results of the mechanical extraction method against the results of total extraction by the slower but more precise conventional methods described below shows discrepancies of considerable magnitude. It was to be expected that different beds would respond differently to mechanical extraction of spores, but it was not anticipated that a "barren" sample from this method might be generously productive by the other. It was discovered that one or more of the groups of comparatively small, thin-walled spores of the black shales fail to disassociate from the matrix and are essentially missing in all mechanically processed samples. Whether the value of the quicker inspection method is impaired beyond this "partial

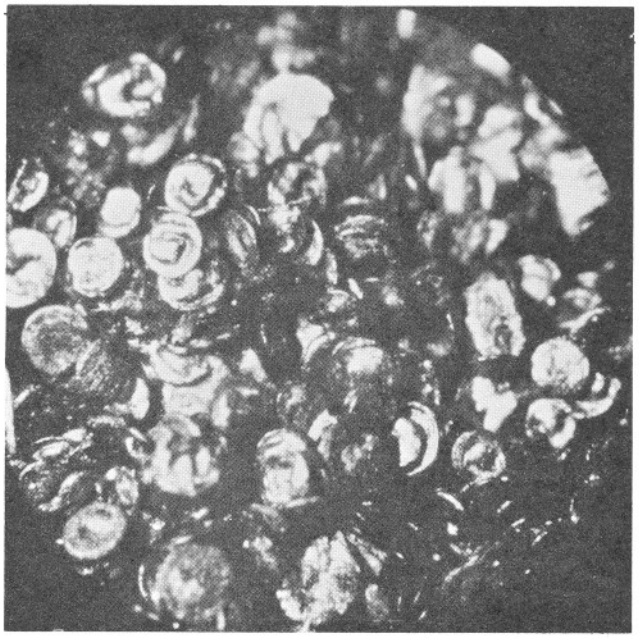

Fig. 1 -- Photomicrograph of mechanically extracted sporomorphs (Tasmanites) from a small sample (about 200 grams) of Grassy Creek shale.

picture" difficulty is not determined. It is hoped that ultimately we will be able to place a simple effective tool for the study of these shales in the hands of the stratigrapher.

Conventional Study of Grassy Creek Sporangites

As noted above, preliminary, acid maceration investigations by the junior author indicate that certain forms of Tasmanites, as well as associated acid-insoluble micro-fossils such as hystrichospherids, chitinozoans, some scolecodonts, and microspores, are not recovered by the carbon tetrachloride, flotation technique. A second aspect of this study directed toward the possibility of establishing biostratigraphic zonation which could ultimately be useful in correlation involved chemical separation. Acid maceration techniques were applied in the investigation of the vertical distribution and relative abundance of various types of Tasmanites recovered from the Grassy Creek shale.

A control section southwest of New London, Missouri, was selected where about 12 feet of Grassy Creek shale is well exposed. At this locality, the Grassy Creek is delimited by middle Devonian green shale below and the Louisiana limestone above. Alternate samples, 9 of the 18 described above, were selected from the Grassy Creek, and the underlying and overlying units were also sampled and processed by the standardized technique outlined below:

1) Large fragments of shale from each sample were washed and scrubbed to remove surface contamination. Each sample was then mechanically crushed into fragements with a maximum size of about one-eighth inch in diameter.

2) About 50 grams of each sample were placed in a glass beaker and the carbonates were removed with hydrochloric acid. Excess acid was washed from the residue with water.

3) The residue was transferred to a copper beaker, and clays and quartz were removed by gentle boiling in hydroflouric acid (52 percent) for 15 minutes. Excess acid was again washed from the residue.

4) Silico-flourides were removed by briefly boiling the residues in dilute hydrochloric acid and excess acid was washed from the residue.

5) The remaining organic sludge was oxidized by treatment for 30 minutes, with commercial bleach (5 percent sodium hypochlorite). Fine, disseminated debris was removed by successive decanting. The Tasmanites were bleached and rendered amenable

to study with transmitted light and high magnification.

6) A water miscible medium (Clearcol) was used to mount the spore-bearing residue on microslides for study.

Microfossils referred to the genus Tasmanites are defined as spherical (originally), unicentric, sporelike bodies lacking haptotypic features or tetrad marks. These sporomorphs, usually compressed to circular discs, are without projecting exterior relief or sculpture, but the coat or exine of most forms is characteristically marked by pores, canals, or punctae. Tasmanites probably does not represent the specialized reproductive spore of any vascular land plant. It is thought by some that it is an independent micro-organism, possibly with algal affinity.

Criteria utilized in the descriptions of forms presented here include gross morphological features, dimensions, thickness of the exine, nature and disposition of the pores, and color. The following "types", which are illustrated in Figure 2 are from the Grassy Creek shale in Section 2, T. 55 N., R.5 W., Ralls County, Missouri.

Tasmanites Type I

This type is represented by sporomorphs that are comparatively small, ranging in diameter

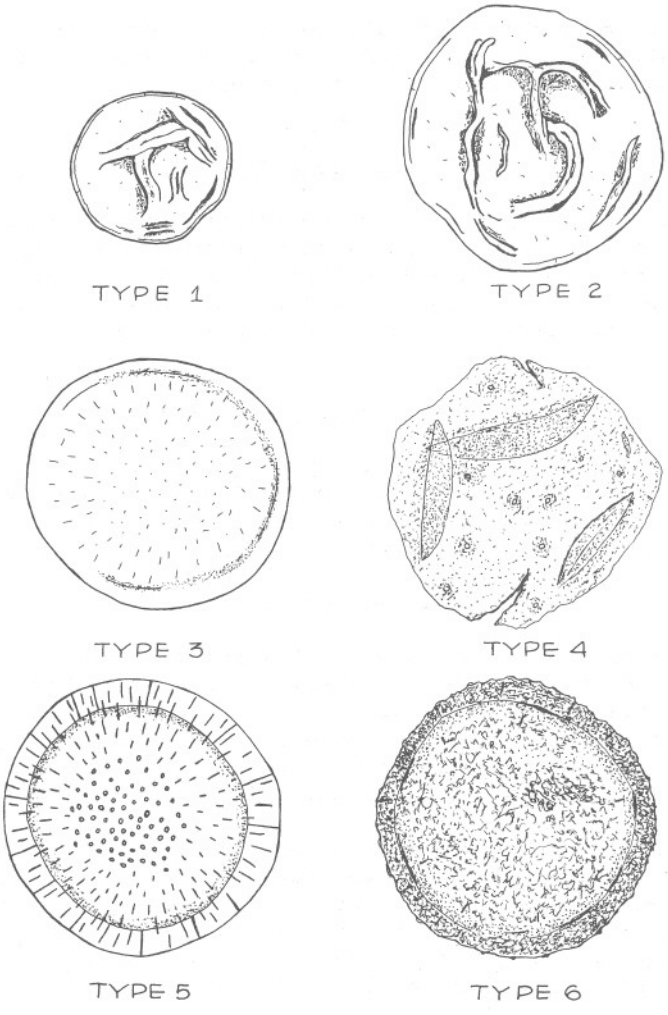

Fig. 2 -- Six types of sporomorphs (Tasmanites) found in the Grassy Creek shale. Freehand sketches, about x200.

from 60 to 130 microns. The exine is smooth, about 4 microns in thickness, and generally intensely folded. The pores are few in number, (indistinct in some specimens) widely dispersed over the surface, and appear to penetrate the entire thickness of the exine. This form, which is transparent and very light yellow in color, is the most abundant type in the upper part of the Grassy Creek shale in the control section.

Tasmanites Type II

This form is similar to Type I, but it is consistently larger, ranging from 175 to 240 microns in diameter. The exine is thicker (up to 8 microns), may or may not be folded, and is rarely marked by pores. It is light yellow in color, and only slightly transparent. This type is abundant in the lower part of the Grassy Creek shale in the control section.

Tasmanites Type III

The diameters of the sporomorphs in this group range from 110 to 260 microns. The exine is 8 to 14 microns thick, is not folded (or only slightly so), and is penetrated by numerous minute pores which assume various orientations on slightly folded specimens. On the central region of unfolded specimens, the pores appear as dots on the surface of the exine. This form is light reddish-brown in color. It is common in all samples and abundant in the lower part of the Grassy Creek control section.

Tasmanites Type IV

The diameters of this form range from 180 to 300 microns. The exine is very thin, is always folded and commonly torn, and is usually badly weathered, corroded, and pitted. The nature of the pores is indeterminate. The type is abundant in the upper part of the Grassy Creek control section.

Tasmanites Type V

The diameters of the sporomorphs of this type range from 175 to 320 microns. The smooth exine is very thick (up to 40 microns), and is penetrated by numerous large pores which appear as radiating canals in optical section and as large dots up to 4 microns in diameter on the surface of the central region. The color is dark reddish-brown. This conspicuous type is present in all samples of the Grassy Creek control section, but its relative abundance is not great.

Tasmanites Type VI

The diameters of the sporomorphs of this type range from 200 to 340 microns in diameter. The exine is thick, dark brown in color, and almost opaque in some specimens. The surface is irregular, pitted and punctate; penetrating pores are inconspicuous. This form is not abundant in any of the samples of the control section.

Analytic Methods and Results

Preliminary observations on the vertical distribution of the six types of Tasmanites reveal an ubiquity of their occurrence in the Grassy Creek shale. The analytic methods adopted were directed toward the possibility of establishing a zonation based on vertical changes of the relative abundance of the six taxonomic designates. From each sample, 400 specimens were counted, and the relative abundance in percent of the total count was computed for each type and each sample. The results are shown graphically in Figure 3.

From this diagram, several successional trends (not otherwise apparent) can be illustrated. The lower part of the Grassy Creek shale is characterized by consistent and important maximal, relative abundance values for Tasmanites Types II and III. Tasmanites Type IV maintains low relative abundance values in the lower part. Significant increases in relative abundance values for Tasmanites Types I and IV with corresponding decreased values for Tasmanites Types II and III, characterize the upper part of the Grassy Creek shale.

It is believed that Tasmanites is not derived from a terrestrial source, and the common occurrence of great numbers of these sporomorphs in marine sediments indicates that they lived in marine or brackish environments. It is conceivable that the demonstrated, successional

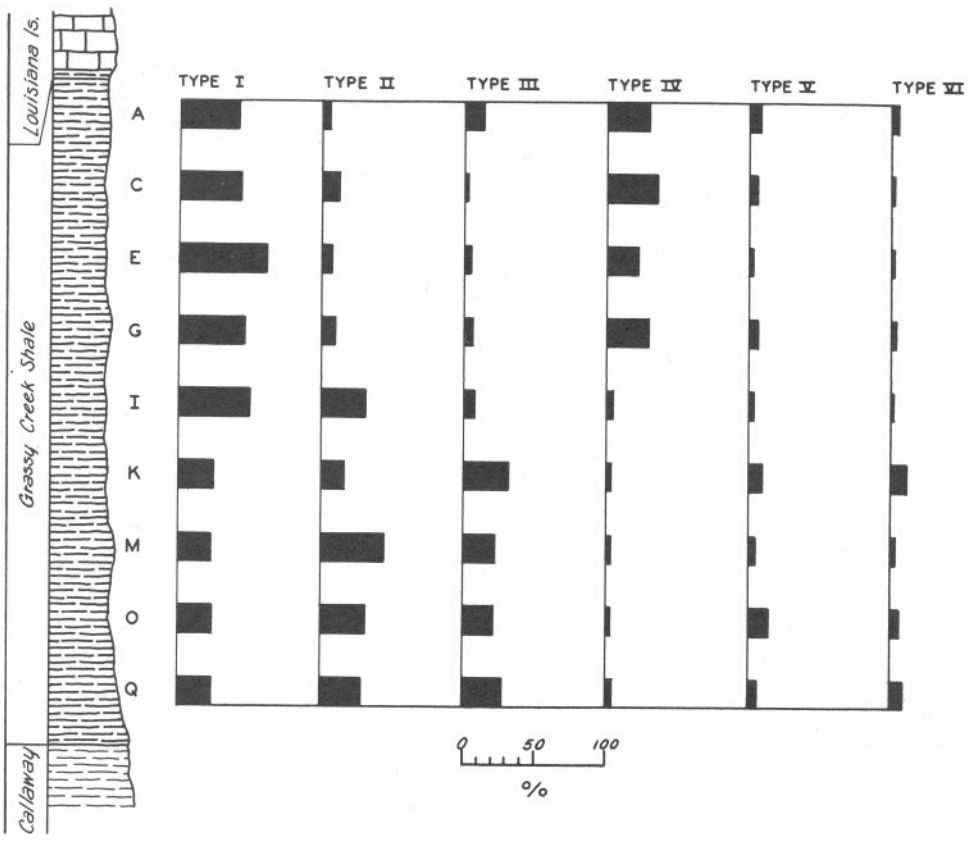

Fig. 3 -- Relative abundance in the distribution of Tasmanites in the Grassy Creek shale in Sec. 2, T. 55 N., R. 5 W., Ralls County, Missouri.

trends of the Tasmanites types in the Grassy Creek paralleled changing environmental regimes during Grassy Creek sedimentation.

In summary, this analysis indicates the presence of two clearly defined biostratigraphic zones in the Grassy Creek shale. Whether or not these zones can be correlated in distant outcrops will be determined by future investigations. More detailed study of the morphological features of these sporomorphs may reveal forms which will permit subdivision of the Grassy Creek and similar formations into even finer zones.

In processing the samples described above, Chitinozoans associated with Tasmanites, were found only in the green shale below the Grassy Creek. Microspores were found only in the Louisiana, but hystrichospherids were found in both the green shale and the Louisiana. Scolecodonts were common in all samples. The green shale and the Louisiana contain forms of Tasmanites which are distinct from those found in the Grassy Creek.

THE KINDERHOOKIAN SERIES IN THE MISSISSIPPI VALLEY

By Charles Collinson

The Mississippian outcrops in western Illinois, southeastern Iowa, and eastern Missouri include most of the standard Mississippian reference sections in North America, so it is of more than ordinary importance that the stratigraphic relationships of formations and faunas there be clearly understood. For that reason, the Illinois Geological Survey has for several years conducted a program of field, subsurface, and faunal research on these strata and in recent times that program has placed special emphasis on the Kinderhookian Series. Despite these studies, several problems such as the relation of the Louisiana limestone to the McCraney limestone, the placement of the lower boundary of the Mississippian System, and the age of the English River formation have been difficult to resolve. Early this year, conodonts were discovered in several of the key formations long considered barren of such fossils and, as a result, the long standing problems of the Kinderhookian have been clarified and the need for revision of the existing classification made evident. The following paper is therefore a resume of the revised classification now being adopted by the Illinois Geological Survey (Figure 1). The present correlation of sequence in the Upper Mississippi Valley is shown in Figure 2. Subsequent publications will record the revisions in greater detail. The paper is published with the permission of the Chief, Illinois State Geological Survey.

Limits of the Kinderhookian Series - In 1861 Meek and Worthen proposed the term Kinderhook Group to include all the beds between the top of the black shale (Grassy Creek) and the base of

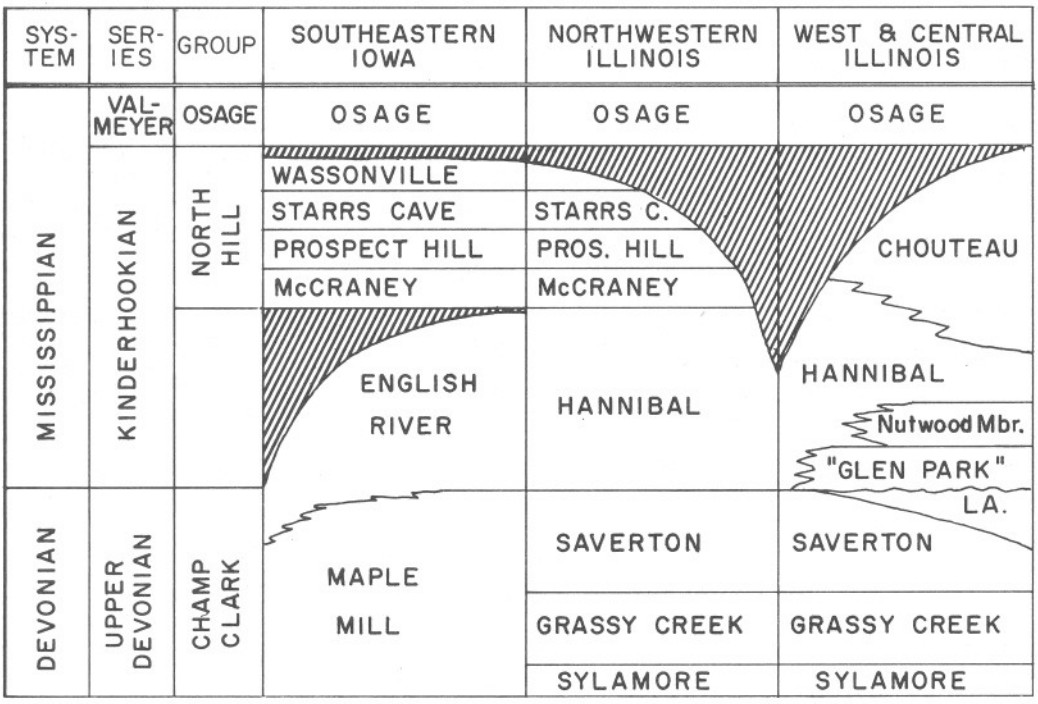

Fig. 1 - Correlation chart of the Kinderhookian and Upper Devonian Series of Illinois and southeastern Iowa.

the Burlington limestone. Moore (1928) broadened the group to include the Grassy Creek and Sylamore formations and in 1933 raised the group to series rank. In 1948, Weller et al. divided the series into the Easley and Fabius Groups wherein the former included all the formations above the top of the Louisiana limestone and the latter all those below the top of the Louisiana. However, in 1956, Workman and Gillette rejected the name Fabius on the ground that the formations belonging to the group are not exposed in the type area along Fabius Creek and substituted the name Champ Clark for the same group of formations. In addition, Workman and Gillette proposed the term Hannibal Group for the "Glen Park," Maple Mill, and English River formations and the name North Hill Group for the McCraney, Prospect Hill, and Starrs Cave

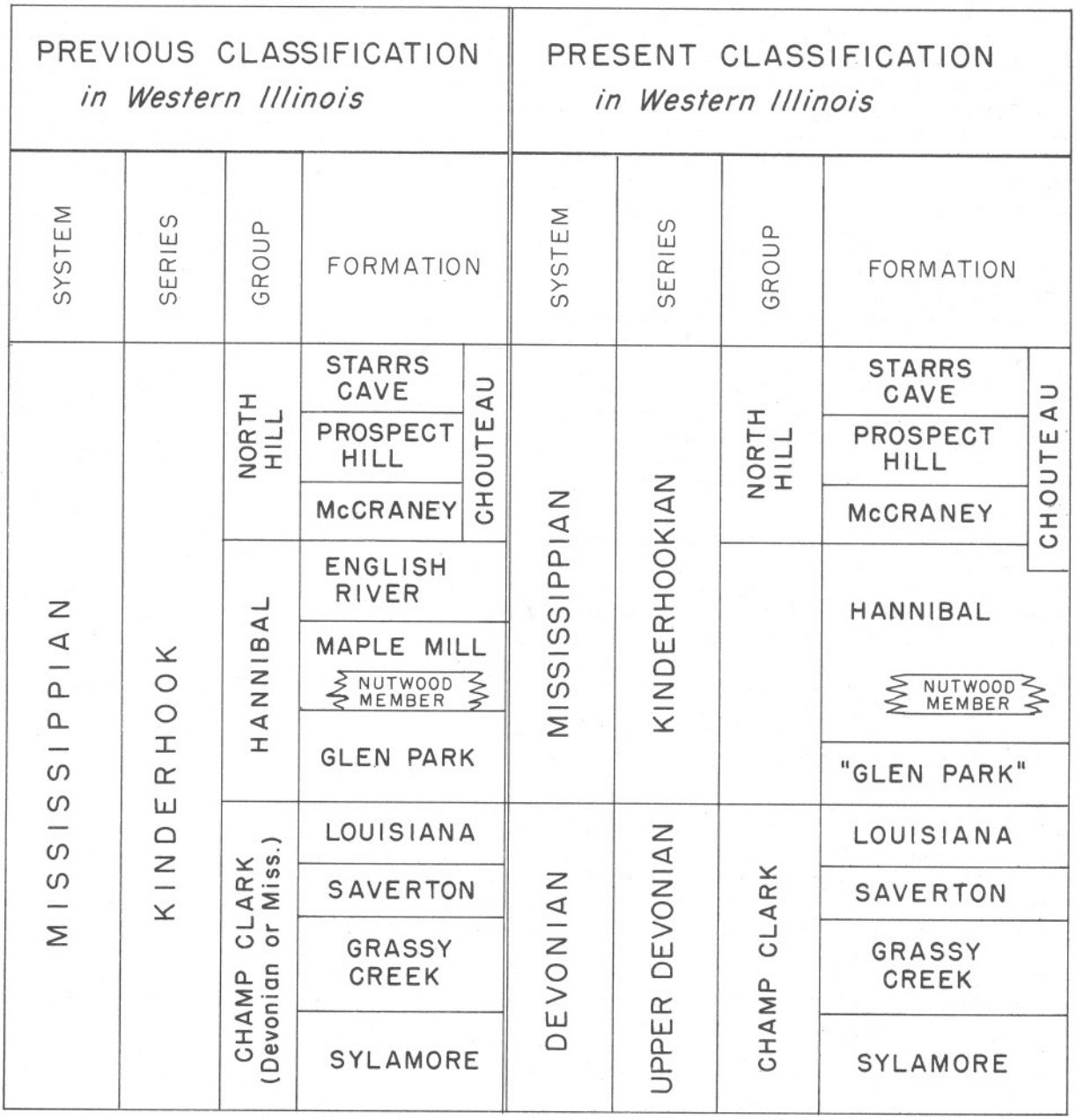

Fig. 2 - Previous classification of Kinderhookian Series in the Mississippi Valley (Workman and Gillette 1956) compared with the proposed classification.

formations. These two groups replaced the Easley Group of Weller et al.

The present revision of Kinderhookian classification results largely from the differentiation of complete and detailed conodont faunal zones for the Mississippi Valley formations and their correlation in detail with the Upper Devonian and Lower Carboniferous stages of western Europe. The European stages are widely accepted as an international standard of reference for the Devonian and Lower Carboniferous. Comparison of the conodont faunas from the Sylamore, Saverton and Louisiana formations (Scott and Collinson, 1961) with the same faunas from western Germany show that these formations are of late Devonian age and represent a continuous, nearly complete Upper Devonian section previously thought by many to be missing in the Mississippi Valley. In addition, recent conodont collections from the "Glen Park" formation of Illinois show a lowermost Carboniferous age for that formation and indicate that the Devonian-Mississippian boundary lies above the Louisiana and beneath the "Glen Park" of Illinois. Accordingly, those formations previously referred to by Weller et al. (1948) and Workman and Gillette (1956) as either Devonian or Mississippian (the Sylamore, Grassy Creek, Saverton and Louisiana) are removed from the Kinderhookian Series and placed in the Upper Devonian Series. As thus redefined the Kinderhookian in the type region is bounded at the top by the base of the Burlington limestone and at the bottom by the base of either the "Glen Park" or the Hannibal. The upper limit of the Upper Devonian Series in western Illinois is placed at the top of either the Saverton or the Louisiana. The lower limit is placed at the base of the Sylamore.

Champ Clark Group - Workman and Gillette (1956) proposed Champ Clark for the succession of formations that lie between the top of the Louisiana limestone and the unconformity that cuts across Devonian, Silurian, and Ordovician strata. As thus defined the group included the strata believed to be Devonian by some workers but Mississippian by others. The name was taken from Champ Clark Bridge at Louisiana, Missouri, in an area where all formations of the group are well exposed. The late Devonian age of the Champ Clark Group is shown by the occurrence of an uppermost Devoninn (Wocklumeria Stufe toVI zone) conodont fauna in the Louisiana limestone and successively older Upper Devonian conodont faunas in the successively older formations of the group. The physical limits of the group coincide with the time-stratigraphic limits of the Upper Devonian Series as developed in the Mississippi Valley.

Sylamore sandstone - In 1956 Workman and Gillette accepted Sylamore for use throughout Illinois as the name for the sandstone at the base of the Kinderhookian Series. The term had been used previously in western Illinois and had been a part of the Missouri, Oklahoma,and Arkansas nomenclature for more than a decade. As used in Illinois, Sylamore is equivalent to the Hardin of Tennessee and the Misener of Oklahoma.

As used in the Mississippi Valley, the Sylamore sandstone occurs above the unconformity which cuts across Devonian, Silurian, and Ordovician strata and lies beneath the black shale of the Grassy Creek formation where that unit is present. Where the Grassy Creek is absent, the sandstone may underlie units as young as Hannibal.

Lithologically, the Sylamore is composed of medium-rounded quartz grains more or less cemented with pyrite, calcite, dolomite, or silica. Chert grains are also found in some places. The sandstone is rarely more than 5 feet thick and generally measures a few inches to a mere streak. The formation is widely, although discontinuously, distributed over much of Illinois, Missouri, Oklahoma, Arkansas, and southeastern Iowa and is generally considered the initial deposit of the series to which it is referred.

Conodont faunas from the Sylamore in Pike County, Missouri, Calhoun, and Jersey Counties, Illinois, indicate a late Devonian age for the Sylamore even where the sandstone is the only Upper Devonian formation in the section and is overlain by such Kinderhookian formations as the "Glen Park" or Hannibal. Because in many places it is the only Upper Devonian formation underlying much younger rocks, Sylamore has in a number of instances been misapplied to younger sandstones. Some of the misunderstanding can be traced to the original description of the Sylamore by Penrose (1891) who described the formation as a sandstone between the Mississippian Boone chert and the Silurian St. Clair limestone in the Batesville, Arkansas, region but noted that the sandstone was better developed in Stone County and the country to the west and referred to the unit as equivalent to the black shale of Tennessee. The name, originally suggested by Branner (Penrose 1891), came from exposures along Sylamore Creek in Stone County where the formation is two feet thick (Mehl, 1961) and is overlain by a black shale that was formerly

called Eureka but is now referred to as Chattanooga. Many of the early workers in northern Arkansas interpreted the Sylamore as equivalent to the Eureka and applied the name to sandstones found above the black shale as well as below. The situation was clarified by Adams and Ulrich in 1905, however, when in the U. S. G. S. Fayetteville Folio they defined the Sylamore sandstone as the basal member of the Chattanooga shale. Conodont faunas in the type Sylamore sandstone section on Sylamore Creek contain typical late Devonian forms (Mehl, 1961) and correlate with the conodont faunas from the Sylamore in the Mississippi Valley. In addition, there seems little doubt that the Sylamore of Illinois can be traced with reasonable confidence to the reference sections in Stone County, Arkansas.

M. G. Mehl (1961) recently recommended that the name Sylamore be omitted from the Missouri list of stratigraphic names on the grounds that there is no uniformity in interpretation of the term and that a redefinition would not be generally acceptable. Accordingly, he has proposed the name Turpin for a six-inch sandstone bed at the base of the Grassy Creek Shale in southeastern Pike County, Missouri, where the term Sylamore is presently used for the same bed.

Although Mehl has pointed out several cases where sandstones younger than the Sylamore have been included in the formation, general usage of the term has been nearly uniform in recent years and proper usages of the term greatly outnumber improper applications. This author can see no gain in the coining of a new term to replace an old and well-known name which is generally understood and properly used.

Grassy Creek formation - Grassy Creek is the term applied to the dark, brownish-black, slightly silty, pyritic, thinly laminated, Tasmanites-bearing shale which overlies the Sylamore sandstone and underlies the greenish-to bluish-gray shales of the Saverton formation.

The name was introduced by Keyes in 1898 for green and black shales on Grassy Creek near Louisiana, Missouri, but he later (1913) separated the green shale from the black and named it the Saverton formation. Since that time, the term Grassy Creek has also been variously used to include the Saverton (Branson and Mehl, 1934; Thomas, 1949) or combined with the term Saverton to form the name Grassy-Saverton (Weller and Sutton, 1941) for the combined green and black shales. Since 1948, however, when Weller et al. accepted Grassy Creek and Saverton as separate and distinct units, Grassy Creek has been consistently used in Illinois for the black shales alone.

The thickness of the Grassy Creek ranges from a featheredge around the flanks of the Ozark Uplift in southwestern Illinois to more than 200 feet in Henderson and Hancock Counties in the northwestern part of the state. Farther northwestward in Iowa the formation has increasing amounts of gray shale in the lower part and eventually grades entirely into the gray shales and argillaceous limestones of the central Iowa sections. Southeastward into the Illinois Basin the Grassy Creek increases from zero to more than 100 feet in thickness in south-central Illinois and merges to the east with the middle portion of the New Albany formation of southeastern Illinois. The Grassy Creek is probably a correlative of the Blackiston formation of Indiana and the Chattanooga of Arkansas, Oklahoma, and Kansas, as well as part of the Chattanooga of Tennessee.

The Grassy Creek appears to be conformable with the units that overlie and underlie it, although it is overlapped by both the Saverton and Louisiana formations in a few areas.

Few fossils are known from the Grassy Creek but conodont faunas from the overlying Saverton and underlying Sylamore indicate that it is entirely early late Devonian in age and correlates with the Manticoceras Stufe (toI) of western Germany.

Saverton shale - The Saverton shale is named for Saverton Station, Ralls County, Missouri, (Keyes 1913), where it is generally less than 20 feet thick and is a bluish-to greenish-gray shale. At the type locality it is overlain by Louisiana limestone and underlain by Grassy Creek shale. The formation crops out widely in western Illinois and northeastern Missouri and ranges in thickness from a wedge edge against the Lincoln Fold and Ozark Uplift to more than 80 feet in the westernmost counties of Illinois. In most places the Saverton is overlain by either the "Glen Park" or the Hannibal and is relatively thick. Where overlain by the Louisiana, the Saverton is generally less than 10 feet thick, but thickens toward the northeast side of the Louisiana lens as that formation thins. On the southwest side of the lens both Louisiana and Saverton thin onto the Lincoln Fold. Beneath the Louisiana, the upper few feet of Saverton consists of shaly siltstone that has been included in the Louisiana by other authors

(Williams, 1943, Branson, 1944) but whose lithology dictates its placement with the Saverton. The assignment of the siltstone is of special importance because it is moderatly fossiliferous and its fauna has in some reports been credited to the Louisiana (Williams, 1943). Accordingly some authors have written that the Saverton and the Louisiana faunas are closely similar. This is in some degree true for the macrofaunas but the conodont faunas of the Louisiana and the conodont faunas of the Saverton beds that directly underlie the Louisiana are significantly different. Conodont faunas of the uppermost Saverton, where Louisiana is missing, are the same as those of the Louisiana, however, and corroborate what the reciprocal thicknesses of the two formations lead one to suspect, that uppermost Saverton is a lateral equivalent of the Louisiana. Conodont faunas are found throughout the Saverton and are exceedingly abundant. Compared with west European conodont faunas they indicate that the formation spans most of late Devonian time -- Cheiloceras Stufe (toII) through Wocklumeria (toVI).

Conodont faunas from the Maple Mill shale of southeast Iowa show that the Maple Mill carries the same fauna as the Saverton, and it is here suggested that the Maple Mill of Iowa which is nowhere exposed in its entirety, be considered a northern, relatively silty, facies of the Saverton.

Where the Saverton is overlain by the siltstone of the Hannibal formation, the two formations may be exceedingly difficult to distinguish except by paleontologic means. In its thicker exposures the Saverton commonly contains a number of siltstone or silty limestone beds in the uppermost ten feet. These complicate placement of the Hannibal-Saverton boundary and make it especially difficult to recognize in the subsurface.

Louisiana limestone - Keyes (1892) proposed the name Louisiana for the "Lithographic limestone" of Swallow (1855), which consists of light gray to grayish-buff limestone and buff to brown dolomite. At its type locality near Louisiana, Missouri, the formation is near its maximum thickness of 50 feet and extends both northwest and southwest from there in a narrow elongate lens which reaches into central Iowa on the northwest and into south-central Illinois on the southeast (Scott and Collinson 1961, Figure 1).

The Louisiana overlies the Saverton shale conformably and shares a reciprocal thickness with it along the northeast side of the lens. Where the Louisiana is thickest, it is generally overlain by the Hannibal but away from the area of maximum thickness it is overlain by the "Glen Park." The unconformable surface between the Louisiana and the "Glen Park" shows two feet of relief in places but apparently represents a very short interval of time.

In describing the fauna of the Louisiana, Williams (1943) showed that the macrofauna of the Saverton is definitely related to that of the Louisiana and that the two formations are gradational through a thin transition zone which he included in the Louisiana. The so-called transition beds have produced a large number of the fossils which have been referred to the Louisiana fauna but, because they came from an argillaceous siltstone, should properly be referred to the Saverton. The siltstone transition beds should perhaps be designated as a member of the Saverton in order to clarify faunal relationships.

Despite the similarity between Saverton and Louisiana macrofaunas, conodont faunas from the Saverton beds which directly underlie the Louisiana are significantly different from the faunas found in the overlying limestone (Scott and Collinson, 1961). Nevertheless, where the Louisiana is missing from the section, uppermost Saverton beds carry the same conodont fauna as the Louisiana. These facts, when considered along with the reciprocal thicknesses of the two formations, seem to indicate that the upper part of the Saverton is laterally equivalent to the Louisiana.

Several authors (Weller, 1900; Stainbrook, 1950; Harris, 1947) have correlated the Louisiana limestone with the McCraney limestone of Illinois and Iowa but surface bed tracing plus conodont faunas from both formations (Scott and Collinson, 1961) show that the Louisiana is distinct from and older than the McCraney. Comparison of Louisiana conodont faunas with the Upper Devonian-Lower Carboniferous faunas of western Germany indicate that the Louisiana is of youngest Devonian age (Wocklumeria Stufe, toVI) and the McCraney is younger than oldest Mississippian (upper Gattendorfia Stude, CuI).

"Glen Park" formation - In 1906, Stuart Weller described an oolitic limestone unit at Hamburg, Illinois, which he considered to be slightly younger than the Glen Park limestone of Jefferson County, Missouri, and equivalent to the upper part of the Louisiana limestone. Eight

years later he named the unit the Hamburg oolite and described it as consisting of 1 to 15 feet of oolitic limestone with interbedded layers of sandy shales lying under the Hannibal and underlain by 1 to 8 feet of brown sandy shale, followed below by the Louisiana limestone. Moore, in 1928, recognized that the name Hamburg was preempted and, basing his conclusions on close faunal similarity, extended the use of the name Glen Park to include the Hamburg oolite. He redefined the unit to include all strata between the base of the Hannibal and the top of the Louisiana limestone and considered it a member of the Hannibal formation. This definition has been followed by most subsequent authors, although Workman and Gillette (1956) included much brownish-gray siltstone in the "Glen Park" that is here considered to belong in the Hannibal formation.

Recently, conodonts collected from several outcrops of the "Glen Park" north of the Lincoln Fold were compared to the conodont faunas of the Louisiana as well as to the conodont fauna of the Glen Park limestone at its type locality in Jefferson County, Missouri, south of the Lincoln Fold. These studies show that the supposed "Glen Park" north of the Lincoln Fold is considerably younger (youngest Mississippian) than the type Glen Park (middle late Devonian) and is also younger than the Louisiana. This situation leaves the northern "Glen Park" without a valid name and the term "Glen Park" (using quotation marks) is used as an expediency for this report, although a manuscript proposing a new name is now in preparation.

The "Glen Park" is highly variable in lithology and may consist of almost any combination of sandy and silty brown or buff limestone, buff siltstone, silty shale, oolitic limestone, limestone conglomerate or thin sandstone beds. The best exposure is in Gresham Hollow about a mile southeast of Hamburg, Illinois, where it consists of 17 feet of calcareous blue-gray siltstone overlying 15 feet of light gray to buff silty dense fine-grained limestone. The limestone contains beds of light gray to brownish-gray dolomitic Tasmanites-bearing siltstone and some lenses of highly fossiliferous, white to buff, medium to coarse, conglomeratic, oolitic limestone. The formation is commonly cross bedded and was deposited in extremely shallow water.

The formation does not exceed 25 feet in thickness on the outcrop but is of widespread distribution in western Illinois. It has been found in only one exposure in eastern Missouri. The "Glen Park" varies in thickness considerably over short distances but the average thickness seems closely related to the underlying Louisiana limestone. The formation does not occur where the Louisiana is thickest but in a very general way lies on and beyond the flanks of the Louisiana lens.

Along the Mississippi bluffs of Calhoun, Pike, and Jersey Counties and in the lower Illinois River valley the "Glen Park" crops out at numerous places and shows the variety that is characteristic of the formation. Near Grafton, in Jersey County, six inches of partly oolitic limestone and siltstone grades down into three inches of conglomerate composed of sand, oolites, fossil fragments, and pebbles of shale. In Jimtown Hollow, in Pike County, the "Glen Park" consists mainly of more than seven feet of pebble and cobble limestone conglomerate in a cross-bedded oolitic limestone matrix. At numerous places in northwestern Pike County, the formation is represented by a massive brown silty limestone bed which is conglomeratic in places.

The "Glen Park" is very fossiliferous at many localities, and Weller(1906) has described the macrofauna. Until the conodont fauna was discovered no microfauna was known. The conodonts indicate that the "Glen Park" is probably the oldest Mississippian formation in the Mississippi Valley and correlates with the lower Gattendorfia Stufe (cuI) of Europe. The formation is also the oldest in the Kinderhookian Series and its base marks the lower boundary for the Mississippian System.

Hannibal formation - The Hannibal formation was named by Keyes (1892) for a series of silty shales and argillaceous siltstones overlying the Louisiana and underlying the Chouteau near Hannibal, Missouri. Keyes wrongly identified the basal beds of the Burlington as Chouteau at Hannibal, but the Chouteau does overlie the Hannibal some 30 to 40 miles to the south. Moore (1928) used Hannibal to designate the siltstone and shale beneath the Chouteau or beneath the Burlington where the Chouteau is absent. In his usage, either the top of the "Glen Park" or the top of the Louisiana served as a base for the Hannibal. He considered the Maple Hill shale, English River siltstone, McCraney limestone, and Prospect Hill siltstone to be members of the Hannibal formation and in 1935 he added the "Glen Park" as a member of the formation.

Laudon (1931) considered the English River a formation equivalent to the Hannibal and designated the McCraney limestone, Prospect Hill siltstone, and the thin oolitic limestone on

top of the Prospect Hill as units belonging to the North Hill member of the Hampton formation of Iowa.

Workman and Gillette (1956) used Hannibal Group for the interval above the Louisiana limestone and beneath the Chouteau. Where the Louisiana is absent, the Hannibal was based on the top of the Saverton or Grassy Creek and where the Chouteau is absent, the upper limit was placed at the base of the McCraney or the Burlington limestone. The Hannibal Group of Workman and Gillette included in succession upward the "Glen Park", Maple Mill shale, and the English River siltstone. A black shale unit in the Maple Mill formation was named the Nutwood member.

Recent stratigraphic and faunal studies of this sequence by the author and Alan J. Scott have clarified its relationships. Abundant conodont faunas from the type sections of the Maple Mill and English River formations in Washington County, Iowa, show the type Maple Mill to be late Devonian in age and a correlative of the Saverton shale of Iowa and Illinois. Hence the name Maple Mill cannot be applied to lower Hannibal strata of Mississippian age. No typical Maple Mill exposure is complete and it is doubtful if more than its upper part has ever been observed in outcrop.

The presence of Upper Devonian clymenid ammonoids in the English River siltstone at Burlington, as well as an Upper Devonian conodont fauna, indicates that the formation is of late Devonian age at Burlington although conodont faunas from the type locality show that at least part of the English River is Mississippian in age. The interval, overlain by the Burlington and underlain by either Louisiana or "Glen Park", to which Moore and Workman and Gillette applied English River and Maple Mill in Illinois is here referred to as the Hannibal formation. Where the Louisiana or "Glen Park" is absent, as in northern Pike County, Illinois, Moore as well as Workman and Gillette applied the term Maple Mill to Saverton strata and the term English River to the entire Hannibal. The Nutwood member of Workman and Gillette is now referred to the Hannibal formation.

The Hannibal is extensively exposed in the upper Mississippi Valley. It reaches a maximum thickness of 100 feet in Pike County, Missouri, and northern Calhoun County, Illinois, and then thins south and southwestward toward the Ozark Uplift. From Pike County, Missouri, southeastward into the Illinois Basin, the Hannibal thins and is eventually incorporated into the upper part of the New Albany formation.

In color the formation ranges from bluish- or brownish-green to gray and buff. It consists almost entirely of siltstone in northwestern Pike County, Illinois, and Pike County, Missouri, but becomes increasingly argillaceous in the lower part to the south, so that the lower half of the formation consists of silty shale in Calhoun and Jersey Counties, Illinois. In both these latter counties, the irregularly occurring dark gray to black fissile shale facies referred to as the Nutwood member is exposed and ranges up to 40 feet in thickness. The Cuivre member of the Hannibal recently proposed by Mehl (1961) appears to be an exact equivalent of the Nutwood.

The conodont faunas of the Hannibal are abundant and occur throughout the formation. They indicate that the formation probably is correlative with the European Gattendorfia Stufe (CuI) and perhaps the lowermost part of the Pericyclus Stufe (cuII). Conodont faunas as well as field and subsurface relationships also show that uppermost Hannibal is correlative to at least lowermost Chouteau.

Chouteau formation - The Chouteau was originally named from Chouteau Springs in central Missouri, where Swallow (1854) described a section consisting of 40 feet of brownish-gray earthy thick-bedded dolomitic limestone which grades downward into 30 feet of fine-grained compact thin-bedded gray limestone. These two units are referred to now as the Sedalia and Compton formations and the entire interval is classified as the Chouteau Group (Beveridge and Clark, 1952). The Chouteau in Illinois is equivalent to the Chouteau Group of the type area. It includes both the Sedalia and Compton equivalents but these are not differentiated in Illinois. The term Rockford from Indiana was used in southeastern Illinois until the older term Chouteau was extended throughout Illinois by Buschbach (1952). Chouteau is used in this classification for the fine-grained gray limestone that rests unconformably beneath the Burlington and lies conformably upon the Hannibal or older formations where units are missing. The Chouteau consists of light brownish-gray fine-grained silty limestone that has some buff dolomitic beds in it and commonly has black or gray chert nodules that are most abundant in the lower part. In the Mississippi Valley the Chouteau is thickest in southern Calhoun County, where it

attains a maximum of 70 + feet. North, east, and southeastward from this area the Chouteau thins and is less than 20 feet thick over most of the Illinois Basin. Along the Mississippi Valley the Chouteau is found only as far north as northern Calhoun County where it thins from a thickness of 40 feet to zero in less than 10 miles.

Outcrop relationships with the underlying Hannibal indicate that the upper part of the Hannibal and the lower part of the Chouteau interfinger laterally. Conodont faunas in both formations verify the relationships. The Chouteau is unconformably overlain by the Osage Group and the abrupt disappearance of the Chouteau in the Mississippi Valley is partly due to erosion at the unconformity.

Conodonts are common and of almost continuous stratigraphic occurrence in the Chouteau of western Illinois and are exceedingly useful in zoning the formation.

North Hill Group - Workman and Gillette (1956) took the North Hill formation of Laudon (1931, 1935) and elevated it to a group including the McCraney limestone (at the bottom), Prospect Hill siltstone, and Starrs Cave formation. They proposed the latter name for Laudon's Schellwienella zone. The formations fit together as a natural unit because their geographic distributions are much alike; all are thin, of limited exposure and apparently are all of approximately the same age. The group is unconformable on the English River siltstone in Iowa but rests with apparent unconformity on the Hannibal in Illinois. The group is overlain by the Wassonville dolomite in Iowa and the Burlington limestone in Illinois. The lithology and age of the Wassonville suggests that it should be included in the North Hill Group. In western Illinois the group is confined to a narrow strip in Pike, Adams, Hancock, and Henderson Counties.

McCraney formation - The McCraney was named by Moore (1928) for a light gray to buff slightly lithographic limestone with alternating layers of buff to brown dolomite that crops out in the Mississippi River bluffs not far north of Kinderhook, Illinois.

In western Illinois, the McCraney conformably overlies the Hannibal and underlies the Prospect Hill siltstone except where that formation has been removed by pre-Burlington erosion and the McCraney lies directly under Burlington limestone. At Burlington, Iowa, the McCraney unconformably overlies English River siltstone of late Devonian age.

Moore considered the McCraney a member of the Hannibal formation, but Workman and Gillette (1956) raised it to formation rank.

The McCraney reaches a maximum thickness of 58 feet in the subsurface of Hancock County in westernmost Illinois. The limestone is a relatively narrow elongate body trending northwest-southeast, parallel to the direction of trend of both the Louisiana formation and the Lincoln Fold. The McCraney lens is not unlike that of the Louisiana, although it is much less elongate. The lens thins rapidly eastward to a featheredge within 15 to 20 miles. To the northwest the McCraney extends into southeastern Iowa. To the southeast, the formation wedges out beneath the pre-Osage unconformity and disappears in northwestern Pike County, Illinois. The McCraney lens may well have been as extensive as the Louisiana before erosion.

For a number of years the evidence for an age assignment of the McCraney has been so meager that some stratigraphers have considered the formation to be Devonian and a northward extension of the Louisiana limestone, whereas others have considered it to be Mississippian in age and an approximate correlative of the Chouteau.

A conodont fauna from the McCraney at Cascade Station in Burlington, Iowa, clearly shows the McCraney to be of Mississippian age and correlative with part of the Chouteau of the Mississippi Valley Region. This evidence agrees closely with information from subsurface and outcrop studies of the formation.

Prospect Hill formation - The term Prospect Hill was introduced in 1928 by Moore for a gray to buff siltstone that occupies a stratigraphic position above the McCraney limestone and below the Starrs Cave limestone. Moore considered the unit a member of the Hannibal but Workman and Gillette named it a formation. The Prospect Hill is confined in Illinois to a narrow belt along the western edge of Hancock and Adams Counties. From its erosional eastern edge it thickens westward and reaches a maximum thickness of 29 feet in Illinois. The Prospect Hill is conformable with the McCraney and Starrs Cave but underlies the Burlington limestone unconformably where the Starrs Cave is missing. An abundant conodont fauna closely similar to that from the upper Chouteau indicates the correlation of the Prospect Hill.

Starrs Cave formation - Laudon (1931) referred to the buff to light gray coarsely oolitic limestone overlying the Prospect Hill siltstone in southeastern Iowa as the Schellwienella zone and included it with the North Hill member of his Hampton formation. Workman and Gillette (1956) gave the unit a geographic name and designated it the Starrs Cave formation from near Starrs Cave north of Burlington, Iowa. The unit is from 2 to 12 feet thick in Illinois, where it has only limited subsurface distribution in western Hancock County. The formation is widespread in Kiowa, however. It overlies the Prospect Hill with apparent conformity and is unconformably overlain by the Wassonville dolomite. Where the Wassonville is absent it may be overlain by either the Burlington or a unit of the Hampton formation. The Starrs Cave bears an abundant macrofauna dominated by brachiopods and has been correlated with the Chouteau on the basis of it. No microfauna has been reported.

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CONODONT FAUNAS FROM THE LOUISIANA AND McCRANEY FORMATIONS OF ILLINOIS, IOWA, AND MISSOURI

by
Alan J. Scott and Charles Collinson

Introduction

Few Paleozoic formations have in recent years been subject to more disagreement concerning their age and correlation than have the Louisiana and McCraney limestones of northeastern Missouri, western Illinois, and southeastern Iowa. Both are distinctive bodies of light gray

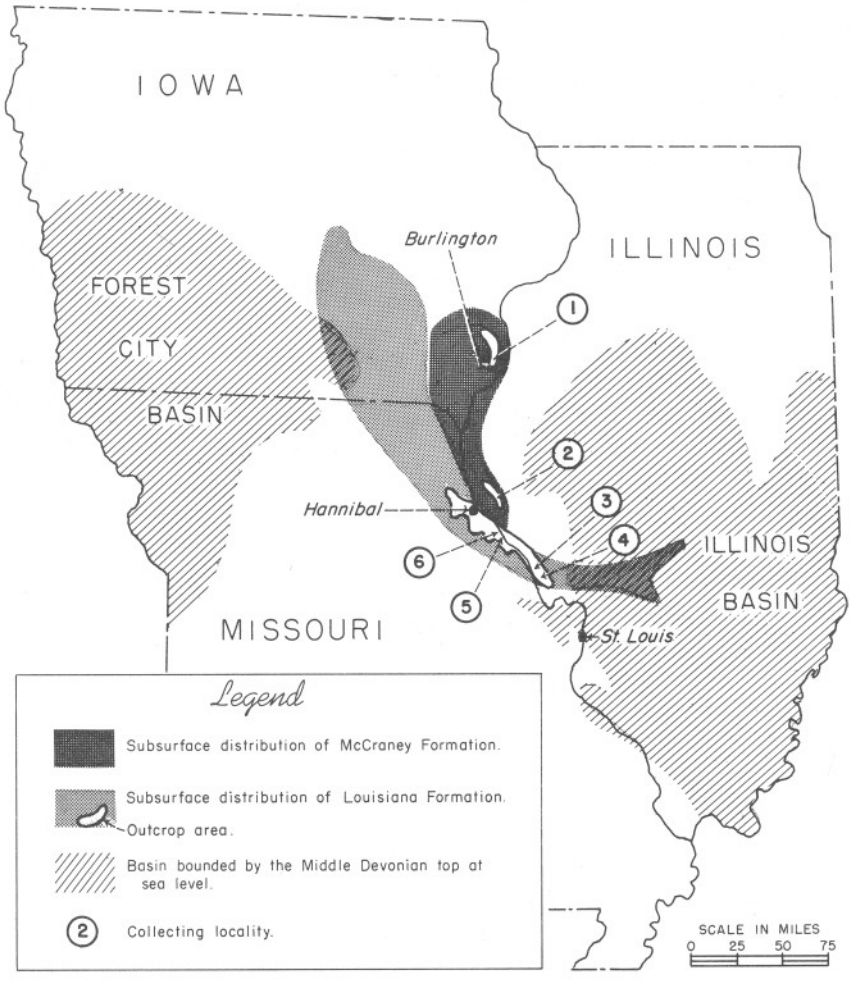

Fig. 1 --Locality map showing the general subsurface and surface distribution of the Louisiana and McCraney formations.

to buff lithographic limestone irregularly interbedded with buff to brown dolomite beds and thin dolomitic shale partings. Over most of their area of occurrence (Fig. 1), both are overlain as well as underlain by buff to gray siltstone (Fig. 2) and both have been generally referred to the Kinderhookian Series. Even though the two formations occur in the same general area, they have never been positively identified in the same section, either surface or subsurface. Thus the relationship of one to the other is still a matter of circumstantial evidence not without a degree of uncertainty.

A number of geologists have considered the Louisiana to be equivalent to the McCraney (Weller, 1900, Weller and Sutton, 1940, Harris, 1947, and Stainbrook, 1950), and an even greater

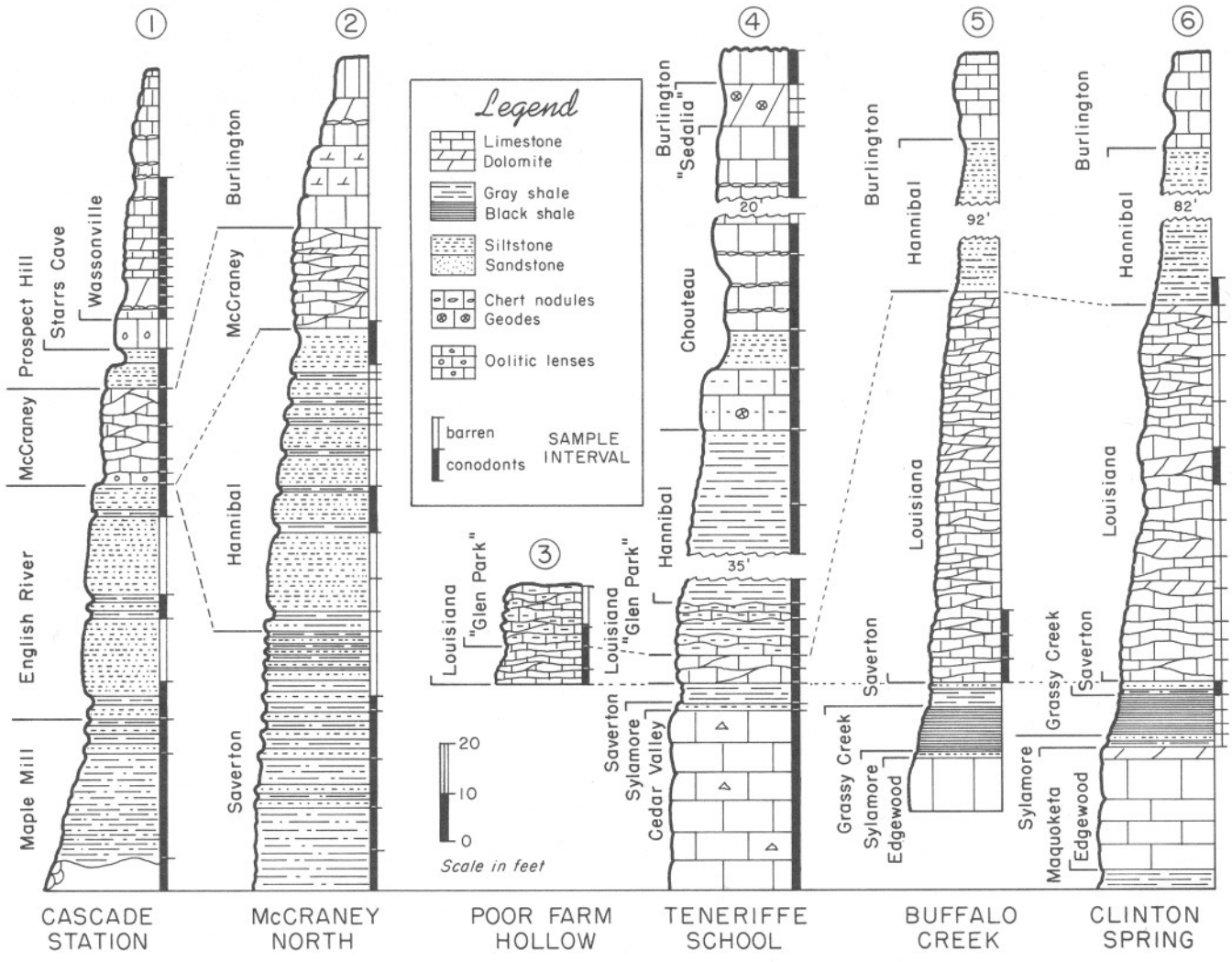

Fig. 2-- Diagram showing the formations exposed at the collecting localities and the position of samples that yielded conodonts.

number have considered the Louisiana to be older than the McCraney (Keyes, 1895; Weller, 1906; Moore, 1928; Laudon, 1931; Williams, 1943; Thomas, 1949; and Workman and Gillette, 1956). For these reasons and because the Louisiana has been referred to the Devonian by some workers (Branson, 1938, Branson and Mehl in Branson, et al., 1938), clarification of the age relationships of the two units is of prime importance in the classification of the Mississippian System in the type region.

Previous attempts to correlate the Louisiana and McCraney limestones have been based primarily on lithic similarity and macrofaunal evidence. The macrofaunas consist predominantly of brachiopods, crinoids, corals, and other sessile benthonic forms. The remarkable lithic similarity of the two formations indicates that they represent similar environmental conditions. It is not surprising therefore that the benthonic faunas of the two formations are also similar.

Various workers have cited the macrofaunal evidence for the assignment of the Louisiana limestone to the Devonian, while others have considered these same fossils as indicative of a Mississippian age. Since no general agreement has been reached, the Louisiana limestone has appeared on correlation charts labeled as Devonian or Mississippian (Weller, et al., 1948). This results partly from the fact that cephalopods are rare in late Devonian and early Mississippian strata in the Mississippi Valley, and it is therefore difficult to correlate with the European cephalopod zones which were agreed upon by the 1927 Heerlen Congress of Carboniferous Stratigraphy as a more or less arbitrary basis for designating the position of the Devonian-Carboniferous boundary in the European reference sections. The standard Middle Devonian, Upper Devonian and Lower Carboniferous stages and ammonoid zones as used in this paper are shown in Fig. 3.

European workers have recently described conodont faunas associated with the classic Devonian-Lower Carboniferous cephalopod zones in western Europe. A few of the more important recent conodont papers are Bischoff, 1956, 1957; Bischoff and Ziegler, 1956; Flügel and Ziegler, 1957; Helms, 1959: Müller, 1956b; Sannemann, 1955a, 1955b; Voges, 1959, 1960; Walliser, 1958; and Ziegler, 1958, 1959, 1961. It is now possible to build up an accurate and detailed Devonian and Lower Carboniferous conodont faunal succession and to compare these with the European cephalopod zones.

Our purpose here is to describe briefly the conodont faunas of the Louisiana and McCraney limestones and to assign ages to the formations by correlating these faunas with faunas described from European reference sections in the Rhenish Schieforgebirge of western Germany. This paper is published with the permission of the Chief, Illinois State Geological Survey.

Conodont faunas have been described from several Devonian and Mississippian formations of the Upper Mississippi Valley by various workers (e.g. Branson and Mehl, 1934a, 1934b, 1938; Branson, 1934; and Thomas, 1949). Although conodonts had been reported from the Louisiana limestone by Branson and Mehl (in Branson, 1938, p. 129) and Branson (1944, p. 173) the fauna

SERIES	MIDDLE DEVONIAN		UPPER DEVONIAN							LOWER CARBONIFEROUS							
STAGES	EIFELIAN	GIVETIAN	FRASNIAN				FAMENNIAN				TOURNAISIAN	VISEAN					
ZONES	*Anarcestes*	*Maenioceras*	*Manticoceras*				*Cheiloceras*	*Platyclymenia*		*Wocklumeria*	*Gattendorfia*	*Pericyclus*				*Goniatites*	
								Prolobites	*Prionoceras*	*Oxyclymenia*						*G. crenistria*	*G. striatus*	*G. granosus*
			to Iα	to Iβ	to Iγ	to Iδ	to II	to III	to IV	to V	to VI	cu I	cu IIα	cu IIβ	cu IIγ	cu IIδ	cu IIIα	cu IIIβ	cu IIIγ

Fig. 3--Standard stages and ammonoid zones of western Europe (after Brinkmann).

was not described or illustrated. There are no previous lists or descriptions of conodonts from the McCraney limestone.

Because they might provide important evidence of the age of the Louisiana and McCraney limestones the authors have made a special effort to obtain conodonts from these units. Small, but significant conodont faunas were obtained from both only after processing hundreds of pounds of limestone in dilute acetic acid.

The Conodont Fauna of the Louisiana Limestone

Branson (1944, p. 173) listed eighteen species of conodonts from the Louisiana. These species are: Ancyrognathus irregularis Branson and Mehl, Bryantodus crassidens Ulrich and Bassler, Hindeodella spp., Icriodus symmetricus Branson and Mehl, Ligonodina sp., Lonchodina latericrescens Branson and Mehl, Palmatolepis glabra Ulrich and Bassler, P. minuta Branson and Mehl, Polygnathus granulosa Branson and Mehl, P. linquiformis Hinde, P. nodocostata Branson and Mehl, P. trianqularis Branson and Mehl, P. varinodosa Branson and Mehl, Polylophodonta linquiformis? Branson and Mehl, Neoprioniodus semiseparatus (Branson and Mehl), Spathognathodus amplus (Branson and Mehl), and Roundya tumida (Branson and Mehl). In discussing this fauna, Branson (1944, p. 174) concluded that the genera listed indicate a late if not latest Devonian age for the Louisiana.

Important in comparing the fauna listed by Branson with the fauna described here, however,

is the fact that he (1944, p. 169) as well as many other workers (Keyes, 1895; Williams, 1943) have included in the Louisiana the yellow-brown siltstone or mudstone beds that immediately underlie the limestone at many localities. Of these beds Branson (1944, p. 170) wrote: "A yellow-brown sandy calcareous mudstone or soft clayey limestone bearing the same fauna as the limestone beds can be commonly recognized at the base of the Louisiana and above the blue mudstone of the [Grassy Creek] Saverton, though at some places it cannot be recognized or is covered. At Buffalo Creek and elsewhere near Louisiana it is 4 inches thick."

The present authors have examined these yellow-brown beds at numerous localities in both Missouri and Illinois. We find them to consist of argillaceous siltstone which is calcareous at most exposures but noncalcareous at some. The yellow-brown beds are identical to many beds found in the underlying Saverton and unlike any lithology found in the overlying limestone. Accordingly, we refer the yellow-brown beds to the Saverton. Because of this difference in classification, Branson and Mehl's collection labeled as Louisiana undoubtedly contains conodonts from beds older than the Louisiana of the present authors. This interpretation seems to be substantiated by the fact that collections made by the authors from the limestone did not contain Ancyrognathus, Icriodus or Polylophodonta listed by Branson whereas these genera are common in samples from the yellow-brown beds and in many samples from the Saverton shale.

Thomas in 1949 (p. 412) indicated that he examined the specimens upon which Branson based his 1944 list and found them to be the same as the conodont fauna of the Grassy Creek. Grassy Creek as used by Thomas included the Saverton shale of the present authors. All the species listed by Branson are represented in our collections from the Saverton, and only two, Palmatolepis glabra and P. minuta, have been found by us in the overlying limestone beds. Additional samples from the Louisiana may extend the range of more of these species, but should not change the overall aspect of the Louisiana conodont fauna.

Collinson, Rexroad and Scott (1959) reported the average abundance of conodonts in samples from the Louisiana limestone to be about eight conodonts per kilogram, but many additional samples have been processed since that paper was published and the average abundance of conodonts in all samples from the Louisiana is now only about two conodonts per kilogram. It should be noted that where the Louisiana is thin, for example at Teneriffe School where it is only two and a half to three feet thick, conodonts are significantly more abundant. Conodonts averaged four specimens per kilogram in the more than 50 kilograms of limestone processed from this locality. The Louisiana limestone at Poor Farm Hollow is four feet thick, and eight kilograms of limestone at that locality yielded an average of 3 conodonts per kilogram. In contrast, where the Louisiana is relatively thick, such as at the Buffalo Creek and Clinton Spring localities, conodonts are exceedingly uncommon. Twenty-two kilograms of material from the former locality contained only 1.5 specimens per kilogram. The Clinton Springs locality was sampled at two-foot intervals and only two of these samples contained conodonts.

The low numbers of conodonts in the Louisiana limestone may be due to two factors: 1) a relatively rapid rate of deposition or 2) an unfavorable environment for conodonts. Our knowledge of the vertical distribution of conodonts within the Louisiana is somewhat limited but conodonts seem to be more common in the lower beds of the formation. The Louisiana becomes increasingly dolomitic toward the top of the unit in many sections. This may represent a more restricted environment with perhaps a high salinity. We are inclined to ascribe the low numbers to high rates of deposition.

We do not believe that the conodonts in the Louisiana represent a stratigraphic admixture mainly because they are extremely well preserved and represent a faunal assemblage that can easily be distinguished from that of the underlying Saverton shale.

Our collections from the Louisiana limestone contain 291 specimens representing 17 genera and 38 species:

Ancyrodella sp.
Apatognathus n. sp. A.
A. inversus Sannemann
A. lipperti Bischoff
Bryantodus sp.
Falcodus variabilis Sannemann
Gnathodus cf. G. commutatus (Branson & Mehl)
G. kockeli Bischoff
Hibbardella divergens Huddle
H. sp. A.
H. sp. B.
Hindeodella deflecta Hibbard
H. emacerata Huddle
H. elongata Huddle
H. cf. H. uncta Hass
H. sp.
Ligonodina sp.
Lonchodina distans Huddle
Neoprioniodus alatus (Hinde)
Neoprioniodus armata (Hinde)
Nothognathella sp.

Ozarkodina plana(Huddle)
O. sp.
Palmatodella delicatula Ulrich & Bassler
Palmatolepis glabra Branson & Mehl
P. gracilis Branson & Mehl
P. minuta Branson & Mehl
P. quadrantinodosa marginifera Ziegler
P. quadrantinodosalobata Sannemann
Polygnathus communis Branson & Mehl
P. communis bifurcata Hass
Scutula bipennata Sannemann
Spathognathodus inornata (Branson & Mehl)
S. n. sp. A.
S. n. sp. B.
S. n. sp. C.
S. sp.
Synprioniodina alternata Ulrich & Bassler

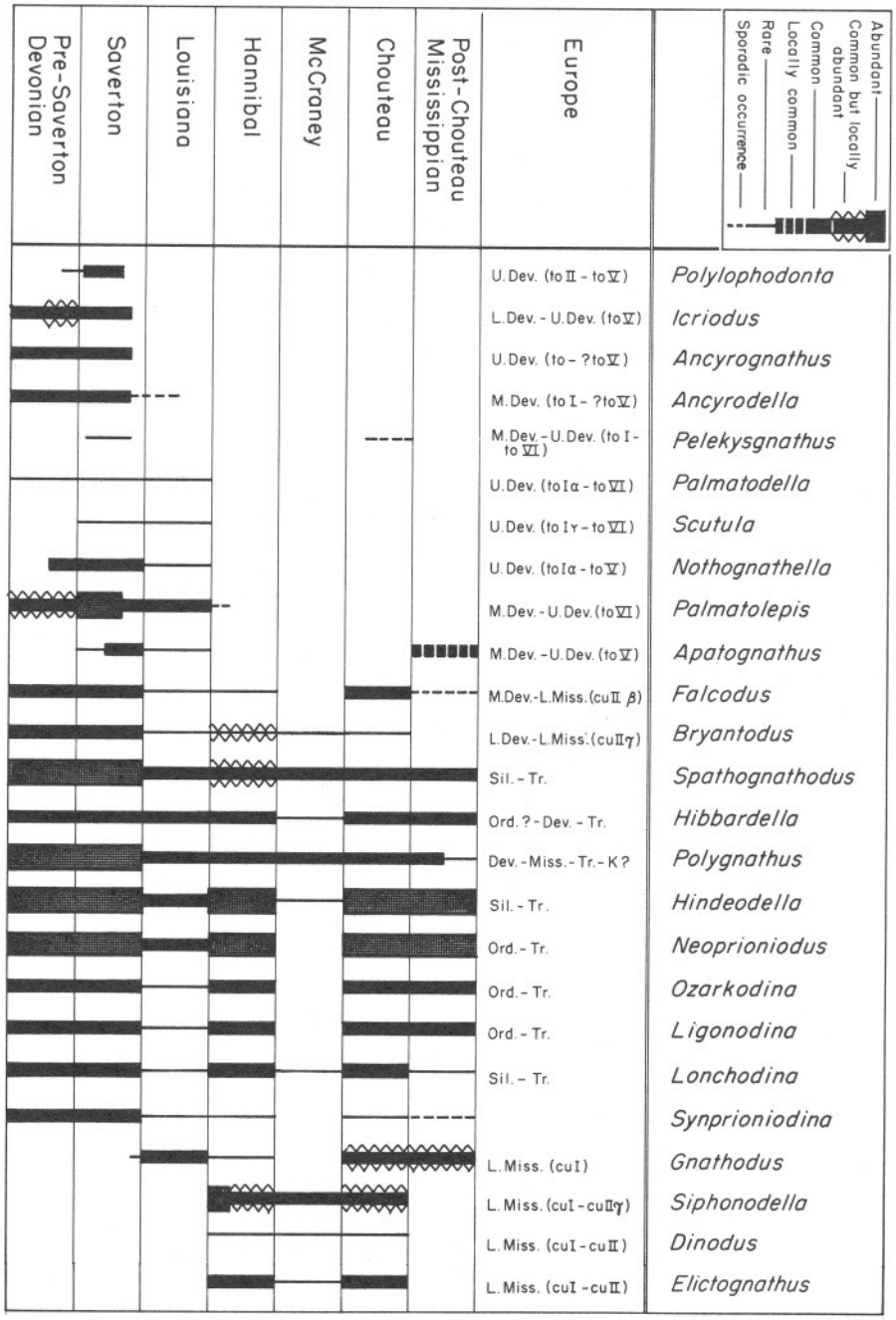

Fig. 4--Range chart of stratigraphically important conodont genera found in Devonian-Mississippian rocks in the Mississippi Valley. The stratigraphic occurrences of genera in Europe are given in terms of the standard European ammonoid zones.

Although the conodont fauna is diverse in the number of genera and species represented, it is numerically dominated by four genera: Polygnathus, Spathognathodus, Gnathodus and Palmatolepis.

Polygnathus communis, the only polygnathid in our Louisiana collection, is represented by over 40 specimens and is by far the most common species in the fauna. It is extremely common in the Hannibal, Chouteau, Fern Glen, and Burlington formations of the Upper Mississippi Valley but is relatively rare in the upper part of the Saverton shale.

Spathognathodus is an important element in the fauna of the Louisiana and is represented by four common species. The most important is Spathognathodus inornata, a common form in the Saverton of the Upper Mississippi Valley that also occurs, but is much less common, in the Louisiana and the Hannibal formations. The species is also a common form in the conodont faunas of the European late late Devonian (to-III-to VI). The three other spathognathodids, Spathognathodus n. sp. A., S. n. sp. B., and S. n. sp. C., have not been positively identified from other stratigraphic units of the Upper Missippi Valley.

The occurrence of Gnathodus cf. G. commutatus and G. kockeli in the Louisiana marks the earliest appearance of this important genus in the Upper Mississippi Valley. These species have been reported from the Gattendorfia and Pericyclus Stufen of Europe by Bischoff (1957) and other German workers.

Figure 5 shows the stratigraphic ranges of conodont species in other Devonian and Mississippian formations in western Illinois and in Europe. Distribution of the species in western Illinois is based upon material in the collections of the Illinois State Geological Survey. The European ranges are based upon reported occurrences by the workers listed earlier.

When compared to West German conodont faunas the Louisiana collections fall into four natural groupings: 1. Species that have never been reliably reported from beds younger than Devonian; 2. Species that are abundant in Devonian rocks but occur in diminished numbers in Lower Carboniferous rocks; 3. Species that have been reported only from the Carboniferous or occur in small numbers in Devonian strata but reach their maximum of variety and numbers in the Carboniferous; 4. Species reported only from the Louisiana.

1. Twelve of the 38 species of the conodont fauna of the Louisiana have not been reliably reported from rocks younger than Devonian in Europe or in the United States. These species are: Ancyrodella sp., Apatognathus inversus Sannemann, A. lipperti Bischoff, Falcodus variabilis Sannemann, Hindeodella deflecta Hibbard, Nothognathella sp., Palmatodella delicatula Ulrich & Bassler, Palmatolepis minuta Branson & Mehl, P. quadrantinodosa marginifera Ziegler, P. quadrantinodosalobata Sannemann, Scutula bipennata Sanneman, and Synprioniodina alternata Ulrich & Bassler. All these species speak strongly for a Devonian age for the Louisiana limestone.

2. Four species occurring in the Louisiana limestone are abundant in Devonian rocks but have also been reported from Lower Carboniferous rocks in Europe: Palmatolepis glabra Ulrich & Bassler, P. gracilis Branson & Mehl, Neoprioniodus alatus (Hinde), N. armata (Hinde). Palmatolepis glabra and P. gracilis are common in Upper Devonian conodont faunas from many parts of the world. Their maximum abundance in Europe is in the Devonian toIII and toIV zones. They also occur in the toV and toVI zones in considerable numbers and Bischoff (1957, p. 9) reports scattered specimens in the lower part of the Gattendorfia Stufe (cuI). In the Upper Mississippi Valley these palmatolepids are abundant in the Saverton shale, common to rare in the Louisiana limestone and occur rarely in the basal beds of the Hannibal formation. The occurrence of P. glabra and P. gracilis in the European Lower Carboniferous, as well as in the Mississippi Valley Hannibal formation may represent stratigraphic admixture but it seems more likely that they are indigenous.

3. Three species occurring in the Louisiana, Polygnathus communis Branson & Mehl, Gnathodus cf. G. commutatus (Branson & Mehl) and G. kockeli Bischoff, are definitely Carboniferous in character. Polygnathus communis is extremely common in Lower Mississippian formations in North America. Bischoff (1957) has reported this species from the Gattendorfia Stufe (cuI) but also notes that it is common in the Upper Devonian toVI zone. This species has not been reported below the toVI zone and, consequently, it marks an easily identifiable range zone from the bottom of the toVI zone through the cuIII zone in Europe.

Neither Gnathodus cf. G. commutatus nor G. kockeli has been reported in Europe lower than cuI, and the latter is considered a guide fossil for the Gattendorfia Stufe (cuI). Both species occur in the uppermost part of the Saverton as well as in the Louisiana limestone in western Illinois. Gnathodus cf. G. commutatus, a simple unornamented gnathodid, is more common in these formations than G. kockeli, which becomes the dominant form in the lower part of the Hannibal formation. We regard G. cf. G. commutatus as the most primitive gnathodid and are

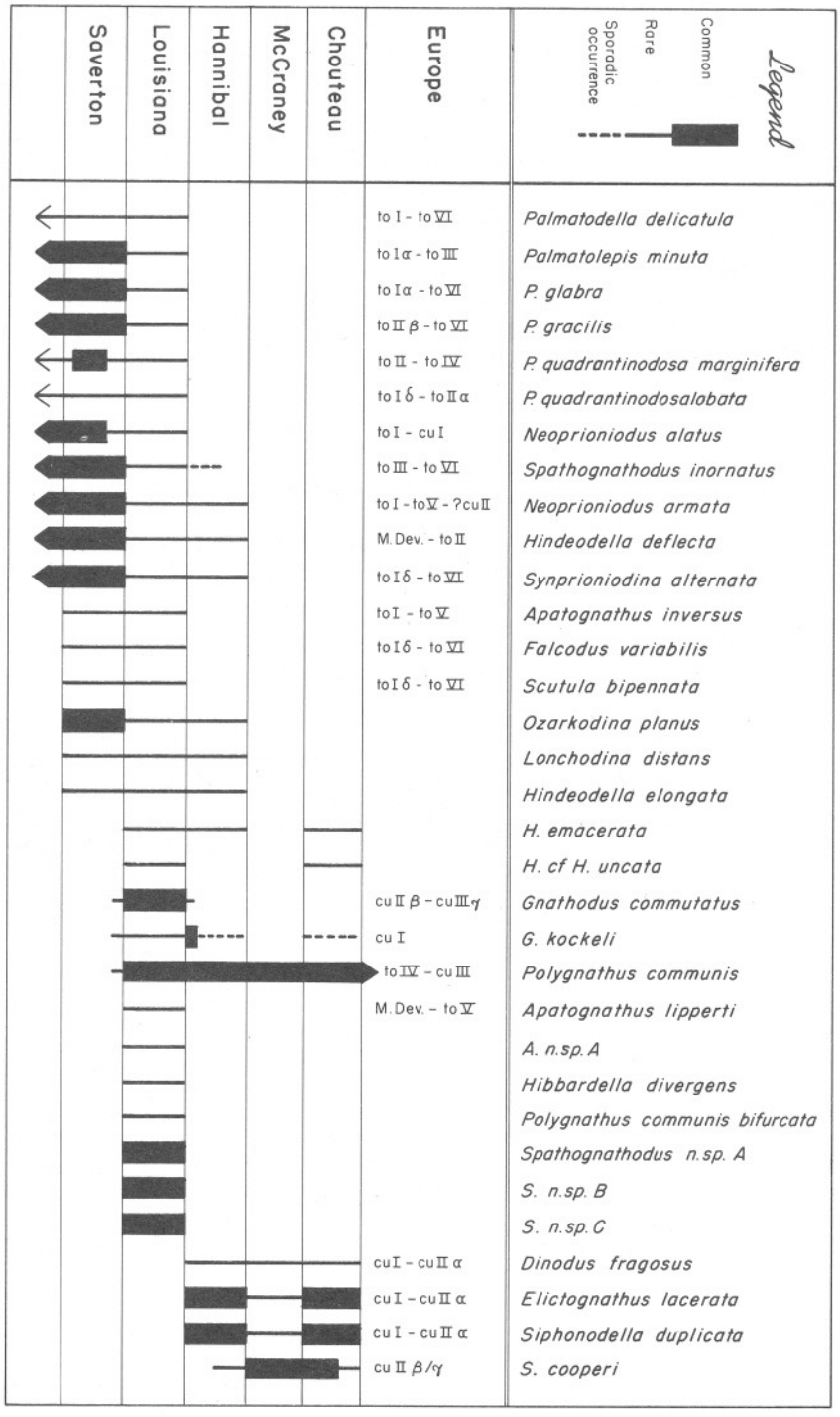

Fig. 5 --Range chart of species found in the Louisiana and McCraney formations of the Mississippi Valley. The stratigraphic occurrences of species in Europe are given in terms of the standard European ammonoid zones.

inclined to believe that the range of Gnathodus should be revised downward into the late Devonian.

4. At least six species occurring in the Louisiana are undescribed forms. Three of these species, Spathognathodus n. sp. A., S. n. sp. B., and S. n. sp. C., are common and will be named in a subsequent paper.

In summary, the overall aspect of the conodont fauna of the Louisiana is Devonian. A Wocklumeria Stufe (toVI) age is favored for several reasons:

1. - The fauna contains nine species which Bischoff (1957) listed as characteristic of, or occurring in, the Wocklumeria Stufe (toVI). Several of these, Polygnathus communis, Palmatolepis glabra, P. gracilis and Spathognathodus inornata, are important elements of the Louisiana fauna.

2. - The fauna of the Louisiana lacks representatives of Siphonodella, Elictognathus and Pseudopolygnathus. These genera are exceedingly common in the basal part of the Hannibal formation and in the European Gattendorfia Stufe (cuI).

3. - Such important Upper Devonian genera as Icriodus, Polylophodonta, and Ancyrognathus are not present in our collections from the Louisiana limestone. Ancyrodella is represented by a single broken specimen. These genera are also absent in samples from the youngest beds of the Saverton shale in western Illinois. They have been reported as high as the toV zone in Europe but apparently are absent in the toVI zone.

4. - The occurrence of two gnathodid species in the Louisiana might be considered evidence for an early Carboniferous age, but the fact that they also occur in the Saverton tends to reduce their significance. The gnathodids may indicate that the Louisiana limestone is actually transitional between latest Devonian (toVI) and earliest Carboniferous.

The Devonian-Mississippian "Faunal Break"

The concept that there is a major break between the conodont faunas of the Upper Devonian and the Kinderhookian has long been accepted. Branson and Mehl (1938, p. 129) have called it one of "the greatest gaps in the history of conodonts" and Mehl (1961, p. 61-64) has recently reaffirmed his belief in this sharp break between Devonian and Mississippian conodont faunal assemblages. He has presented a chart (1961, Fig. 1, p. 63) showing the ranges of several stratigraphically significant genera. Icriodus, Palmatolepis, Apatognathus, Ancyrognathus, Ancyrodella, Nothognathella and Angulodus are shown as diagnostic of and confined to the Devonian, and the genera Siphonodella, Elictognathus, Pinacognathus, and Gnathodus are represented as making their first appearance in beds of undisputed Mississippian (Lower Carboniferous) age. Mehl (1961, p. 62) further suggests that there is a major hiatus between the two systems in North America "with the possibility that toV and even toIV (toV and toVI of this paper) may not be represented in North America."

Our studies show that although there is a great change in conodont faunas between the youngest Saverton and the oldest Hannibal in northeastern Missouri, these Saverton beds are no younger than toIII or toIV and represent the middle faunal zone of the Saverton where it crops out further northeast away from the Lincoln Fold. Recently, significantly younger faunas have been collected from the Saverton and Louisiana in that area where the sections are thicker and more nearly complete. These collections show that the change from Devonian to Mississippian faunas is one of gradual disappearance of old genera (Fig. 4) and species and the gradual appearance of new forms.

The conodont fauna of the Louisiana limestone is a transitional fauna. It contains a few forms that have been considered early Mississippian in age and many other forms considered diagnostic of the late Devonian.

Comparison of the Louisiana Conodont Fauna with Other North American Faunas.

Mississippi Valley - The authors recognize lower, middle and upper conodont zones with the Saverton, but where the Saverton underlies the Louisiana, generally only the lower and middle

zones are represented. The Louisiana fauna is related to but may easily be distinguished from the lower and middle faunas of the Saverton, and the conodonts listed by Branson (1944) from the "Louisiana" are from out middle Saverton faunal zone. A younger fauna, marking the upper Saverton zone and almost identical with that of the Louisiana limestone, has been collected from a few exposures in western Illinois. The physical relations of the two formations also suggest that the Louisiana and the uppermost Saverton of western Illinois are lateral equivalents.

The absence in the Louisiana of such genera as Icriodus, Ancyrognathus, and Polylophondonta and the lack of any significant numbers of Nothognathella, Ancyrodella, and Apatognathus serve to differentiate the fauna of the Louisiana from the middle and lower zones of the Saverton shale. The presence of Dinodus, Elictognathus, and abundant representatives of Pseudopolygnathus and Siphonodella differentiates the Hannibal from the Louisiana.

Samples from southeastern Iowa have failed to yield a fauna comparable with that of the Louisiana limestone, though such a fauna may exist.

New Albany shale of Indiana. - Huddle (1934) and Campbell (1946) have studied the distribution of conodonts in the New Albany shale of southern Indiana. Huddle recognized three (upper, middle, and lower) conodont zones within the New Albany. The lower was from the lowermost part of the formation (Blocher), the middle came from the lower part of the upper half of the formation (upper Blackiston), and the upper came from the uppermost ten feet (Sanderson, Falling Run, Underwood and Henryville formations). The upper fauna contains such conodont genera as Elictognathus and Siphonodella and correlates with the fauna of the Hannibal. Huddle's middle faunal zone contains the genera Ancyrodella, Ancyrognathus, Icriodus, and Polylophodonta and appears to be equivalent to the middle and lower faunal zones of the Saverton.

The dark fissile New Albany shale is difficult to disaggregate and many of the conodonts studied by Huddle (1934) were preserved on bedding planes. He described many spectacular bar- and blade-like forms from such genera as Hindeodella, Lonchodina, Ligonodina, and Falcodus. Unfortunately these forms are not as useful stratigraphically as are platform genera such as Palmatolepis, Polygnathus, Ancyrodella, and Siphonodella. Study of the stratigraphic distribution of platform elements should reveal beds equivalent to the Louisiana limestone near the top of Huddle's middle faunal zone or at the base of his upper zone.

Devonian-Mississippian boundary in Ohio. - Hass in 1947 described five faunal zones from near the Devonian-Mississippian boundary in Ohio, as follows:

1. Upper Sunbury shale zone (at the top).
2. Basal Orangeville - basal Sunbury shale zone.
3. Basal Bedford shale zone.
4. Cleveland - upper Ohio shale zone.
5. Huron - lower Ohio shale zone.

The conodont faunal succession described by Hass is almost identical with the succession collected by the authors from the Devonian-Kinderhookian rocks in western Illinois and northeastern Missouri. The lowermost zone (Huron-lower Ohio shale) correlates with the middle zone of the Saverton shale.

The Cleveland-upper Ohio shale zone is characterized by Polygnathus cf. P. triangularis, Spathognathodus inornatus, S. aculeatus, and abundant representatives of the genera Hindeodella and Neoprioniodus. This fauna is similar to faunas from the upper part of the Saverton shale in western Illinois and from the English River siltstone at Cascade Station in Burlington, Iowa.

Hass (1947, p. 135-136) reports a sparse conodont fauna from the basal part of the Bedford shale collected "very close to the Devonian-Mississippian boundary." This fauna is characterized by three species of Spathognathodus: S. inornatus, S. aciedentatus, and "a new species of Spathognathodus that possesses a single horn-like process on the inner side of the blade immediately anterior to the pulp cavity". Hass further notes that this species has not been found in any of the other conodont zones. This spathognathodid is almost identical with S. n. sp. A. from the Louisiana. Examination of additional material from the basal beds of the Bedford shale may reveal a conodont fauna equivalent to the fauna of the Louisiana limestone. The next highest conodont assemblage is the basal Orangeville-basal Sunbury shale zone. The presence of

Pseudopolygnathus prima, Polygnathus communis, Spathognathodus aciedentatus, and Siphonodella plana indicates a correlation with the lower part of the Hannibal formation.

The upper Sunbury shale zone contains several species suggesting a correlation of this zone with the middle and upper part of the Hannibal formation.

Chattanooga shale of central Tennessee. - The fauna of the Louisiana limestone shares several stratigraphically important species with a fauna from immediately beneath the phosphate nodule zone at the top of the Gassaway member of the Chattanooga shale of central Tennessee (Hass, 1956). This thin zone contains Palmatolepis quadrantinodosalobata (listed as P. sp. A. on Hass' plate 3, figures 1-3, 13), P. gracilis, P. glabra, Spathognathodus inornatus, and Palmatodella delicatula, and lies just above a zone containing Polylophondonta and Ancyrognathus. Hass also reports a single representative of Polygnathus communis from this zone. These occurrences suggest a close correlation between the uppermost part of the Gassaway member of the Chattanooga and the Louisiana limestone.

Arkansas novaculite of western Arkansas and the Houy formation of central Texas. - The conodont faunal succession in the Arkansas novaculite has been described by Hass (1951), and Cloud, Barnes and Hass (1957) have described the conodont faunal assemblages from the Houy formation in central Texas. The occurrences in these two areas are generally comparable with the Upper Mississippi Valley faunal successions. However, a fauna equivalent with that of the Louisiana limestone has not been recognized.

The Conodont Fauna of the McCraney Limestone

No conodonts have previously been described or listed from the McCraney limestone, and more than 25 kilograms of limestone from outcrops along Flint River near Starrs Cave north of Burlington, Iowa were processed without the finding of a single identifiable conodont. At Cascade Station (Locality 1, Figs. 1, 2), however, 41 kilograms of material from an interval three to six feet from the base of the McCraney yielded 33 specimens. Eight kilograms of material in a composite sample taken from the upper two feet of the Hannibal formation and the lower foot of the McCraney limestone at McCraney North (Locality 2, Figs. 1, 2) yielded 10 specimens. These latter specimens may have come from the uppermost part of the underlying siltstone but they contribute directly to interpretation of the age of the McCraney. Other samples from the McCraney limestone at McCraney North yielded no conodonts.

The conodont fauna of the McCraney consists of 10 genera and 11 species:

Bryantodus sp.
Dinodus fragosus (E. B. Branson)
Elictognathus lacerata (Branson and Mehl)
Hibbardella sp.
Hindeodella sp.
Lonchodina sp.
Polygnathus communis Branson and Mehl
Siphonodella cooperi Hass
S. duplicata (Branson and Mehl)
Spathognathodus sp.

Most of the specimens in our collections are fragmentary but the age of the fauna nevertheless is unequivocal. The fauna is dominated by the genus Siphonodella, a widespread and abundant guide to the Kinderhookian Series, and consists entirely of Mississippian forms. The species represented by the most specimens (seven) is Siphonodella cooperi which occurs abundantly in the Chouteau of western Illinois. Siphonodella duplicata is also represented in the fauna of the McCraney as well as in the Hannibal, Chouteau, English River, Prospect Hill, and Wassonville formations in western Illinois and southeastern Iowa. In the German Rhenish Schiefergebirge, Bischoff (1957) records S. duplicata from the lower part of the Pericyclus Stufe (cuIIB and Voges (1959) records the species from both the upper part of the Gattendorfia Stufe (cuI) and the lower part of the Pericyclus Stufe. There are no reliable reports of Siphonodella below the base of the Carboniferous in Europe or the base of the Hannibal in the type area of the Kinderhookian Series. Polygnathus communis is second only to the siphonodellids in numbers in the McCraney and is the only significant species shared with the Louisiana limestone. It is one of the most common lower Mississippian species in North America and ranges stratigraphically from uppermost Saverton through the entire Kinderhookian Series up

into the Burlington limestone. In Europe the species ranges from the Upper Devonian toVI zone to the Lower Carboniferous cuIII zone.

Two other stratigraphically useful species, Dinodus fragosus and Elictognathus lacerata, occur in the McCraney and the former also occurs in the Hannibal and Chouteau. In Europe the species is found only in the upper part of the Gattendorfia Stufe and the lower part of Pericyclus Stufe. Elictognathus lacerata is common in the Hannibal and Chouteau in western Illinois and northeastern Missouri as well as the upper part of the English River and the Prospect Hill in southeastern Iowa. It apparently occurs no lower than the lower part of the Hannibal. The European range is from the Gattendorfia Stufe (cuI) through the lower part of the Pericyclus Stufe (cuII). The bryantodids, hibbardellids, lonchodinids, and spathognathodids that occur in the McCraney are of limited value for detailed stratigraphic correlation.

In summary, the fauna of the McCraney limestone compares closely to that of the upper part of the Hannibal and the lower half of the Chouteau. The McCraney shares its entire conodont fauna with the overlying Prospect Hill siltstone and most of it is similarly shared with the Wassonville dolomite. The fauna of the McCraney is clearly younger than the fauna of the Louisiana limestone. A fauna recently collected by the authors from the uppermost three feet of English River siltstone that underlies the McCraney at Cascade Station contains Icriodus and other characteristic Devonian genera as well as Devonian clymenid ammonoids, which seems to prove that the English River is considerably older than the McCraney at that locality. We have sampled the English River siltstone elsewhere in southeastern Iowa and have found faunas of undoubted Mississippian age. The conodont fauna of the McCraney correlates with the faunas of the upper part of the Gattendorfia Stufe (cuI) and the lowermost part of the Pericyclus Stufe (cuII) in Europe.

Collecting Localities

McCraney limestone

1. Cascade Station, Burlington, Iowa, E/2 NW/4 Sec. 4, T. 69 N., R. 2 W., Des Moines County, Iowa. Ten feet of McCraney limestone crops out high in the face of an east-facing quarry along the Chicago, Burlington and Quincy Railroad. The McCraney is overlain by three and one-half feet of Prospect Hill siltstone and underlain by 23 feet of English River siltstone. The entire formation was sampled using five composite samples (Fig. 2), and 37 kilograms of limestone were processed. Most of the 33 specimens collected came from the interval three to six feet above the base of the limestone.

2. McCraney North, SE/4 SE/4 Sec. 14, T. 4 S., R. 7 W., Pike County, Illinois. The McCraney is exposed in an abandoned quarry high in the west-facing bluffs of the Mississippi River. The McCraney is 10 to 11 feet thick and is overlain by 20 feet of crinoidal Burlington limestone. It is underlain by 30 feet of siltstone belonging to the Hannibal formation. An eight-kilogram sample collected from the uppermost two feet of the Hannibal and the lowermost foot of the McCraney yielded ten specimens.

Louisiana limestone

3. Poor Farm Hollow, SW/4 NW/4 Sec. 22, T. 10 S., R. 2 W., Calhoun County, Illinois. Four feet of characteristic Louisiana limestone crops out in an east-flowing stream on the south side of the Poor Farm Hollow road. The Louisiana is overlain by more than six feet of silty, wavy-bedded limestone of the Glen Park formation. The samples were taken where the two units form a waterfall in the stream. Eight kilograms of material from the Louisiana limestone yielded 22 specimens.

4. Teneriffe School, SE/4 NE/4 Sec. 8 and SW/4 NW/4 Sec. 9, T. 7 N., R. 13 W., Jersey County, Illinois. The Louisiana limestone crops out low in the bluff north and south of Teneriffe School in poorly exposed ledges. The formation is two and a half to three feet thick and is underlain by 6 to 12 inches of greenish gray shale belonging to the Saverton. More than 50 kilograms of material were processed from the Louisiana. The upper half of the unit yielded 78 specimens, the lower half produced 13. An additional 100 specimens were found in bulk composite samples representing the entire formation.

5. Buffalo Creek, NW/4 Sec. 28, T. 54 N., R. 1 W., Pike County, Missouri. The Louisiana

limestone is well exposed on the south side of Buffalo Creek near its mouth. The formation is 39 feet thick, but only the lowermost 15 feet were sampled. The limestone is overlain by 92 feet of siltstone belonging to the Hannibal formation and underlain by 2 feet of Saverton shale. About 10 kilograms of material were processed and 28 specimens were recovered.

6. Clinton Spring, NW 1/2 Sec. 20, T. 54 N., R. 1 W., Pike County, Missouri. Thirty-eight feet of Louisiana limestone are exposed in the lower part of Clinton Hill north and south of Clinton Spring Roadside Park. The Louisiana limestone is overlain by 82 feet of siltstone and shale belonging to the Hannibal formation but the latter is largely covered. The limestone is underlain by a foot of siltstone and shale belonging to the Saverton formation and it in turn is underlain by three and a half feet of Grassy Creek shale. The entire Louisiana was sampled but conodonts, all fragmentary, were found in only two samples; 20 to 24 feet and 4 to 6 feet, respectively, above the base of the formation. Only six specimens were found in 12 kilograms of material.

Note. - The systematic portion of this paper has been kept to a minimum for the sake of brevity. Most of the species are well known forms and are not described in detail. Only partial synonymies are given.

Ranges of species found in the Louisiana and McCraney limestones are shown in Fig. 5 along with the relative abundance of these species in other Devonian and Mississippian formations in western Illinois. These ranges are based on the authors' collections. European ranges have been compiled from the German literature cited earlier in this paper and are based upon the oldest and youngest reported occurrences. No attempt has been made to indicate relative abundance.

SYSTEMATIC PALEONTOLOGY

Genus ANCYRODELLA Ulrich & Bassler, 1926

Type species - Ancyrodella nodosa Ulrich & Bassler, 1926

ANCYRODELLA sp.

Remarks. - A single broken specimen referable to Ancyrodella was collected from the Louisiana limestone at Teneriffe School. This genus is considered a characteristic Devonian conodont. In western Illinois ancyrodellids are common in the Sylamore sandstone as well as in the lower and middle faunal zones of the Saverton shale. They are rare in the youngest beds of the Saverton and do not occur in our collections from the Hannibal or younger formations.

Genus APATOGNATHUS Branson & Mehl, 1934

Type species - Apatognathus varians Branson & Mehl, 1934

Remarks. - Several workers (e.g. Branson & Mehl, 1934, p. 181; Mehl, 1961, p. 61) have considered Apatognathus characteristic of and confined to the Upper Devonian. Recently Clarke (1960) reported the occurrence of Apatognathus in the Lower Carboniferous of Scotland, and Carl B. Rexroad (personal communication) has found abundant apatognathids in the St. Louis limestone of western Illinois. Apatognathids are not represented in our collections from the Hannibal and Chouteau formations and other Lower Mississippian units of western Illinois, northeastern Missouri and southeastern Iowa. The seemingly anomalous occurrence of Apatognathus in the Middle Mississippian may represent a case of homeomorphy similar to that discussed by Rexroad (1958). The conodont fauna of the Louisiana limestone contains an unusually diverse group of apatognathids, probably due to conditions favorable for preservation of these delicate forms. Three distinct species of this genus have been recognized from the Louisiana.

APATOGNATHUS INVERSUS Sannemann

Pl. 2, fig. 20

1955 Apatognathus inversus SANNEMANN, Senck. leth., Bd. 36, p. 127, pl. 6, fig. 18a-c.

Remarks.- The figured specimen from the Louisiana limestone differs from the holotype of this species in the development of minute denticles along both edges of the apical denticle. Specimens nearly identical with the holotype also occur in the Louisiana limestone and the Saverton shale.

APATOGNATHUS LIPPERTI Bischoff

Pl. 2, fig. 10

1956 Apatognathus lipperti BISCHOFF, Notizbl. hess. L.-Amt Bodenf., p. 121-122, pl. 9, fig.27, 31.

Remarks. - The figured specimen differs from the holotype of this species in having a smaller apical angle between the two lateral limbs and a less prominent apical denticle. The Louisiana specimen is immature; however, the position of the limbs and the pattern of denticulation on these limbs are characteristic of A. lipperti.

APATOGNATHUS n. sp. A

Pl. 2, figs. 26, 27

Remarks. - This species differs from all previously described apatognathids in having subparallel limbs joined throughout most of their length by a thin lamella.

Genus BRYANTODUS Ulrich & Bassler (in Bassler, 1925)

Type species - Bryantodus typicus Ulrich & Bassler, 1926

BRYANTODUS sp.

Pl. 1, fig. 32

Remarks.- Several distinctive bryantodids are common in the Sylamore and Saverton formations. The genus also occurs but is less common in the Hannibal, McCraney, and Chouteau. The specimen figured from the Louisiana resembles certain Saverton forms but cannot be referred to any species with certainty.

Genus DINODUS Cooper, 1939

Type species - Dinodus leptus Cooper, 1939

DINODUS FRAGOSUS (E. R. Branson)

Pl. 2, fig. 21

1934 Palmatodella fragosa E. R. BRANSON, Univ. Missouri Studies, v. 8, no. 4, p. 333, pl. 27, fig. 5.

Remarks. - The figured specimen from the McCraney limestone is broken. It compares closely with unbroken representatives from the Hannibal and Chouteau formations of the Upper Mississippi Valley and the Chappel formation of north-central Texas.

Genus ELICTOGNATHUS Cooper, 1939

Type species - Solenognathus bialata Branson & Mehl, 1934

ELICTOGNATHUS LACERATA (Branson & Mehl)

1934 Solenognathus lacerata BRANSON & MEHL, Univ. Missouri Studies, v. 8, no. 4, p. 271, pl. 22, figs. 5, 6.
1959 Elictognathus lacerata HASS, U. S. Geol. Survey Prof. Paper 294-J, p. 386-387,pl. 49, figs. 1-8, 12. [Includes more complete synonymy list.]

Remarks. - This species of Elictognathus is characterized by a prominent lateral ridge on the inner side and a narrow ridge on the outer side. The ridges extend the entire length of the unit and closely parallel the lower edge. The upper edge of the unit is denticulate and has two high points, one located over the compressed apical denticle and another near the anterior end.

This is a common Kinderhookian species and ranges from the lower part of the Hannibal to the top of the Chouteau in western Illinois.

Genus FALCODUS Huddle, 1934

Type species - Falcodus angulus Huddle, 1934

FALCODUS VARIABILIS Sannemann

Pl. 2, fig. 25

1955 Falcodus variabilis SANNEMANN, Senck. leth. Bd. 36, pl. 14, figs. 1-4.

Remarks.- This species is characterized by a short, strongly arched unit. The anterior process is flexed sharply in. The denticles are very closely spaced.

Genus GNATHODUS Pander, 1856

Type species - Gnathodus mosquensis Pander, 1856

Remarks. - Previously, the lowest reported occurrence of the genus Gnathodus in the Upper Mississippi Valley has been from the Cuivre shale (Mehl, 1961, p. 64). The Cuivre formation according to Mehl (1961, p. 99) is a dark fissile shale underlying the Hannibal and unconformably overlying the Louisiana in parts of northeastern Missouri. Our collections from the uppermost beds of the Saverton shale, the Louisiana limestone, and the "Glen Park" formation contain numerous representatives that can definitely be referred to the genus Gnathodus. Gnathodus probably developed from Spathognathodus during the late Devonian (toVI).

The oldest reported occurrence of Gnathodus in Europe is by Bischoff (1957), who reported Gnathodus kockeli from the Lower Carboniferous cuI zone. Gnathodus cf. G. commutatus occurs below G. Kockeli in the Upper Mississippi Valley and represents the most primitive gnathodid.

GNATHODUS cf. G. COMMUTATUS (Branson & Mehl)

Pl. 1, figs. 23-27

Remarks. - This species is characterized by an essentially smooth unornamented platform formed by the expansion of the basal lip at the posterior end of the unit. The species is one of the most common forms in the conodont fauna of the Louisiana limestone. It also occurs in samples from the uppermost beds of the Saverton shale and the lowest beds of the Hannibal formation.

Branson and Mehl (1941a and b) first reported G. commutatus from the Upper Mississippian Caney and Pitkin formations. They postulated (1941b) that the genus Gnathodus was probably derived from an older,but comparable, species. The apparent long range of this species in

North America may be explained in two ways. First, it is likely that a very simple gnathodid such as G. commutatus might have persisted for a considerable length of time. Secondly, the occurrence of Gnathodus cf. G. commutatus in the Saverton and Louisiana may represent a case of homeomorphy.

Bischoff (1957) recognized three subspecies of Gnathodus commutatus: (1) G. commutatus commutatus (Branson & Mehl), a subspecies of G. commutatus with a smooth unornamented platform; (2) G. commutatus nodosus Bischoff, 1957, a subspecies with a strongly developed oblong node on the upper surface of the inner and outer sides of the platform; (3) G. commutatus punctatus Bischoff, 1957, a subspecies characterized by an irregular row of nodes developed on the upper surface of the inner and outer halves of the platform near the carina. Cooper (1939) had previously used the name "punctatus" for a species referable to the genus Gnathodus. Ziegler (1959) proposed the new name Gnathodus commutatus homopunctatus for this form.

The majority of the individuals from the Louisiana are referable to G. cf. G. commutatus commutatus; however, a few (e.g., Pl. 1, fig. 25) are transitional with G. commutatus homopunctatus.

GNATHODUS KOCKELI Bischoff

Pl. 1, fig. 28

1957 Gnathodus kockeli BISCHOFF, Abh. Hess. L. -Amt. Bodenf., p. 25, pl. 3, figs. 27 a-b, 28-32.

Remarks. - This species is characterized by a nearly circular platform that is ornamented on the upper surface by one or two rows of nodes that trend parallel to the blade. Gnathodus kockeli may be easily distinguished from G. cf. G. commutatus. The latter has a relatively high blade or carina and a low platform (Pl. 1, fig. 24), whereas the carina of G. kockeli does not extend much above the upper surface of the platform.

Genus HIBBARDELLA Ulrich & Bassler (in Bassler, 1925)

Type species - Prioniodus angulatus Hinde, 1879

Remarks. - Specimens having a symmetrical denticulated anterior arch, minute basal pit or escutcheon and a denticulated medial posterior bar are here assigned to the genus Hibbardella. Müller (1956b, p. 825) studied topotypic material of Prioniodus angulatus Hinde, the type species of Hibbardella, and concluded that the species lacks a denticulated posterior bar. He therefore proposed a new genus, Ellisonia, to include forms with a well developed denticulated median posterior bar and a minute basal pit. Many workers, notably Hass (1959) who had the opportunity to familiarize himself with Ulrich and Bassler's figured specimens and topotypic material, have not recognized the validity of Ellisonia. We are retaining the name Hibbardella until this problem is resolved.

HIBBARDELLA DIVERGENS Huddle

Pl. 2, fig. 2

1934 Hibbardella? divergens HUDDLE, Bull. Amer. Paleontology, v. 21, p. 31, pl. 10, fig. 6.

Remarks. - This species is characterized by numerous closely spaced denticles on the limbs of the anterior arch and a short apical denticle. The limbs of the anterior arch are compressed and deep. This species has previously been reported from the upper part of the New Albany shale in Indiana.

HIBBARDELLA sp. A

Pl. 2, figs. 1, 3, 6

Remarks. - The lateral limbs of the anterior arch of this species bear four to eight closely spaced denticles that are discrete near their tips. The aboral edges of these limbs are straight and form an angle of about 60°. The apical denticle is short and laterally compressed.

The anterior arch of this species is similar in outline to that of Hibbardella plana Thomas (1949); however, the latter has much heavier limbs.

This species is relatively common in the Louisiana limestone.

HIBBARDELLA sp. B.

Pl. 2, fig. 5

Remarks. - The sharp change in the angle formed by the lower edges of the lateral limbs of this species distinguishes it from all previously described hibbardellids. These limbs form an angle of about 40° near the escutcheon; at about the midpoint of limbs they are bent sharply outward and form an angle of about 150°. These lateral limbs bear numerous minute closely crowded denticles which alternate in size. The apical denticle is short.

Genus HINDEODELLA Ulrich & Bassler (in Bassler, 1925)

Type species - Hindeodella subtilis Ulrich & Bassler, 1926

1925 Hindeodella BASSLER, Geol. Soc. Amer. Bull., v. 36, p. 219.
1926 Hindeodella ULRICH & BASSLER, U. S. Natl. Mus. Proc., v. 68, art. 12, p. 17, 38, 39.
1959 Hindeodina HASS, U. S. Geol. Survey Prof. Paper, 294-J, p. 382.

Remarks. - This genus is a common element in almost all conodont faunas ranging in age from the Silurian to the Triassic. Several factors limit the stratigraphic usefulness of hindeodellids: (1) Certain general forms apparently have long ranges; (2) There has never been an adequate evaluation of the degree of intraspecific variability in this genus; (3) Many species have been based upon fragmentary material, making specific identifications tenuous at best.

Several unbroken hindeodellids from the Louisiana lack a prominent main denticle. Hass (1959, p. 382) proposed the new genus Hindeodina to include forms formerly assigned to Hindeodella but having a small main cusp. It is the opinion of the present authors that this difference is not significant at the generic level. We therefore consider Hindeodina Hass (1959) a junior synonym of Hindeodella Ulrich & Bassler (1925).

HINDEODELLA DEFLECTA Hibbard

Pl. 2, fig. 17

1927 Hindeodella deflecta HIBBARD, Amer. Jour. Sci., 5th ser., v. 13, p. 207-208, fig. 4c.
1955 Hindeodella deflecta SANNEMANN, Senck. leth., Bd. 36, p. 129-130, pl. 2, fig. 5, pl. 5, fig. 8. [Contains more complete synonymy list.]

Remarks. - This species is characterized by a prominent main cusp. The posterior bar has denticles of two different sizes; the larger set of denticles increase in size toward the posterior end. The anterior process is flexed downward and inward only slightly and bears three to five relatively large subequal denticles.

HINDEODELLA ELONGATA Huddle

Pl. 2, fig. 15

1934 Hindeodella elongata HUDDLE, Bull. Amer. Paleontology, v. 21, no. 72, p. 42, pl. 5, figs. 5, 6.

Remarks. - The main denticle of this species is small, the posterior bar is extremely long and slender and bears numerous closely spaced denticles that alternate in size. The anterior process is relatively long and is deflected downward and slightly inward. The specimen figured from the Louisiana differs from the holotype in having a slightly curved posterior bar.

HINDEODELLA EMACERATA Huddle

Pl. 2, fig. 16

1934 Hindeodella emacerata HUDDLE, Bull. Amer. Paleontology, v. 21, no. 72, p. 45, pl. 5, fig. 16.

Remarks. - The posterior bar of this species is compressed and bears denticles of two different alternating sizes. Anterior to the short main cusp the unit is deflected downward and slightly inward.

Huddle (1934) reports that this species is common at several collecting localities in the upper part of the New Albany shale in Indiana.

HINDEODELLA cf. H. UNCATA (Hass)

Pl. 2, figs. 18, 19

1959 Hindeodina uncata HASS, U. S. Geol. Survey Prof. Paper 294-J, p. 383, pl. 47, fig. 6.

Remarks. - This species of Hindeodella is characterized by a sharp 90° flexure of the unit anterior to the small main cusp. The anterior and posterior portions of the blade are compressed.

The anterior process of Hindeodella brevis is also flexed sharply inward; however, this species has a heavier posterior bar and a well developed main cusp.

The specimen on Plate 2, figure 18, differs from the holotype and the other figured specimen from the Louisiana in having extremely long denticles on the anterior process and the posterior bar.

HINDEODELLA ? sp.

Pl. 2, fig. 14

Remarks. - The specimen figured on Plate 2, figure 14, from the McCraney is unusual in that the denticles on the posterior bar are longer or at least have larger bases than the main cusp located near the escutcheon. These denticles increase in size toward the posterior end of the unit.

Genus LIGONODINA Ulrich & Bassler (in Bassler, 1925)

Type species - Ligonodina pectinata Ulrich & Bassler, 1926

LIGONODINA sp.

Pl. 2, fig. 23

Remarks. - The figured specimen from the Louisiana differs from other ligonodinids in having an anticusp nearly one and a half times as long as the main denticle. The anticusp bears four large, discrete and recurved denticles that extend anterior to the main denticle. The basal cavity located beneath this denticle is large and has a flared basal lip. The posterior bar is broken but bears several widely separated discrete denticles.

Genus LONCHODINA Ulrich & Bassler (in Bassler, 1925)

Type species - Lonchodina typicalis Ulrich and Bassler, 1926

LONCHODINA DISTANS Huddle

Pl. 2, figs. 11, 28

1934 Lonchodina distans HUDDLE, Bull. Amer. Paleontology, v. 21, no. 72, p. 84, pl. 6, fig. 13; pl. 10, fig. 3.

Remarks. - This species is characterized by a large basal cavity, short apical denticles and long denticulated limbs. Huddle (1934) reports the occurrence of this species in the upper part of the New Albany shale in Indiana.

Genus NEOPRIONIODUS Rhodes & Müller, 1956

Type species - Prioniodus conjunctus Gunnell, 1931

NEOPRIONIODUS ALATUS (Hinde)

Pl. 2, fig. 29

1879 Prioniodus ? alatus HINDE, Quart. Jour. Geol. Soc. London, v. 35, p. 361, fig. 5.

Remarks. - This species is characterized by a large, broad, compressed, main denticle and a long anticusp. The posterior bar bears several short denticles that are fused in mature individuals.

The specimen figured from the Louisiana differs from typical representatives of this species in having longer denticles on the posterior bar and lacking a flared basal lip on the inner side of the escutcheon.

NEOPRIONIODUS ARMATA (Hinde)

Pl. 2, figs. 22, 24

1879 Prioniodus armatus HINDE, Quart, Jour. Geol. Soc. London, v. 35, p. 360, pl. 15, figs. 20, 21.
1955 Prioniodina armata SANNEMANN, Senck. leth. Bd., 36, no. 112, p. 151, pl. 3, figs. 2, 3. [Contains more complete synonymy list.]

Remarks. - This species is characterized by a long narrow main cusp and a short stout anticusp. The posterior bar is long, thick and bears several discrete denticles.

Genus NOTHOGNATHELLA Branson & Mehl, 1934

Type species - Nothognathella typicalis Branson & Mehl, 1934

Remarks. - This genus has long been considered characteristic of and confined to late Devonian conodont faunas. It is common in the Sylamore sandstone, Maple Mill shale, and the lower and middle portion of the Saverton shale of the Upper Mississippi Valley. The single specimen figured from the Louisiana represents the youngest occurrence of Nothognathella in our collections.

NOTHOGNATHELLA sp.

Pl. 2, fig. 12

Remarks. - This species is characterized by subequal limbs that are arched and flexed

inward sharply. A narrow shelf-like platform is developed on the inner side of the unit. The uniform size of the denticles in this species differentiates it from most other nothognathellids which have a prominent apical denticle and long denticles on the anterior limb.

This species is similar to N.? abnormis Branson & Mehl (1934), N. brevidonta Youngquist (1947) and N. bricristata Youngquist & Miller (1948).

Genus OZARKODINA Branson & Mehl, 1933

Type species - Ozarkodina typica Branson & Mehl, 1933

OZARKODINA PLANA (Huddle)

1934 Bryantodus planus HUDDLE, Bull. Amer. Paleontology, v. 21, no. 72, p. 75-76, pl. 10, fig.8.
non: 1934 Bryantodus planus BRANSON & MEHL, Univ. Missouri Studies, v. 8, no. 4, p. 284, pl. 23, fig. 8.

Remarks. - This species is slightly arched and has a small elongate escutcheon. The denticles are discrete, similar in shape, sharply terminated and somewhat irregular in size. The apical denticle is not prominent. The unit is laterally compressed and lacks the flange-like swelling so characteristic of the genus Bryantodus. We are therefore assigning this species to the genus Ozarkodina.

OZARKODINA sp.

Pl. 2, fig. 9

Remarks. - This species is characterized by a slightly arched, highly compressed unit. The aboral edges of the anterior and posterior limbs form an angle of about 145°. The unit is flexed inward only slightly. The escutcheon is small and surrounded by a flared elliptical basal lip. The apical denticle located over the escutcheon is about twice the size of the other denticles. The anterior limb is nearly twice the length of the posterior limb and bears 11 subequal compressed denticles. The denticles on the posterior limb are slightly smaller and seven in number.

Genus PALMATODELLA Ulrich & Bassler (in Bassler, 1925)

Type species - Palmatodella delicatula Ulrich & Bassler, 1926

PALMATODELLA DELICATULA Ulrich & Bassler

Pl. 2, fig. 13

1926 Palmatodella delicatula ULRICH & BASSLER, U. S. Natl. Mus. Proc., v. 68, art. 12, p. 41, pl. 10, fig. 5.

Remarks. - This species of Palmatodella is characterized by a short, compressed posterior bar, bearing subequal denticles that are discrete near their tips. A long anticusp extends downward from the main cusp. The anterior edge of this anticusp bears numerous minute denticles.

Genus PALMATOLEPIS Ulrich & Bassler, 1926

Type species - Palmatolepis perlobata Ulrich & Bassler, 1926

Remarks. - Palmatolepis is a common platform element in almost every Upper Devonian conodont fauna and the entire palmatolepid group was studied in detail by Müller 1956. In addition, many other European workers, notably Sannemann (1955a, 1955b), Bischoff (1956, 1957), Ziegler (1958, 1961) and Helms (1959) have recorded the occurrences of the genus in Europe. As information on the distribution of species of the genus accumulates, Palmatolepis promises to become one of the most useful of Upper Devonian fossils.

Five species of Palmatolepis have been identified from our collections from the Louisiana limestone.

PALMATOLEPIS GLABRA Ulrich & Bassler

Pl. 1, figs. 1, 2

1926 Palmatolepis glabra ULRICH & BASSLER, U. S. Natl. Mus. Proc., v. 68, art. 12, p. 51, pl. 9, figs. 18-20.

Remarks. - This species is characterized by a narrow sigmoidal outline. The upper surface of the platform is ornamented by faint sinuous ridges. No secondary carina nor keel is developed.

Scott & Collinson (1959) studied the intraspecific variability of this species from a sample collected from the middle part of the Saverton shale. The sample contained six common morphotypes which were designated by the Greek letters α, β, γ, etc. and the relative abundance of each was plotted (1959, p. 557). Although insufficient material was available to construct a similar diagram for the Louisiana limestone all specimens from the Louisiana are referable to the α or the ζ morphotypes of Scott & Collinson.

PALMATOLEPIS GRACILIS Branson & Mehl

Pl. 1, fig. 5

1934 Palmatolepis gracilis BRANSON & MEHL, Univ. Missouri Studies, v. 8, no. 3, p. 238, pl. 18, figs. 2, 5, 8.
1957 Palmatolepis gracilis Bischoff, Abh. hess. L.-Amt. Bodenforsch. v. 19, p. 41, pl. 6, figs. 6-10. [Includes more comprehensive synonymy list.]

Remarks. - This species of Palmatolepis is characterized by a small, narrow posterior platform and a long anterior free blade.

PALMATOLEPIS MINUTA Branson & Mehl

1934 Palmatolepis minuta BRANSON & MEHL, Univ. Missouri Studies, v. 8, no. 3, p. 336, pl. 18, figs. 1, 6-7.
non: 1934 Palmatolepis minuta HUDDLE, Bull. Amer. Paleontology, v. 21, p. 109, pl. 9, fig. 24= juvenile of P. perlobata Ulrich & Bassler.

Remarks. - This species is characterized by a small triangular or nearly bilaterally symmetrical posterior platform. The blade is free near the anterior end of the unit. The platform of this species is wider and not as thick as that of P. gracilis.

PALMATOLEPIS QUADRANTINODOSA MARGINIFERA Ziegler

Pl. 1, fig. 3

1961 Palmatolepis quadrantinodosa marginifera ZIEGLER, Fortschr. Geol. Rheinld. u. Westf., v. 6, p. 11-12, pl. 1, fig. 6, pl. 2, figs. 6-8. [Includes synonymy list.]

Remarks. - Palmatolepis quadrantinodosa is characterized by a short wide plate, which is suboval in outline. The inner side of this platform extends to the anterior end of the unit and is ornamented by faint sinuous ridges. Ziegler (1961) has recognized two subspecies of P. quadrantinodosa on differences in the ornamentation of the anterior end of the outler platform: P. quadrantinodosa quadrantinodosa Branson & Mehl has one or more rows of nodes on the outer platform parallel to the carina; P. quadrantinodosa marginifera Ziegler has a narrow ridge-like parapet rather than nodes parallel to the carina on the outer platform.

Palmatolepis quadrantinodosa marginifera is fairly common in the Saverton shale. The ridge-like parapet is not prominent on representatives from the Louisiana.

PALMATOLEPIS QUADRANTINODOSALOBATA Sannemann

Pl. 1, fig. 4

1955 Palmatolepis quadrantinodosalobata SANNEMANN, N. Jb., Geol. Paläont. Abh., v. 100, p. 328, pl. 24, fig. 6.

Remarks. - This species has a well developed lobe on the inner side of the platform opposite the azygous node. The outer platform anterior to the azygous node is ornamented by one or more rows of low nodes parallel to the carina. A low secondary keel is developed on the aboral side.

The ornamentation of the outer platform of this species is similar to P. quadrantinodosa quadrantinodosa. The two forms may easily be distinguished by the presence or absence of a prominent inner lateral lobe.

Genus POLYGNATHUS Hinde, 1879

Type species.- Polygnathus dubius Hinde, 1879

POLYGNATHUS COMMUNIS Branson & Mehl

Pl. 1, figs. 6-10; pl. 2, fig. 30

1934 Polygnathus communis BRANSON & MEHL, Univ. Missouri Studies, v. 8, no. 4, p. 293, pl. 24, figs. 2-4.

Remarks. - This species is characterized by a lanceolate posterior platform, the upper surface of which is usually smooth or faintly ornamented.

Polygnathus communis is one of the most common early Mississippian polygnathids. It is extremely common in the Hannibal and Chouteau and ranges into the Burlington. The lowest occurrence of the species in western Illinois is in the upper part of the Saverton shale. It is the most abundant species in the conodont fauna of the Louisiana limestone and is also common in the McCraney limestone.

Hass (1959, p. 390) noted that the outline of the posterior platform of P. communis is somewhat variable. He further suggested that this characteristic might prove stratigraphically useful. An examination of representatives of this long-ranging species from the Upper Mississippi Valley has revealed several morphologic variants that are excellent stratigraphic markers. Representatives of the species from the Louisiana limestone are of three broad types: (1) specimens with an unusually broad ovate platform (e.g., Pl. 1, fig. 7); (2) specimens with one or two low nodes located near the anterior end of the platform on either side of the carina (e.g., Pl. 1, fig. 8, 10); and (3) specimens (e.g., Pl. 1, fig. 9) with low transverse ridges ornamenting the entire upper surface of the platform. This latter morphotype is extremely abundant in samples collected from the basal part of the Hannibal in western Illinois and northeastern Missouri.

Representatives of P. communis from the McCraney limestone generally lack ornamentation on the upper surface of the platform. The outline of the plate may be ovate (e.g., Pl. 2, fig. 30) or may have a narrow sharply pointed posterior tip. Specimens having these characteristics are also extremely common in the upper part of the Hannibal formation and in the Chouteau and Fern Glen formations in western Illinois.

POLYGNATHUS COMMUNIS BIFURCATA Hass

Pl. 1, fig. 11

1959 Polygnathus communis bifurcata HASS, U. S. Geol. Survey Prof. Paper 294-J, p. 390, pl. 48, figs. 11, 12.

Remarks. - This subspecies of P. communis is characterized by the presence of a secondary

carina and secondary keel near the posterior end of the platform.

This form is rare in the Louisiana limestone and has not been found in collections from other formations in the Upper Mississippi Valley.

Genus SIPHONODELLA Branson & Mehl, 1944

Type species - Siphonognathus duplicata Branson & Mehl, 1934

Remarks. - This genus is an excellent marker for the Kinderhookian Series in the Upper Mississippi Valley. It first appears in the lowest beds of the Hannibal formation and ranges upward through the Chouteau formation. It is not present in the conodont fauna of the "Sedalia" formation or younger units in western Illinois.

Siphonodella evolved directly from Polygnathus by the development of anterior rostral ridges on the upper side of the platform. Juvenile specimens of Siphonodella have an elongate escutcheon and a wide trough-like keel on the aboral side of the platform. Polygnathids generally have a small ovate escutcheon and narrow ridge-like keel with a narrow slit-like median groove. A few Devonian polygnathids have rostral ridges but these ridges tend to be set at an angle rather than parallel to the carina.

The presence of Siphonodella duplicata and S. cooperi in the conodont fauna of the McCraney limestone and their absence in the Louisiana is extremely useful in differentiating and dating these two formations.

Siphonodella cooperi HASS

Pl. 2, figs. 31, 33, 35

1959 Siphonodella cooperi HASS, U. S. Geol. Survey Prof. Paper 294-J. p. 392, l. 48, figs. 35, 36.

Remarks. - Until recently all siphonodellids with a narrow elongate outline and two or three rostral ridges at the anterior end of the platform were assigned to Siphonodella duplicata (Branson & Mehl). Hass (1959) recently proposed two new species, S. obsoleta and S. cooperi, that are similar to S. duplicata in outline and number of rostral ridges, but have slightly different ornamentation on the upper surface of the platform.

The rostral ridge on the outer platform of S. cooperi is curved slightly and terminates at the margin of the platform anterior to the basal pit. It is longer than the rostral ridge on the inner platform. The outer platform is ornamented by transverse ridges and the inner platform by nodes.

The McCraney representatives of S. cooperi are transitional with S. duplicata. Both species are present in the McCraney and Chouteau formations.

SIPHONODELLA DUPLICATA (Branson & Mehl)

Pl. 2, fig. 32

1934 Siphonognathus duplicata BRANSON & MEHL, Univ. Missouri Studies, v. 8, no. 4, p. 2960297, pl. 24, figs. 16, 17.

Remarks. - This siphonodellid is characterized by a relatively wide, elongate platform with two short prominent rostral ridges that are parallel to the carina. The holotype of the species has transverse ridges ornamenting the inner and outer platforms posterior to the termination of the rostral ridges. Specimens having nodes rather than transverse ridges on the inner platform have also been referred to S. duplicata by many workers.

Genus SPATHOGNATHODUS Branson & Mehl, 1941

Type species - Spathodus primus Branson & Mehl, 1933

1933, Spathodus BRANSON and MEHL [not Boulenger, 1900], Univ. Missouri Studies, v. 8, no. 1, p. 46.
1941 Spathognathodus BRANSON and MEHL, Jour. Paleontology, v. 15, p. 98.
1959 Branmehla HASS, U. S. Geol. Survey Prof. Paper 294-J, p. 381.

Remarks. - HASS (1959) proposed a new genus, Branmehla, for several species formerly assigned to Spathognathodus and designated S. inornata as the type species. According to Hass (1959, p. 381), Branmehla differs from Spathognathodus in having the pulp cavity (escutcheon) located near one end of the unit rather than in a subcentral position. The escutcheon of S. inornata (Hass' type species of Branmehla) is generally located about one third the total length of the unit from the posterior end, although the position of the escutcheon is somewhat variable. Gnathodus Pander has the escutcheon located at the extreme posterior end of the unit. We do not think this criterion alone is sufficient for the erection of a new genus for forms intermediate between Spathognathodus and Gnathodus and we therefore consider Branmehla a junior synonym of Spathognathodus.

Spathognathodids are an important part of the conodont fauna of the Louisiana limestone. The genus is also present in the McCraney limestone, but is much less common.

SPATHOGNATHODUS INORNATA (Branson & Mehl)

Pl. 1, figs. 21, 22

1934 Spathodus inornatus BRANSON & MEHL, Univ. Missouri Studies, v. 8, no. 3, p. 185, pl. 17, fig. 23.
1959 Branmehla inornata HASS, U. S. Geol. Survey Prof. Paper 294-J, p. 381-382, pl. 50, fig. 3.

Remarks. - This spathognathodid is characterized by a subcircular or ovate escutcheon located about one-third the length of the unit from the posterior end. The upper outline of the unit is highest directly over the escutcheon. Hass (1959, p. 381) designated this species as the type of the genus Branmehla. As noted above, the present writers consider Branmehla a junior synonum of Spathognathodus.

Spathognathodus inornata is one of the most common spathognathodids in the conodont fauna of the Saverton shale. It also is quite common in the Maple Mill formation of southeastern Iowa. It occurs in the Louisiana limestone and the lower part of the Hannibal formation but is less common. Our collections from various stratigraphic units in the Upper Mississippi Valley contain thousands of specimens of S. inornata, and we have had the opportunity to study closely the degree of intraspecific variability. The figured specimens (Pl. 1, figs. 21, 22) from the Louisiana limestone differ from the holotype in having much longer needle-like denticles. We feel that these specimens fall within the limits of intraspecific variability of S. inornata.

SPATHOGNATHODUS n. sp. A

Pl. 1, figs. 12-15

Diagnosis. - This distinctive species of Spathognathodus is characterized by the presence of a single well developed lateral denticle on the inner side of the unit immediately anterior to the escutcheon.

Remarks. - This species is one of the most characteristic forms in the conodont fauna of the Louisiana limestone. Several spathognathodids for example S. aculeatus (Branson & Mehl) and S. tridentatus (Branson) have lateral denticles. All previously described species with lateral denticles either have more than one denticle or have the single denticle located over or posterior to the escutcheon. Hass (1947, p. 136) has mentioned the presence of a spathognathodid in the basal part of the Bedford shale of Ohio having a description almost identical with S. n. sp. A.

SPATHOGNATHODUS n. sp. B

Pl. 1, figs. 16-19, 33

Diagnosis. - The denticular pattern of the upper edge of the unit serves to distinguish this species from all previously described spathognathodids. Anterior to the escutcheon there are five to eight large denticles that are triangular in outline. Three or four much smaller, closely crowded denticles may be found between large denticles. The upper edge is much lower posterior to the escutcheon and bears four to five small subequal denticles.

Remarks. - The two sizes of denticles on the anterior portion of the unit are considered diagnostic of this species but the characteristic is best seen in juvenile and intermediate forms. The denticles on large specimens (Pl. 1, figs. 16, 19) tend to become fused and the smaller sets of denticles are gradually lost.

Spathognathodus n. sp. B, a common Louisiana form, is similar in gross shape to S. inornata but the details in the arrangement of the denticles serve to distinguish these species.

SPATHOGNATHODUS n. sp. C

Pl. 1, figs. 29-31

Diagnosis. - The outline of the upper edge of the unit serves to distinguish this species from previously described forms. The upper edge if nearly straight (Pl. 2, fig. 31) or more commonly slightly higher at both ends of the unit (Pl. 2, fig. 29). The summit of the outline of other spathognathodids is at the anterior end of the unit or immediately over the escutcheon.

SPATHOGNATHODUS sp.

Pl. 1, fig. 20

Remarks. - The lower edge of this distinctive species is deeply excavated throughout the entire length of the unit and is flared outward.

The deeply excavated base of this species is similar to S. fissilis (Branson & Mehl), a species which has been considered a junior synonym of S. inornata by Hass (1959, p. 381) and other workers. The denticulation of the Louisiana specimen is quite distinctive and consists of about 21 short, triangular, sharply compressed subequal denticles.

Genus SYNPRIONIODINA Ulrich & Bassler (in Bassler, 1925)

Type species - Synprioniodina alternata Ulrich & Bassler, 1926

SYNPRIONIODINA ALTERNATA Ulrich & Bassler

Pl. 2, fig. 7

1926 Synprioniodina alternata ULRICH & BASSLER, U. S. Natl. Mus. Proc., v. 68, art. 12, p. 42, text-fig. 22.

Remarks. - The unit is pick-shaped and has a short, denticulated, highly compressed anticusp.

Several genera Synprioniodina, Eurprioniodina, and Neoprioniodus have essentially the same outline and differ only slightly in such details as the presence or absence of denticles on the anticusp. Although we have not studied the problem in detail there appears to be an extreme number of forms intermediate between two or more of these genera. European workers such as Sannemann (1956), Bischoff (1956), and Helms (1959) have assigned all such specimens to the genus Prioniodina. The type species of Prioniodina, P. subcurvata, does not closely resemble these forms. It seems apparent that a detailed revision of the pick-shaped units is necessary; however such a revision is beyond the scope of the present study.

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EXPLANATION OF PLATE 1

All figures X40

All specimens collected from the Louisiana limestone at Teneriffe School, Jersey County, Illinois, unless otherwise noted.

FIGS. 1-2. - Palmatolepis glabra Ulrich & Bassler. 1, Upper view of immature specimen of "♂ morphotype" (4P3056); 2, upper view of immature individual of "♀ morphotype" (4P3049).

3. - Palmatolepis quadrantinodosa marginifera Ziegler. Upper view of specimen (4P3-22) with a reduced parapet.

4. - Palmatolepis quadrantinodosalobata Sannemann. Upper view (4P3073).

5. - Palmatolepis gracilis Branson & Mehl. Upper view (4P3021).

6-10. - Polygnathus communis Branson & Mehl. 6, Upper view of specimen (4P3088) from the Louisiana limestone at Buffalo Creek; 7, upper view of specimen (4P3048) with large ovate platform; 8, upper view of specimen (4P3094) with transverse ridges near the anterior end of the platform; 9, upper view of specimen (4P3083) with the platform ornamented by weak transverse ridges; 10, lateral view of specimen (4P3071) showing position of escutcheon near anterior end of the platform.

11. - Polygnathus communis bifurcata Hass. Lower view of specimen (4P3025) illustrating characteristic secondary keel near posterior end of the platform.

12-15. - Spathognathodus n. sp. A. Inner lateral views of several specimens illustrating range in variability. 12, Specimen (4P3068) with poorly developed lateral denticle; 13, specimen (4P3010) with prominent lateral denticle located just anterior to large flared escutcheon; 14, large individual (4P3045) with fused denticles, high outline, and large lateral denticle; 15, specimen (4P3053) with a reduced lateral denticle.

16-19, 33. - Spathognathodus n. sp. B. Lateral view of four specimens illustrating range of intraspecific variability. 16, Specimen (4P3074); 17, immature individual (4P3085) collected from the Louisiana limestone at Poor Farm Hollow, showing well developed discrete denticles of two sizes; 18, specimen (4P3055) illustrating typical denticular pattern of this species; 19, specimen (4P3007) with denticles more fused and subequal in size; 33, aboral view of same specimen (4P3055) illustrated in Figure 18.

20. - Spathognathodus sp. Specimen (4P3008) with extremely large basal excavation.

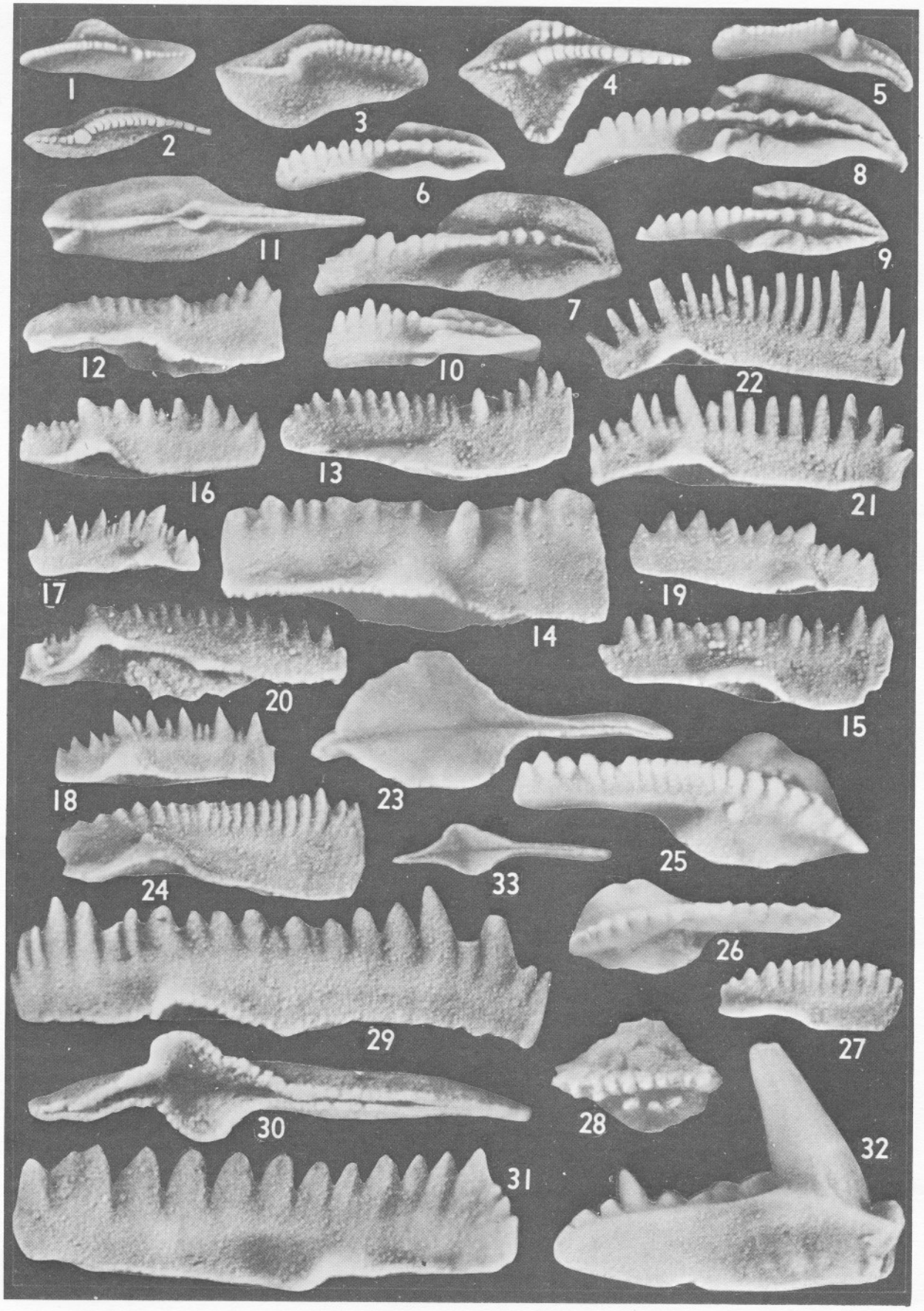
21-22. - Spathognathodus inornata (Branson & Mehl). 21, Specimen (4P3006); 22, specimen (4P3004) with needle-like denticles.

23-27. - Gnathodus commutatus (Branson & Mehl). 23, Aboral view of same specimen (4P3015) illustrated in Figure 25; 24, lateral view of specimen (4P3013) showing low platform and high blade outline near posterior end of the unit; there is a single low node on upper surface of platform; 25, large individual (4P3015) with a few scattered low nodes on the upper surface of the platform; 26, upper view of specimen (4P3014) with smooth unornamented platform; 27, lateral view of immature specimen (4P3012).

28. - Gnathodus kockeli Bischoff. Upper view of broken specimen (4P3016).

29-31. - Spathognathodus n. sp. C. 29, Lateral view of specimen (4P3003) with large denticles at both extremities of the unit; 30, lower view of specimen (4P3002) having flared asymmetrical escutcheon; 31, specimen (4P3000) having nearly straight upper outline.

32. - Bryantodus sp. Lateral view of broken specimen (4P3052).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EXPLANATION OF PLATE 2

All figures X40

All specimens collected from the Louisiana limestone at Teneriffe School, Jersey County, Illinois, unless otherwise noted.

FIGS. 1,3,6. - Hibbardella sp. A. Posterior view of three specimens. 1, Broken specimen (4P3077); 3, specimen (4P3042) with complete anterior arch; 6, immature specimen (4P3063).

2. - Hibbardella divergens Huddle. Specimen (4P3041) showing short discrete denticles.

4. - Scutula bipennata Sannemann. Anterior view of specimen (4P3039).

5. - Hibbardella sp. B. Posterior view of specimen (4P3040).

7. - Synprioniodina alternata Ulrich & Bassler. Specimen (4P3091) from the Louisiana limestone at Buffalo Creek locality.

8. - Ozarkodina plana (Huddle). Specimen (4P3033).

9. - Ozarkodina sp. Specimen (4P3037).

10. - Apatognathus lipperti Bischoff. Immature specimen (4P3029).

11,28. - Lonchodina distans Huddle. 11, Specimen (4P3050); 28, anterior limb of specimen (4P3093) from the Louisiana limestone at Buffalo Creek locality.

12. - Nothognathella sp. Specimen (4P3043).

13. - Palmatodella delicatula Ulrich & Bassler. Specimen (4P3046).

14. - Hindeodella? sp. Specimen (4P15006) from the McCraney limestone at Cascade Station.

15. - Hindeodella elongata Huddle. Specimen (4P3035).

16. - Hindeodella emacerata Huddle. Specimen (4P3033).

17. - Hindeodella deflecta Hibbard. Specimen (4P3034).

18,19. - Hindeodella cf. H. uncata(Hass). 18, Specimen (4P3066); 19, specimen (4P3036) from the Louisiana limestone at Poor Farm Hollow.

20. - Apatognathus inversus Sannemann. Specimen (4P3023).

21. - Dinodus fragosus (E. R. Branson). McCraney limestone, Cascade Station, specimen (4P15015).

22,24. - Neoprioniodus armata (Hinde). 22, Louisiana limestone, Buffalo Creek, specimen (4P3090); 24, same locality, specimen (4P3092).

23. - Ligonodina sp. Specimen (4P3076).

25. - Falcodus variabilis Sannemann. Specimen (4P3044).

26,27. - Apatognathus n. sp. A. 26, Specimen (4P3086) from the Louisiana limestone, Poor Farm Hollow; 27, unbroken specimen (4P3027).

29. - Neoprioniodus cf. N. alatus (Hinde). Specimen (4P3032).

30. - Polygnathus communis Branson & Mehl. McCraney limestone, Cascade Station, specimen (4P15014).

31, 33-35. - Siphonodella cooperi Hass. All specimens from the McCraney limestone at Cascade Station: 31, (4P15013); 33, (4P15005); 34, (4P15006); 35, (4P15016).

32. - Siphonodella duplicata (Branson & Mehl). Specimen (4P15010) from the McCraney limestone, Cascade Station.


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LOWER OSAGEAN STRATIGRAPHY OF EAST-CENTRAL MISSOURI

by
Don L. Kissling

Introduction

The area of east-central Missouri forms the juncture of three extensive belts of lower Osagean exposures whose lithic and faunal components undergo modifications to the north, west and especially to the southeast. This discussion deals with the stratigraphic and areal variations of these components and their environmental implications in the Fern Glen and lower Burlington formation. Lower Osagean exposures, typified as cherty limestones, trend northwest-southeast within the area. These strata, dipping gently toward the northeast, are overlain in that direction by younger Mississippian rocks and are underlain by Kinderhookian and Ordovician rocks to the southwest.

Evaluation of measured sections and collections including 1,100 rock specimens and 6,000 fossils was aided by the preparation and study of nearly 500 polished sections, 60 thin sections, 200 insoluble residue analyses, and sectional examination of the coralline fauna. The writer wishes to acknowledge his indebtedness for the valuable counsel, interest, and assistance extended him by Dr. L. R. Laudon, University of Wisconsin; Dr. A. C. Spreng, Missouri School of Mines and Metallurgy; and the Missouri Geological Survey and its personnel.

Fern Glen Limestone

The Fern Glen limestone was named by Weller in 1906 (p. 438) and described (1909, p. 266) from exposures at Fern Glen, Missouri. Its known distribution occurs throughout eastern St. Charles, St. Louis, Jefferson, Ste. Genevieve, and northern Perry counties, Missouri, and southern Jersey and western Monroe counties, Illinois. Thickness variations of the formation (Fig. 1) demonstrate an eastward thinning. In addition to a local facies development, the Fern Glen limestone may be subdivided into three lithologically distinct members: the lower noncherty limestone, the middle shaly limestone, and the upper cherty limestone.

Lower noncherty limestone member. -- The thickness of the lower member decreases southeastward from 15 to 20 feet in the northwest to a minimum of 4 feet near Kimmswick, Missouri. The limestones are yellowish-gray to light olive gray, medium-bedded, medium-grained, and semicrinoidal, becoming more crinoidal and entirely yellowish-gray toward the northwest. At Fern Glen and Brickeys, Missouri, and Valmeyer, Illinois, the member is partly pale red-- a condition that is accompanied by an increased detrital content. The crinoidal debris is almost wholly composed of completely disarticulated columnals, not uncommonly aligned parallel to bedding.

Detrital, insoluble material of the lower member is largely composed of fine silt and clay and generally makes up 3 to 7 percent of the rock, but shaly partings, up to 15 percent insoluble, often occur in the upper part. Aggregates of minute quartz crystals and glauconite grains appear as characteristic components of the residue. The member is especially characterized by its relative paucity of chert. One to four zones of white to pale red, fossiliferous, ellipsoidal chert nodules occur at several exposures to the northwest, but no chert is found southeast of Fern Glen. Calcite or quartz filled geodes 1 to 4 inches in diameter, common to all lower Osagean strata, are particularly abundant in the upper 2 feet of this member.

Middle shaly limestone member. -- The middle member, which is thin or absent in the northwesternmost exposures, attains a maximum thickness of 22 feet at Fern Glen, and ranges from 12 to 15 feet thick to the southeast. The limestones are shaly to argillaceous, pale red to greenish-gray, very thin-bedded or laminated, medium-grained, almost entirely semicrinoidal, and may locally be dolomitic and yellowish-gray where intensely weathered. The distinctive, pale red aspect of the member increases eastward. The completely disarticulated crinoidal debris, commonly aligned parallel with bedding, shares with other macrofossils the role of clasts in a fine matrix of clay, silt, and carbonate particles.

Detrital material constitutes 18 to 32 percent of the limestone at the base of the member and gradually decreases upward to 12 to 18 percent at the top. Nearly all residue samples

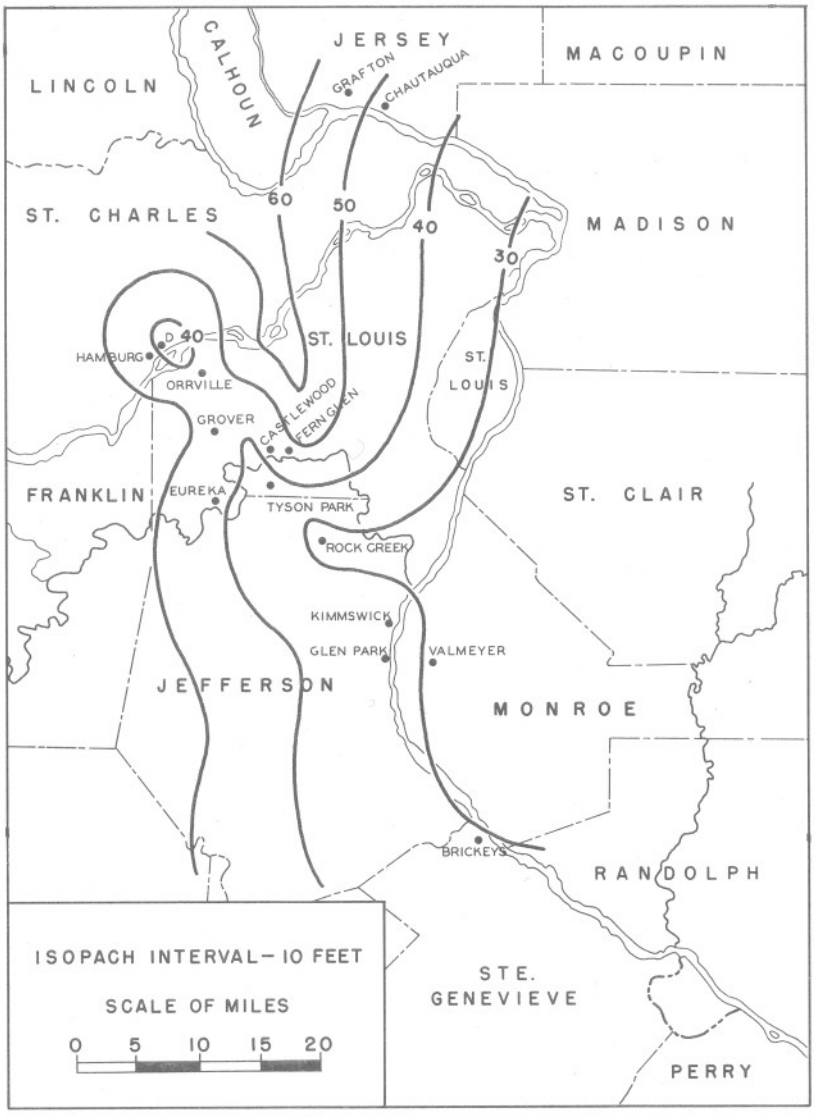

Fig. 1 - Location of exposures and thickness of the Fern Glen limestone.

contain fine, siliceous, fossil fragments and tubes and a few arenaceous Foraminifera. In the northwestern part of the area, thin beds and nodular zones of chert occur throughout the member. Toward the southeast, the pale red to greenish-gray, fossiliferous chert rises upward relative to the base of the member and except for scattered nodules occupies only the upper beds. The chert beds and nodular zones are evidently continuous since single or sequential beds can be readily traced for many miles. Thin lenses of siliceous limestone, 75 to 95 percent insoluble, but possessing all textural features common to the surrounding, gradational, shaly limestone, occur in the lower part of the member. A single, thin bed of siliceous limestone was recognized throughout a 38 mile traverse.

Upper cherty limestone member.-- This upper member varies in thickness from 7 feet at Brickeys to 34 feet at Grafton, Illinois, but over most of the area it approximates 12 feet. The limestone is normally light gray to light greenish-gray or yellowish-gray, thin-bedded, and sparsely crinoidal to semicrinoidal. The uppermost beds in Jersey County, Illinois, are locally crinoidal. The crinoid columnals, dispersed in a fine-grained matrix, have notably less alignment than in the lower members.

Limestones of the upper member contain 3 to 7 percent insoluble materials. Although local, dolomitic beds and thin argillaceous beds may be 8 to 16 percent insoluble. Light gray to light greenish-gray, fossiliferous chert beds and nodules are interbedded with the limestone. Individual chert beds extend for several miles. Irregular limestone patches, similar to the interbedded limestone, are enclosed within some of the upper chert beds.

"Valmeyer" facies. -- At Valmeyer, Illinois, nearly 24 feet of pale red to pale brown, semicrinoidal, thin-bedded limestone overlies the lower Fern Glen member. These limestones, only 3 to 7 percent insoluble and containing just three chert layers, are regarded as a facies of the middle and upper Fern Glen members.

Faunal distribution.-- Apparently no fossils are unique to the lower Fern Glen member. Although only moderately fossiliferous, it contains relatively the largest crinoid fauna. Productina sampsoni (Weller), Schizophoria postriatula Weller, and Cliothyridina glenparkensis Weller appear to be restricted to the lower member and the lower half of the middle member. Amplexus brevis Weller, A. rugosa Weller, and Brachythyris fernglenensis (Weller) are confined to the exceedingly fossiliferous, middle shaly limestone member. Palaeacis depressus (Meek and Worthen) occurs only in the middle member, and in the moderately fossiliferous upper Fern Glen member, in which Echinoconchus alternatus (Norwood and Pratten) and Spirifer carinatus Rowley first appear. Fossils occurring in all members, but evidently restricted to the Fern Glen, or beds of equivalent age, include Rhipidomella jerseyensis Weller, Spirifer rowleyi Weller, S. vernonensis Swallow, and Evactinopora sexradiata (Meek and Worthen).

In order to test the reality of an apparent biofacies in the middle Fern Glen member, the ratios of several taxonomic groups to the entire sampled population of 4,100 individuals were calculated for each of 10 localities. The statistical methods used are designed to reveal distribution differences of proportions between any two binomial populations.

The ratio of corals to brachiopods (Fig. 2) increasing eastward from 1/4 to 1, demonstrates the most conspicuous biofacies of the middle member. With but two exceptions, significant differences of at least 95 percent certainly exist between, but not within, faunal compositions at (1) Chautauqua, Orrville, and Eureka; (2) Grover, Castlewood, Rock Creek, Kimmswick, and Glen Park; and (3) Fern Glen. The fauna at Brickeys appears medial between groups (1) and (2). Smaller, more delicate brachiopods such as Rhipidomella jerseyensis Weller and Leptaena analoga (Phillips) appear to be most abundant to the east, whereas more robust forms such as Spirifer rowleyi Weller and S. vernonensis Swallow are most abundant to the west. The heavy-shelled Cliothyridina obmaxima (McChesney) and Brachythyris subordicularis (Hall) were found in this member only at Chautauqua, Orrville, Eureka, and Brickeys.

Stratigraphic relations.-- North of Grover the Fern Glen limestone overlies the Kinderhookian, Chouteau limestone with apparent conformity, although Moore (1928, p. 147) recognized an unconformity at Grafton, Illinois. Nevertheless, the distinctive color, texture, bedding characteristics, clastic content (averaging 8.3 percent), chert, and fauna of the Chouteau limestone clearly distinguish it from the overlying lower Fern Glen member. South of Orrville, the Fern Glen rests unconformably upon the Bushberg sandstone and, where the Bushberg is absent, upon the upper Ordovician Maquoketa shale. Basal Fern Glen beds overlying these strata contain abundant quartz sand grains. Throughout the area, the Fern Glen is conformably overlain by the lower Burlington limestone with which it is often texturally gradational.

Lower Burlington Limestone

In east-central Missouri, the lower Burlington limestone (part of the Burlington of James Hall, 1857) includes two lithologically distinct units: a lower very cherty, slightly argillaceous carbonate, and an upper less cherty, purer carbonate.

Lower unit.-- Although present throughout most of the area, the lower unit is not recognized in Jersey County, Illinois, and Perry County, Missouri. Variations of thickness of 15 to 44 feet indicate an eastward thickening. The limestones are typically light gray to light olive gray, thin to medium bedded, dense, fine grained, and sparsely crinoidal, becoming progressively more crinoidal toward the top but rarely displaying parallel alignment of columnals. Clay and fine silt constitute 2 to 7 percent of the limestone. Thin, argillaceous beds may be 12 percent insoluble. Yellowish-gray, dolomitic beds occur locally but do not maintain broad stratigraphic continuity.

At several exposures, especially to the southeast, chert represents nearly half of the lower unit. The very light to light gray, fossiliferous chert beds and nodules commonly anastomose and embody numerous limestone patches. Although more or less continuous, individual beds are not traceable for great distances. The sparse fauna is characterized most by Spirifer carinatus Rowley and Echinoconchus alternatus (Norwood and Pratten).

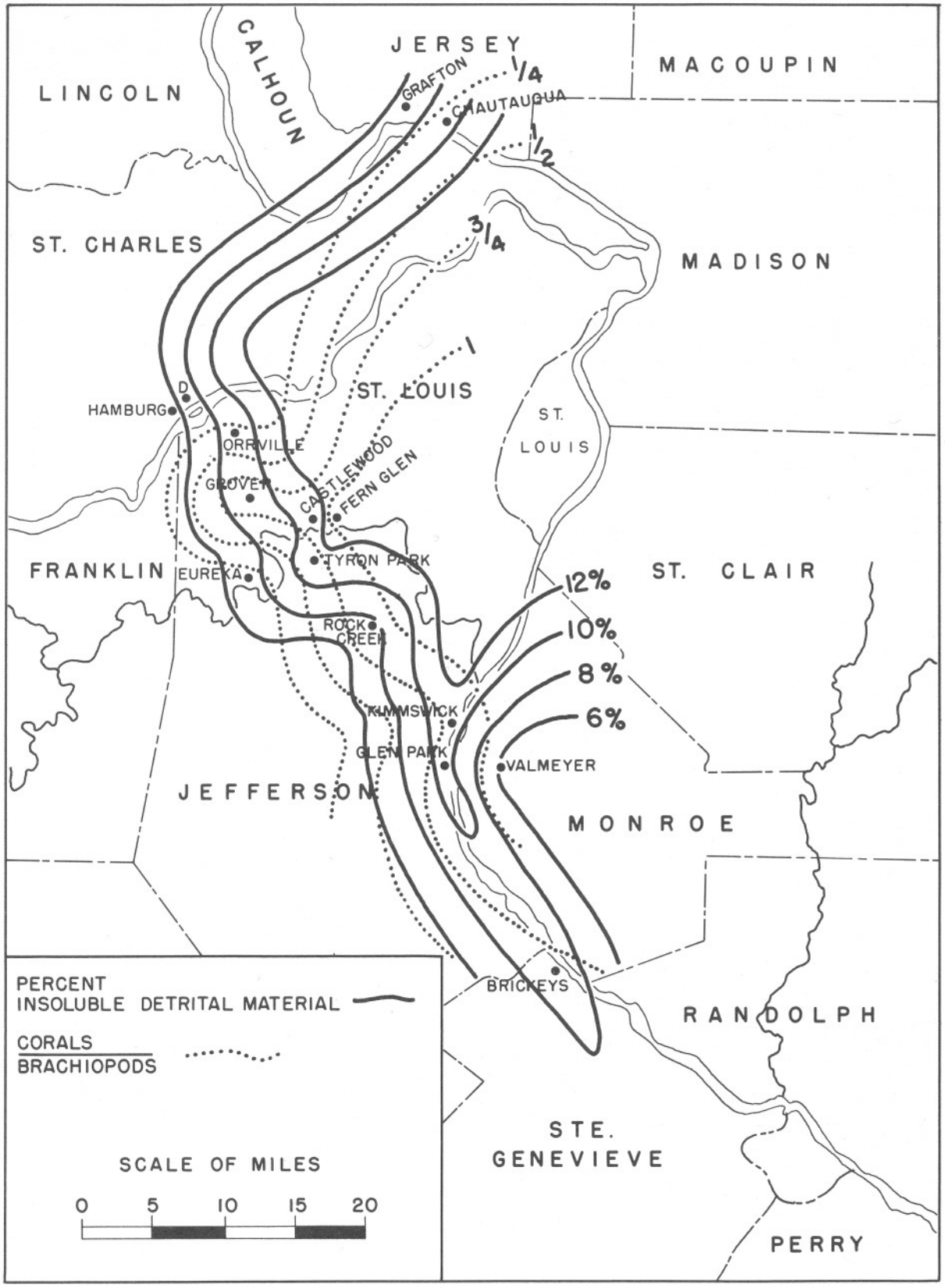

Fig. 2 - Percentage distribution of insoluble detrital material of the Fern Glen limestone. Coral-brachiopod ratio distribution for the middle Fern Glen member.

Upper unit. --Except in Jersey County, upper lower Burlington strata, generally more than 40 feet thick, conformably overlie the lower unit throughout the area. The limestones are light gray to grayish orange, medium to thick-bedded, coarsely crinoidal, and only 0.5 to 3.0 percent insoluble. The profusion of crinoid columnals, which are notably coarser than those of older Osagean strata, commonly displays parallel alignment. Localized dolomitization is accompanied by an increased detrital content and is almost certainly a very late alteration. Very light gray to white, fossiliferous chert occurs as thick, irregular, lenticular beds and nodules possessing little continuity. Agaricocrinus planoconvexus Hall typifies the crinoid-dominated fauna.

Correlation

Correlation of the Fern Glen members (Fig. 3) is based primarily on two horizons: (A) the previously mentioned siliceous limestone bed, and (B) the base of a sequence of continuous chert beds recognized at all exposures. Because of their areal persistence, these horizons are assumed to be approximately time equivalent throughout their extent.

The lower Fern Glen member, representing basal Osagean in east-central Missouri, contains slightly older and younger strata toward the northwest. Upper beds of this member are considered a facies of the lower development of the middle Fern Glen member southeast of Eureka. Upper beds of the middle member are equivalent to the lower part of the upper member at Hamburg and Grafton, and both members are equivalent to the "Valmeyer" facies. The top of the middle member, defined where the shale content of the rock decreases abruptly, nowhere represents the same time horizon. As indicated by the first appearance of Spirifer carinatus Rowley, the top of the Fern Glen becomes progressively younger toward the northwest.

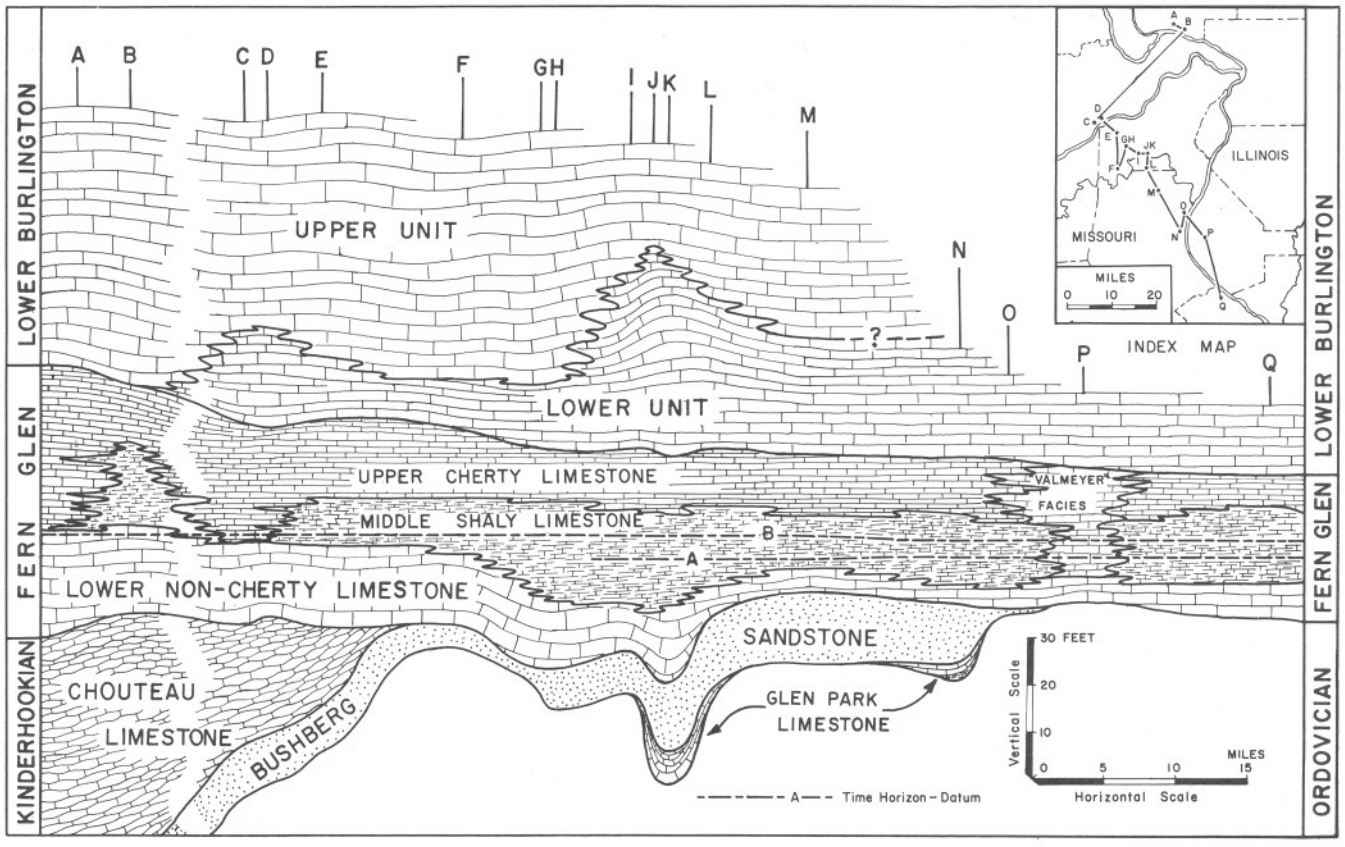

Fig. 3 - Cross section of the lower Osagean and Kinderhookian strata through east-central Missouri.

The Fern Glen limestone has been correlated with the Pierson limestone of southwestern Missouri by Weller (1909, p. 322). The similarity of the Pierson and Fern Glen lithologies and faunas is well known; however, a tabulation of lower Pierson faunas (Spreng, 1952) contains several species that are not present in the Fern Glen and that represent decidedly older forms. The upper part of the Pierson is considered approximately equivalent to the lower part of the Fern Glen.

Moore (1935, p. 241) considered the upper Fern Glen "...paleontologically and lithologically almost identical with the Reeds Spring limestone of southwestern Missouri." Although inadequately known, the fauna of the Reeds Spring strongly suggests its equivalence to the upper Fern Glen, but not to strata younger than Fern Glen. Weller (1909, p. 327) correlated the Fern Glen with the Lake Valley formation of southern New Mexico. Laudon and Bowsher (1941, p. 2133) recognized part of the Alamogordo member of the Lake Valley as equivalent to the Fern Glen and perhaps to part of the Lower Burlington. Fern Glen and lower Burlington faunas are apparently represented homogeneously in the lower Lake Valley strata.

Lithologic differences of the lower Burlington limestone of northeastern Missouri and east-central Missouri reflect a southeastward increase of chert and fine clastics. Fauna of the upper unit of the lower Burlington suggest these beds are most closely allied to the Physetocrinus ventricosus zone of Laudon (1937).

Depositional Environment

The earliest Osagean sea in east-central Missouri, having transgressed from the east or northeast, probably surrounded the Ozark region to the southwest, but did not submerge it. Sands, eroded and broadly distributed by the advancing sea, were incorporated in the basal carbonates. Crinoids were perhaps the most abundant life forms in the early Fern Glen sea and apparently lived in greater profusion in an arcuate belt of shallow water bordering the shore to the west where their disarticulated remains formed thick lime deposits. Carbonate deposition began later and proceeded more slowly toward the southwest.

Red clay and silt, probably weathered from Cambrian and Ordovician cherty dolomites exposed in the Ozark region, were introduced into the sea by streams and wave action, whence they were washed over the shallower western area and deposited along with lime muds and organic remains in a slight basin in eastern St. Louis County. This action persisted throughout much of early Fern Glen time. With the advent of middle Fern Glen deposition, larger quantities of red detritus were swept northeastward, and with the progression of time, throughout most of the eastern area. Low-clastic, skeletal limes continued to be deposited along the shallower, western belt. Preservation of the red color and the abraded surfaces of fossils indicate that the sea, probably even in its deeper parts, was quite shallow. Crinoids, brachiopods, and corals dominated the sea during middle Fern Glen time. Brachiopods, especially the more robust forms, were most abundant toward the west. Corals lived in greater numbers toward the east, in perhaps deeper, quieter waters with a more suitable substratum.

Toward the end of middle Fern Glen time, clastic deposition was abruptly reduced. Sedimentation during late Fern Glen and earliest Burlington time depended largely upon the deposition of calcareous muds and skeletal remains. Detrital material was deposited in ever decreasing amounts until about middle lower Burlington time when the sea had transgressed over most or possibly all of the Ozark region, and sediments were essentially formed from crinoidal debris. Crinoids were certainly the most conspicuous inhabitants of the sea at this time, and the horizontal alignment and almost complete disarticulation of their remains attest to the shallow, agitated nature of the Burlington sea.

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THE MIDDLE MISSISSIPPIAN SERIES (OSAGEAN AND MERAMECIAN) OF NORTHEASTERN MISSOURI

by
Alfred C. Spreng

Introduction

This paper is a review and summary of the stratigraphy of the middle two Mississippian Series in the type region of the Mississippian System.

Good exposures of these Mississippian rocks can be seen along both sides of the Missouri River north of St. Louis and south of St. Louis from Dupo, Illinois, to Ste. Genevieve, Missouri. The best exposures occur where the river has cut through fold trends such as the Lincoln fold, Dupo fold, and other less important trends.

Lithologically the formations involved are carbonates except for parts of the Warsaw and Salem formations. Because these Middle Mississippian formations show a gross similarity, the carbonates can be taken as an entity to which the termslithosome or megagroup of Swann and Willman (1961) would apply.

Some of the more important stratigraphic-sedimentational problems which have been encountered in the study of the Osagean and Meramecian rocks in this area are as follows: 1) Does the boundary between the two series represent a significant unconformity? 2) What are the facies relationships between the Warsaw and Salem formations, and what is their relationship to the type Salem? and 3) What is the origin of the St. Louis breccia? Formations indexed in the two series are: Burlington, Keokuk, Warsaw, Salem, St. Louis, and Ste. Genevieve. These formations are briefly discussed below.

Osagean Series

Burlington formation.-- At the type area near Burlington, Iowa, the Burlington formation is about 70 feet thick. Its areal distribution is a little less than that of the overlying Keokuk formation. The Burlington is well exposed along the Lincoln fold where it is more than twice as thick as in Iowa. It crops out again in St. Louis County and southward along the eastern side of the Ozark uplift where it thins to about 75 feet. The outcrop trend continues, even more prominently around the northern and western side of the Ozark uplift. It is about 145 feet thick in the Springfield, Missouri, area, although to the south and southwest the formation as a lithic entity pinches out.

The coarse-grained, crinoidal, light-colored, stylolitic character of the limestone is distinctive. Cherts are light colored, nodular, and often fossiliferous. Thick sequences of noncherty, calcitic limestones suitable for quarrying cannot be obtained in the northeast Missouri area.

In southeastern Iowa, the formation has been subdivided into a lower and upper division on faunal bases. A similar lithologic division can be made in most areæ; the lower part is rather dolomitic and brown weathering in contrast to the upper part. As mentioned later in the discussion of the Keokuk, the top of the Burlington has a fish-tooth zone at the top. The base of the Burlington overlies various Kinderhookian units in this area.

In northeastern Missouri, the Burlington is exposed in numerous places in Marion, Monroe, Pike, Lincoln, and St. Charles counties. In west-central Illinois, the formation is exposed east of Burlington, Iowa, and south of Quincy in Adams, Pike, and Calhoun counties. The Burlington in these areas has also been divided into lower and upper parts. The distinction is not too definite, but the lower part is less cherty and usually contains dolomitic layers. Of the lower part, the basal 22 to 27 feet is a distinctive unit in which the chert content is very low. The chert occurs in two or three layers just above the middle of this unit. The remainder is a high calcium limestone (96 to 98 percent $CaCO_3$) which is quarried and mined in many places in the Hannibal-Quincy area. Locally it is called the "White Ledge" or the

"Quincy member". Occasionally part of this limestone will be light brown in color and ferruginous, but the matrix is calcitic rather than dolomitic.

In Lincoln County and areas to the west, the basal few feet of the Burlington is a brown, calcitic limestone. This portion may be equivalent to the Pierson of west-central Missouri, but this possibility has not yet been investigated thoroughly.

Underlying the formation is either the Hannibal formation or the Chouteau group. In the St. Louis County area a red,or red and green limestone and shale occurs between the Burlington and the beds assigned to the Chouteau group. This is the Fern Glen formation which is discussed in another paper in this guidebook.

Considering the large amount of crinoidal remains, it would be expected, and rightly so, that the formation can be zoned or at least identified by crinoids. A regional crinoid zonation of the formation by Laudon (1937) shows that the Burlington can be divided into 7 zones and that the oldest Burlington zones occur in southwestern to northeastern Missouri and only the younger Burlington occurs in the type region. Crinoid markers are: the batocrinids Uperocrinus pyriformis, Eutrochocrinus christyi, and Macrocrinus vereuilianus. Cactocrinus, Steganocrinus, and Physetocrinus are important Burlington actinocrinids. Unfortunately, complete calyces are hard to find, so that the crinoids are not always helpful for zonation, especially at oft-studied exposures. The highest zone is characterized by the blastoid Pentremites elongatus. Brachiopods are common; some diagnostic ones are Spirifer grimesi and Dictyoclostus burlingtonensis. Most corals are of the horn coral type. These are usually long-ranging forms like Triplophyllites. Amplexus is also common.

Keokuk formation.-- The Keokuk formation is gradational to both the underlying Burlington and the overlying Warsaw formations in northeastern Missouri and adjacent regions.

In the type area at Keokuk, Iowa, and vicinity, Van Tuyl (1922) reclassified the Keokuk into two units. His classification is still currently followed. The lower unit consists of 2- to 10-inch beds of gray, usually medium- to coarse-grained, fossiliferous limestone and nodular and bedded, blue-gray chert. Chert makes up about 30 to 50 percent of the section and is present in both parts. The upper part of the section consists of gray or blue-gray limestone which contains increasingly thick beds of shale toward the top where the formation grades into the Warsaw. The lower unit (sometimes called the "Montrose chert") is 30 feet thick; the upper unit is about 40 feet thick according to Van Tuyl. The formation becomes at least 100 feet thick in southwestern Missouri. Locally, parts of beds will be dolomitic. The blue-gray color of the limestone and chert is the most obvious criterion for distinguishing the formation from the underlying Burlington, although in many and perhaps in most places a line of separation is not obvious. In Iowa, a phosphatic, fish-tooth zone has been noted in the top bed of the Burlington, but this marker is not apparent in the northeastern Missouri sections.

A sharp boundary between the Burlington and Keokuk formations cannot be drawn in the Lincoln fold area. On the Missouri side of the Mississippi River, a total of about 235 feet of Burlington-Keokuk is present, and the upper one-third contains the typical Keokuk chert. A sharp boundary is not present in the area. On the Illinois side, Rubey (1952, p. 46) includes 60 to 70 feet of section in the Keokuk, although he states that the contact between the two formations is not sharp.

In St. Louis and Ste. Genevieve counties, the combined thickness of two formations remains much the same as in the Lincoln fold area. Where the Burlington and Keokuk cannot be readily differentiated in this area, the beds are designated Burlington-Keokuk.

The faunas of the Keokuk and Burlington have useful elements which are of value in, but not requisite to, distinguishing the two formations. Species of Archimedes begin in the upper Keokuk. Agaricocrinites, a desmidocrinid, is common in the Keokuk, but it also occurs in the Burlington. The actinocrinitids and batocrinids are more common in the Burlington, but many genera continue into the Keokuk. The batocrinid, Alloprosallocrinus, is confined to the Keokuk. The inadunate crinoids are not common enough to be useful. They are more helpful in the Meramecian beds. Spirifer keokuk, S. logani, Brachythyris suborbicularis, Tetracamera subtrigona, and Orthotetes keokuk are common (but not exclusively) Keokuk brachiopods.

Osagean-Meramecian Boundary

Concepts of the significance of the Osagean-Meramecian boundary have varied from

considering it of little importance with the two series being combined to make one (the Valmeyeran Series) to considering it a very important break, especially in regard to the fauna. The problem also involves the placement of the boundary, either above or below the Warsaw or above the Salem. Originally, it was placed at the base of the Warsaw of the Meramec group by Ulrich. Opinions since held by various authors are shown in the following table:

<table>
<tr><th></th><th>Worthen, 1866</th><th>Ulrich, 1904</th><th>S. Weller 1904</th><th>Van Tuyl 1925</th><th colspan="2">Moore, 1933</th><th colspan="2">J.M. Weller & Sutton, 1940</th><th>Laudon, 1948</th><th>J.M. Weller <u>et al</u>., 1948</th></tr>
<tr><td>Ste. Genevieve</td><td rowspan="3">St. Louis group</td><td rowspan="3">Meramec group</td><td>Ste.Genevieve group</td><td rowspan="3">Meramec group</td><td rowspan="4">Valmeyer Series</td><td rowspan="3">Meramec group</td><td rowspan="4">Iowa Series</td><td rowspan="3">Meramec group</td><td rowspan="3">Meramec Series</td><td rowspan="3">Meramecian Series</td></tr>
<tr><td>St. Louis</td><td rowspan="2">Meramec group</td></tr>
<tr><td>Salem</td></tr>
<tr><td>Warsaw</td><td rowspan="3">Osage group</td><td rowspan="2">Osage group</td><td rowspan="2">Osage group</td><td rowspan="2">Osage group</td><td rowspan="2">Osage Series</td></tr>
<tr><td>Keokuk</td><td>Keokuk group</td><td>Osage group</td><td>Osage group</td><td rowspan="2">Osagean Series</td></tr>
<tr><td>Burlington</td><td>Burlington limestone</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

The consensus of opinion of the compilers of the Mississippian correlation chart (Weller, J. M., et al., 1948) was that the boundary between the Osagean and Meramecian should be placed where it had been originally, between the Keokuk and Warsaw formations.

The sequence of beds in southwestern Missouri lends support for minimizing the significance of the Osagean-Meramecian break between the Keokuk and Warsaw formations. In Dade and Barton counties, west of Springfield, Missouri, sections starting with the Burlington limestone and continuing into the St. Louis limestone can be fitted together. This sequence, consisting of carbonates and cherty carbonates, does not appear to be interrupted by unconformities. The fact that very little clastic material accumulated in this part of Missouri would suggest that either the Warsaw formation is not developed here or that it is represented by a different facies than is found nearer the type region. However, within the interval of about 100 feet above the Short Creek oolite, there are limestones, such as are present in the marble quarries at Carthage, which contain fossils such as Marginirugus magnus, Spirifer bifurcatus, S. pellaensis, a few specimens of Brachythyris subcardiformis and Penetremites conoideus. These fossils suggest the approximate horizon of the Warsaw formation that is present in the Mississippi Valley. Limestones of Salem age may be represented by beds below definite St. Louis limestone. These doubtful Salem beds contain Tetracamera acutirostra and Eumetria cf. E. verneuliana. The only features which suggest possible interruptions of deposition are the Short Creek oolite and a thin, 3-foot shale sequence containing lenses of limestone that is in the lower part of the possible Warsaw. The regional significance of the shaly unit is yet to be evaluated. Neither the oolite nor the shale sequence seems to be associated with an unconformity.

Meramecian Series

Warsaw and Salem formations-- The Warsaw and Salem formations are not impressively distinct either lithologically or topographically in the area covered by this field conference. It is for this reason that they are treated as a unit, at least until the lithofacies relationships can be better understood.

The type section of the Warsaw formation occurs in the field conference area at Warsaw, Illinois. At this locality, the Warsaw and what is called the Salem are readily separable, partly because the section is well exposed.

The lower part of the Warsaw, about 36 feet in thickness, is definitely distinguishable from the underlying Keokuk in the type area. It consists of fine-grained, earthy, gray, or brownish-gray, geode-bearing dolomitic limestone at the base,with the beds becoming shalier near the top but still containing geodes. This portion of the Warsaw is the most easily recognized and extends as far south as Ste. Genevieve County, Missouri, where the geodes are usually absent.

The upper division is composed of bluish-gray shale interbedded with fossiliferous limestone and a few thin beds of calcareous sandstone. The limestone beds contain abundant bryozoan remains, mostly Fenestella, Archimedes, Glyptopora, and Lioclema. The unit disappears north of the cities of Keokuk and Warsaw and thickens to the south, at least on the Illinois side of the Mississippi River. At various times it has been, and probably still is, included with the overlying Salem. The thickness of this unit is approximately 40 feet.

Indicative of the rapid change in the formation, it may be noticed that across the river from the type section at Keokuk, Iowa, the thickness of the formation is less than 50 feet, and the beds of fossiliferous limestone are less common. The upper unit is about 25 feet thick and unfossiliferous, while the lower part is bryozoal, contains some geodes, and is less than 20 feet thick.

At Warsaw, Illinois, beds generally called the Salem in that area consist of 3 to 8 feet of cross-bedded, brown-weathering biocalcarenite which laterally grades into a calcareous sandstone (Weller, 1908, p. 163). As Weller and Sutton (1940, p. 812) have pointed out, this unit is not very persistent lithologically and varies in thickness. What are apparently equivalent beds in southeastern Iowa and south of Warsaw on the Illinois side consist of cross-bedded, crinoidal limestone, massive dolomitic limestone and massive, brown, silty dolomite, or even fine-grained sandstone.

Because the upper part of the Warsaw is similar to the Salem, at least where the Salem is calcareous and where the Warsaw is not geodic as it is to the south of the type Warsaw, there are many localities where the formations cannot be readily differentiated, hence the term Warsaw-Salem has come to be used in such cases. It has been suggested a number of times (Weller and Sutton, 1940, pp. 809-810, and Laudon, 1948, pp. 289-290) that carrying the name Salem into this area was ill-advised. A major problem here is to determine the lithofacies distribution of the Salem and its relationship to the Warsaw. J. M. Weller long ago (1934) stated that no consistent upper boundary of the Warsaw can be recognized in the Mississippi Valley. The faunal differences or similarities of these formations have not yet been resolved in this area.

For the area in the vicinity of the Lincoln fold, Rubey feels that the Warsaw and Salem can readily be distinguished, at least in Calhoun County, Illinois. Here their combined thickness is about 130 feet. The Warsaw, which makes up a little less than half the thickness, consists of shales with interbedded limestones and dolomitic limestones with calcitic geodes near the top and bottom. The Salem is a harder, more massive, dull brown, dolomitic limestone containing quartz geodes and small chert nodules.

However, it is difficult to recognize a sharp boundary between the Warsaw and the Salem on the west side of the Mississippi River and on the south side of the Lincoln fold where at least 115 feet of Warsaw-Salem occur. There are localities west of the Mississippi River bluff and in the vicinity of the Lincoln fold where the bluish-gray shale of the Warsaw may be observed, but generally there are no good exposures in this area.

Numerous exposures of probable Salem which are present along Missouri Highway 47 on the south side of the Lincoln fold contain some dolomitic limestone and numerous beds of crinoidal limestone that are interbedded with shale. Fossils include fenestellid bryozoans, Productella (?), Echinoconchus sp., Composita spp., Spirifer pellaensis, and Camerotoechia sp. About 3 feet from the top of the Salem, there is a bed of crinoidal limestone several inches thick containing abundant coalified plant stems.

Better exposures of the Salem and Warsaw formations occur west and northwest of St. Louis near O'Fallon and along the Meramec Highlands.

From St. Louis southward, the Warsaw and Salem lithologies are generally separated by a thin, transition zone. In Ste. Genevieve County, the Warsaw consists of a 50-foot lower shale

unit with some limestone beds that are locally dolomitic. The Salem here is 150 or more feet thick, with a cross-bedded, oolitic calcarenite at the base, followed by a Warsaw-like, blue-gray, dolomitic, fossiliferous limestone, oolitic limestone, and a coarse-grained limestone containing Lithostrotion proliferum and Lithostrotionella castelnaui. Southeast of this area in Union County, Illinois, the Warsaw and Salem become thick limestones which are not readily distinguished.

St. Louis formation.-- The St. Louis limestone, in the field conference area, overlies the Salem or Warsaw-Salem, but to the northwest in Iowa the St. Louis overlies Osagean units.

The formation is overlain by the Ste. Genevieve limestone. It is more extensive in occurrence than the Ste. Genevieve, being exposed at or near the surface in numerous exposures in the southeastern counties of Iowa south and west of Burlington. Exposures of the formation have been made in recent years by quarrying operations in Lewis and Clark counties in the northeastern corner of Missouri. To the south, on both flanks of the Lincoln fold, thicker St. Louis is developed. The next exposures to the south occur in St. Louis County, the type section, and in adjacent areas in Illinois where the formation is estimated to be 270 feet thick.

St. Louis lithology is distinctive and easy to recognize (except where it has been dolomitized) by its gray color, fine-grained to sublithographic texture, and limited but distinctive fossil content, particularly the corals Lithostrotion proliferum and Lithostrotionella castelnaui.

In southeastern Iowa the St. Louis has been divided into two members. At the base is the Croton member which consists of about 30 feet of dolomitic limestone which grades laterally into nondolomitic limestone. The upper St. Louis, called the Verdi member, consists of a maximum of 35 feet of dense, gray, medium-bedded limestone which reportedly grades into fine sandstone; gray shale beds and partings occur in most sections. These units may locally be brecciated. Approximately the same thickness of St. Louis occurs in Lewis and Clark counties in northeastern Missouri. The lower part is often locally dolomitized, cherty, brecciated, and may contain the corals Lithostrotion proliferum and Syringopora sp. The breccia, in contrast to that higher in the section, is composed of small fragments, usually less than 2 inches across. Not enough sections are available for study to determine whether this part can consistently be separated from the more uniform, calcitic upper part, as has been done in Iowa.

The upper limestone portions in Lewis and Clark counties are medium to fine grained and generally contain above 94 percent $CaCO_3$ except near the Ste. Genevieve contact where the silica content increases due to the presence of quartz grains. The upper part may also locally contain bluish-gray shale such as is present in the quarry southwest of Monticello in Lewis County and in the Brooks Quarry 2 miles northeast of Kahokia in Clark County. The upper part of the section is also brecciated.

In the area of the Lincoln fold, the St. Louis thickens to 100 to 135 feet and increases to 170 feet along the Illinois River near Pere Marquette State Park. Excellent exposures in 40- to 60-foot bluffs occur along the Mississippi River in southern Calhoun County, Illinois, and again in the Alton-St. Louis area.

In western Calhoun County, along the Mississippi River, the St. Louis is again fine-grained, gray, medium- to thick-bedded limestone which is characteristic of most of the section. A breccia zone, with a shale matrix, at least 15 feet in thickness occurs near the base, and two fractured breccia zones encompassing 50 feet in the upper half of the section have been observed in cores from this area. Near the base of the section, chert and ripple-marked limestone are occasionally found.

At about 130 feet above the base of the St. Louis formation in Calhoun County, the section becomes oolitic, glauconitic, sandy, and occasionally brecciated. Fossils are very sparse in these beds, but on the basis of lithologic character it has been presumed that this change marks the base of the Ste. Genevieve formation although Rubey (1952) prefers to keep these beds at the top of the St. Louis.

Farther south in the vicinity of the type area, the St. Louis limestone is much thicker, as mentioned above. Quarries along the Mississippi River bluff will expose only about 100 feet, because the formations have been eroded back along the bluffs and are covered with loess.

South of St. Louis, the St. Louis limestone caps prominent bluffs on the Illinois side of the Mississippi River in Monroe and Randolph counties and to a lesser extent on the Missouri side. In Union County, Illinois, the St. Louis is considerably thicker, 350 to 400 feet (Weller and Sutton, p. 814), but is also considerably more cherty than in the area to the north.

Ste. Genevieve formation.-- The Ste. Genevieve limestone represents the youngest Mississippian rocks in the field conference area, but it is not well developed. Here the formation is overlain either by beds of the Pennsylvanian, Desmoinesian Series or by Pleistocene drift or loess. Outcrops of the Ste. Genevieve formation as well as the underlying St. Louis occur along the Mississippi River bluffs in the northeastern corner of Missouri and in the adjacent parts of Illinois and Iowa.

In Iowa,the formation rests disconformably on the St. Louis, sometimes on lower St. Louis beds. The base is generally a sandstone or calcareous sandstone, usually not more than 3 feet thick. This is overlain by gray, calcareous, often fossiliferous limestone and fine-grained, gray argillaceous limestone, both of which are interbedded with gray shale. The limestone beds may reach 15 feet in thickness.

In northeastern Missouri, less of the section is usually present. The basal sandstone bed is present and forms a cross-bedded white sandstone which disconformably or paraconformably overlies the St. Louis, the top of which is sandy in Clark County. The sandstone is followed by limestone similar to that in Iowa, although usually only a few feet are present in sections south of the Des Moines River.

Both the shale and limestone are fossiliferous, brachiopods and bryozoans being the most common constituents.

These beds were originally called the "Pella beds", but the similarity of fauna suggested a correlation with the Ste. Genevieve type area south of St. Louis. Because of the very uncertain connection between the two areas and the dissimilarity of the rocks, the original name of the beds would seem preferable. The problem of the inclusion of this formation with the Chesterian Series or the Meramecian will have to be solved where more of the formation is developed and where it is overlain by Chesterian beds.

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PENNSYLVANIAN GEOLOGY OF THE LINCOLN FOLD

by
Walter V. Searight and Thomas K. Searight

Structure

Missouri is dominated by two major structural features, the Ozark uplift and the Forest City basin (Fig. 1). The Ozark uplift, a broad structural dome, occupies the central and southeastern part of the state, whereas the Forest City basin lies in the northwestern part. Much of the dome lies within the state, but the basin extends northward into Nebraska and Iowa and westward and southwestward into Kansas.

The boundary between the Ozark dome and the Forest City basin is not a smooth, even incline, but it is an area broken into northwestward trending structural segments of considerable magnitude (Fig. 1). Two of these are structurally depressed and two are elevated. For convenience, these are referred to as Tri-State plateau, a depressed area in the southwestern part of the state, the West-central salient, a structurally elevated area in west-central Missouri, and the East-central recess, a depressed area which separates the West-central salient from the Lincoln fold.

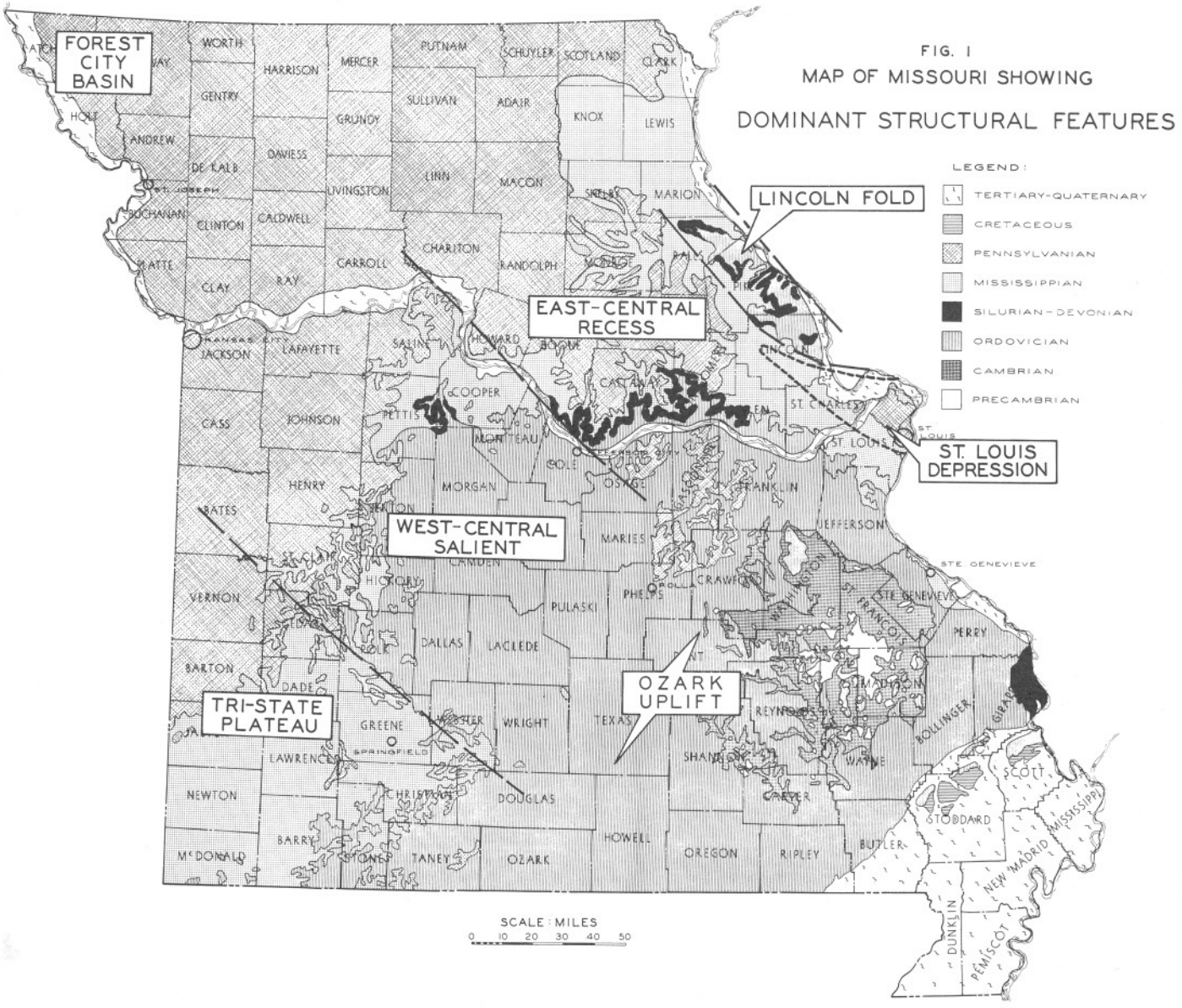


FIG. 1
MAP OF MISSOURI SHOWING
DOMINANT STRUCTURAL FEATURES

Two lesser structural features are worthy of note here (Fig. 1), the Saline County arch which lies along the northeastern boundary of the West-central salient and the elongate St. Louis depression which lies immediately south and southwest of the Lincoln fold in Missouri.

Stratigraphy

The Pennsylvanian strata of Missouri represent the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian Series (Searight, W. V., 1961). Known Morrowan beds consist only of outliers of the Hale formation (sandstone) in Barry County, remote from the Lincoln fold. To the Atokan are referred the Cheltenham and associated residuum and clastics, the McLouth, the Burgner (Searight, W. V., 1961; Searight, W. V., and Palmer, 1957) and the Riverton (Searight, W. V., and others, 1953) formations. The McLouth formation appears to be confined to the Forest City basin where it attains a thickness of 200 feet or more in Missouri. The Burgner formation, consisting of coal, shale, and limestone, has been identified in the Joplin district and on the northwest flank of the Ozark uplift. Limestone below the lowest Desmoinesian in the Forest City basin is likewise referred to the Burgner as well as scattered outcrops elsewhere in western Missouri from Cedar County southward. The Riverton crops out, and is also present in the subsurface, on the Tri-State plateau. Dark gray and black shales, clays, and coal beds lying at similar stratigraphic position in the Forest City basin are also referred to it. Both the Burgner and Riverton formations appear to be absent on the West-central salient, between the Tri-State plateau and the Forest City basin, presumably owing to pre-Desmoinesian erosion. The relations between the Cheltenham and the McLouth are not understood, although both lie below the Burgner.

The Desmoinesian of Missouri is divided into the Venteran and Cygnian Stages (Searight, W. V., and others, 1953). The Venteran, of late Pottsville age, is represented by the sandstones and conglomerates, shales, clays, coals, and thin limestones of the Krebs subgroup of the Cherokee group. The uppermost limestone is the Seville. The Krebs is well known in western Missouri on the Tri-State plateau and on the northwest part of the West-central salient, but it pinches out east of Randolph and western Macon and Adair counties. However, it is represented north of the Lincoln fold in Scotland and Clark counties and in southeastern Iowa along the Des Moines River valley. Connection with beds of the same age in western Illinois was thus made around the northern extension of the Lincoln fold.

Upper Cherokee group strata, the Cabaniss subgroup, consist, where completely represented, of shale,, sandstones, underclays, coals, and limestones, most of which are relatively thin. These are arranged as cyclic successions, most of which are identifiable over wide areas. More than 15 coal beds have been recognized, and most of these are persistent and identifiable over several counties, some apparently coextensive or nearly coextensive with the outcrop area. The Cabaniss subgroup has been divided into 12 formations (Searight, W. V. and others, (1953) which from the base upward are the Weir, Tebo, Scammon, Mineral, Robinson Branch, Fleming, Croweburg, Verdigris, Bevier, Lagonda, Mulky, and Excello. Except for the uppermost formation, the upper boundary is drawn at the top of an identifiable coal bed or at the position of such a bed where it is absent. The Cabaniss has been recognized within the general area of outcrop, which includes the Lincoln fold and the northern flank of the Ozark uplift, although in these areas the subgroup exhibits considerable modification.

The Marmaton group, which lithologically resembles the Cabaniss subgroup but includes thicker and more numerous limestones, lies at the top of the Desmoinesian. It includes several coal beds. It is divided into a lower Fort Scott subgroup and an upper Appanoose subgroup (Searight, W. V., 1961). The Fort Scott subgroup, from the base upward, comprises the Blackjack Creek, Little Osage, and the Higginsville formations. The Appanoose subgroup in upward succession is made up of the Labette, Pawnee, Bandera, Altamont, Nowata, Lenapah, and Holdenville formations. These are widespread over the outcrop area and in the subsurface, but strata above the Nowata crop out so far from the Lincoln fold that they need not be considered here.

The only Pennsylvanian rocks younger than the Marmaton which lie near the Lincoln fold are sandstones and shales which lie in the Moberly channel or those which rest on Marmaton in the St. Louis outlier. These deposits are referred to the Pleasanton group of early Missourian age.

Pennsylvanian Strata Associated with the Lincoln Fold

Atokan Series

Basal Clastics and Residuum

Chert residuum, chert conglomerate, and sandstone rest on and separate the Cheltenham from strata ranging in age from Ordovician to Mississippian as young as Meramecian. These deposits range in thickness from a few inches to perhaps as much as 50 feet. The sandstone is commonly known as "rimrock" in the clay belt, particularly where the Cheltenham clays are contained in filled-sink structures. The deposits have been adequately described as "Graydon" by McQueen (1943) and by Unklesbay (1952). Beds in western Missouri to which the name Graydon was formerly applied are Desmoinesian in age whereas the clastics below the Cheltenham are referred to the Atokan, although there is the possibility that some are older.

Outliers of these basal Pennsylvanian clastics lie high on the southwest flank of the Lincoln fold in Pike and Lincoln counties.

Cheltenham Formation

The name Cheltenham was originally applied to the refractory clays (Wheeler, 1896) of the Cheltenham district of the St. Louis, Pennsylvanian outlier. This usage was continued and expanded by McQueen (1943) to include all the dominantly kaolinitic clays of Missouri in the clay belt as well as those deposits which are lithologically similar and which lie at the same stratigraphic interval between the basal clastics and overlying Pennsylvanian beds which range widely in age.

There is considerable variation in character from non- or only slightly plastic burley, diaspore, flint, and semi-flint clays to plastic clays.

All of these clays, however, are similar in the high percentages of kaolin (85 percent or more) and low percentages of illite (15 percent or less) except as they are contaminated by free quartz (Allen, 1935; Harold, 1943; Grim and Allen, 1938). Thus, all are highly refractory.

Some, perhaps all, are underclays which contain Stigmaria and rootlets, some of which are coalified and others represented only by impressions. These are known in successions of flint clay separated by as many as three coal beds. Like other Pennsylvanian strata of Missouri and Illinois, they are multicyclic. The most pronounced differences between these clays and later Pennsylvanian clays appears to be their near basal position and their petrographic and chemical character.

The Cheltenham formation on the northern flank of the Ozark uplift is contained in sink-like depressions as well as in more or less continuous patches. These are clearly erosional remnants of widely distributed clays which represent a nearly, if not completely, laterally continuous succession of deposits (McQueen, 1943). They extend from the area of the Lincoln fold southwestward into Morgan and Miller counties, a distance of more than 100 miles. Outliers northeast of the Lincoln fold in Illinois (Lamar, 1931) extend the distance more than 30 miles farther. The north-south extent is from Shelby County, west of the fold, southward approximately 100 miles.

Age. -- The Cheltenham is overlain by deposits varying in age from Atokan through early Cygnian to latest Cygnian. In westernmost outcrops in Miller and Morgan counties, the Cheltenham is overlain by coal which is in turn overlain by limestone and chert containing pre-Desmoinesian fossils. The coal and limestone are correlated with the Atokan Burgner formation and are assigned to it. The Cheltenham clay in that area appears to be cyclically related to the coal and limestone and is, therefore, likewise referred to the Atokan Series. Inasmuch as it is not possible to demonstrate great disparity in age between any of the Cheltenham deposits, the formation is assumed to be of Atokan age.

Relations of the Cheltenham formation to the Lincoln fold. -- The Cheltenham lies well up on the structure west and south of the crest of the fold (Fig. 2). In the Whiteside area in northwestern Lincoln County, flint clays on basal clastics rest on the Burlington formation

within a mile of the cropline of the Ordovician. Preservation from erosion results from the location of the clay on the down-thrown side of the Cap au Gres fault. The formation likewise crops out within a few miles of the fault to the southeast in Lincoln County. South of the fold in the Little Eagle area in Calhoun County, Illinois, the Cheltenham formation is also present. Farther east in Illinois the clay occurs in the Alton area.

On the northeastern flank of the fold in Pike and Calhoun counties, Illinois (Lamar, 1931), are scattered remnants of refractory clay apparently identical with those across the fold in Missouri.

The evidence thus indicates that the Cheltenham formation continued across the site of the Lincoln fold and that the fold was not a significant topographic feature during the Atokan.

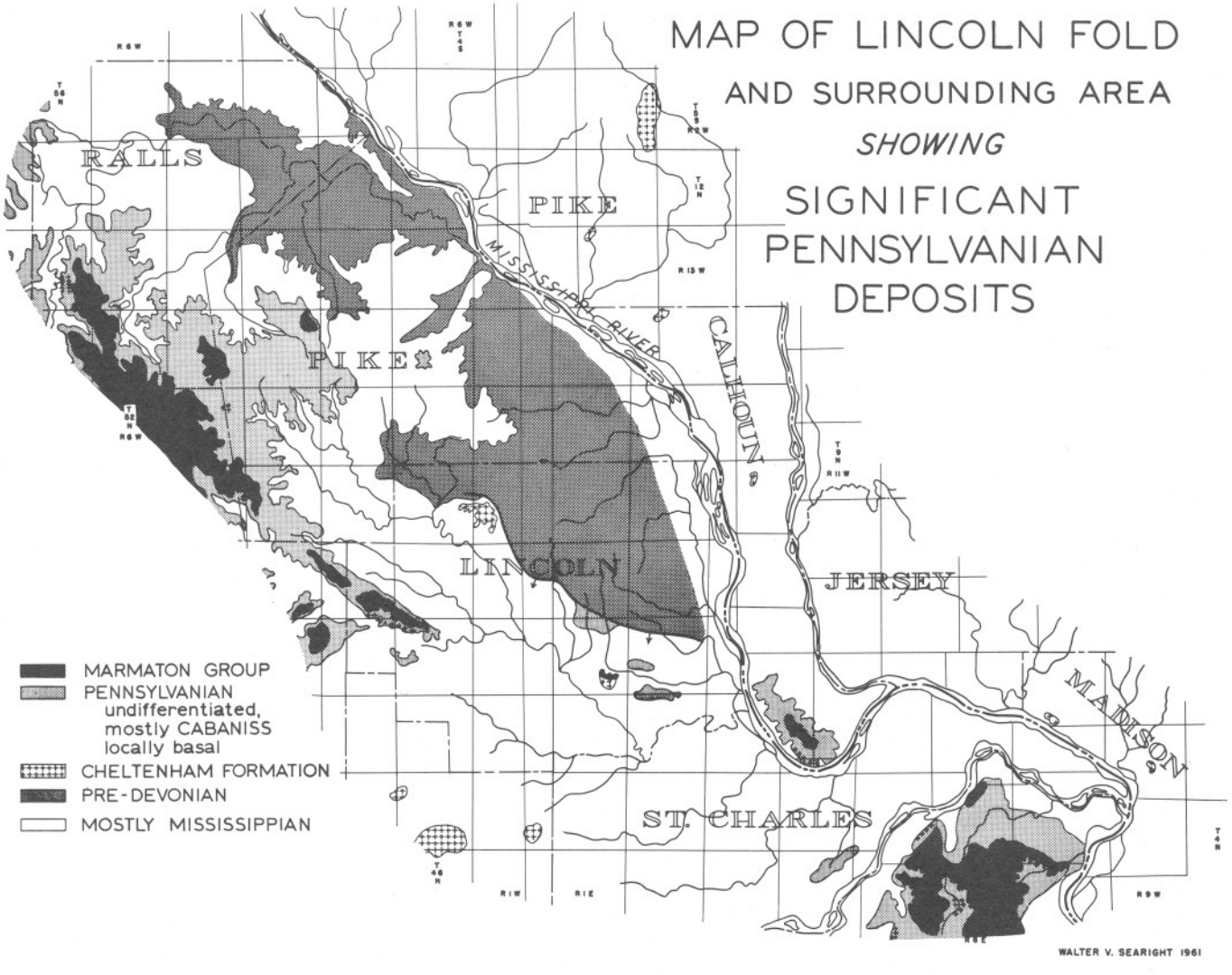
Desmoinesian Series

Cherokee Group

Krebs Subgroup

Krebs subgroup deposits pinch out immediately west of the East-central recess and occur no nearer to the Lincoln fold than eastern Chariton and western Randolph counties. They are

FIG. 2



present, however, north of the Lincoln fold in Scotland and Clark Counties and were probably once continuous around the north end of the fold with similar deposits of the same age east of the fold in western Illinois. Thus, it may be assumed that the Lincoln fold, as well as the East-central recess, was somewhat elevated and that erosion of the Cheltenham was in progress during Venteran, earliest Desmoinesian, time.

Cabaniss Subgroup

Cabaniss strata are developed on the North-central recess (Fig. 2), but the typical succession of western Missouri is considerably modified (Searight, T. K., 1959). Certain formations are partly or wholly suppressed whereas others overlap. Except for the highest Cabaniss beds, all formations pinch out southward onto the northern flank of the Ozark uplift and eastward toward the Lincoln fold. In the St. Louis depression, however, Cabaniss beds are also present, but these thicken eastward toward the Illinois basin. Lower Cabaniss formations are suppressed in the St. Louis depression. In order to indicate the relation of the Cabaniss to the Lincoln fold, reference will be made to each formation of the complete succession as it is known in western Missouri and in the Forest City basin.

Weir formation.-- The Weir formation is completely suppressed and cannot be recognized on the North-central recess southeast of central Macon County.

Tebo formation.-- The Tebo formation is thin, and it commonly consists of the underclay of the Tebo coal. The coal is either represented not at all or by a coal or smut streak. In the Mexico area, however, it has been observed to be as much as 15 inches thick but only in very small areas.

Scammon formation.-- The Tiawah limestone of the Scammon formation (in part "Leutre" of McQueen) is commonly seen in Boone, Randolph, and central Audrain Counties. It pinches out toward the Lincoln fold and toward the Ozark uplift. It occurs also in a small patch in the eastern part of the St. Louis outlier (Brill, K.G., personal communication, 1961). West of the Lincoln fold and in the St. Louis outlier, the Scammon above the Tiawah is suppressed or is represented only as an unidentifiable part of the underclay below the Croweburg coal bed.

Mineral, Robinson Branch, and Fleming formations. These formations are completely suppressed or are represented in the underclay of the Croweburg coal bed, both west of the Lincoln fold and in the St. Louis depression.

Croweburg formation.-- The Croweburg formation is represented in the East-central recess and the St. Louis depression only by the underclay of the coal and the coal bed. This coal bed, the most persistent in Missouri, is as much as 20 inches thick in southern Randolph County, but it pinches out along an uneven line extending from southern Ralls County to eastern Callaway County. The bed is thus developed nearer the fold toward the north where it possibly occurs within 20 miles of the crest; however, it apparently pinches out 35 miles from the crest of the fold farther south in Audrain County. The coal bed is present in the St. Louis depression and appears to be present as far to the northeast as western Lincoln County.

Verdigris formation.-- The most readily identifiable succession of the Verdigris formation is the persistent Ardmore member which is underlain by black fissile shale. This black shale contains abundant flattened phosphatic concretions. The Ardmore is composed of limestone units separated by shale. The member is as much as 16 feet thick in northwestern Boone County and is 24 feet or more thick in northern Randolph County. Like the Croweburg coal bed below, it pinches out along a line which crosses southwestern Ralls County, eastern Audrain County, and northwestern Montgomery County and extends southwestwardly across Callaway County. The Ardmore appears also to be represented southeast and south of the Lincoln fold in the St. Louis depression by patches of limestone in Lincoln County and in the St. Louis outlier. It appears likely that a connection south of the fold existed between these deposits and the St. Louis depression, not with the Ardmore of the East-central recess, but rather toward the east with the lower limestone of the Oak Grove of Illinois.

The Wheeler coal bed, at the top of the Verdigris formation, thins eastward from Boone, Howard, Randolph, and Macon Counties and pinches out toward the east and southeast.

Bevier formation.-- The Bevier formation of much of the East-central recess consists of the Bevier coal bed and thin clay an inch or less thick which constitutes the clay parting

which separates it from the Wheeler coal bed below. This parting becomes the ganister-like "bench-rock" of western Randolph County. The Bevier coal bed has its thickest development west of the midline of the East-central recess. The bed thins unevenly toward the east. It thins northward, pinching out in southern Monroe County, and eastward toward Montgomery County. Some evidence indicates, however, that a thin representative section persists farther toward the east in a constriction of the Lincoln fold in northern Pike County.

A thin coal above the Ardmore in the St. Louis outlier probably represents the Bevier in that area (Brill, personal communication, 1961), but it is most unlikely that the coal in the St. Louis area was continuous with that of the East-central recess but rather with the Illinois coal basin toward the east.

Lagonda formation.-- The Lagonda formation typically consists of gray shale and gray sandstone. Where it is thickest, in central Boone and northern Howard Counties, it is somewhat more than 35 feet thick. It thins toward the Lincoln fold to the northeast and toward the Ozark uplift to the southeast. The formation becomes increasingly shaly toward the fold and toward the uplift and pinches out along a line approximately 20 miles southwest of the crest of the fold.

The Lagonda is present, however, in the St. Louis depression where the formation consists mostly of red and maroon shale rather than gray mudstone and sandstone representative elsewhere in Missouri. In the St. Louis outlier the direction of thickening is eastward (Brill, personal communication, 1961) toward the Illinois basin.

Mulky formation.-- The Mulky formation consists of the underclay of the coal and the Mulky coal bed. This coal is the highest coal bed of the Cabaniss subgroup and, therefore, the highest Cherokee coal. It thickens and thins somewhat unevenly in the East-central recess. Areas of thicker coal, however, lie northeast of the thickest Wheeler and Bevier coals below. This condition indicates a definite shift in the deposition of the Mulky bed toward the Lincoln fold and northeastward on the East-central recess. This tendency is especially pronounced toward central Ralls County and again across eastern Audrain County toward northern Pike County. Although the Mulky has been almost entirely removed by post-Pennsylvanian erosion, the evidence suggests that it is not unlikely that the bed covered the Lincoln fold, at least from Pike County, Missouri, northward.

Excello formation.-- The Excello at the top of the Cherokee is perhaps the most persistent stratigraphic unit in the Cherokee of the northern Mid-Continent. Typically, the formation is composed of black fissile shale with abundant flattened phosphatic concretions. This is one of the black sheety or pimply shales of Illinois. Above this black shale, there is more or less gray shale, commonly calcareous, which separates the black shale from the lower Marmaton above. Toward mildly positive areas, the black fissile shale grades into greenish gray clayey shale which, however, retains the phosphatic concretions characteristic of the black fissile facies.

Thickening of the Excello is uneven, but here again, the area of thickest development is shifted northeastward toward the Lincoln fold. The evidence indicates that the Excello was continuous into western Illinois, where it is represented by green and sheety shales lying between the Summum No. 4 coal and the Hanover limestone. The Excello formation was also persistent southward, high on the northern flank of the Ozark uplift where it locally overlaps the Cheltenham formation, a condition indicated by scattered remnants which have escaped erosion.

The Excello formation is represented in the St. Louis depression by clayey shale with phosphatic concretions that rests on thin Mulky coal or a smut streak which represents the coal bed.

Marmaton Group

Fort Scott Subgroup

The Fort Scott subgroup of the Marmaton group is well represented in outcrops in the East-central recess and on the southwestern and southern flanks of the Lincoln fold, (Fig. 2). The subgroup from the base upward comprises the Blackjack Creek, the Little Osage, and the Higginsville formations.

Blackjack Creek formation.-- The Blackjack Creek is almost wholly limestone. The distribution and thickness of the Blackjack Creek formation is particularly instructive. The thickest expressions of the formation are in central Callaway and western Audrian Counties, where the formation attains a thickness of 12 to 20 feet. The unit thins toward the Lincoln fold, but it thins less than 4 feet, if at all, even high on the southwest flank of the fold or on the north flank of the Ozark uplift. It is well developed in the St. Louis outlier. Outcrops are known within 4 miles of the Cap au Gres fault in southeastern Lincoln County, and less than 2 miles from the Devonian outcrops in Pike County. Apparently these outcrops of the Blackjack Creek are erosion remnants of a rock unit which was once continuous over the site of the Lincoln fold.

Little Osage formation.-- The Little Osage formation is well developed on the North-central recess and in the St. Louis outlier. The Houx limestone member is particularly well developed. This limestone corresponds with the St. David limestone northeast of the fold in western Illinois. The limestone is likewise well developed in the St. Louis outlier.

Higginsville formation.-- The Higginsville formation, a limestone unit, is well developed in Boone, Randolph, and Macon Counties, but eastward, as at Mexico in central Audrian County and in the St. Louis outlier, it cannot be differentiated from the Houx.

Appanoose Subgroup

The Appanoose subgroup is made up, in ascending order, of the Labette, Pawnee, Bandera, Altamont, Nowata, Lenapah, and Holdenville formations. Outcrops of these formations as high as the Pawnee occur as far east as central Audrain County. Except in the St. Louis outlier, they have been removed by erosion nearer to the Lincoln fold. Appanoose subgroup beds as high as the Nowata crop out in the St. Louis outlier (Searight, W. V., p. 15).

Missourian Series

Sandstones with some siltstone and shale occupy the Moberly channel which trends somewhat south of west from northeastern Monroe County toward the "Big Bend" of the Missouri River. Sandstone resting on Marmaton is present also in the St. Louis outlier. All of these deposits rest unconformably on or cut through Marmaton. They are referred to the Pleasanton. Their relation to the history of the Lincoln fold is uncertain.

Conclusions

1. The Cheltenham and associated residuum, conglomerate, and sandstone were deposited across the eroded site of the Lincoln fold.

2. The Lincoln fold was not an elevated topographic feature in Atokan time.

3. The North-central recess was not separated from the Lincoln fold during Venteran time. The Cheltenham suffered more or less erosion while the Krebs subgroup was being deposited elsewhere during this interval.

4. The East-central recess was depressed below the Lincoln fold and probably below the West-central salient during early Cygnian time; i.e. while Cabaniss subgroup strata were being deposited. The Lincoln fold and the Ozark uplift were high enough to restrict deposition to the area within the East-central recess and to prevent deposition across the Lincoln fold.

5. The St. Louis depression, extending northwestward from the St. Louis outlier, originated in early Cygnian time. Connection with the area of deposition on the East-central recess apparently did not exist. Instead, it appears that there was a connection with the Illinois basin to the east.

6. Uppermost Cherokee deposition, the latest early Cygnian, possibly beginning with the underclay of the Mulky coal, was across the Lincoln fold.

7. In the beginning of late Cygnian time, Marmaton sediments were deposited across the

Lincoln fold and high on the northern flank of the Ozark uplift.

8. Erosion followed deposition of the Marmaton, and Pleasanton sandstones were deposited on the eroded surface.

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IRON AND LEAD EXPLORATION IN MISSOURI

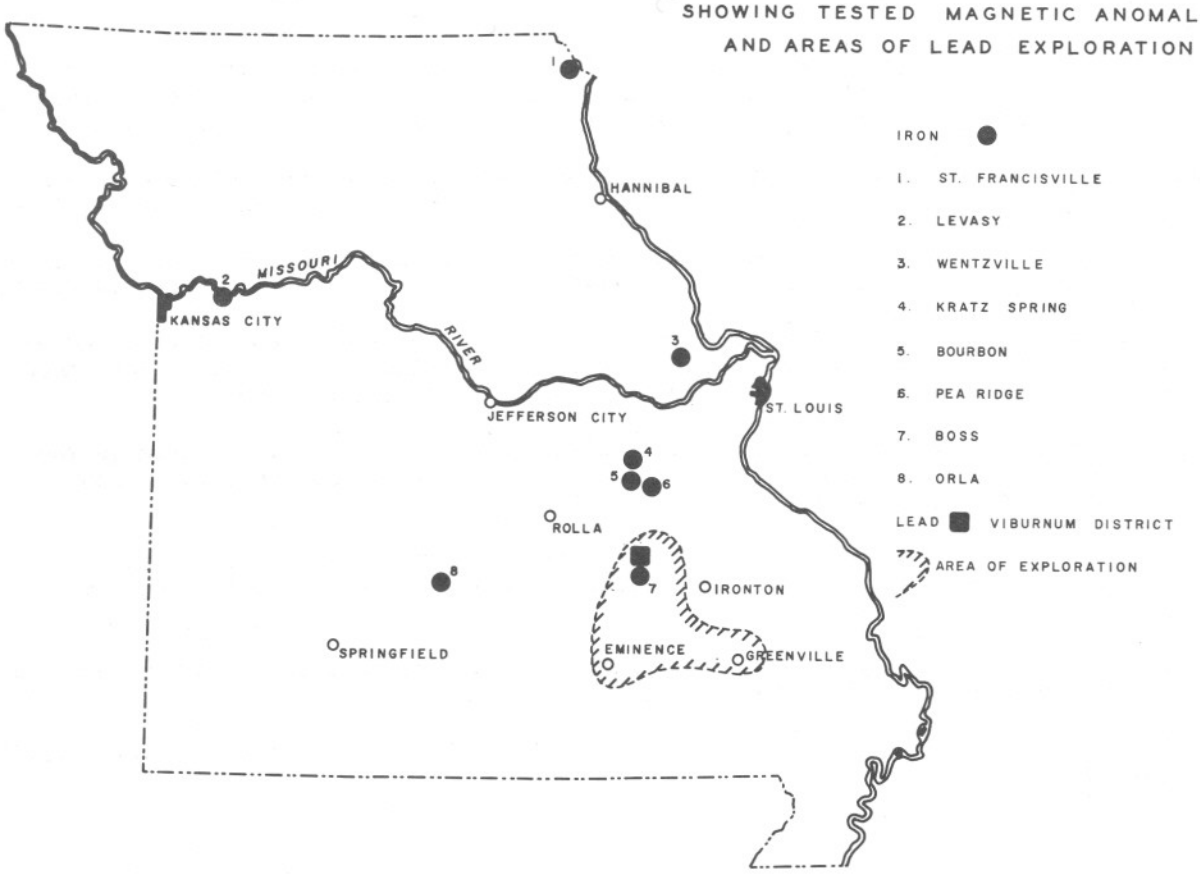
by
William C. Hayes

Introduction

Missouri ranked first in the Nation in lead production for the 52nd consecutive year in 1959 (Diamond & Hayes). Although iron has been produced almost continuously since 1815, Missouri has not been a leading producer of iron ores.

Since 1957, Missouri has enjoyed the most intensive and extensive exploration for iron and lead deposits than it has ever experienced. The announced discoveries by the St. Joseph

FIG. 1
MAP OF MISSOURI
SHOWING TESTED MAGNETIC ANOMALIES
AND AREAS OF LEAD EXPLORATION



Lead Company of the Pea Ridge iron deposit (8 miles south of Sullivan), and the Viburnum lead deposits (20 miles east of Salem) provided the impetus for many other mining companies to establish exploration programs in southeast Missouri. Magnetic anomalies that have been tested for possible iron deposits and the area of intensive lead exploration are indicated in Fig. 1.

Iron

Previous history.-- The Ashbran furnace erected in 1815 near Ironton, Iron County, was a significant step in the mining industry of Missouri as it was the first iron furnace west of the Mississippi. It treated nearby, hard hematite ores that had been found in Precambrian

porphyry rocks. Mining of the Precambrian ores at Iron Mountain, St. Francois County, began in 1844, and two years later ore was smelted on the site. Missouri was an important iron producer in the period of 1850 to 1888 and at the outbreak of the Civil War ranked 6th in the Nation in the production of pig iron. Discovery of the great iron deposits of the north ranges in the late 1880's made such a tremendous impact on the iron ore reserves that production of Missouri ores since that time has been a small percent of the Nation's annual production (Cozzens, 1941).

To date, Missouri has produced approximately 10 million tons of iron ores from Precambrian rocks and has had production in all but a few years since 1844. The deposits of Iron Mountain have been the main source of the Precambrian iron ores.

The history of discovery of the Pea Ridge and Bourbon iron deposits cover a span of over 25 years and exemplifies the application of basic geology in mineral exploration. During the relocation of U. S. Highway 66 in the 1920's, surveyors noted deflection of compass needles in the Bourbon-Sullivan area, and in 1929, the Missouri Geological Survey made preliminary geophysical investigations in the Bourbon area that confirmed the presence of a magnetic anomaly. Detailed surveys were conducted in 1931 and 1932 and summary results were published in 1933 (Grohskopf and Reinoehl). In this report it is stated that the anomaly at Bourbon is probably not caused by a Precambrian knob or ridge and that"....the only other assumption is that it is caused by some unusual concentration of magnetic material" and that the anomaly is probably caused either by "....a buried basic intrusive, or a body of magnetic iron ore" (Grohskopf and Reinoehl, 1933, p. 15).

A reconnaissance ground survey of the state was made during the 1930's, and the results were published as a "Magnetic Map of Missouri", showing anomalies of vertical intensity in 1943.

During the interim from October 1943 to November 1944, the U. S. Bureau of Mines drilled four holes on a magnetic anomaly about one mile south of Bourbon. The results were summarized in their Report of Investigations 3961 by W. D. McMillan. The Precambrian was encountered at depths of from 1,406 to 1,482 feet. A maximum of 832 feet of Precambrian rhyolite porphyry was penetrated in the drilling of the four test holes.

> "Hole 1 was apparently located southeast of the source of the anomaly and encountered only small stringers of magnetite. Hole 2 penetrated four mineralized zones having a total thickness of 125.7 feet and an average weighted content of 43.52 percent iron and 31.62 percent silica. These zones were tested again by a deflection hole, 2A, which gave nearly identical indications. Hole 3,500 feet north of hole 2, penetrated 58 feet of mineralized rhyolite containing an average of 43.4 percent iron," (McMillan, 1946, p. 1).

The grade of this ore at this relatively great depth did not make the deposit economically attractive, and further exploration was discontinued for almost 10 years.

In 1947, Edward L. Clark, then State Geologist, began negotiations for a joint financing by the Missouri Geological Survey, major mining companies, and the U. S. Geological Survey of aeromagnetic mapping of a part of southeast Missouri. An area covering approximately 14 quadrangles (15') was flown and the quadrangle aeromagnetic maps published; some in 1949; and the remainder in 1951.

The total intensity aeromagnetic map of the Sullivan Quadrangle, which was published in 1951, shows an intense magnetic high at the now-known site of the Pea Ridge magnetic deposit. The Pea Ridge high had been missed on the 1943 ground magnetic map because this earlier map was in a large part a reconnaissance map drawn from data taken at two-mile intervals along roads. Where roads were nonexistent, as at Pea Ridge, no data was obtained.

The St. Joseph Lead Company drilled Pea Ridge in the early part of 1953, but the drilling, which did not reach the basement igneous rocks, did not produce favorable results in terms of lead ore. An agonizing decision was posed by these unfavorable results. With the knowledge that the Bourbon high was demonstrated to be caused by magnetite at depth, should expensive drilling be carried on down to the igneous rocks with the possibility of little or no iron ore to justify the expense and physical problems?

Dr. John S. Brown, formerly Chief Geologist for the St. Joseph Lead Company, assumed the

responsibility of recommending deep drilling with the full knowledge that he could not guarantee success.

That Dr. Brown's decision was right is now history. Deep drilling disclosed a body of magnetite at depths of from 1,400 feet to at least 3,000 feet, which has a very high iron content and represents a reserve of from 50 to 100 million tons.

Recent discoveries and current exploration.-- According to Brown (1958) the Pea Ridge ore body is a tabular veinlike mass which replaces felsitic porphyry breccia. The ore body is slightly crescent shaped, strikes east-west, and dips steeply to the south. The top of the Precambrian, as well as the top of the mineralized zone, is encountered at depths of from 1,300 to 1,400 feet, and the deposit extends to a depth of 3,000 feet (the maximum depth of exploratory drilling).

Magnetite is the main ore mineral, but in places hematite may account for as much as 20 percent of the ore. Pyrite, chalcopyrite, and apatite are principal gangue minerals. About 60 percent of the ore is reported to be high grade (plus 60 percent Fe), and the average iron content of the ore is expected to be 50 percent Fe. The ore is amenable to concentration and contains up to 25 percent SiO_2(in the low grade ore), from 0.3 to 0.9 percent S, and from 0.4 to 1.0 percent P. The sulfur occurs in pyrite and chalcopyrite; the phosphorous, in apatite. The metallurgical characteristics of the ore are discussed by Fine and Frommer in the March 1959 issue of Mining Engineering.

Two circular shafts, 19 feet, 11 inches in diameter, are being sunk in the footwall by the Meramec Mining Company--a joint venture of the St. Joseph Lead Company and Bethlehem Steel Company. It is anticipated that approximately 2 million tons of concentrate will be produced annually.

At the 1,675 foot level in the No. 1 shaft, a crosscut has been driven approximately 850 feet to intersect the ore body. In June 1960, the ore was reached, and as exploratory drifts and crosscuts were driven the ore has been stock piled. Although the No. 1 shaft is now an all-purpose shaft, it will eventually be used for men and materials when the ore shaft (No. 2) is completed.

Since 1956 the American Zinc, Lead, and Smelting Company and the Granite City Steel Company have jointly been prospecting the Bourbon area. At the end of 1960, some 18 deep test holes had been collared and most of them have been bottomed. Magnetic iron ore from 700 to 1,700 feet thick has been encountered between 1,700 and 3,500 feet below the surface. The ore is reported to be fine grained and of a lower percentage iron than the ore in the Pea Ridge deposit. However, initial beneficiation tests have proved satisfactory for upgrading the ore to 65 percent iron.

Most of the recent exploration of the Bourbon area has been in the townsite of Bourbon, more than a mile north of the drilling conducted by the U. S. Bureau of Mines in 1943.

In the exploration for iron deposits, the St. Joseph Lead Company has drilled several additional magnetic anomalies in the state. Two areas about a mile apart were drilled on the Kratz Spring anomaly, about 4 miles north of Sullivan. It is reported that one area consists of 45 percent iron and has a considerable number of basic dikes associated with the mineralization. The other area consists essentially of hematite which was probably formed by weathering and oxidation of magnetite. Both ore bodies are tabular with moderate dips.

A magnetic anomaly near Orla, about 14 miles south of Lebanon, Laclede County, was drilled by the St. Joseph Company, and the basement was encountered at a depth of 1,817 feet. The rock is reported to be a gray green to dark green gabbro cut by minor granitic veins and to contain a considerable amount of biotite and chlorite, and minor disseminated magnetite.

The Avon anomaly, Ste. Genevieve County, was drilled by the St. Joseph Lead Company to a depth of 1,094 feet. Precambrian rock was encountered at a depth of 674 feet where a dark gabbroic and granitic material (probably diorite or granodiorite) was encountered that contains disseminated magnetite.

The St. Joseph Lead Company drilled the magnetic anomaly near St. Francisville, Clark County, where the top of the Precambrian was encountered at 2,931 feet. The rock ranges from

a fine to extremely coarse-grained diorite with an appreciable quantity of amphiboles and disseminated magnetite.

Near Boss, in extreme eastern Dent County, the American Zinc, Lead, and Smelting Company has drilled 12 exploratory holes, three of which indicate 100 feet of ore grade copper. All of the holes have indications of iron mineralization. The top of the Precambrian was encountered from depths of 800 to 1,300 feet.

The Midwest Ore Company, a subsidiary of the M. A. Hanna Company, discovered an iron deposit on the flanks of Pilot Knob, Iron County, in 1957. Studies have indicated the economic feasibility of the property to support a beneficiation plant producing a sintered or pelletized concentrate.

An anomaly in extreme northeastern Jackson County, near Levasy, has been drilled by Sheffield Steel Division of ARMCO Steel Corporation and by American Zinc, Lead, and Smelting Company. The top of the Precambrian in this area is from 2,200 to 2,300 feet deep.

A magnetic anomaly in western St. Charles County, near Wentzville, has been drilled by the National Lead Company, but the results are not known. The top of the Precambrian is reported at a depth of 3,120 feet.

Missouri Cliffs, Inc., a subsidiary of Cleveland Cliffs, Inc., is drilling in the vicinity of the Floyd Tower area, northwest of Potosi in Washington County.

Lead

Previous history.-- Lead deposits were discovered in 1720 at the famous Mine La Motte, about four miles north of Fredericktown (known in the early mining days as St. Michael). In 1864 the St. Joseph Lead Company was founded at Bonne Terre, and although the home office of the company is now in New York, its Southeast Missouri Mining and Milling Division office is still in Bonne Terre. Since the organization of the St. Joseph Lead Company, it has been one of the leaders in exploration and mining methods and is now the largest lead producing company in the United States. They introduced the diamond drill in the Lead Belt area in 1869 and in 1890 moved their furnaces from Bonne Terre to Herculaneum, south of St. Louis on the west bank of the Mississippi River, where they are still in operation.

In 1952 Missouri attained its peak annual production of lead which amounted to 8,648,322 tons of ore valued at over 40 million dollars. By the end of 1959, Missouri had produced over 1 billion 325 million dollars worth of lead with about 90 percent having been produced from the Southeast Missouri Lead Belt. The past five years have been important to the lead industry of the state because of expanded and improved exploration techniques and mining methods.

Recent discoveries and current exploration.-- Lead production from a recent discovery by the St. Joseph Lead Company began in 1954 from their Indian Creek Mine, 11 miles northwest of Potosi. The ore body is reported to be some 4,000 feet long, 500 to 600 feet wide, and 150 feet thick in some places (Bain, 1953). Galena (PbS) the lead-bearing mineral, occurs disseminated in the Bonneterre dolomite formation in a similar manner to the ore in the Lead Belt and is about 900 feet below the surface.

This discovery is particularly important as it is one of the few commercial lead deposits mined outside the Lead Belt. Thus, geologic ideas concerning areas of future exploration were revised, and new concepts of lead occurrence in southeast Missouri were seriously considered.

Although lead has been known for years in the Palmer district of Washington County, it was not until 1948 that extensive drilling was conducted in this area. In 1953 the St. Joseph Lead Company began exploratory drilling in the Viburnum area in the southeast corner of Crawford County, and their first pay hole was drilled in 1955. By early 1957 commercial quantities of lead ore had been substantiated by drilling, and a shaft was started in September of that year. This shaft is their No. 27 or Kilmer Shaft in NE 1/4 NW 1/4 Sec. 15, T. 35 N., R 2 W., Crawford County.

Continued exploration proved three substantial lead ore bodies that will eventually produce a combined 6,000 tons per day. The No. 28 or Conway Shaft is about a mile east of the

village of Viburnum in SW 1/4 SE 1/4 Sec. 26, T. 35 N., R. 2 W., Iron County. The third ore body is in Washington County a few miles from the No. 27 and No. 28 shafts, but to date only the ventilation shaft has been sunk.

In the Viburnum district, galena occurs disseminated in the Bonneterre formation, and at the Kilmer shaft it is mined on two levels approximately 75 feet apart at depths of 600 and 675 feet. The principal ore mineral is galena, but the ore contains a lesser amount of sphalerite and some copper-bearing sulphides. Average ore is reported to assay 3.0 to 3.5 percent Pb. Anticipated production at full capacity is 2,000 tons per day from each mine. The two active mines were developed by concrete lined, circular shafts, 12 feet 7 inches in diameter and drilled ventilation shafts 52 inches in diameter.

The mill and beneficiation are described by Knoerr (1961) as two 3,000-ton parallel units providing a capacity of 6,000 tons per day when production from the three mines is obtained. The first 3,000-ton unit handles ore from the No. 27 and No. 28 shafts and was put in operation in July 1960.

Since the announcement in 1958 by St. Joseph Lead Company of their Viburnum discovery, base metal exploration has expanded to cover the west and south flanks of the St. Francois Mountains from near Steelville, Crawford County, south of the vicinity of Eminence, Shannon County, and east to Wayne County.

Extensive, relatively close spaced drilling has been underway in several areas south of Viburnum. In the West Fork, Bee Fork, and Oates areas of Reynolds County, several companies have extensive land options and are drilling favorable areas. Indications to date are that several commercial lead deposits are being drilled and exploratory shafts will be sunk in the near future. Extensive drilling is being conducted by a company in northeast Shannon County near Blair Creek where it is reported considerable lead mineralization has been encountered.

When considering the deposits at Viburnum, Oates, Bee Fork, West Fork, Blair Creek, and the geologic potential of additional commercial lead discoveries on the west and south flanks of the St. Francois Mountains, it appears that there is a strong possibility that a "new lead belt" is being developed in southeast Missouri.

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PAST FIELD CONFERENCES

NUMBER	YEAR	AREA COVERED
1	1927	Northeastern Missouri and Eastern Iowa
2	1928	Ozark Mountains of Missouri and Arkansas
3	1929	Black Hills Area, Northwestern Nebraska, and Southeastern Wyoming
4	1930	South-Central Colorado, Northeastern and North-Central New Mexico, and Texas Panhandle
5	1931	Wichita and Arbuckle Mountains of Oklahoma and Ouachita Mountains of Arkansas and Oklahoma
6	1932	Carboniferous Rocks of Eastern Kansas, Eastern Nebraska, and Western Missouri
7	1933	Older Paleozoic Rocks of Missouri, Arkansas, and Oklahoma
8	1934	Younger Paleozoic Rocks of Southwestern Kansas and Adjacent Parts of Colorado, New Mexico, Oklahoma, and Texas
9	1935	Upper Mississippi Valley of Wisconsin, Illinois, Iowa, and Minnesota
10	1936	Pennsylvanian and Permian Rocks of Northeastern Kansas and Northwestern Missouri
11	1937	Pennsylvanian Rocks of Southeastern Kansas and Northeastern Oklahoma
12	1938	Front Range of the Rocky Mountains in Colorado
13	1939	Paleozoic Rocks of Southeastern Missouri and Southwestern Illinois
	1939	Summary of the Tertiary and Quaternary History of the "Equus Beds"
	1939	Silver City and Rose Dome Areas, Woodson County, Kansas
14	1940	Western South Dakota and Eastern Wyoming
15	1941	Paleozoic Rocks of Central and Northeastern Missouri and Western Illinois
	1946	Permian and Pennsylvanian Rocks, Winfield to Sedan, Kansas
	1946	Permian Rocks, Augusta to Elmdale, Kansas
	1947	Southeastern Kansas
	1949	Permian and Pennsylvanian Rocks, Winfield to Sedan, Kansas
	1949	Lower Kansas River Valley
	1949	Western Shawnee and Eastern Wabaunsee Counties, Kansas
	1951	Permian and Pennsylvanian Rocks in Lyon County, Kansas
16	1952	West-Central and Southwestern Missouri
17	1954	Southeastern and South-Central Missouri
18	1955	Southwestern Kansas
19	1956	Kansas Turnpike, Lawrence to Emporia
20	1956	Northwestern and Central Arkansas
21	1957	Eastern Kansas
22	1958	South-Central Colorado
23	1959	Northeastern Kansas
24	1959	South-Central Kansas
25	1960	Northeastern Oklahoma


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