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SALEM LIMESTONE IN SOUTHWESTERN ILLINOIS

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ABSTRACT

The Salem Limestone, which crops out in and adjacent to the Mississippi River bluffs in southwestern Illinois, is here subdivided into the Kidd, Fults, Chalfin, and Rocher Members in Monroe, Randolph, and St. Clair Counties.

The Kidd and Rocher Members (and less commonly the Chalfin Member) at places contain high-calcium limestone. The best areas for the thicker deposits of high-calcium limestone are in the vicinity of Prairie du Rocher, Fults, and Kidd. Thirty-one chemical analyses and data on the insoluble residue of several hundred samples give specific information on composition for nine selected locations.

The Kidd Member, which is 50 to 90 feet thick, is primarily a biocalcarenite composed largely of crinoid fragments and bryozoan debris.

The Fults Member, which is about 30 feet thick, consists of alternating fine-grained dolomitic limestone and calcarenite. The base is marked by laminated, very silty, argillaceous limestone which, except locally, is dolomitic. Banded and nodular chert are prominent.

The lithology of the Chalfin Member varies. Part of the member is fine-grained limestone. Dense microcrystalline limestone occurs at the top and bottom, and the upper portion has prominent beds composed of nonskeletal pellets the size of silt and fine sand. Local features include breccia, channel cut-and-fill deposits, plant fossils, and possibly algal limestone.

The Rocher Member consists predominantly of calcarenitic limestone composed largely of *Endothyra* and is commonly more or less oolitic. Its thickness ranges from 10 to more than 60 feet in bluff exposures and locally increases in wells drilled east of the bluff.

The environment of Salem deposition possibly was similar to that now existing on the Great Bahama Banks.

PART I

INTRODUCTION

The Salem Limestone crops out in the bluffs and tributary valleys of the Mississippi River in Monroe County and adjacent parts of Randolph and St. Clair Counties in southwestern Illinois (fig. 1). Limestone beds of highly diverse character constitute the Salem Formation in this area, but heretofore their stratigraphic succession and continuity have not been studied in detail. The Salem Limestone is herewith subdivided into four members.

The name "Salem Limestone" was formally proposed by Cumings (1901) for the limestone extensively quarried in Indiana as the "Bedford" or "Indiana" building stone. Hall (1864) had mentioned western Illinois as well as the famous Indiana localities - Spergen Hill and Bloomington - in his original description of the fauna of this limestone. Therefore,"Salem" was accepted for the western and southwestern Illinois sections by Weller (1908). "Salem" is used by both the Indiana and Illinois State Geological Surveys, although "Spergen" is applied to the same unit by the United States Geological Survey and several other organizations. The history of the nomenclature of the formation has been discussed by Wilmarth (1938), Weller (1908), and Weller and St. Clair (1928).

The Salem Limestone is in the Valmeyer Series, the middle of the three Mississippian age series recognized by the Illinois State Geological Survey (table 1). In southwestern Illinois the Salem conformably overlies the Warsaw Formation and is conformably overlain by the St. Louis Limestone. The Salem is distinguished from the Warsaw by being largely composed of relatively pure nonargillaceous limestone,whereas the Warsaw is less pure, contains shale interbedded with its limestone layers, is usually darker colored, finer grained, and has more unbroken macrofossils. The Salem is largely composed of fragmental macrofossils, microfossils, and oolites in a calcareous matrix.

Table 1. - Formations of the Valmeyer Series in Southwestern Illinois

Formation	Member
Ste. Genevieve	
St. Louis	
Salem	Rocher* Chalfin* Fults* Kidd*
Warsaw	
Keokuk-Burlington	
Fern Glen	

* Proposed herein.

The overlying St. Louis Limestone is characterized by microcrystalline and very fine-grained limestone, but rocks characteristic of the two formations (and carrying fossils considered diagnostic of both formations) are interbedded so that the selection of the contact is somewhat arbitrary. Details of the upper and lower contacts of the Salem are treated in the discussion of the bounding members.

The Salem Limestone is about 200 feet thick in southwestern Illinois and can be divided into four members, which are here named the Kidd, Fults, Chalfin, and Rocher Members.

The Kidd Member, 50 to 90 feet thick, occurs at the base of the formation and consists primarily of quite pure bioclastic limestone, composed largely of medium- to coarse-grained, broken crinoid columnals and bryozoans.

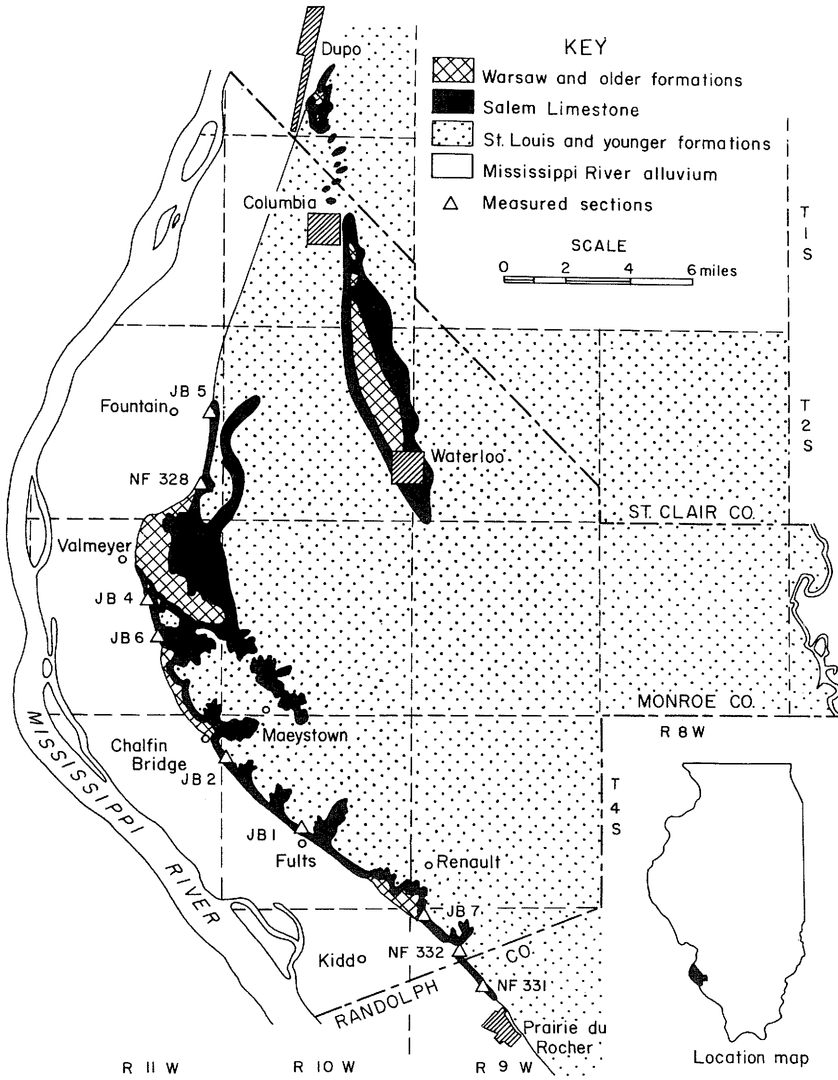


Fig. 1. - Areal distribution of Salem Limestone in southwestern Illinois with locations of measured sections. Modified from Weller and Weller (1939).

The Fults Member, about 30 feet thick, consists of fine- to medium-grained, rather argillaceous, cherty and silty limestone, much of it dolomitic, with only minor amounts of interbedded calcarenite.

The Chalfin Member averages about 40 feet thick. Its varied lithology includes conspicuous beds of microcrystalline limestone, brecciated limestone, and pellet-calcarenite, which are uncommon or do not occur in the other members.

The Rocher Member, at the top of the formation, consists largely of calcarenite in which foraminiferal tests including *Endothyra baileyi* (Hall) and oolites are abundant. Its thickness ranges from 10 to more than 60 feet in bluff exposures.

Outcrops of Salem Limestone occur in southern St. Clair, Monroe, and northern Randolph Counties, principally in and adjacent to the Mississippi River bluffs (fig. 1).

In southern St. Clair and northern Monroe Counties, Salem Limestone is well exposed east of Dupo, where the Dupo Anticline is cut by the Mississippi River bluff. There are isolated outcrops along the trend of the anticline to the south. Salem beds occupy a continuous belt around the Waterloo Anticline - a southeast extension of the Dupo Anticline - from east of Columbia to south of Waterloo.

The Salem Limestone crops out almost continuously along the Mississippi River bluff in the central and southern parts of Monroe County and extends about 2 miles into Randolph County (figs. 1, 2). The largest gap, about 2 miles long, is where the formation is eroded from the crest of the Valmeyer Anticline. Because exposures of the entire formation are rare, it is generally necessary to combine partial sections to learn about the whole formation.

Outcrops of the underlying Warsaw and older formations are confined to the axes of the major anticlines and two smaller anticlines near Chalfin Bridge and Renault, although outcrops of the overlying St. Louis Limestone are common. For this reason, the upper part of the Salem is better exposed in the river bluffs than the lower part.

The outcrop belt of the Salem is continued on the Missouri side of the Mississippi River floodplain to the south in Ste. Genevieve County (Weller and St. Clair, 1928), and to the north in St. Louis County (Hinchey et al., 1947), with minor changes in the character of the formation.

The Warsaw and Salem are not separated in the outcrops in southernmost Illinois (Weller and Ekblaw, 1940; Weller, 1940), where both formations are represented by current-sorted, cross-bedded bioclastic limestone. To the north, in western Illinois and the nearby parts of Missouri and Iowa, the Warsaw is largely shale, but the equivalents of the Salem are silty or sandy carbonates, and calcareous shales, siltstones, and sandstones (Weller, 1908; Wanless, 1957).

In the area of this report, and including its extension into Ste. Genevieve County, Missouri, the Salem equivalents are most nearly like the type section in Indiana.

The second part of this paper deals primarily with economic geology. The third part is a detailed stratigraphic study in which the petrology and depositional environment are evaluated.

Acknowledgments

This paper is the result of research carried out at the Illinois State Geological Survey and is adapted from a doctoral dissertation completed at the University of Illinois. Harold R. Wanless, professor of geology at the University of Illinois, thesis advisor, contributed greatly to the progress of the investigation.

Staff members of the Illinois State Geological Survey, particularly J. E. Lamar, Charles W. Collinson, R. M. Kosanke, and David H. Swann, contributed to the project. David A. Schaefer assisted in both the field and laboratory work. Field notes and samples taken some years ago by H. B. Willman were used.

The limestone operators of southwestern Illinois also cooperated in many ways.

PART II

ECONOMIC GEOLOGY

The Salem Limestone crops out in the bluff of the Mississippi River, with a few interruptions, from Prairie du Rocher northwestward about 24 miles to a point about 6 miles north of Valmeyer. A part of the formation is a source of high-calcium limestone,which is produced from two underground mines a short distance north of Prairie du Rocher.

The present investigation, based on 9 measured sections (fig. 2), was made to obtain detailed knowledge of the chemical and lithologic characteristics of the Salem Formation as it occurs in and near the bluffs of the Mississippi River in Monroe and Randolph Counties. The investigation was directed particularly to an evaluation of the Salem Formation as a source of high-calcium limestone.

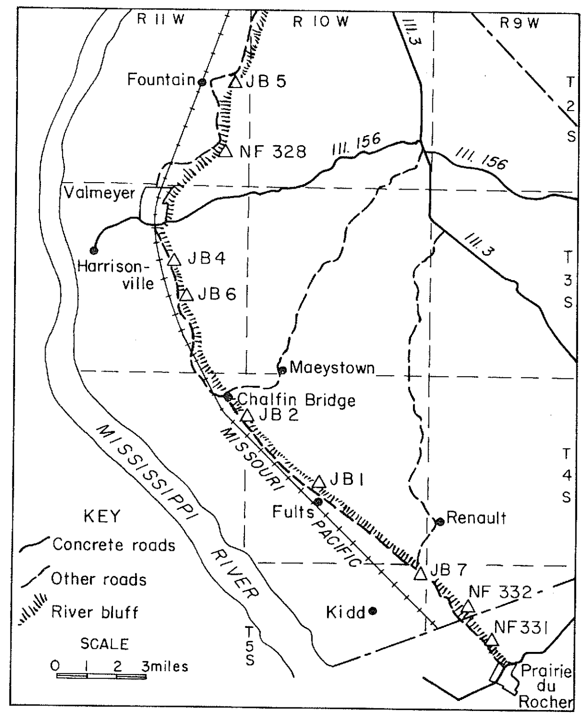


Fig. 2. - Map of the Mississippi River Bluff and its environs in southwestern Illinois showing location of measured sections.

STRUCTURE

The structure of the rocks in the Mississippi River bluffs from Fountain to Prairie du Rocher is shown diagrammatically at the top of plate 1 (in pocket). The vertical scale is greatly exaggerated in order to show the approximate position of rock units that compose the Salem Limestone.

The rock strata rise gently to the northwest from Prairie du Rocher to the crest of a small upfold whose axis intersects the bluff opposite Renault. This structure brings the Warsaw Formation into the lower portions of the river bluff. Erosion of the structure has partly removed the Salem Limestone in the vicinity of the crest of the anticline. North of the crest the strata descend with minor upfoldings to a point between Fults and Chalfin Bridge, whence they again rise toward the northwest, reaching a crest between Maeystown Hollow and Monroe City Hollow.

This structure results in the reappearance of the Warsaw Formation in the bluff, the development of rather gentle foreslopes on shales of the Warsaw Formation, and poor exposures of the Salem Limestone in the higher part of the bluff. From this crest the rocks descend at a uniform rate almost to Valmeyer. Erosion of the Valmeyer Anticline causes the Salem Limestone to be absent in the bluffs near Valmeyer, but about 2 miles northwest of that town the limestone reappears at the top of the bluff and gradually dips to the north until it disappears below the flat of the Mississippi River about 6 miles northwest of Valmeyer.

SAMPLES

In the course of the field studies many samples of the rocks were taken at about one-foot intervals. The amount and character of material insoluble in hydrochloric acid (insoluble residue) were determined and recorded for each sample. Composite samples for chemical analyses were prepared from the field samples on the basis of the amount and character of the insoluble residues and field observations of the presence or absence of chert. Most of the samples were taken from natural outcrops and therefore were more or less weathered. It is possible that the limestone back from the outcrops might be somewhat purer than the outcropping stone.

SUBDIVISION OF THE SALEM LIMESTONE

The Salem Limestone has been divided into four members which, from the bottom of the formation upward, are named the Kidd, Fults, Chalfin, and Rocher Members. The basis for distinguishing them is the character and composition of the rock. Plate 1 shows a generalized distribution of the various members in the cross section of the bluffs. It also shows the structure and outcrops where the samples were taken or detailed descriptions were made.

CHARACTERISTICS OF THE MEMBERS

Kidd Member

The lowest or oldest of the members of the Salem Limestone, the Kidd Member, is well exposed in the bluffs east of the village of Kidd, just south of the junction of the bluff road and the road leading to Renault in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 1, T. 5 S., R. 10 W. (fig. 2 and pl. 1, JB 7 B-E). Typically it consists of gray or brownish gray, fine- to coarse-grained limestone that is composed of fragmented fossils, chiefly crinoid columnals and bryozoan detritus.

The amount of noncarbonate material in the Kidd Member is shown on plate 1 opposite the appropriate portions of the graphic logs. The percentage of residue is generally low, especially in outcrops near the southern end of the outcrop belt (samples JB 7 and NF 332), but to the north the limestone is commonly less pure.

Silt and sand, consisting principally of quartz, are the most common constituents of the insoluble residues. Clay and chert are present in lesser amounts, and secondary quartz, replacing fragmented fossils, is a major component of certain residues.

The chemical composition of the Kidd Member is indicated by the analyses of samples JB 1 A and B, JB 2 A and B, JB 7 B through E, and NF 332 A (table 2). Samples NF 332 A and JB 7 B through E were taken from outcrops near the southern end of the outcrop area where the Kidd Member is largely composed of high-calcium limestone. Samples JB 7 B through D, representing 81$\frac{1}{2}$ feet of limestone, were found to contain 97 percent or more calcium carbonate ($CaCO_3$), less than 0.4 percent aluminum oxide (Al_2O_3), and less than 0.2 percent iron oxide (Fe_2O_3).

Sample NF 332 A, representing 43$\frac{1}{2}$ feet of limestone, shows an equally high calcium carbonate content. The total thickness of high-calcium limestone where sample NF 332 A was obtained is not known but it may be greater than sampled. The lower strata of the Kidd Member were inaccessible because they were covered by talus at the bottom of the river bluff. The maximum noted thickness of strata belonging to the Kidd Member was about 90 feet.

In outcrops sampled farther north, the Kidd member is commonly less pure and has a calcium carbonate content which generally ranges between 90 and 95 percent. Some parts of the formation, however, are siliceous and dolomitic (as sample JB 2 B), and the silica and magnesium content of the member becomes greater northward from Kidd.

The most favorable bluff area for the occurrence of high-calcium limestone in the Kidd Member is from the Randolph-Monroe county line north to Fults where a maximum thickness of about 90 feet has been observed - most of it high-calcium limestone in beds that are thicker than elsewhere. It appears that most deposits of the limestone could be worked by underground mining. Limited open pit quarrying may be possible in Monroe County about one mile northwest of the county line, in the point of the bluff west of the road to Renault.

Fults Member

The Fults Member is well exposed in the Mississippi bluffs about three-fourths of a mile northwest of Fults in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 20, T. 4 S., R. 10 W. (fig. 2 and pl. 1, JB 1 C). The member consists predominately of alternating beds of fine-grained, more or less dolomitic limestone and medium-grained limestone composed of fragmented fossils. The base of the member is marked by 4 to 6 feet of bluish gray or yellowish brown, thinly laminated, earthy, dolomitic limestone which may grade laterally into a dolomite or dolomitic siltstone. Chert, a conspicuous component of the member, is especially common in the fine-grained beds.

The beds of the Fults Member vary in thickness, ranging from thin laminations to comparatively thick-bedded units. It is not well exposed north of Valmeyer but is about 35 feet thick in outcrops near Fults and Chalfin Bridge.

The amounts of insoluble residues for the Fults Member are shown at four localities on plate 1. The large amount of residue illustrates the impurity of the limestone. Bands and nodules of chert are additional impurities.

The insoluble residues from the lower earthy beds are composed of clay and fine quartz silt. The residue from fine-grained beds higher in the member consists mostly of quartz silt with some clay, traces of carbonaceous matter, and minute particles of glauconite or a related mineral. Beds which contain admixtures of medium-grained fossil detritus have residues in which quartz that replaced parts of the fossils is often the predominant component.

The chemical composition of the Fults Member is indicated by analyses JB 1 C, JB 2 C and D, and NF 332 B and C, as shown in table 2. The calcium carbonate content ranges between 40 and 95 percent, and, like the Kidd, the Fults becomes progressively higher in magnesium carbonate and silica to the north.

The usefulness of the Fults Member is limited by the apparent variability in its chemical composition, the presence of banded and nodular chert, and the relative thinness of the various kinds of limestone that compose it.

Chalfin Member

The Chalfin Member is well exposed in the Mississippi River bluffs one mile southwest of Chalfin Bridge in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 7, T. 4 S., R. 10 W. (fig. 2 and pl. 1, JB 2 E, F). In general, the Chalfin Member consists of varying thicknesses of fine-grained limestone; fine- to medium-grained, fossiliferous, locally oolitic limestone; and semilithographic limestone, some of it brecciated. In most outcrops a combination of varieties of limestone is present, in others one of these varieties may be dominant (pl. 1).

Table 2. -

Sample No.	Member	T.	R.	Section	Near	Thickness Sampled	Height above base of outcrop
JB 4A	Chalfin	3S	11W	15 Cen. N½ N½	Valmeyer	10'6"	82'-92'6"
JB 4B	Chalfin	"	"	" " " "	"	11'	92'6"-103'6"
JB 4C	Chalfin	"	"	" " " "	"	11'	111'6"-122'6"
JB 4D	Rocher	"	"	" " " "	"	15'	139'6"-154'6"
JB 6A	Chalfin	3S	11W	22 NE NW NE	Valmeyer	16'	40'6"-56'6"
JB 6B	Chalfin	"	"	" " " "	"	5'6"	56'6"-62'
JB 6C	Rocher	"	"	" " " "	"	11'6"	62' -73'6"
JB 2A	Kidd	4S	10W	7 NE NW SW	Chalfin Bridge	16'	7'-23'
JB 2B	Kidd	"	"	" " " "	" "	21'	23'-44'
JB 2C	Fults	"	"	" " " "	" "	10'	44'-54'
JB 2D	Fults	"	"	" " " "	" "	19'	54'-73'
JB 2E	Chalfin	"	"	" " " "	" "	18½'	73'-91'6"
JB 2F	Chalfin	"	"	" " " "	" "	22'	91'6"-113'6"
JB 2G	Rocher	"	"	" " " "	" "	20'	114'6"-134'6"
JB 1A	Kidd	4S	10W	20 NW SE NE	Fults	11'	0-11'
JB 1B	Kidd	"	"	" " " "	"	15'	18'2"-33'2"
JB 1C	Fults	"	"	" " " "	"	15'3"	47'2"-62'5"
JB 1D	Chalfin	"	"	" " " "	"	15'	68'5"-83'5"
JB 1E	Rocher	"	"	" " " "	"	38'	97'5"-135'5"
JB 7A	Warsaw Fm.	5S	10W	1 NE SE NE	Kidd 1.7 mi.NE	11'2"	28'10"-40'
JB 7B	Kidd	"	"	" " " "	" " "	12'6"	40' -52'6"
JB 7C	Kidd	"	"	" " " "	" " "	27'0"	52'6"-79'6"
JB 7D	Kidd	"	"	" " " "	" " "	40'6"	81' -121'6"
JB 7E	Kidd	"	"	" " " "	" " "	10'6"	121'6"-132'
NF 332A*	Kidd	5S	9W	Prairie du Rocher, 3 mi. NW		43'6"	0-43'6"
NF 332B*	Fults	"	"	" " " " " "		13'	43'6"-56'6"
NF 332C*	Fults	"	"	" " " " " "		15'7"	56'6"-72'1"
NF 332D*	Fults-Chalfin	"	"	" " " " " "		15'11"	72'1"-88'
NF 332E*	Chalfin	"	"	" " " " " "		27'5"	88'-115'5"
NF 331A*	Rocher	5S	9W	Prairie du Rocher, 1¼ mi. NW		36'8"	8'9"-47'5"
NF 331B*	Rocher	"	"	" " " " " "		22'	50'2"-72'2"

* Lamar, J. E., Chemical analyses of Illinois limestones and dolomites: Illinois Geol. Survey Rept. Inv. 200, 1957, p. 22, 24.

Chemical Analyses

$CaCO_3$ †	$MgCO_3$ †	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Loss on Ign.	Miscellaneous
85.80	11.82	2.24	.48	.25	5.65	48.08	43.56	
92.65	1.09	6.21	.31	.13	.52	51.92	41.05	
62.75	25.50	8.76	1.89	.44	12.23	35.16	41.15	
93.48	4.29	2.21	.37	.17	2.05	52.38	42.92	
98.10	.54	1.53	.29	.06	.26	54.92	43.00	Channel deposit
97.55	.94	1.20	.41	.13	.45	54.66	43.10	
97.53	.71	1.96	.32	.07	.34	54.65	42.77	
94.91	2.76	2.69	.33	.08	1.32	53.18	42.57	
73.47	13.55	12.59††	.60	.32	6.48	41.17	38.82	
40.24	25.97	27.79††	3.56	1.18	12.42	22.55	31.55	
71.29	19.14	9.20††	.69	.31	9.15	39.95	40.67	
88.44	6.75	4.64	.54	.24	3.23	49.56	41.83	
93.47	2.03	4.30††	.83	.21	.97	52.38	41.71	
97.47	1.07	1.50	.50	.07	.51	54.62	43.15	
94.73	2.89	2.36	.46	.22	1.38	53.08	42.79	
92.01	3.33	4.45	.46	.18	1.59	51.56	41.88	
90.51	1.94	6.67††	.70	.23	.93	50.72	40.47	
96.14	1.02	2.43	.39	.11	.49	53.87	42.58	
98.14	.94	1.28	.28	.10	.45	54.99	43.14	
88.80	4.60	4.84	1.39	.47	2.20	49.76	41.36	
98.60	1.05	0.70	.36	.16	.50	55.25	43.58	
97.53	1.69	1.03	.35	.16	.81	54.65	43.38	
96.92	1.63	1.69	.28	.11	.78	54.31	43.13	
94.07	1.02	5.27	.22	.11	.49	52.71	41.50	
97.80	.77	1.55	1.01	.12	.37	54.80	42.71	
75.29	1.67	19.86	2.82	.59	.80	42.19	33.70	
94.83	1.19	3.63	1.40	.18	.57	53.14	41.52	
95.90	2.51	1.80	.84	.18	1.20	53.74	42.81	
96.60	1.32	2.35	.79	.22	.63	54.13	42.38	
98.17	1.17	.65	1.43	.09	.56	55.01	43.03	{ MnO 0.002, SO_3 0.10, P_2O_5 0.010
96.67	.82	1.01	1.72	.13	.39	54.17	43.01	

†Calculated from MgO and CaO.

††Cherty limestone; chert included in sample.

Prominent semilithographic beds occur at the base and at the top of the Chalfin. Chert is present locally in the upper part of the member, which at some places also contains dolomitic and siliceous strata, most commonly in the northern bluff exposures. Bedding is variable, ranging from an inch to 2 feet thick. The Chalfin Member ranges from 30 to 57 feet thick. Insoluble residues average about 5 percent, but in its northernmost exposures portions of the member contain more than 30 percent insoluble material (pl. 1).

Quartz silt is the most common constituent in residues from the fine-grained limestone. Quartz, which has replaced fossil material, is the major insoluble constituent of the limestone composed of fossil fragments. Minor amounts of brown clay occur in most residues. Sand is rare.

The chemical composition of the Chalfin Member is shown by the analyses of samples NF 332 D and E, JB 1 D, JB 2 E and F, JB 6 A and B, and JB 4 A through C (table 2). South of the Chalfin Bridge the member contains as much as 27 feet of high-calcium limestone (sample NF 332 E). At Chalfin Bridge and to the north of it the member generally contains less calcium carbonate (sample JB 4 C). Some strata are dolomitic (samples JB 4 A and C).

An unusual feature of the Chalfin Member is a bed of crinoidal limestone that occurs near the top of the unit approximately 2 miles south of Valmeyer in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 22, T. 3 S., R. 11 W. The bed consists of light gray limestone which has a slight brownish tinge, is medium to coarse grained, is composed almost entirely of crinoid columnals in a clear calcite matrix, and has a maximum thickness of 16 feet. South of the point of maximum thickness the bed is present for several hundred feet,ranging from 2 to 12 feet thick, but pinches out before reaching Monroe City Hollow. Within 150 feet north of the point of maximum thickness the bed gradually thins and disappears. A few large bodies of chert several feet long and about a foot thick occur near the bottom of the thickest part of the bed. The bed is represented by sample JB 6 A,which contained 98.10 percent calcium carbonate.

Rocher Member

The Rocher Member is a commercial source of high-calcium limestone near Prairie du Rocher and has its maximum exposed development in that area (fig. 2 and pl. 1, NF 331). It also crops out in the bluffs of the Mississippi River in Monroe County. The member consists of pale brownish gray to nearly white, fine- to medium-grained limestone. It is composed to a large extent of marine fossils, predominantly minute foraminifera but including crinoid columnals, bryozoan fragments, brachiopods, individual and colonial corals, and a few other forms. The member is commonly more or less oolitic and locally some beds are almost completely composed of oolite grains.

The Rocher Member in the Prairie du Rocher area consists of thick limestone beds separated by more thinly bedded strata. Stylolites are common. Weathered outcrops scale or spall off in slabs at right angles to the bedding planes.

The member is thickest near Prairie du Rocher where a maximum of about 60 feet was observed. It thins to the north and is 10 to 15 feet thick at Valmeyer. The amount of insoluble residue in the Rocher Member (pl. 1) is low, generally less than 5 percent and, in most sections, averages 2 to 3 percent. In samples taken at localities in the northern portions of the outcrop area, however, the insoluble residues average more than 5 percent.

The major constituents of the residues are secondary quartz and detrital silt with minor amounts of brown clay and minute globules of white, banded chert.

The chemical character of the Rocher Member is indicated by the analyses of samples NF 331 A and B, JB 1 E, JB 2 G, JB 4 D, and JB 6 C (table 2). The calcium carbonate content generally ranges from 96 to 98 percent and magnesium carbonate content from 0.5 to slightly more than 1 percent. However, in the northernmost sample, JB 4 D, the magnesium carbonate content is greater than 4 percent.

POSSIBILITIES FOR UNEXPOSED DEPOSITS OF HIGH-CALCIUM LIMESTONE

The Salem Limestone extends inland from its outcrops in the Mississippi bluffs but is generally covered by the St. Louis Limestone and at places by other rock units. However, the possibilities of underground mining of the high-calcium Kidd and Rocher units in areas inland from the bluffs was investigated by examining data in the Survey's files relating to wells drilled in the area. The data con-

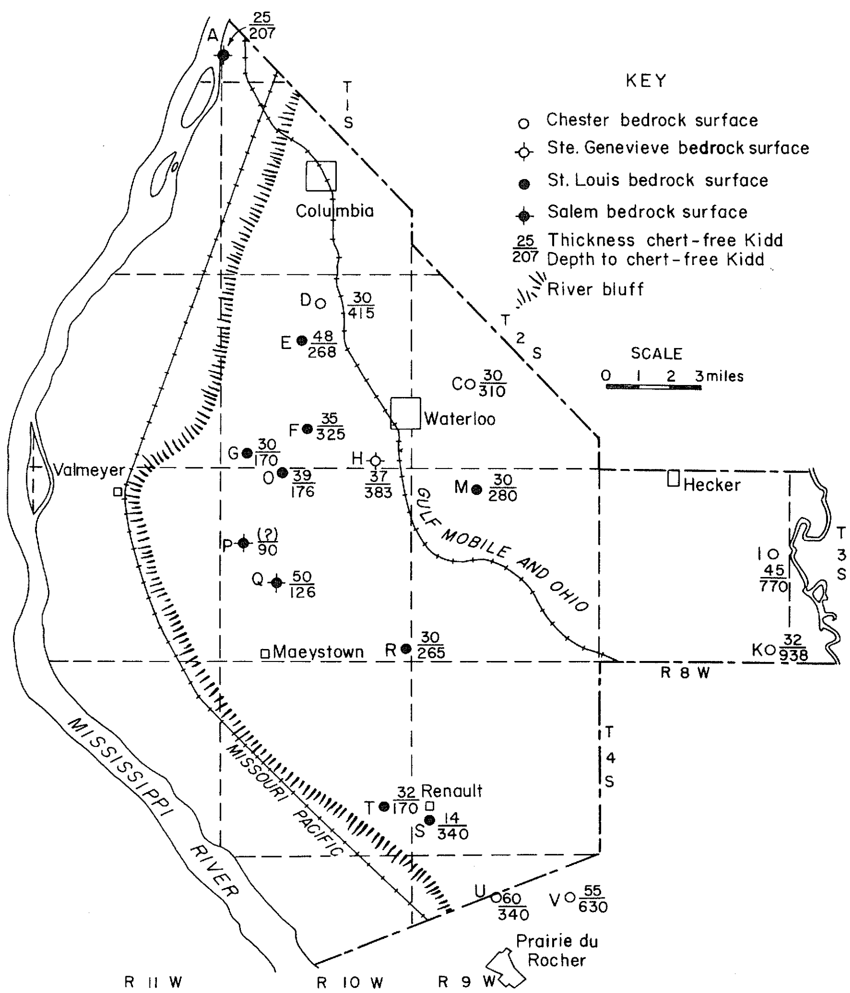


Fig. 3. - Subsurface thickness and depth of chert-free beds in the Kidd Member. Datum wells listed in table 3.

Table 3.- Source Wells for Samples of Salem Limestone

Well	Company	Farm	T.	R.	Sec.	Location
A	Morris et al.	Gummershimer	1N	10W	31	SW NW NW
B	Cummins	Boyer	1S	10W	19	SE SW SE
C	Venuto	Krestner	2S	9W	20	NE SE NE
D	Hotze-Noxon	Osterhage	2S	10W	3	Cen. SW SW
E	G. A. Morris	Crowder	2S	10W	16	NW NW NE
F	Hughes Pet. Co.	W. Meyers	2S	10W	28	NE SW SE
G	Carl Jensen	Stumpf	2S	10W	31	SE SE NE
H	Millard M. Butler	Waterloo City #1	2S	10W	35	SE NE SE
I	Borden	A. P. Schuster	3S	8W	13	NW NW SW
J	Hecker Oil Co.	Cowell	3S	8W	28	NW SW NE
K	W. F. Morris	C. Fehr	3S	8W	36	NE NE SW
L	Mosbacher and Welker	Stumpf	3S	9W	1	NW SE SW
M	Waterloo-Columbia Synd.	McHugh Bach	3S	9W	4	Cen. NW SW
N	G. G. Rolston	L. C. Rickert	3S	9W	32	Tax Lot #1 NE
O	Boyd et al.	Wolfe	3S	10W	5	NE NE NE
P	F. Luth	I. D. Harbaugh	3S	10W	18	Cen. NW
Q	Hotze-Noxon	F. Feltmeir	3S	10W	20	SE SE SE
R	Collins	Hempe	3S	10W	36	NE NE SW
S	Haverstick Well Co.	Comm. Unit School Dist. #5	4S	9W	30	SW SE
T	Henry Kyatt	Jacobs	4S	10W	25	SW SW NW
U	L.W. Gwin Drilling Co.	Paul Hess #1	5S	9W	9	SE NE SW
V	Ames Oil Co.	Nicholson #1	5S	9W	12	SW NW NW

sist of well drillers records and rock chips saved during the course of drilling. The accuracy of the well records and the care with which the cuttings were saved and identified as to depth doubtless varied.

The locations of wells that reached the Salem Limestone, and from which samples were available, in Monroe and Randolph Counties are shown in table 3.

Kidd Member

Figure 3 shows the thickness and depth of chert-free beds in the Kidd Member. These beds may be high-calcium limestone at some places. Samples from well Q indicate that at least 50 feet of chert-free, possibly high-calcium Kidd Limestone was encountered at a depth of 126 feet. This well is on the gentle northeastern flank of the Posten School extension of the Valmeyer Anticline, and probability is good that this portion of the Kidd Member may be found at shallower depths to the southeast. In well P the top of the Kidd Member was encountered at a depth of 90 feet, but the record is not detailed enough to permit evaluation of the character of the Kidd strata.

Cuttings from well S near Renault showed only 14 feet of typical high-calcium type Kidd Limestone with much of the normal Kidd interval consisting of a mixture of limestone and very silty, dolomitic limestone.

Rocher Member

The Rocher Member commonly is thicker in the subsurface north of Chalfin Bridge than it is in the bluffs north of that point. Figure 4 shows the thickness and depth of chert-free, probably high-calcium, Rocher beds in the subsurface of Monroe County and near Prairie du Rocher in Randolph County. An obviously favorable area for high-calcium limestone is near Prairie du Rocher where the member is thick and of good purity. Little subsurface information is available, however, away from the bluff in that area. Wells U and V indicate that the beds dip rather rapidly to the southeast.

One mile northwest of Foster Pond, 41 feet of Rocher beds, which probably are high-calcium limestone, were penetrated at a depth of 51 feet (fig. 4, well G). The cuttings contain a few pieces of lithographic limestone and an occasional piece of chert. They may have come from a part of the Rocher Member or they might have fallen into the well from the overlying St. Louis Limestone during drilling.

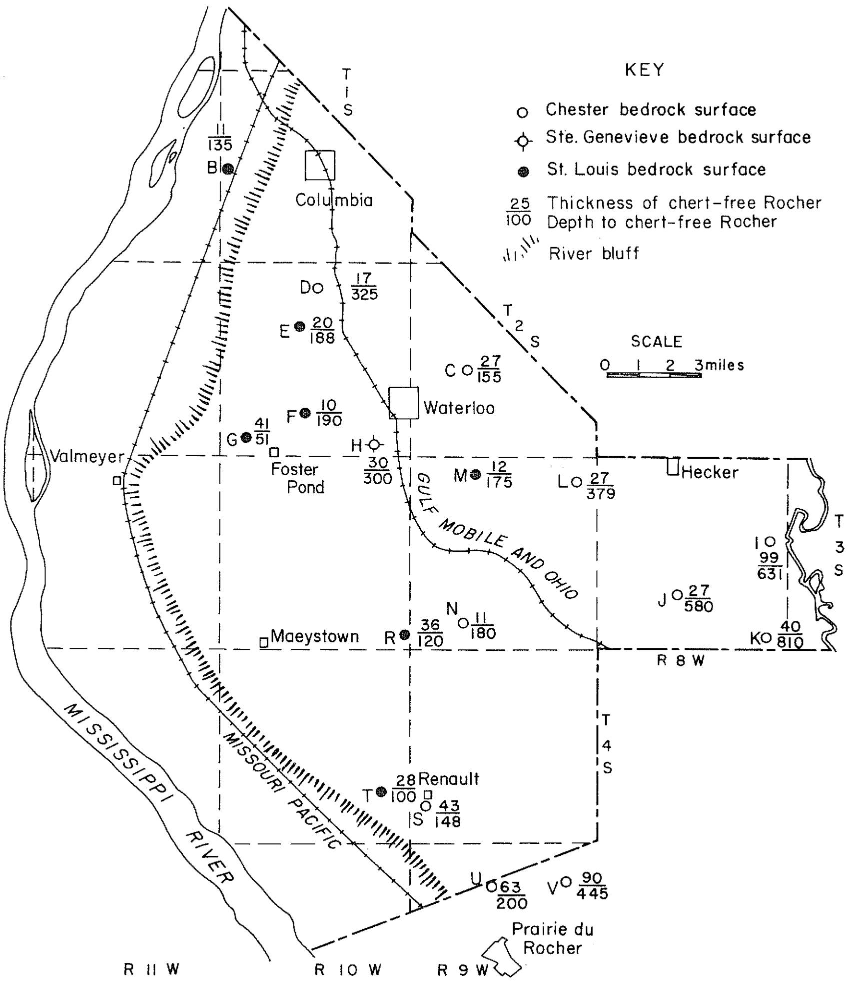


Fig. 4. - Subsurface thickness and depth of chert-free beds in the Rocher Member. Datum wells listed in table 3.

PART III

STRATIGRAPHY

The Salem Limestone is largely a calcarenite and shows many features that indicate mechanical deposition, such as rounded rock fragments, rounding and fragmentation of fossils, current sorting and stratification, preferred orientation by grain shape, and rare graded bedding. The composition of the calcarenites and the variable percentage of particulate materials serve as a basis for subdividing the formation into its members.

Some 220 thin sections were prepared from samples of three sections to give a complete sequence. The thin sections were studied by conventional methods, and the abundance of various constituents was estimated from photographs of the thin sections or by reference to the actual sections.

PARTICULATE MATERIAL

The calcarenite grains, the most important constituent of the Salem Limestone, include broken and whole macrofossils and microfossils, oolite grains, pellets and brecciated fragments of microcrystalline limestone, and obscure nodules of possible algal origin. Although fossil fragments of echinoids, corals, brachiopods, ostracodes, gastropods, and plants occur, only crinoids, bryozoa, and foraminifera make significant volumètric contributions to the rock. The relative abundance of the major constituents in different parts of the formation is shown diagrammatically in figure 5.

Crinoid Fragments

Columnals and plates of crinoids occur as unit-extinguishing crystals. Most are completely detached and show evidence of fragmentation and abrasion. Clear calcite commonly has been deposited in optical continuity with the crinoid fragments. Secondary calcite from two or more adjacent fragments may meet to form curved contacts resulting in a very coarse-grained crystalline appearance. There is some sorting by size from bed to bed, but most of the fragments are 0.2 to 1.5 mm across.

Bryozoan Debris

Bryozoa are common constituents of many limestones. Salem representatives belong to the genera *Fenestella*, *Polypora*, and *Sulcoretipora* (Weller, 1908). Some excellently preserved specimens occur, but commonly the cell-like colonial structure is broken. Fragments several millimeters long occur in some beds but in others the material is broken into grains as small as 0.1 mm across.

Algal Structures

Some microcrystalline limestone has a mottled appearance due to the inclusion of rounded or irregular bodies of unusually opaque and exceptionally fine-grained material within a matrix of less opaque and slightly coarser microcrystalline calcite (pl. 3,C). These bodies do not show cell structure but many of them exhibit obscure concentric banding of more and less dense layers. They range from nearly an inch across to much smaller. At the fine-sand range they are indistinguishable from fine-grained pellets of other origin and are attributed to deposition by algal colonies. Similar algal bodies are minor constituents in a few cemented calcarenites, particularly in the Chalfin Member.

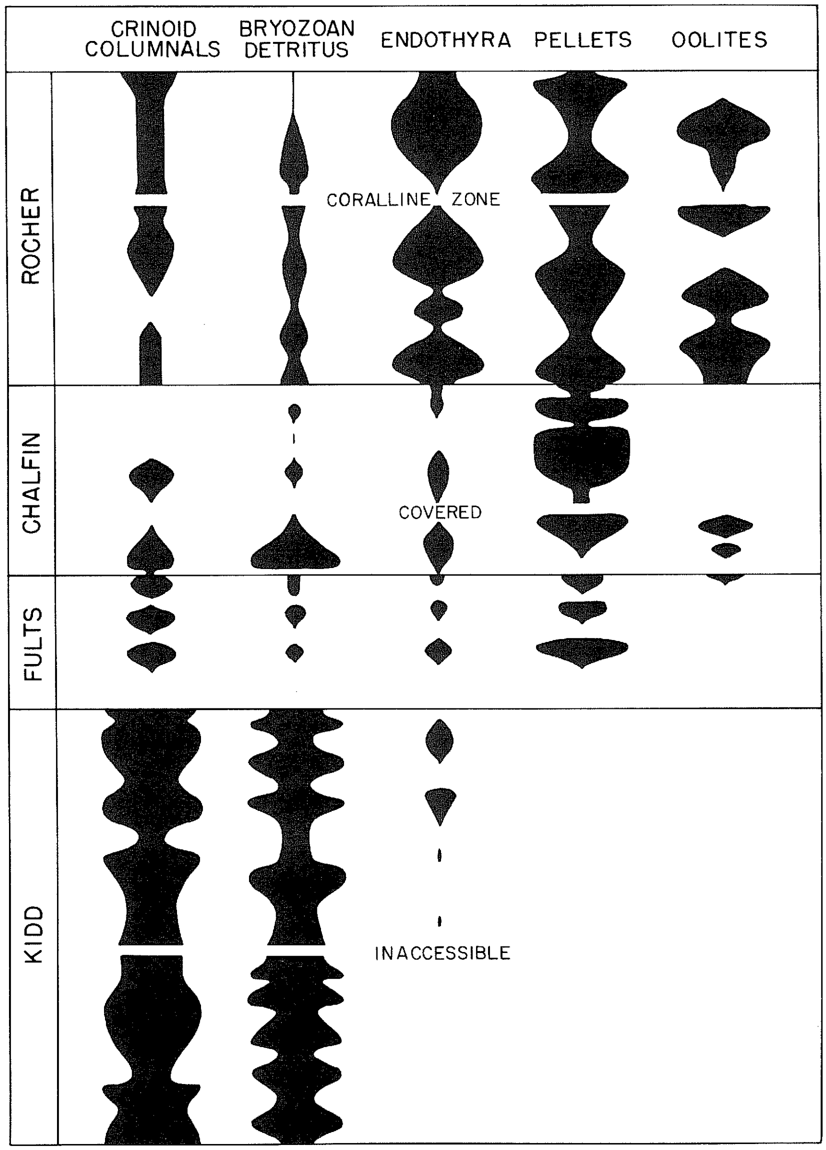


Fig. 5. - Diagrammatic summary of stratigraphic distribution and abundance of calcarenitic components in the Salem Formation as determined by study of thin sections of the type sections of the Kidd, Chalfin, and Rocher Members and of a typical exposure of the Fults Member.

Lycopsid Plants

Plant fossils were found in the Salem at two places. Abundant calcified and partly carbonized branch, leaf, stem, and possible root structures were found in the Trout Hollow area in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 36, T. 2 S., R. 11 W., and less abundantly but at the same stratigraphic horizon at the type section of the Chalfin Member in the NE$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 7, T. 4 S., R. 10 W. A collection from these two sources is described as follows:

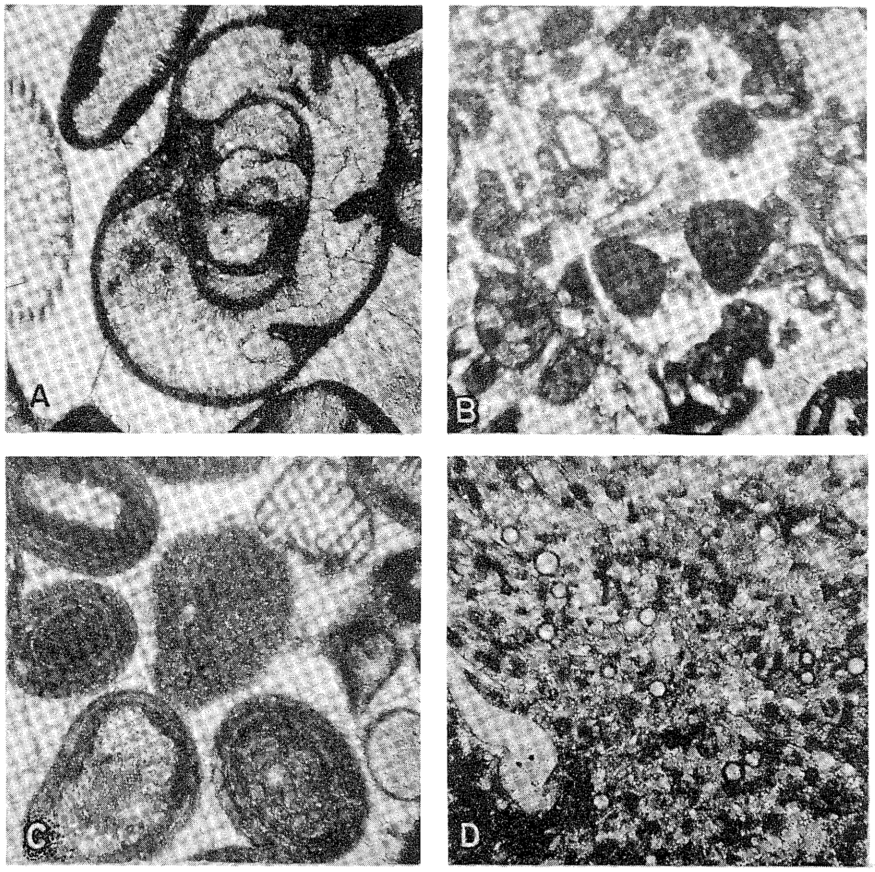


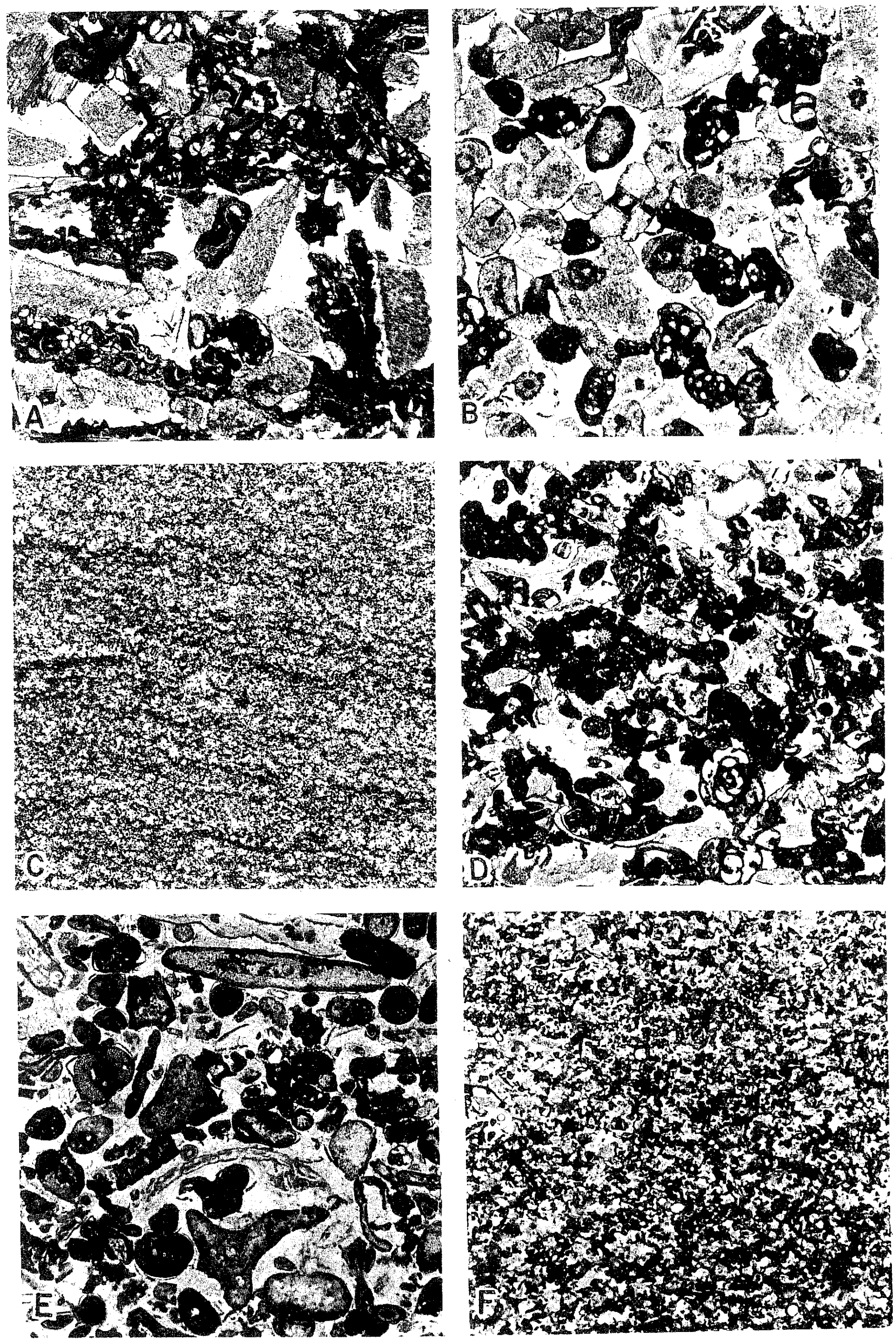
Fig. 6. - Particulate material. Magnification 43X.

A - *Endothyra*. The grain to the left is a crinoid columnal or an echinoid fragment.
B - Finely fragmented skeletal material, largely unrecognizable, with five nearly opaque, rounded pellets of microcrystalline calcite.
C - A pellet of microcrystalline calcite surrounded on the left and bottom by four oolites formed around skeletal and pellet centers. The grain in the upper right is an echinoid fragment.
D - Calcisphaerids, minute microfossils of unknown affinity.

"The collection contains plant fossil material of the lycopsid alliance. Microscopic examination of the residue after acid treatment indicates that the material retained on a 65-mesh sieve consists of pieces of highly carbonized material, a few fragments of cuticle, and a number of spinose particles which probably are parts of trilete megaspore exines. The residue passing the sieve contained abundant degraded organic matter and a small piece of septate fungal hypha but no spores were observed. Megaspores of the lycopsid alliance are known to occur in the upper portions of the Mississippian." (Kosanke, R. M., personal communication.)

Endothyra

Unbroken tests of the calcareous foraminifer *Endothyra* that show little evidence of wear are prominent in calcarenites in the upper portion of the Salem (fig. 6 A). Their internal structure is preserved with varying degrees of perfection and their size is generally in the range of 0.2 to 0.5 mm.



TYPICAL TEXTURES OF THE SALEM LIMESTONE (MAGNIFICATION ABOUT 12X).
A-B, KIDD MEMBER; C-D, FULTS MEMBER; E-F, CHALFIN MEMBER

CARBONATE CEMENT

The cementing material of the calcarenite is largely clear, crystalline calcite. Detrital carbonate particles which are a single crystallographic unit, such as fragments of crinoid columnals, almost always are surrounded by clear calcite which is in optical continuity with them.

Some calcarenites were noted that have a matrix of microcrystalline or exceedingly fine-grained calcite which probably represents a lime mud that was deposited with the skeletal grains.

MICROCRYSTALLINE LIMESTONE

Microcrystalline limestone is restricted to the Chalfin Member. Commonly, microcrystalline limestone shows various degrees of disruption and brecciation (pl. 3,A, B). The geologic significance of such limestone is uncertain although origins suggested for it include chemical precipitation, precipitation by bacterial action (Drew, 1914), and rotting of algal skeletons with the release of argonite needles (Lowenstam and Epstein, 1957).

NONCARBONATE CONSTITUENTS

The noncarbonate components of the Salem Limestone in southwestern Illinois are described briefly below. Their general character is similar to that of the insoluble residues of the Salem of the Illinois Basin (Payne, 1940, p. 232).

Chert

Chert in insoluble residues occurs as minute, white, chalcedonic and banded globules; buff chert which may grade into authigenic quartz; dull, white chert; and discrete, sand-sized oolite grains.

Authigenic Quartz

Authigenic quartz - brown, glistening, crystalline, secondary silica - is most abundant in biocalcarenitic beds. It replaces fossil material, largely crinoid columnals, and generally retains the form of the material it replaces. It is commonly associated with chalcedonic chert and appears to grade into light gray, compact chert.

Quartz Sand

Sand-sized quartz grains are, with few exceptions, restricted to the upper part of the Kidd Member. The grains are 1) clear, very fine- to fine-grained, and subhedral or 2) frosted, fine- to medium- or rarely coarse-grained, and subrounded.

Silt

The most prominent constituent of Salem residues is fine to coarse silt-sized silica. It is rarely absent and generally is a major constituent.

Clay

Clay, material finer than 4 microns, is, except for the more impure beds, a minor constituent of the Salem.

Although the identity of the clay mineral in the residues was not determined in this study, the clay component of Salem outcrops has been described as illite (Grim, Lamar, and Bradley, 1937).

Other Constituents

Other noncarbonate constituents of the limestone are minute, dark, carbonaceous particles and very rare, green particles which may be glauconite or some related mineral.

CHARACTER OF LOWER CONTACT

The Warsaw Formation has transitional contact with the Salem Limestone indicating continuous deposition of calcareous materials from Warsaw to Salem time.

A 20-foot zone of slightly argillaceous limestone that contains rather large unbroken brachiopod shells occurs near the top of the Warsaw Formation and is helpful in distinguishing between the two formations. *Spirifer washingtonensis* Weller and *Marginirugus magnus* (Meek and Worthen) are particularly abundant. The transition into the Salem Formation occurs about 15 to 25 feet above a bed approximately one foot or less thick which contains numerous *Spirifer washingtonensis*.

The lowest beds placed in the Salem are relatively pure bioclastic limestone composed of crinoid columnals and bryozoan detritus in approximately equal amounts. In general, the limestone of the upper part of the Warsaw is darker, less pure, and contains more unbroken fossils than the lower beds of the Salem.

The Warsaw-Salem contact is exposed where the beds rise on the Dupo Anticline, the Valmeyer Anticline, and on two minor flexures south of Valmeyer. At Dupo, in St. Clair County, Salem Limestone lies 20 feet above a bed containing spirifers. The lower part of the interval separating the Salem from the bed containing spirifers is largely gray to dark gray, medium- to coarse-grained, granular limestone that contains crinoid columnals and bryozoa. The upper part is largely fine-grained, cherty, buff to bluish gray dolomite, which is reported at one time to have been mined to make natural cement. Weller (1908, p. 94) referred the cement rock to the Salem, but I am inclined to assign such impure beds in the transition zone to the Warsaw.

At Trout Hollow $3\frac{1}{2}$ miles northeast of Valmeyer on the north flank of the Valmeyer Anticline, high-purity limestone typical of the lower part of the Salem lies 20 feet 7 inches above a bed containing spirifers. The intervening beds are mostly fossiliferous limestone of variable purity, the lower ones similar to the cement rock.

The Warsaw-Salem contact also is exposed in the Mississippi River bluff southwest of the village of Renault. The transition to Salem lithology is fully accomplished 23 feet 2 inches above a bed containing spirifers. The intervening limestone is assigned to the Warsaw and is purer than limestone of the same interval at Trout Hollow but not as pure as the overlying limestone assigned to the Salem.

KIDD MEMBER

The Kidd Member is named from an outcrop in the Mississippi River bluff east of the village of Kidd and just south of the junction of the bluff road with the road leading to Renault in the NE $\frac{1}{4}$ sec. 1, T. 5 S., R. 10 W. Because the Warsaw-

Salem contact is above the talus slope, the complete member is exposed along this part of the bluff.

Stratigraphic Relations

The Kidd Member conformably overlies the Warsaw Formation and is conformably overlain by the Fults Member of the Salem. Both contacts are transitional, but the upper occurs within a vertical distance of a few inches.

Lithology

The Kidd Member contains a variety of rock types (pl. 2, A and B) but consists largely of brownish gray to light gray, fine- to coarse-grained, granular to crystalline limestone. This limestone is composed of about equal amounts of medium- to coarse-grained fragments of crinoid columnals and fine-grained detritus of other, largely bryozoan, fossils.

Chert is present locally but otherwise is rather inconspicuous. Some beds contain rounded quartz grains.

Although bedding is variable, thick to massive beds are common but at many weathered outcrops the rocks appear to be thin bedded because they tend to break down in plates parallel to the bedding. Some of the more granular beds tend to spall at right or nearly right angles to the bedding. Cross-bedding occurs on a small scale within the Kidd but is not as common as in some other parts of the formation.

Composition of Calcarenites

The Kidd Member is predominantly a calcarenite composed of crinoid columnals and bryozoan debris (fig. 5). The relative abundance of the two varies but commonly they occur in nearly equal amounts with crinoids more prominent. Portions of the upper half of the member at the type locality contain *Endothyra* which, in some beds near the top of the member, compose as much as 25 percent of the calcarenite grains (pl. 2, B).

The predominant cementing material of the Kidd Member is clear calcite that is deposited in optical continuity with crinoid ossicles. Deposits of calcite around adjacent grains commonly meet, giving the limestone a crystalline appearance. Some thin sections contain much fine-grained carbonate material interstitial to calcarenite grains; other thin sections are almost completely composed of the fine-grained carbonate material.

Thickness

In most outcrops of the Kidd Member in Monroe County only the upper part of the member can be observed because the lower contact is either below the level of the bottomland or covered by talus. East of the village of Kidd, the Warsaw-Salem contact rises above the talus slopes where an unnamed anticline intersects the bluff southwest of Renault. At this location the Kidd is approximately 90 feet thick.

The upper beds of the Warsaw Formation also crop out in the vicinity of Maeystown and Monroe City Hollows, at Dennis Hollow on the steep flank of the Valmeyer Anticline, and for a short distance on either side of Trout Hollow on the gentle flank of the anticline. At the Trout Hollow location 33 feet of limestone having Kidd lithology is exposed but because it occurs below a 30-foot covered interval the total thickness cannot be measured. At Dupo, in southern St. Clair County, however, the Kidd Member has a total thickness of 66 feet.

Type Section

The following is a description of the type section of the Kidd Member in the NE $\frac{1}{4}$ sec. 1, T. 5 S., R. 10 W.

	Thickness Feet	Inches
Surficial material	(Not measured)	
Salem Formation		
Rocher Member		
Limestone	25	0
Chalfin Member		
Limestone	46	10
Fults Member		
Limestone	27	6
Limestone, very argillaceous, silty, dolomitic, thin-bedded to thinly laminated	6	0
Kidd Member		
Limestone, brownish gray, medium- to coarse-grained, abundant fossil fragments, crinoids, and *Endothyra*, beds 2-3 feet thick	13	6
Limestone, brownish gray, very fine- to medium-grained, mostly fine-grained, beds 6 to 25 inches thick	5	0
Limestone, brownish gray, coarse-grained, crinoid fragments and *Endothyra*	4	0
Limestone, brownish gray, fine- to coarse-grained but mostly medium-grained	5	6
Limestone, brownish gray, largely fine detritus, a few medium-grained crinoid fragments	4	6
Limestone, pale brownish gray, fine- to medium-grained, mostly thick-bedded with tendency to spall parallel to bedding, composed of crinoid columnals and fine bryozoan detritus	5	6
Limestone, slightly cherty (less than 1%), pale brownish gray, fine-grained, thin to medium beds	4	6
Limestone, pale brownish gray, medium-grained, cross-bedded	1	0
Limestone, cherty (about 5%), yellowish gray, fine- to medium-grained, many small solution cavities	5	6
Limestone, slightly cherty (less than 1%), fine- to medium-grained, a few large bryozoan fragments, crinoid columnals and brachiopods	2	6
Limestone, brownish gray, fine- to coarse-grained, bedding obscure	4	6

Limestone, very light brownish gray, fine- to medium-grained, coarse crinoidal and bryozoan debris, bedding obscure	3	0
Limestone, light brownish gray, medium- to coarse-grained, fossiliferous, crinoids, bryozoa, essentially a single massive bed	12	6
Limestone, brownish gray, fine- to medium-grained, fossil detritus, white crinoid fragments in lower 6 inches	6	0
Limestone, slightly argillaceous, pale yellowish gray, mostly very fine-grained with some medium to coarse crinoid fragments, forms re-entrant in the bluff	2	6
Limestone, light gray, fine- to medium-grained, largely fossil detritus, beds 14 to 16 inches thick	12	6
Warsaw Formation		
Limestone, light gray, medium- to very coarse-grained, granular, 4-inch argillaceous zone at top	4	8
Limestone, very argillaceous, dolomitic, brownish gray to bluish gray, thin-bedded, thin gypsum veins (satin spar), forms re-entrant	3	0
Limestone	27	10
Shale	1	0
Limestone	3	6

Base of section approximately 95 feet above road level.

FULTS MEMBER

The Fults Member is named from outcrops in the bluffs of the Mississippi River in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 20, T. 4 S., R. 10 W., near the village of Fults in southern Monroe County.

Stratigraphic Relations

The Fults Member conformably overlies the Kidd Member and is conformably overlain by the Chalfin Member. The lower contact with the Kidd has already been discussed. The contact with the Chalfin Member is at the base of its easily recognized semilithographic bed.

Lithology

The composition of the Fults Member varies but in general three types of rock predominate: 1) very fine-grained, argillaceous, silty, earthy, mostly dolomitic limestone; 2) mostly fine-grained dolomitic limestone with less detrital clay and silt; and 3) medium-grained, bioclastic limestone.

Earthy beds at the base of the member in most places total about 6 feet thick. They consist of argillaceous, silty, yellowish brown and bluish gray, thinly laminated, dolomitic limestone or in some places calcitic or dolomitic siltstone. The limestone or siltstone is commonly carbonaceous with the carbonaceous matter present in minute particles. In some places chert may be present near the base but more commonly the lower portion of the member is free of chert. In the steeper parts of the bluffs, deep re-entrants have formed in the earthy beds because they weather more rapidly than adjacent beds. In sections other than those in the steep parts of the bluffs, the position of the beds is commonly marked by covered intervals.

Above the earthy zone, the Fults Member consists largely of alternating thicknesses of cherty, brownish gray to yellowish brown, mostly fine-grained limestone which is more or less dolomitic (pl. 2, C) and medium-grained bioclastic limestone which contains *Endothyra* (pl. 2, D). The thickness of the beds is variable but medium to thick bedding prevails, although outcrops may weather so as to appear thin bedded. The coarser bioclastic beds have a tendency to spall off in plates roughly at right angles to the bedding. Chert is conspicuous throughout the Fults but is most abundant in bands and nodules associated with fine-grained limestone directly above the earthy zone and at or near the top of the member.

Composition of Calcarenites

The thin section analysis of the Fults Member was based upon samples collected at the type section of the overlying Chalfin Member. It showed an intermittent occurrence of calcarenites containing skeletal elements and nonskeletal pellets.

The skeletal elements include crinoid columnals, bryozoan detritus, and *Endothyra* (fig. 5). Calcisphaerids are a common but minor constituent of the calcarenites, and oolites were observed in a thin section from the top foot.

Thickness

The maximum thickness of the Fults Member, 34 feet, was observed at the south end of the outcrop area, approximately $3\frac{1}{2}$ miles northwest of Prairie du Rocher. One mile southeast of Chalfin Bridge the member is 31 feet thick. At Trout Hollow, northeast of Valmeyer, a large covered interval makes it impossible to measure thickness, but at Dupo in southern St. Clair County the Fults Member is 25 feet thick.

Type Section

The following is a description of the type section of the Fults Member as exposed in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 20, T. 4 S., R. 10 W. The base of the section is exposed on the south side of the first gully north of Fults Hollow, and the described portion of the section is accessible in the bluff south of that point.

	Thickness	
	Feet	Inches
Surficial material	Not measured	
St. Louis Limestone		
Limestone	Not measured	
Salem Limestone		
Rocher Member		
Limestone	38	0
Chalfin Member		
Limestone	32	0
Limestone, brown to gray, microcrystalline, coarsely fossiliferous streak near the top	3	0

	Thickness Feet	Inches
Fults Member		
Limestone, cherty (10%), light brown, very fine-grained, thin- to medium-bedded	3	0
Limestone, cherty (5%), fine- to medium-grained, essentially a single ledge-forming bed but with numerous faint indications of bedding	8	0
Interbedded; limestone, brownish gray, fine-grained; chert (15%), in bands and nodules; shale, gray, thin-bedded	1	3
Limestone, silty, brownish gray, fine to medium-grained, ledge-forming bed with chert (3%) nodules at base, faint crossbedding in lower part	3	0
Limestone, very cherty (20%), silty, argillaceous, at places slightly dolomitic, very fine-grained	9	0
Limestone, very argillaceous, silty, dolomitic, yellowish brown, fine laminations, very fine-grained, forms deep re-entrant in bluff	5	0
Kidd Member		
Limestone, slightly sandy, brownish gray, fine- to medium-grained with irregular coarse-grained streaks in lower 4 to 6 inches	3	0
Limestone	30	2

Base of section approximately 7 feet above road level.

CHALFIN MEMBER

The Chalfin Member is named from an exposure in the Mississippi River bluff in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 7, T. 4 S., R. 10 W., one mile southeast of Chalfin Bridge.

Stratigraphic Relations

The Chalfin Member conformably overlies the Fults and is conformably overlain by the Rocher. The top and bottom of the Chalfin are delimited by microcrystalline limestone at the type section. The lower contact occurs at the base of a microcrystalline bed and the upper contact at the top of a similar bed. In each case the bed may be locally a limestone breccia. In the Prairie du Rocher area, however, microcrystalline limestone does not occur at the top of the Chalfin. There, the top beds of the Chalfin consist of fine-grained limestone which is mostly not visibly clastic to the unaided eye and is not as fine grained and dense as microcrystalline limestone. It also contains fine sand-sized, subrounded pellets in the top two feet.

Lithology

The Chalfin Member varies lithologically, vertically and laterally, but it is largely fine-grained limestone. In general, the member is more calcarenitic and hence somewhat coarser at the south end of the outcrop area than elsewhere. Thin, brownish gray, microcrystalline beds having a conchoidal fracture occur at or near the top and at the bottom of the member. These beds usually show various degrees of disruption and at some places are breccias that commonly consist of angular fragments of microcrystalline limestone in a fine-grained matrix (pl. 3, A and B). Other microcrystalline limestone beds, mainly at or near the top of the member, display algal structures (pl. 3, C). Microcrystalline limestone occurs in beds from an inch to 2 feet thick. Most outcrops have a " natural whitewash" due to the accumulation of very fine-grained residues on the surface of the weathered outcrops.

Calcarenitic limestone is interbedded with fine-grained limestone of the Chalfin in the Prairie du Rocher area but decreases in amount northward. Medium-grained calcarenitic limestone (pl. 2, E) occurs near the base of the member throughout most of the bluff area and is locally oolitic. Calcarenite does not occur in this position at Dupo in southern St. Clair County.

The calcarenite of the Chalfin is very similar to that occurring higher in the Salem but is usually coarser due to a larger content of crinoid fragments and bryozoan debris. Although the thickness of bedding is variable, thick to massive beds are the most common. At many places what appears to be bedding features actually are stylolitic partings. Outcrops tend to spall off in plates roughly at right angles to the bedding.

The Chalfin Member also includes fine- to medium-grained dolomitic limestone that most commonly occurs above the foraminiferal-oolitic bed. It is brownish gray, mostly fine grained, but locally shows an increase in average grain size because of increases in the amount of fossil detritus. It is mostly medium to thick bedded, but weathered outcrops appear to be thin bedded. Exposed strata in which the amount of fossil detritus is above normal tend to spall. Chert bands are locally abundant, especially in the top few feet.

The upper portion of the Chalfin Member, exclusive of the microcrystalline bed at the top, consists of very fine-grained, brown to grayish brown limestone (pl. 2, F). Bedding is commonly thin to medium but some beds are as much as 2 feet thick. Scattered chert nodules also occur. Locally these beds contain fossil plant material and thin coalified veinlets. The plant material consists of flattened calcified branches, stems, and possibly root structures with carbonaceous films. Samples have been identified as representatives of the lycopsid alliance.(R. M. Kosanke, personal communication, 1958.)

A massive crinoidal limestone bed occurs near the top of the Chalfin Member in the Mississippi bluff approximately 2 miles south of Valmeyer in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 22, T. 3 S., R. 11 W. It is composed of light gray limestone with a very slight brownish tinge, is medium to coarse grained, and consists almost completely of crinoidal fragments with some foraminifera in a clear calcite matrix. No oolite grains were noted. The thickness of the bed ranges from 0 to 16 feet. It disappears abruptly to the north but extends southward for possibly as much as half a mile. The deposit is a filling in a channel which cuts into and truncates underlying strata.

Composition of Calcarenites

There are marked differences in the number of skeletal grains in thin sections from the type section of the Chalfin Member. The lower 10 feet is predominantly a calcarenite composed of bryozoan detritus, crinoid columnals, *Endothyra*, and some nonskeletal microcrystalline pellets. Oolites occur sparsely but are mostly of the single-ring type. Locally the interval is more oolitic, particularly in the bluffs between Valmeyer and Monroe City Hollow. Skeletal elements diminish rapidly in the upper two-thirds of the type section as nonskeletal pellets become prominent. The pellet limestone (pl. 2, F) is very fine grained with most pellets falling into the very fine sand and silt size ranges. *Calcisphaera* is abundant in the pellet limestone and present in microcrystalline limestone that occur near the top of the member.

Thickness

The thickness of the Chalfin Member ranges from a maximum of 57 feet less than one mile southeast of Valmeyer to approximately 26 feet at Dupo. The average thickness in Monroe County is 45 feet.

Type Section

The type section of the Chalfin Member crops out in the Mississippi River bluff approximately a mile southeast of Chalfin Bridge in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 7, T. 4 S., R. 10 W. The lower portion of the exposed sequence includes the Fults Member and upper beds of the Kidd Member, and is exposed in and above an abandoned quarry; the Chalfin is exposed in the bluff between the quarry and the first major break in the bluff, which is cut by a small creek that runs through the southeast quarter of section 7.

	Thickness Feet	Inches
Surficial material	Not measured	
St. Louis Limestone (transition beds)		
Limestone, light brownish gray, fine- to medium-grained, pseudo-oolitic, beds 2 to 6 inches thick, weathers to smooth fairly rounded surfaces; partly covered	19	0
Limestone, pale brownish gray, very fine-grained, two beds approximately 1 foot thick at base, becoming thin-bedded in upper 3 feet with 2 feet covered	7	0
Covered interval	5	0
Limestone, pale yellowish gray, microcrystalline, cherty	1	0
Covered interval	17	0
Salem Limestone		
Rocher Member		
Limestone	6	0
Limestone, light gray to pale brownish gray, fine- to medium-grained, foraminiferal-oolitic, individual corals in lower 3 feet	14	0
Covered interval	1	0
Chalfin Member		
Limestone, brownish gray, microcrystalline, in part possibly algal	4	0
Limestone, brownish gray, very fine- to medium-grained, particulate	3	0

	Thickness Feet	Inches
Limestone, slightly cherty (5%), brownish gray, very fine- to extra fine-grained	4	0
Limestone, brownish gray, microcrystalline, brecciated	1	0
Limestone, slightly cherty in upper part (2%), light brownish gray, very fine- to fine-grained, medium to thick bedding	9	0
Dolomite, very calcareous, light brownish gray, essentially medium to thick bedding, partly covered	6	0
Limestone, light brownish gray, fine-grained, medium to thick beds, slight re-entrant at base	2	0
Limestone, light brownish gray, fine- to coarse-grained, fossiliferous, bryozoa, crinoids, *Endothyra*, partly oolitic	9	0
Limestone, gray, microcrystalline, fossiliferous, minute brachiopods, clear calcite in crescent-shaped segregations	1	6
Fults Member		
Limestone, slightly cherty, fine-grained, thin-bedded, calcarenitic streaks	4	0
Limestone	25	0
Kidd Member		
Limestone	44	0

Base of section approximately 24 feet above road level.

ROCHER MEMBER

The Rocher Member is named from exposures in the Mississippi River bluffs in northern Randolph County less than a mile north of the town of Prairie du Rocher. The member is well exposed and accessible around the entrances to mines which have been driven into the steep bluff.

Stratigraphic Relations

The Rocher Member conformably overlies the Chalfin Member and is in turn conformably overlain by the St. Louis Limestone. The basal contact has been discussed under the Chalfin Member; the upper contact is described in a later section.

Lithology

The Rocher Member consists of pale brownish gray to nearly white, fine- to coarse-grained, bioclastic limestone (pl. 3, D-F). It is composed to a large extent of marine fossils, predominantly foraminifera but also including crinoid and bryozoan fragments, brachiopods, individual and colonial corals, echinoids, and other forms. Generally the Rocher Member ranges from slightly oolitic to true oolite (pl. 3, F).

The Rocher Member in its type area consists of a series of massive beds separated by thin- to medium-bedded strata which are less oolitic and less calcarenitic. Stylolites occur at frequent intervals in the massive layers and give weathered outcrops a bedded appearance. Some beds exhibit faint cross-bedding marked by the accumulation of coarse fossil material along planes inclined to the major direction of bedding.

Weathering causes outcrops to spall in a direction transverse to the bedding plane. This phenomenon is especially prominent in and diagnostic of foraminiferal-oolitic limestone of the Rocher. The fragments and slabs which exfoliate from the outcrops generally range from a fraction of an inch to 2 inches thick and from 3 inches to a foot across.

Composition of Calcarenites

Endothyra and oolite grains are the most diagnostic elements of the Rocher Member (fig. 5). Crinoid columnals also are abundant but bryozoa are relatively less abundant and their number decreases rapidly in the upper 20 feet. Pellets are present but many of them probably are recrystallized *Endothyra* tests. A few specimens of *Calcisphaera* were observed in about half of the samples.

The matrix of the rock is mainly clear calcite. Where it is in contact with crinoid columnals it is in optical continuity with the calcite of the columnals.

Thickness

The maximum outcrop thickness of the Rocher Member occurs in the Mississippi River bluffs of northern Randolph County, approximately $1\frac{1}{4}$ miles north of Prairie du Rocher, where it is 69 feet thick. The member thins to the north. In sec. 21, T. 4 S., R. 10 W., Monroe County, three-quarters of a mile northwest of Fults, the Rocher is 38 feet thick, and in section 7 of the same township it is 21 feet thick. Along the section of the bluff between Monroe City Hollow and the town of Valmeyer, the Rocher Member is mostly oolitic and has a thickness of 12-15 feet. At one place just south of Schaeffer Hollow, the thickness of the pure Rocher stone is somewhat less than 10 feet because a part of this interval is occupied by a brown, earthy bed. Where the Rocher beds again appear in the bluffs, northeast of the intersection of the bluff line with the Valmeyer Anticline, the thickness is approximately 15 feet.

Type Section

The type section of the Rocher Member is above the spring one mile south of the Monroe-Randolph county line at the site of a limestone mine in T. 5 S., R. 9 W. It is in a portion of the township that has not been divided into sections. The following is a description of the Rocher as it is seen along the face of the bluff north of the spring.

	Thickness Feet	Thickness Inches
Surficial material	Not measured	
St. Louis Limestone		
Limestone	Not measured	
Limestone, brown to gray, not visibly clastic, well bedded, beds 6 to 10 inches thick, 1-inch chert band 1 foot from top, very thin shale partings.	5	3

	Thickness Feet	Inches
Salem Limestone		
Rocher Member		
Limestone, light brownish gray to light gray, fine- to medium-grained, foraminiferal, oolitic, mostly with clear calcite matrix; scattered coarse streaks especially in the lower four feet; stylolites at intervals of a few inches to several feet	19	6
Limestone, pale brownish gray, fine-grained, foraminiferal, 3- to 8-inch beds; thin shale partings, especially at top	2	2
Limestone, pale brownish gray, fine- to medium-grained, foraminiferal, oolitic, clear calcite matrix, scattered solitary and colonial corals; forms re-entrant in bluff	2	6
Limestone, light gray with slight brownish tinge, fine-grained, broken fossil fragments, very slightly oolitic, solitary and colonial corals	5	10
Limestone, light brownish gray, medium-grained, oolitic, foraminiferal, crinoid fragments, brachiopods, solitary and colonial corals	14	0
Limestone, brownish gray, fine- to medium-grained, foraminiferal, rather oolitic; cross-bedded; minute stylolites parallel to inclined bedding	6	10
Limestone, brownish gray, fine- to medium-grained; stylolitic	3	6
Limestone, brownish gray, fine- to medium-grained, very slightly oolitic, foraminiferal; commonly a single bed; rather continuous stylolites 6 to 18 inches apart	2	6
Limestone, pale brownish gray, fine- to very fine-grained, 2- to 3-inch beds, forms re-entrant in bluff; thickness varies	1	2
Limestone, pale brownish gray, fine- to medium-grained, oolitic, foraminiferal, crinoids; in part faintly cross-bedded with concentration of brachiopods along inclined bedding; stylolitic	11	4
Chalfin Member		
Limestone, brownish gray, fine-grained, contains minute subrounded pellets	2	0
Limestone, pale yellowish brown, fine-grained, 4- to 6-inch beds, horn corals, stylolitic	4	6
Limestone	7	6

Base of section at water level at spring.

CHARACTER OF UPPER CONTACT

Limestone deposition continued without interruption from Rocher into St. Louis time. The lithologic characteristics of the formations contrast sharply but selection of the actual contact between the two generally is arbitrary. The Rocher

Member of the Salem is characterized by calcarenitic limestone and the St. Louis by predominance of fine-grained limestone.

In Randolph and southern St. Clair Counties, the Salem - St. Louis contact is taken to be the top of the foraminiferal-oolitic beds which are a commercial source of limestone both at Prairie du Rocher and at Ste. Genevieve, Missouri. The limestone is pale brown to nearly white, more or less oolitic, and contains large numbers of foraminiferal tests, including *Endothyra baileyi* (Hall), which is used as an index fossil of the Salem. These beds are commonly referred to the Salem despite the occurrence of *Lithostrotionella castelnaui* Hayasaka and *Lithostrotion proliferum* Hall. Weller and Sutton (1940, p. 809) pointed out that at other locations these colonial corals are considered to be indicative of the St. Louis.

The foraminiferal-oolitic limestone at the summit of the Salem thins to the northwest in river bluff exposures but constitutes a recognizable marker throughout the outcrop area in Monroe County. Subjacent to the foraminiferal limestone, the Salem has beds which share many aspects of St. Louis lithology. The Salem beds are characterized by fineness of grain, the presence of impure dolomitic layers, and some chert; they become more conspicuous as the formation is traced northward in the bluff from Prairie du Rocher. Where the foraminiferal-oolitic beds are thin or absent, Weller (1908, p. 95) placed the fine-grained Salem beds in the St. Louis. The present investigation shows, however, that at least as far north as Dupo there is an oolitic-foraminiferal zone at the stratigraphic position of the commercial limestone beds of Prairie du Rocher.

RESUMÉ OF DEPOSITIONAL HISTORY

The depositional history of Salem Limestone involves an early period of calcarenite deposition during Kidd time. The degree of fragmentation, rounding of fossil fragments, and presence of cross-bedded strata suggest transportation under relatively shallow water conditions. There is little evidence for active chemical precipitation of carbonates.

Fults time, a period of unstable conditions during which deposition of calcarenite alternated with deposition of calcilutite, began by the deposition of calcilutite that contained an appreciable amount of detrital silt and clay, probably derived from a land source. Laminated deposits that consist of alternations of carbonate and silt probably are related to chance variations in the velocity of transporting currents in shallow water.

Sedimentation during Chalfin time began with a calcilutite phase that was followed by the deposition of rather extensive, locally oolitic biocalcarenite. Calcarenite deposition gradually diminished and a pellet and calcilutite phase came into prominence.

The deposition of pellet and microcrystalline limestone is probably related to one of two mechanisms which have been suggested for similar ancient sediments. Beales (1958), for some Canadian limestones, favors chemical precipitation of a calcilutite phase and the formation of pellets or "bahamite" grains by progressive aggregation of particles in the manner suggested by Illing (1954). Hadding (1957) believes that pellet or "clotted" limestone is formed through the agency of calcareous algae and that homogeneous microcrystalline or lithographic limestone is the end product of the attack of bacteria upon these algal segregations. Local subaerial exposure of lime mud resulted in desiccation and disruption. In places channel cut-and-fill occurred.

In the vicinity of Prairie du Rocher, conditions of deposition during Chalfin time differed from those elsewhere. The accumulation of considerable thicknesses of oolitic and skeletal calcarenites indicates an early beginning of conditions leading to deposition of Rocher sediments.

Rocher time was a period of biocalcarenite deposition and moderate to locally prominent development of oolite grains. The skeletal element in the calcarenite is predominantly foraminiferal. Oolite grains formed where local conditions were favorable.

ENVIRONMENT OF DEPOSITION

Carbonate deposition is now occurring on the Great Bahama Banks off the east coast of Florida, and nonskeletal grains compose a major part of the material deposited on the interior portions of the banks (Illing, 1954). The similarity of these deposits to pellet limestone in the Chalfin Member of the Salem in southwestern Illinois suggests that at least locally during a part of Salem time, conditions similar to those now prevailing on the Bahama Banks influenced Salem deposition. Deposition of the Salem Limestone in southwestern Illinois probably occurred on a coastal shoaling area which locally for a time became semirestricted to allow concentration of carbonate in solution.

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