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St. Louis limestone, stratigraphy and petrography, near its type locality

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ST. LOUIS LIMESTONE, STRATIGRAPHY AND PETROGRAPHY, NEAR ITS TYPE LOCALITY

BY

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THESIS

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ABSTRACT

The St. Louis Limestone of the Upper Meramecian Series, Mississippian System, is typically lithographic, light-to light-olive gray in color, dense, and fractures conchoidally. It is brecciated, especially in the lower part, and contains some chert nodules. Oolites are present close to the top of the formation. The Salem-St. Louis contact is placed at the base of the lowest breccia zone and the top of Salem is characterized by crystalline quartz and abundance of chert nodules. The appearance of typical Ste. Genevieve oolites with sand-size quartz grains indicates the St. Louis-Ste. Genevieve contact.

The St. Louis Limestone is characterized by dominance of fine-grained texture (micritic) with fossil fragments and minor spar. Foraminifers and bryozoans are the main fossil constituents followed by algae, crinoid fragments and corals. Of the corals, *Lithostrotionella* and *Lithostrotion* are significant but of less obvious correlative value. Brachiopods and gastropods are present but to a lesser extent. The formation has about 3 to 5 percent insoluble residues (except close to the boundaries), consisting mostly of quartz. The degree of dolomitization is widely variable from one section to another. The St. Louis Limestone is high in CaO content except in the dolomitized zones. The explanation of the origin of brecciation in the St. Louis Limestone presents some difficulty.

The St. Louis Limestone is tentatively subdivided into three units. The deposition of limestone was continuous from Salem through St. Louis time under quiet and shallow water environments. In the study area, the St. Louis Limestone is used for cement manufacture and road construction.

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The writer is deeply indebted to Dr. Alfred C. Spreng, Professor of Geology, Geology Department at the University of Missouri-Rolla, not only for his guidance throughout the research and his constructive suggestions, but also for allowing this writer to use one of his described stratigraphic sections. He also supplied transportation to the writer during the field work.

Thanks are also due the Missouri Portland Cement Company of St. Louis, Missouri as they made two of their drill hole cores available and allowed measurement of the stratigraphic section at their Fort Bellefontaine Quarry. Mr. W. Dean Weixelman of that company made some data available. Fred Weber Contractor, Inc., also allowed the measurement of stratigraphic sections at the Vigus North Quarry. The Geology Department at UMR made laboratory facilities available.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Charts

LIST OF TABLES

CHAPTER I

INTRODUCTION

The study of the petrology of the St. Louis Limestone was suggested to the writer by Dr. A. C. Spreng. The main reasons for such a study are: the desirability of making a study of the St. Louis Limestone in the type area, as such a study has not been made before, the need to apply a current classification of carbonate rocks, and to discuss the origin of the limestone in such an economically important deposit. The factors that made this study possible are the presence of fairly complete stratigraphic sections in two different quarries, availability of drill cores, and natural outcrops of the formation along the Mississippi River bluff in western Calhoun County in Illinois.

The name St. Louis was given to the formation by Englemann in 1847 to cover the limestone cropping out in the vicinity of the city of St. Louis, Missouri. The Gateway Arch, a St. Louis landmark, is set on the St. Louis Limestone as its foundation.

A. Purpose of Investigation

The purpose of the study of the St. Louis Limestone is to give a presentation of the lithologic features of the formation, particularly in regard to the aspects listed below. The occurrence of the study area within the type area of the formation may provide a better understanding of the St. Louis Limestone. The various problems dealt with are:

1. To study the petrography of the St. Louis Limestone in a portion of the type area.
2. To review the formation boundaries: the lower Salem-St. Louis contact and the upper St. Louis-Ste. Genevieve contact.

3. To apply the limestone classification of Folk (1959) to the St. Louis Limestone in an attempt to find what rock carbonate types occur in the formation.
4. To correlate the different stratigraphic sections studied and presented in this report.
5. To discuss the origin of breccia, silica, and dolomite in the St. Louis Limestone.
6. To determine the environments of deposition of the St. Louis Limestone.

B. Location

The St. Louis Limestone was studied at four different locations. Two of the stratigraphic sections are located in St. Louis County, Missouri; the first is at the Missouri Portland Cement Company quarry at Fort Bellefontaine, Columbia Bottoms Quandrangle and the second is at the Vigus North quarry, which is located in Creve Coeur Quandrangle. The other two stratigraphic sections are located in the Winfield 7½-minute Quandrangle, Calhoun County, Illinois. One of them is an outcrop along the Mississippi River bluff and the other is a drill hole core made by the Missouri Portland Cement Company. The drill hole core studied here is from drill hole number 5. Table 1 shows a summary of the location of each stratigraphic section measured, indicating the section number, township and range, county and state. The locations are shown in Figure 1.

C. Physiography, Climate and Drainage

St. Louis County, Missouri and Calhoun County, Illinois, where the stratigraphic sections are located, are included within the Central

Fig. 1. Index map showing the general locations of the stratigraphic sections. Modified after Rubey, 1952.

Location Name	Symbol	Section	Quadrangle	County	State
Missouri Portland Cement Company Fort Bellefontaine Quarry	A	NW¼,NE¼,NW¼,sec. 9, T. 47 N., R. 7 E. (projected)	Columbia Bottoms	St. Louis	Missouri
Vigus North Quarry Fred Weber, Contractor	B	NE¼,SW¼,sec. 9, T. 46 N., R. 5 E. (projected)	Creve Coeur	St. Louis	Missouri
Mississippi River bluff at Cap-au-Gres fault	C	NW¼,NW¼,sec. 5, T. 13 S., R. 2 W.	Winfield	Calhoun	Illinois
Missouri Portland Cement Company Project NMRC, drill hole #5	D	NE¼,SE¼,sec. 5, T. 13 S., R. 2 W.	Winfield	Calhoun	Illinois

Table 1. Summary of the locations of the stratigraphic sections.

Lowland Province of the major physiographic division, the Interior Plains. Calhoun County is located east of the Mississippi River within the Till Plain section, whereas St. Louis County is situated west of the Mississippi in the Dissected Till Plain section. The Till Plain section is characterized by young till plains, rare morainic topography and no lakes. The Dissected Till Plain section is characterized by submaturely to maturely dissected till plains. The two counties are considered the southern borders of glacial cover. The Ozark Plateau Province of the Interior Highland constitutes the southern border of the study area and at the same time, it is the southwestern limit of the Central Lowland Province.

The climate involves cool winters and hot, rainy to dry summers. The annual average temperature is 55° F. in the City of St. Louis which is assumed to be more or less representative of the study area, as there are no long term temperature records within the area. The average maximum temperature is 100° F. and the average minimum is 10° F. The mean annual rainfall is between 35 and 41 inches with the most of the rain falling during April through June and August through October. The rainfall is adequate for most agricultural purposes.

The major rivers in the area are the Mississippi, Illinois, and the Missouri Rivers, which join together in the study area. Besides, there are smaller streams draining to the south and joining the major ones. The general drainage pattern is dendritic.

The relief within the area is discussed here very briefly for each location. The Missouri Portland Cement quarry is at an elevation of 400 to 500 feet, where the maximum and minimum elevations in the quadrangle are 610 and 400 feet, with possible amount of relief of about

210 feet. The Vigus North quarry area has an elevation of 450 to 550 feet and the maximum and minimum elevations within the quandrangle are about 680 to 440 feet with possible amount of relief of 240 feet. The other two sections are located in the Winfield Quandrangle, which has maximum and minimum elevations of 750 to 450 feet and the amount of possible relief within the quandrangle is about 320 feet. The Mississippi River bluff section has an elevation of 430 to 600 feet and well number 5 is located at an elevation of 600 feet above mean sea level. A comparatively higher relief is present in these two sections as compared to the first ones. The elevation of the Mississippi River in this part of the study area is 430 feet.

D. Previous Work

As for the present writer's knowledge, he does not know of a detailed petrographic study that has been devoted specifically to the St. Louis Limestone in this considered type area. Englemann (1847) introduced the name "St. Louis" for the kind of limestone outcropping in the vicinity of the City of St. Louis. It appears from early descriptions of the formation that he included all the stratigraphic section from the Warsaw up to the highest Mississippian (Chesterian). After that, the name was given various stratigraphic ranks by later writers as may be noticed from Table 2.

It is of interest here to mention some writers whose works may be related or have contributed to this study. Some of these works were within or close to the study area. Others discuss related problems especially brecciation. Shumard (1860) used the name Ste. Genevieve for the upper part of the St. Louis as used by Englemann (1847) and

Ulrich (1905), after defining the Salem (Spergen)*, restricted the St. Louis to the stratigraphic unit above the Salem and below the Ste. Genevieve Formation. Stuart Weller (1908, pp. 88-90) in his discussion of the Salem Limestone in Illinois defined the Salem-St. Louis contact. Van Tuyl (1925, pp. 230-287) described the occurrence of St. Louis Limestone in Iowa and presented descriptions of the stratigraphic section there and also discussed the St. Louis brecciation problem. Fenneman (1911, pp. 41-42) in his report on the geology of St. Louis Quandrangle, described the formation and discussed the St. Louis Limestone sedimentation. J. M. Weller (1940, p. 814) mentioned the physical character of the formation, its geographic distribution in Illinois, and its fossil content. Hinchey, Fischer, and Calhoun (1947) gave a detailed stratigraphic description of seven different locations in the vicinity of St. Louis; they also gave complete chemical analyses of 105 samples taken from these locations. Their study is mainly for economic purposes.

Grohskopf and McCracken (1949, pp. 18-19) pointed out some criteria for recognizing the St. Louis boundaries based on insoluble residue analyses in the subsurface. W. W. Rubey (1952, pp. 48-51) described some St. Louis outcrops along the Mississippi River bluff in western Calhoun County, Illinois; he also reviewed the fossils of the St. Louis Limestone in his section on fossil collections. Collinson and Swann (1958, p. 13) suggested the solution of evaporites as a possible origin of breccia in the lower part of the St. Louis Limestone near Alton, Illinois. Smith (1961, pp. 275-287) suggested submarine rock slump as causing the brecciation of the St. Louis Limestone in the Harris quarry in

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*The name Salem is used here in preference to Spergen.

Putnam County, Indiana. Spreng (1961) put the lower boundary of St. Louis Limestone at the base of the lower breccia zone in the formation. Marcher (1962, pp. 827-832) in his presentation on "Petrography of Mississippian limestone and chert in northwestern highland rim of Tennessee" suggested the environment of deposition of the St. Louis Limestone as ranging from quiet, deep to shallow, agitated water. He also mentioned that foraminifers were rock builders in that area.

Other contributions were made mainly on the occurrence of conodonts in St. Louis Limestone and their uses in determining the boundaries of the formation. These contributions were made by Collinson, Scott and Rexroad (1962), Rexroad and Collison (1963), and Thompson (1966). Martin and Wells (1966) described two stratigraphic sections in St. Louis County and Spreng (1970) made unpublished descriptions of stratigraphic sections along the Mississippi River bluff in Calhoun County, Illinois one of which is included in this report.

E. Method and Procedure

The study of the St. Louis Limestone was suggested to this writer by Dr. A. C. Spreng, who accompanied him to the area in June 1969 to make a general examination of the formation, to determine the location, to point out the lithology and stratigraphy, and to discuss the upper and lower boundaries. The first visit was made to the Missouri Portland Cement quarry followed by the Vigus North quarries. In September 1969, the exposures along the Mississippi River bluff in Calhoun County in Illinois was studied and one of the two cores supplied by the Missouri Portland Cement Company was studied too.

The study made included field descriptions, sampling the outcrop for laboratory work, and detailed laboratory work covering megascopic and microscopic study as well as insoluble residue analyses.

The location of the stratigraphic sections studied is shown in the topographic location map, Figure 1, and listed in Table 1 as previously indicated. In order to save space, the different sections of this report are referred to in the text as follows:

Stratigraphic Section	Letter Symbol
Missouri Portland Cement quarry section	A
Vigus North quarries	B
Mississippi River bluff	C
Cores of drill hole number 5	D

The sample designation and also the thin section slide numbers used in the field and throughout the laboratory study were as follows:

Stratigraphic section A: The different lithologic units were given serial numbers from 0 to 26 and the samples were given alphabetic letters A, B, ... The designation was the unit number followed by the letter separated by a hyphen, e.g., 13-B means that this sample is from unit 13 and it is the second of that unit.

Stratigraphic section B: The units and samples of each unit are given numerical figures separated by a hyphen, except for the lower part. There the samples were designated by letters as this part is transitional from Salem to St. Louis.

Stratigraphic section C: This section was not sampled in the same details as the ones before because it is very close to drill hole number 5 (section D), so it is taken here as one unit during sampling and the different samples were given serial numbers, e.g., sample designated as 1-8 means that it is the eighth sample from section C.

Stratigraphic section D: The numbering of the units follows that used by the Missouri Portland Cement Company and the units are given numbers from the upper to lower part in the order the cores were taken out of the hole. The samples are numbered in numerical figures and the unit number is put above the sample number separated by a line, e.g., 30/3 means that this sample is the third of unit number 30.

This designation technique is used to avoid mixing of samples and also to refer easily to the stratigraphic section and the location of the sample in that section. The number of samples taken of each stratigraphic section are given in the following table:

Section	Number of Samples
A	51
B	91
C	19
D	55

A thin section slide was made of each sample, making a total number of 216 slides. All the thin sections were cut normal to the bedding planes of the formation and an arrow was drawn on each slide pointing to the top of the formation. Insoluble residue analyses for every sample was made using an amount of rock ranging in weight from 6 to 11 grams. The sample was dissolved in dilute HCl acid of about 10 percent concentration. Moderate heating was needed to decrease the dissolution time of dolomite.

Thin section slides were studied under the petrographic microscope while the insoluble residues were examined under the binocular microscope. Not all the thin sections made will be discussed here because some of them are similar to others in the same unit, whereas others carry no features of interest, especially in the dolomitic units. The slides studied here are summarized in Table 3. A total of 100 thin sections are shown in that table. It may be added that during sampling it was intended for the samples to be representative of the stratigraphic interval considered.

CHAPTER II

STRATIGRAPHY

A. Introduction

The St. Louis Limestone belongs to the Meramecian Series of the Mississippian System. It overlies the Salem Limestone and is overlain by the Ste. Genevieve Limestone. The name St. Louis was given by Englemann (1947). Apparently, according to Englemann early description of the formation, he included all the stratigraphic interval between the Warsaw below and the Aux Vases Formation above. Shumard (1860) split the upper part of the limestone and gave it the name "Ste. Genevieve Limestone". The remainder continued to be known as the St. Louis Limestone until Ulrich (1905) restricted it to include only the rocks above the newly named Salem and below the Ste. Genevieve Limestone.

It may be suitable to review here some aspects of the Mississippian System and Meramecian Series before dealing with the detailed discussion of the St. Louis Limestone. This discussion will continue to cover the remainder of this section and the following sections of this report.

1. Mississippian System

Most of the information mentioned here is summarized from the "Correlation of Mississippian Formations of North America" (J. M. Weller, Chairman, 1948).

The Mississippian as a name is derived from rocks in the Mississippi Valley where it was typically developed. The name was used before 1906 for rocks of Lower Carboniferous age. Chamberlin and Salisbury in 1906 formally recognized the Mississippian as a System and since then the name was widely used in North America to designate rocks above the Devonian and below the Pennsylvanian systems.

Worthen (1866) was the first to subdivide the Mississippian into four groups in Illinois. They are (from the base upward): the Kinderhook group, the Keokuk group which overlies Burlington Limestone, the St. Louis group, and the Chester group. After his subdivisions were published, the stratigraphic units, formations and groups were used interchangeably. Table 2 shows the development in classification of the Mississippian in the type area. As can be seen from that table, the Mississippian System is divided into four series with further subdivisions of two of them into subordinate groups. They are from below: Kinderhookian Series consisting of the Fabius Group overlain by the Easley Group, the Osagean Series, the Meramecian Series, and the Chesterian Series at the top consisting of the Hamburg and Elvira groups in stratigraphic order.

Stuart Weller et al. (1920) divided the Mississippian into: Lower and Upper, where the Kinderhookian, Osagean and Meramecian Series are included in his Lower Mississippian. J. M. Weller (1952) replaced the Lower and Upper divisions of S. Weller by the Iowa and Chester series. J. M. Weller and A. H. Sutton (in Moore, 1933) proposed Valmeyer as a series name to include the Osagean and Meramecian Series. This was accepted by Swann (1963) who modified the term to Valmeyeran to conform with current usage. The Lower (Kinderhookian) and Upper (Chesterian) remained the same.

2. Meramecian Series

The Meramecian Series includes all rocks above the Osagean Series and below the Chesterian Series. The name was first applied by Ulrich (1903) to the type of rocks along the Meramec River in eastern Missouri. Later the Meramec was used as a group name. The different formations included in the Meramecian Series in ascending order are: Warsaw, Salem, St. Louis

Standard Section	Worthen 1866	Shumard 1873	Broadhead 1874	Williams 1891	Keyes 1892	Keyes 1893	Weller 1898	Ulrich 1905		Weller 1907	Ulrich 1911		Weller 1914	Weller 1920		Cumings 1922		Moore 1928	Moore 1933		Moore 1937	Branson 1938–44	Weller & Sutton 1940		Weller (1948)	
Kinkaid ls.																										
Degonia ss.																										
Clore fm.																										
Palestine ss.																										
Menard ls.															Upper		Upper							Elvira group		Elvira group
Waltersburg ss.																										
Vienna ls.																										
Tar Springs ss.	Chester group		Chester group																							
Glen Dean ls.					Kaskaskio group	Kaskaskio group			Chester group	Chester group		Chester group	Chester group	Chester series		Chesterian		Chester group		Chester series	Chester series	Upper Mississippian	Chester series		Chesterian series	
Hardinsburg ss.		Archimedes group		Genevieve group			Ste. Genevieve group				Tennessean series				Middle		Stephensport							Homberg group		Homberg group
Golconda fm.																										
Cypress ss.								Tennessean series																		
Paint Creek fm.																										
Bethel ss.																										
Renault ls.															Lower		West Baden							New Design group		New Design group
Aux Vases ss.																										
Ste. Genevieve ls.													Ste. Gen. gr.					Ste. Gen. gr.								
St. Louis ls.	St. Louis group		St. Louis group			St. Louis group				Meramec group			Meramec group		Meramec group		Meramecian	Meramec group		Meramec group	Meramec group			Meramec group		Meramecian series
Salem ls.									Meramec group			Meramec group										Middle Mississippian				
Warsaw ls.																										
Keokuk ls.	Keokuk gr.	Encrinital ls.	Keokuk group	Osage group	Osage group	Augusta group	Osage group		Osage group	Osage group			Osage group		Osage group		Osagian		Valmeyer series							
Burlington ls.	Burlington ls.											Osage group						Osage group		Osage group			Valmeyer series	Osage group		Osagean series
Fern Glen fm.														Iowa series												
Gilmore City ls.																					Waverly series					
Sedalia ls.	Kinderhook group	Chemung group						Waverlyon series		Kinderhook group			Kinderhook group		Kinderhook group							Lower Mississippian				Easley group
Chouteau ls.			Chouteau group	Chouteau group	Kinderhook group	Kinderhook group	Kinderhook group		Kinderhook group		Waverlyon series						Kinderhookian									
Hannibal sh.																									Kinderhookian ser.	
Louisiana ls.												Kinderhook group						Kinderhook group		Kinderhook series				Kinderhook series		
Saverton sh.																										Fabius group
Grassy Creek sh.																										

Table 2. Development of nomenclature of Mississippian names. After J. M. Weller (1948).

and Ste. Genevieve. As mentioned before, the Valmeyeran Series (Swann, 1963) is equivalent to the Meramecian and the underlying Osagean Series of the standard section. In this report, Meramecian is used as a series including the Ste. Genevieve Limestone at the top (See Figure 2).

The contact of the Meramecian with the overlying Chesterian has been put by many geologists at the top of the Ste. Genevieve. There is some disagreement on that especially in western Kentucky where "certain fauna led Ulrich to refer the Ste. Genevieve to the Chesterian" (J. M. Weller, *et al.*, 1948, p. 99). The lower boundary of the Meramecian with the Osagean is much more controversial. Whether there has been a faunal change from Keokuk to the overlying Warsaw or not is not agreed upon. The United States Geological Survey classes the Warsaw as Meramecian and so does the Missouri Geological Survey, whereas the geological surveys of Indiana, Iowa and Illinois classify the Warsaw with the Osagean. Here the lower boundary of Meramecian is taken to include the Warsaw Formation.

B. St. Louis Limestone

The characteristics of the St. Louis Limestone as described by Englemann (1847) are briefly as follows: very hard, light yellowish or grayish, mostly pure limestone, mixed with sand or including irregular siliceous masses in some beds, fine-grained (lithographic) to coarse or even completely crystalline. As pointed out previously, his description included the stratigraphic interval between the Warsaw and Aux Vases and hence is not particularly appropriate here.

The St. Louis Limestone as used here, is the limestone overlying the Salem Limestone and overlain by the Ste. Genevieve Limestone as previously stated. The formation is widespread, extending from Kentucky in the south to Iowa in the north and from Illinois in the east to Kansas and

System	Series	Formation	Thickness	Dominant lithology
PENNSYLVANIAN	Atokan	Cheltenham	0-30	Clay (refractory)
MISSISSIPPIAN	Meramecian	Ste. Genevieve	0-50	Limestone, sandy, oolitic.
		St. Louis	200±	Limestone, litho-graphic, brecciated
		Salem (Spergen)	100-175	Limestone, dolomite cherty.
		Warsaw	70	Shale, limestone, cherty.
	Osagean	Keokuk	200±	Limestone, cherty.
		Burlington	200±	Limestone, cherty.
		Fern Glen	0-6	Limestone, cherty, shaly.
	Kinderhookian	Chouteau	5-80	Limestone, dolomite argillaceous.

Fig. 2. Portion of general stratigraphic column, St. Louis and St. Charles Counties, Missouri, modified from J. A. Martin and J. S. Wells, 1966.

Oklahoma in the west. The time equivalent of the St. Louis in the east is the Hilldale Limestone which is present in Virginia and West Virginia.

This paper is concerned only with the description and study of the four stratigraphic sections as mentioned in the previous chapter. No further extension of the study was made beyond this area which is the type area of the St. Louis Limestone.

In the remainder of this chapter, the detailed descriptions of the measured stratigraphic sections will be presented followed by a review of the boundary problems, namely, the lower Salem-St. Louis contact and the upper St. Louis-Ste. Genevieve contact. It might be mentioned here that the boundary problems may need more attention especially the St. Louis-Ste. Genevieve contact.

C. Detailed Description of the Stratigraphic Sections

The rest of this chapter is devoted to the detailed study and descriptions of the four stratigraphic sections, followed by a review of the lower and upper contacts of the formation. The symbols used in the description as well as the abbreviated terms are clarified in the following pages before the descriptions are given. For each stratigraphic section, a small introduction will be made concerning the location and some general information about that section.

1. Stratigraphic section A: Missouri Portland Cement quarry, Fort Bellefontaine, St. Louis County: This quarry is known as "Fort Bellefontaine quarry", it is located to the north of the City of St. Louis in the NW¼, NE¼, NW¼, sec. 9, T. 47 N., R. 7 E. (projected), Columbia Bottoms Quandrangle, St. Louis County, Missouri (See Figure 3).

The quarry is operated in two faces. The upper face is about 55 feet thick and is mostly free of dolomite, but it is sandy in its uppermost part. The lower is about 70 feet thick and contains relatively high MgO ratio especially in the dolmite units (See unit number 8). The limestone in this quarry is used for cement manufacture.

The Salem-St. Louis contact is placed at the base of the lower brecciated and fragmented limestone, which is very distinctive. Below this is a dolomite unit which is not well exposed in this section. The brecciated unit (unit 0) is fine-grained (lithographic), and of typical St. Louis color. The St. Louis-Ste. Genevieve contact is hard to place for there seems to be a transitional zone from the St. Louis to the Ste. Genevieve. It is placed here at the upper surface of unit 24 on the basis of:

1. High percentage of silica mostly quartz of sand size.
2. Change from the typical St. Louis color of light gray to very light gray or yellowish-gray.
3. The change in texture, from fine-grained (lithographic, to medium or coarse grained and the presence of typical Ste. Genevieve oolites.

In this location, a persistent and good marker unit is a coral zone (Lithostratotion) (see unit 7 and Plate 4, Fig. 6 and Plate 9, Fig. 1). However, this unit has not been clearly identified in the other sections. The section contains more than one brecciated zone (units 0, 19 and 21). The breccia might serve as a good stratigraphic marker, but because of their variation both laterally and vertically, their use for correlation purposes is limited (see Fig. 4).

2. Stratigraphic section B: Vigus North quarries (Fred Weber, Contractor, Inc.): This quarry is located to the northwest of the City of St. Louis

in the NE¼, SW¼, sec. 9, T. 46 N., R. 5 E. (projected), Creve Coeur Quandrangle, St. Louis County, Missouri (see Figure 5).

The section measured here is in the south pit, which has a complete succession of strata from the Warsaw below through most of the St. Louis. This section presents an excellent opportunity for the study of the contacts because of the fresh rock surface.

Lithologically, the St. Louis Formation here is mostly dolomite and the rock is used mainly for road construction; the high MgO present would restrict its use for the cement industry or other uses which require less MgO. The Salem-St. Louis contact here is placed above the chert zone, (unit-3) because the rock above that unit is of typical St. Louis character. The chert in the underlying unit is considered to be at the top of the Salem Limestone, even though Fenneman (1911) pointed out that Salem is chert-free in this region.

The upper contact of the St. Louis with the Ste. Genevieve Formation is not present here and instead the formation is covered with loess (fine sand, silt, and clay). The section here contains some brecciated beds (units, -3, 6, 13, 14 and 17), but the breccia here is not similar to the commonly described breccia because the angular fragments are separated only by thin fractures and not clay or calcite.

Scattered green shale masses are included in unit 12 and the lower part of unit 11. In the lower part of unit 17 are some conspicuous oolite beds (1 to 1½ feet thick). Above unit 17, a 3 to 5 inch thick, persistent, pinkish to yellowish-red chert is present. A Lithostrotion zone about one foot thick is present in the upper part of unit 16 and lower part of unit 17. These characteristic units may help in correlating the different sections (see Fig. 6).

3. Stratigraphic section C; Mississippi River bluff section: This section is exposed along the Mississippi River bluff on the south side of Cap-au-Gres flexure located in NE¼, NW¼, sec. 32, T. 12 S., R. 2 W., south of Dogtown Hollow, Winfield Quandrangle, Calhoun County, Illinois (see Fig. 7).

This section is mostly described by Dr. A. C. Spreng and the material presented is modified after him. The lower St. Louis beds are steeply inclined at angles of 10 to 30 degrees dipping to the south, due to nearness to the Cap-au-Gres flexure. This presents the only natural outcrop of the St. Louis Limestone seen in the study area. Talus covers a large part of the section (about 39 feet). It is believed that the lithology of the covered part at least includes the dolomitic units (units 25 and 26) in nearby drill hole number 5. The only exposure present (about 1.7 feet thick) within the covered part is mostly oolitic. The stratigraphic position of this unit is questioned.

The Salem-St. Louis contact here is placed at the top of the cherty and locally sandy lens. This unit overlies a dolomite unit containing chert nodules and of nearly the same texture and color as in section A and B and also drill hole number 5. This lower unit of St. Louis Limestone is fractured and slightly brecciated.

The St. Louis-Ste. Genevieve contact is not encountered here. This section is the only section that shows noticeable ripple marks which occur about 41 feet above the base. More than one zone of lithostrotionoids are present here. There are about three zones below the ripple-marked bed and two zones close to the upper part of the section with more crinoidal fragments and stems which are associated with the upper part of the section.

Eleven and two tenths of 12 feet from the top, the section is a red chert bed which may be correlative with the cherts which occur in section B approximately at the same stratigraphic position. The part of the section just above the covered zone is mostly fractured and brecciated forming a prominent and irregular ledge about 7 to 8 feet thick.

The scattered green masses of shale which are present in section B, are not present here in this section; they may be associated with the talus covered part. The dominant texture of the section is fine-grained (lithographic to sublithographic), and the breccia is present in more than one location within the section (see Fig. 8).

4. Stratigraphic section D; drill hole no. 5: The section is located at NE¼, SE¼, sec. 5, T. 13 S., R. 2 W., Winfield 7½-minute Quandrangle, south of Dogtown Hollow, Calhoun County, Illinois (see Fig. 7).

The land is covered by soil and for the first 100 feet, the drill hole encountered soil, Recent deposits, Pennsylvania shale and the Ste. Genevieve Formation. The Salem-St. Louis contact is placed here at nearly the same stratigraphic position as in section C, i.e., including the crystalline quartz above the cherty dolomite beds (unit 37). The St. Louis-Ste. Genevieve contact is placed close to the top of unit 18 based on the change from the typical color of the St. Louis to a yellowish or white color, presence of sand-sized quartz grains, presence of typical Ste. Genevieve oolites, change in limestone texture from fine- and/or medium-grained to coarse-grained and finally the presence of a shaly, cherty zone about 3 to 5 inches thick (the chert particles are more likely to be conglomeratic or brecciated pebbles).

The section here contains some 12 feet of dolomite overlain by brecciated and lithographic beds (See units 25 and 26, Fig. 9). This thickness of dolomite is not present in the nearby section C, where it probably occurs in the talus-covered part. There are more than one lithostrotionoid zones in this section, also fragmented and brecciated beds as well as cherty zones are present here as shown in Figure 9.

D. Boundaries of the St. Louis Formation

The lower contact ofthe Salem with the St. Louis and the upper contact of the St. Louis with the Ste. Genevieve Formation are reviewed here. It is convenient to review the boundaries in the light of the definition as given in the "Code of Stratigraphic Nomenclature". In that code, it is mentioned on page 650, article 5, that:

> "Boundaries of rock-stratigraphic units (formation in our case), are placed at positions of lithologic changes. Boundaries are placed at sharp contacts, or may be fixed arbitrarily within zones of gradation. Both vertical and lateral boundaries are based on lithologic criteria that provide the greatest unity and practical utility."

There are no sharp lithologic changes from the Salem to the St. Louis or from the St. Louis to the Ste. Genevieve formations, so the first part of this article is not satisfied. This means that the boundaries could be fixed arbitrarily within a transitional zone. But to be consistent, there should be some kind of criteria to help find such a zone. The following criteria can be of some value in such a procedure of definition. It will be noticed that some of them have actually been applied in the previous part of this section. The criteria are as follows:

1. Change of color between the formations. (Applied mostly at the upper contact.)
2. Occurrence of brecciated zones. (Especially at the base of the St. Louis Limestone.)
3. Change in texture of limestone at the contact between the St. Louis and Ste. Genevieve.

4. Occurrence and kind of fossils.

5. Occurrence of chert nodules (At the base of the St. Louis Limestone).

6. Change in type of silia from euhedral quartz at the base to sandy grains of quartz with appreciable increase in percentage of quartz near the top of the St. Louis Limestone.

7. Occurrence of interruption or disconformities or any discontinuity of deposition. (Not applicable here)

8. Presence of typical Ste. Genevieve oolites in the upper part.

As many of these criteria as possible have been used in placing the boundaries, and are reviewed here.

1. Salem-St. Louis Contact

S. Weller (1908) mentioned that the contact can be distinguished by either lithologic or faunal characters. The Salem is frequently oolitic having beds of light color, nearly white, which have a peculiar method of weathering. On the other hand, the St. Louis Limestone is dense, bluish-gray with conchoidal fracture and usually lithographic. Moreover, the Salem Limestone does not have any brecciated rocks which are so characteristic of the St. Louis Limestone. He also reported that the Salem Limestone is usually more fossiliferous than the St. Louis, and he added that there is no evidence of any sedimentation break between the Salem and St. Louis limestones.

Grohskopf and McCracken (1949), according to their study of insoluble residue of subsurface cuttings, put the Salem-St. Louis contact at an increase of 50 percent residue mostly of gray speckled chert. They also mentioned that the residue of the lower part of the St. Louis is mostly euhedral quartz crystals. This lower part of the section corresponds to the cherty zone located at the base of the formation. A. C. Spreng (1961) has placed the contact at the base of the main brecciated limestone of St. Louis. Baxter (1965) mentioned that "the location of the actual contact is arbitrary due to continuous deposition without interruption from Salem to St. Louis". But in another locality, in Randolph and southern St. Clair County in Illinois, he placed the contact at the top of the foraminiferal-oolitic beds, which is stratigraphically higher than defined by S. Weller (1908).

From the descriptions of the stratigraphy presented before, it is seen that the contact in three of them (sections A, B, and C) has been placed at the base of the lower brecciated beds and also below this brecciated zone a chert zone has been found in sections B, C, and D. It is located in sections C and D at about 3 to 5 feet below the base of the brecciated beds and in section B the contact was also above the chert zone which is within dolomite rocks.

2. St. Louis-Ste. Genevieve Contact

The Ste. Genevieve is generally crystalline, sandy, oolitic, cross-bedded limestone. The common rock type is medium crystalline limestone with crinoid stems and fragments, oolites, brachiopod shells and bryozoans. The contact of the St. Louis with the Ste. Genevieve was observed only in two locations, section A and drill hole number 5. Because of this fact, it is hard to arrive at a certain conclusion about the nature of the contact from the measured sections only.

Grohskoph and McCracken (1949, p. 18) mentioned three factors in placement of the St. Louis-Ste. Genevieve contact. These are:

1. Appearance of typical lithographic limestone in the St. Louis Limestone.

2. Appearance of white to gray chert in the St. Louis Limestone.

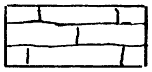
3. Occurrence of beds of dolomite in the St. Louis Limestone.

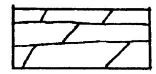
This is a rather wide range of defining the contact. N. Short (1962) placed the contact at a thin limestone conglomerate bed which is overlain by a zone of algal pellets.

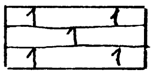
It seems that a break in sedimentation between the St. Louis and the Ste. Genevieve is not present here and the top of the St. Louis is placed, as pointed out in the description of the stratigraphic sections, at the appearance of typical Ste. Genevieve oolites with a spar matrix. Also, the presence of sandy beds, and the absence of the lithographic and brecciated limestone is significant.

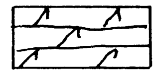
Explanation of the symbols and abbreviations used in the description of the stratigraphic columns:

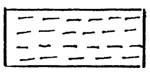
1 - Legend:

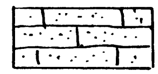
 Limestone

 Dolomite

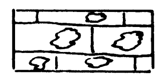
 Dolomitic limestone

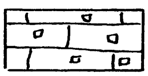
 Calcareous dolomite

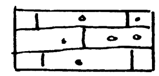
 Shale

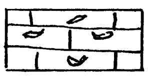
 Sandy limestone

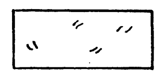
 Chert nodules

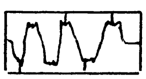
 Brecciated limestone

 Crystalline calcite

 Oolitic limestone

 Fossiliferous limestone

 Scattered shale spots

 Stylolite

2 - The following abbreviations are used in the description:

Argil: argillaceous
brn: brown or brownish
cal: calcareous
dk: dark
f: fine
gns: grains
lgt: light
ls: limestone
med: medium
qtz: quartz
sh: shale
sty: stylolite or stylolitic
wh: white
xln: crystalline
yell: yellow or yellowish

blk: black
c: coarse
cht: chert or cherty
dol: dolomite
gnd: grained
gy: gray
lithog: lithographic
lwr: lower
prt: part
s: sand or sandy
sl: slightly
v: very
w'rd: weathered
xls: crystals

The thicknesses are given in feet and tenths of feet. The unit number is given at the upper edge of the graphic representation of the unit and the vertical scale is one inch representing five feet.

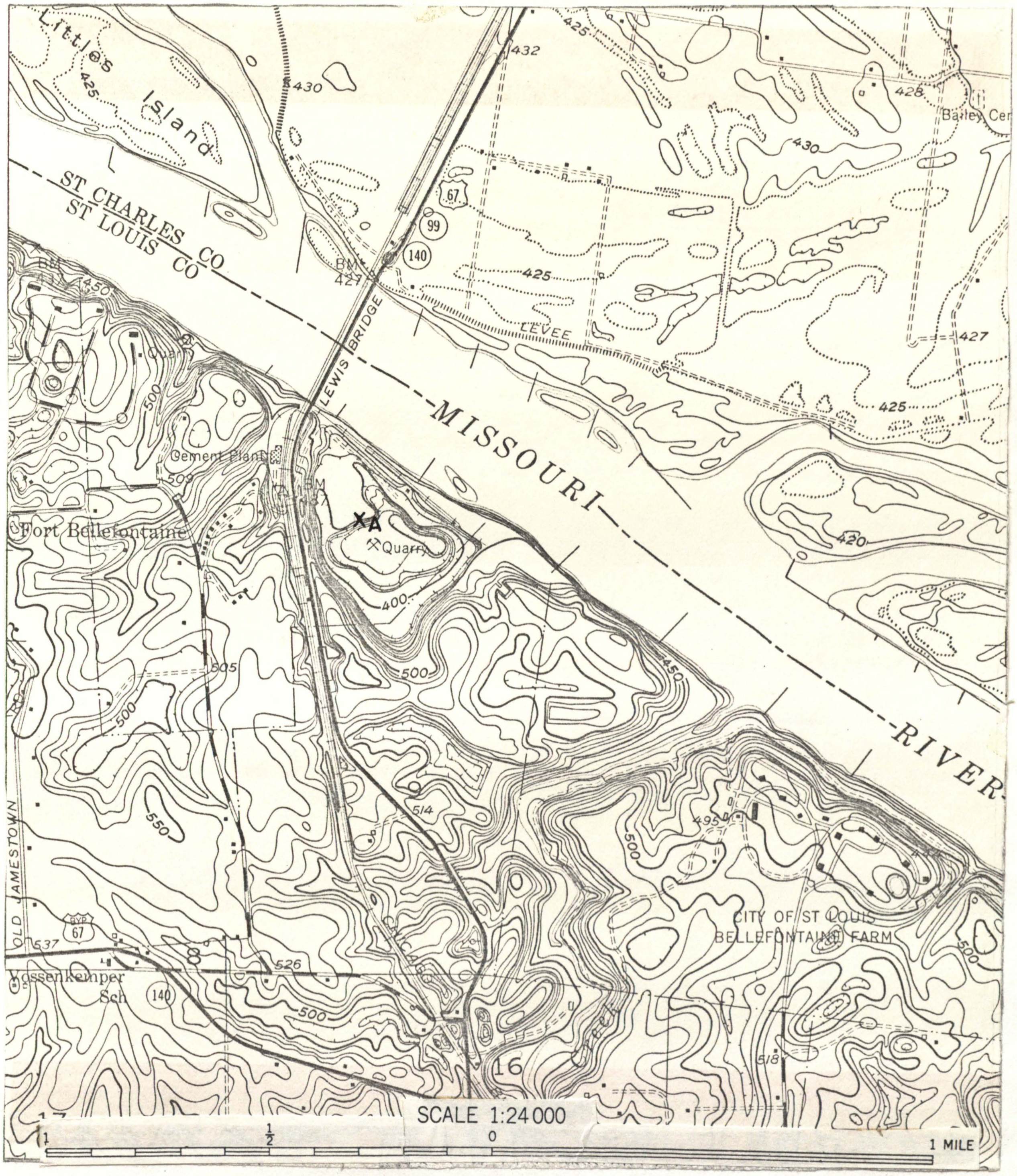
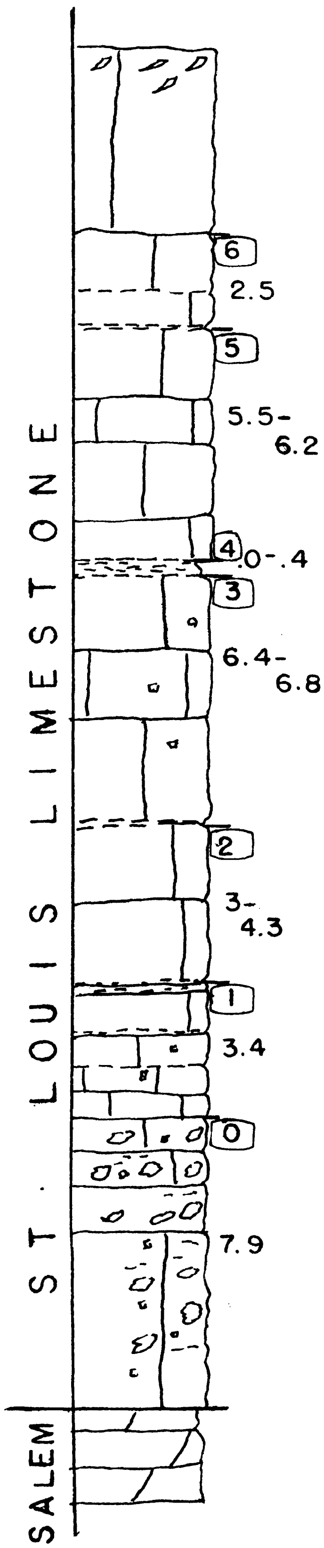


Fig. 3. Location of Missouri Portland Cement quarry at Fort Bellefontaine, Columbia Bottoms Quadrangle, St. Louis, County, Missouri. (U.S. Geological Survey, 1951).

PLATE 1

Fig. 1. Missouri Portland Cement Quarry at Fort Bellefontaine. The photo shows the upper face. The cross-bedded limestone to the upper left is the Ste. Genevieve Limestone.

Fig. 2. Missouri Portland Cement Quarry at Fort Bellefontaine. The photo shows the lower face. The topmost beds are the top of unit 13 in Figure 4.



Ls, lgt blue gy;f-gnd;argil,w/cal sh partings, med-sized productids at top.

Ls, as unit (3) w/sty bands in middle and persistent near the top, also calcite xls in thin plates.

Sh, gy-gn.
Ls, as below;v lgt gy; contains ls masses surrounded by sh; med to c-gnd w/calcite xls.

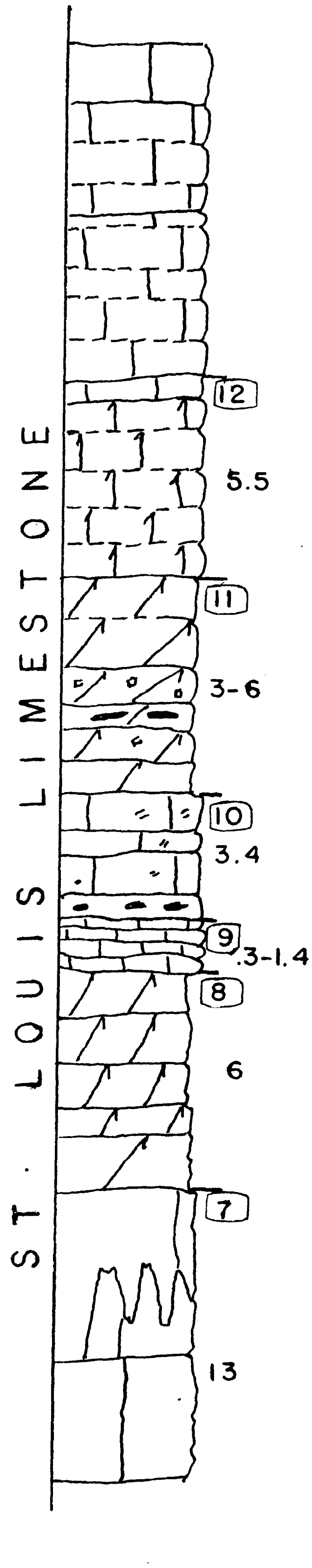
Sh.
Ls,v lgt to lgt olive gy, med to c-gnd w/calcite; thick to massive w/lgt gy buff sh parting at top.

Sh.
Ls, lgt gy to lgt olive gy; lithog w/some calcite xls;med-bedded (10-20 inches); thick; w/gn sh up to 0.5 inch parting

Ls, brecciated; lgt gy to lgt olive gy; f-to med gnd; a few scattered calcite xls; breccia ranges from 0.05 to 1.5 inch in size usually w/gn sh between fragments; massive to thick-bedded; gn sh at top of unit; v fossiliferous-productids and bryozoans.

Dol, lgt brn-gy;f-gnd; med bedded; exposed in sumps and drains. This unit is exposed in lwr face of Westlake Quarry, ½ mile west.

Fig. 4. Stratigraphic section of Missouri Portland Cement Quarry at Fort Bellefontaine



Ls, buff; lithog;med-bedded; thin gn sh partings.

Ls, dol; alternating dull smoky-gy and dull dk-gy; med-bedded, dker layers are dolomitic; thin gn sh parting.

Dol, smoky-gy to wax-dull and yell-gy;med-gnd; med-bedded; contains calcite veinlets, w'rd prt sl cal; locally contains dk brn nodular cht layers ½ inch thick;light brn sh at top and bottom; v sl. cal.

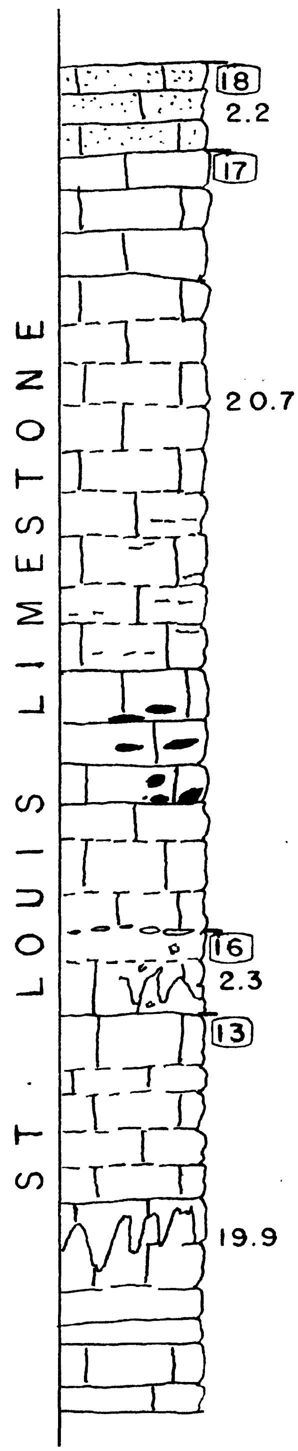
Ls, lgt olive-gy; (calcarenite);blk dk-gy cht nodules above base w/ferruginous matter; dk streaks at top w/gn scattered sh spots and calcite veinlets.

Ls, lgt olive-gy;lithog; irregular at base; thin-bedded.

Dol, dull smoky-gy (fresh), yell-gy w'rd surface;med gnd grades into lithog ls; dolomitic prt has slickensides; whole unit alters to ls except lwr one ft; sl cal.

Ls, lgt olive gy; f-gnd at base w/spar blocks; med-gnd (calcariet) in upper 3 ft; massively-bedded, persistent coral zone (<u>Lithostrotion</u> about 5 ft. above base; sty in upper prt.

Fig. 4. (continued)



Ls, lgt gy;med-gnd (calcarenite)w/spar cement; one bed; med to f-gnd qtz sand and pyrite grains are present.

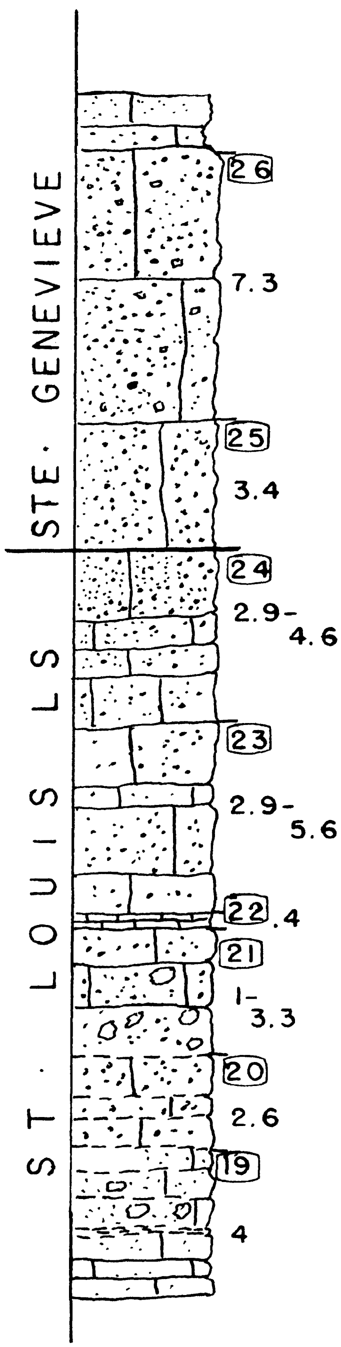
Ls, yell-gy to lgt olive gy; lithog;med-bedded (several, up to 6 beds) to thin (less than one inch thick);blk irregular nodular cht layers in lwr prt; several gn-gy sh partings are present.

Ls, v lgt gy to yell and/or olive gy;f-gnd (lithog),w/calcite veinlets and/or v thin sh parting;sty; med-bedded.

Ls, as below; contains large productids;w/gn sh partings.

Ls, lgt gy;med-gnd;med-bedded w/lgt gy sh parting;one bed has conspicuous sty; calcarenite w/spar cement.

Fig. 4. (continued)



Ls, yell-gy;med to c-gnd;fossil debris;w/sparry cement; massive; some fragments have calcite coating; high insoluble percentage.

Ls, yell-gy; lithog matrix,med to c qtz sand grains;massive; up to 30% insoluble residue.

Ls, gy to lgt olive gy;c-gnd due to spar replaced fossil debris;lithog matrix; 45% insoluble residue of sand size qtz grains; fossiliferous: small <u>Composita</u> and <u>S. pellaensis</u>.

Ls, yell-gy;sl w'rd;oolitic;spar cement w/pyrite grains;med- to thick-bedded.

Ls, buff; med-gnd;argil;sl sandy; thin-bedded.

Ls, lgt gy; lithog;brecciated' med-bedded; oolitic and fossiliferous.

Ls, lgt gy, pyritic, laminated, uneven partings; angular frosted qtz; small pyrite xls, w/some clay inclusion;oolitic and fossiliferous.

Ls, yell-gy matrix w/med-gy breccia fragments; f-gnd (sublithog) in lwr prt; one bed has breccia fragments; thin to med-bedded.

Fig. 4. (continued)

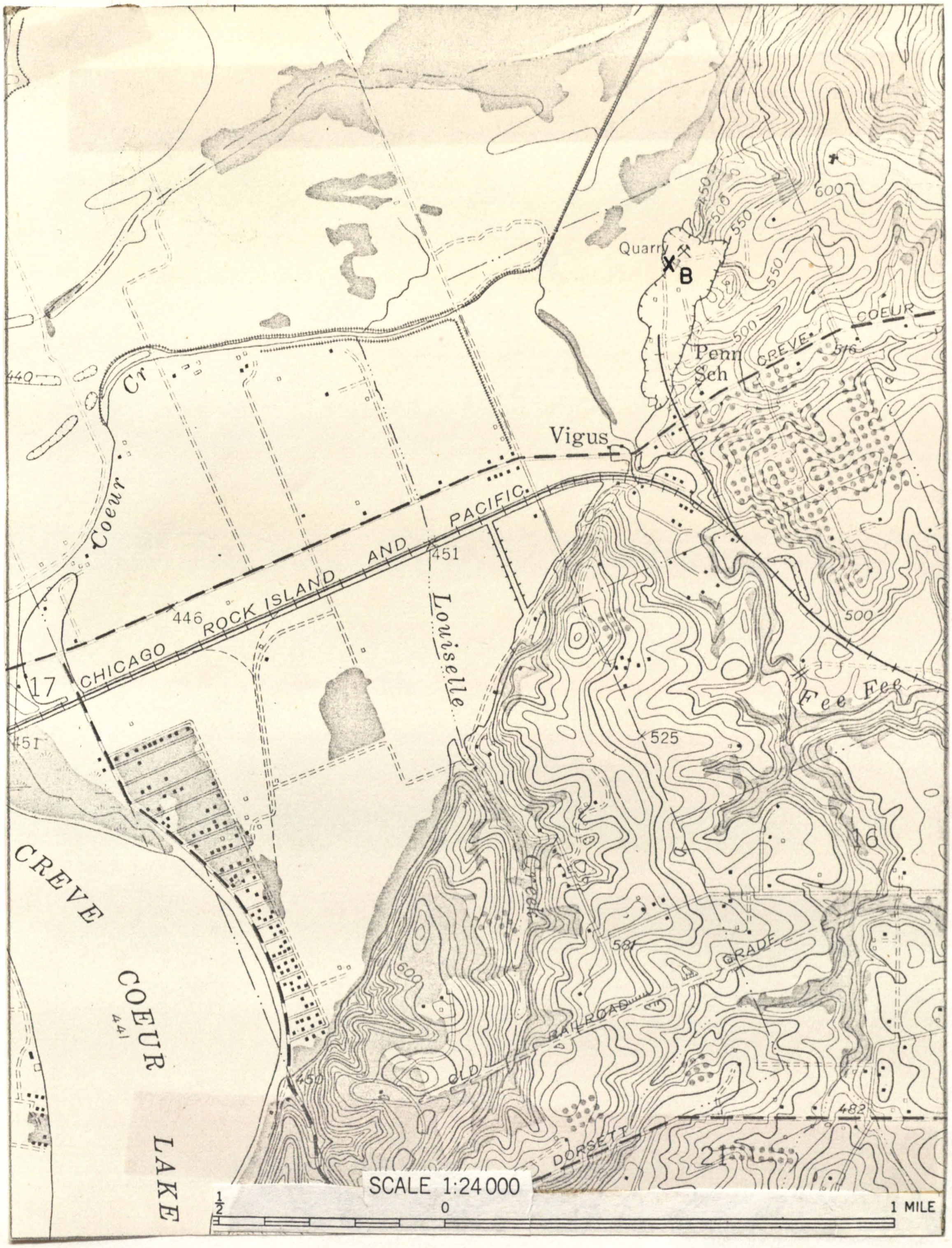
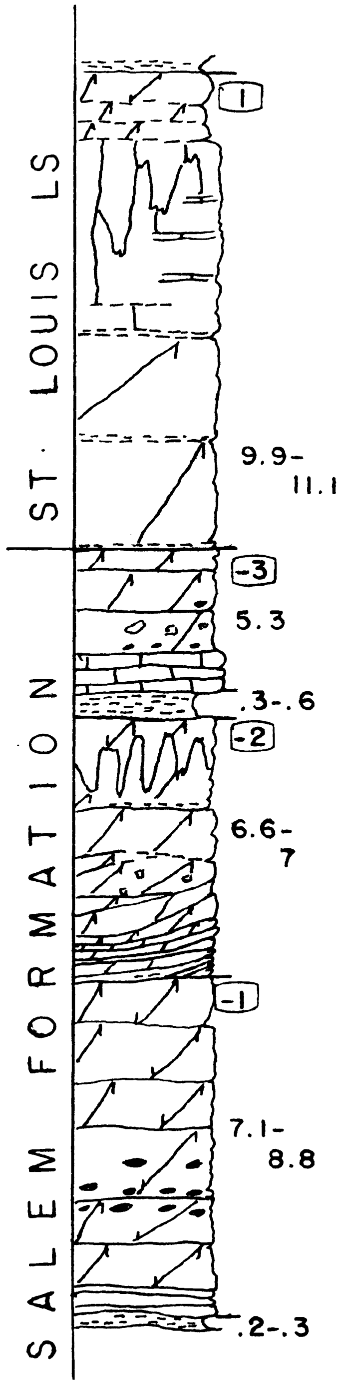


Fig. 5. Location of Vigus North quarry, Fred Webber, Contractor, Inc., Creve Coeur Quadrangle, St. Louis County, Missouri.

PLATE 2

Vigus North Quarry (south pit)



Sh, w/thin laminae.
Dol, cal;v lgt to pinkish-gy w/thin gy-sh streaks; f- to med-gnd;thin-bedded; color changes laterally;sh partings.
Ls, dol; v lgt gy w/brn or blk streaks of yell w'rd sh; med to c-gnd;massive w/several v thin laminations;sty at top, blk or dk-gy sh partings.

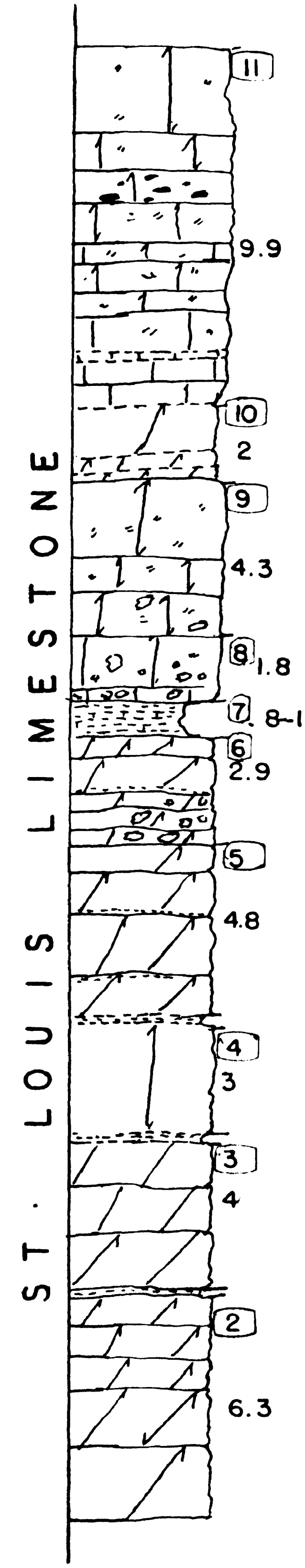
Sh, v thin streak.
Dol, sl cal; lgt gy to lgy olive-gy or sl brn; f- to med-gnd; thick-bedded w/some thick sh partings.

Sh, gn.
Dol, v sl cal; lgt gy to sl brn at base; med gnd at top, f- or med-gnd at base; sl brecciated at base;some cht nodules along bedding planes.
Ls, lgt-gy;f- to med-gnd; thin-bedded.
Sh, sl gn to gy.
Dol, sl cal; lgt gy to sl-brn below;med-gnd; thin to laminated and undulating in lwr prt, thick to massive above; vugs and large calcite xls in lwr prt; sl cross-bedded and argil partings;sty.

Sh, yel-w'rd; v thin-bedded to fissile.
Dol, v sl cal; v pale orange or bluish to lgt-gy; med to sl c-gnd; cht nodules concentrically banded, spherical to elongated 3-4" long to 2-3" wide;med to sl massive-bedded w/some lamination at base.

Sh, dk-gn to blk; undulating; fissile to plty bedded.

Fig. 6. Stratigraphic section of Vigus North Quarry



Ls, sl dol; lgt gy; f- to med-gnd; med-to thick-bedded.

As below, but more of gn sh spots, cht nodules of wh color and calcite xls.

Ls, dol; lgt gy; f- to med-gnd; thin-to med-bedded; sh on bedding planes w'rd to wh or yell in color; abundant scattered gn spots of sh.

Dol, sl cal; lgt gy to lgt olive gy; f- to med-gnd thin to med-bedded; several sh partings.

Ls, sl dol; lgt gy to lgt olive gy; sl mottled; occasional sh streaks and scattered gn sh spots; med to f-gnd; med-to-thick bedded; sl brecciated.

Ls, sl dol; lgt gy; f- to med-gnd (sublithog), thin to med bedded w/some laminations; sl brecciated; fractures filled w/calcite xls.

Sh, bluish gy; fissile or laminated.

Dol, sl cal; lgt gy to lgt olive gy; f- to med-gnd sl laminated; brecciated at base; med-to thin-bedded; sh partings; vugs and fractures filled w/calcite xls.

Dol, cal; v lgt gy at base; f-gnd (sublithog); med to thick-bedded w/intercalated sh.

Sh.

Ls, sl dol; lgt gy to lgt olive gy; or yell gy med-to f-gnd; thick bedded.

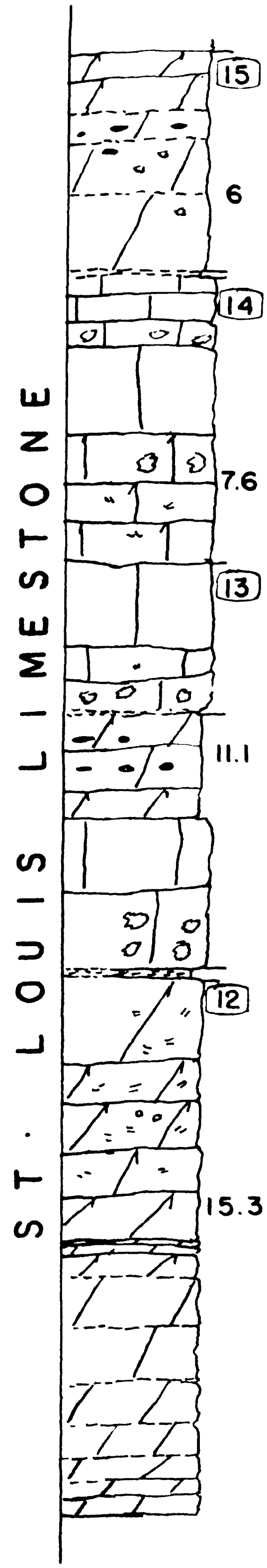
Sh.

Dol, v lgt gy to lgt yell lgt olive or brn lgt gy and v lgt gy color occur in parallel banding; f-gnd (sublithog) at base to med-gnd above; thick-to-med bedded; laminated.

Sh, dk gy; fissile; w'rd.

Dol, cal; lgt to lgt olive gy; med-to c-gnd; thick-bedded at base to med bedded above.

Fig. 6. (continued)



Dol, w/cht; lgt to med gy and lgt olive gy, dker color mostly in upper and lwr prts, lgt color in between; f- to med-gnd, thick-bedded below to med-bedded in upper prt;intercalated sh, pores and vugs occur in dker prts; calcite xls.

Sh.

Ls, lgt gy to lgt olive gy; v sl brecciated;f- to med-gnd;thick-bedded in lwr prt to med bedded in upper prt.

Ls, sl dol,lgt gy to lgt olive gy;f- to med-gnd (lithog);partly brecciated; med-bedded; few scattered gn spots of sh.

Ls, lgt gy to lgt olive gy;pinkish gy in places; f-gnd (lithog) in upper prt; med bedded below to massive above; more shaly and brecciated in lwr prt.

Ls below; dol in upper prt, ls is brecciated; cht nodules in upper prt; lgt to med gy and lgt olive gy w/spotted and/or mottled pattern in upper prt;ls is f-gnd; dol med to c-gnd massive to thick bedded in lwr prt, med-bedded in upper prt; sh partings on bedding planes.

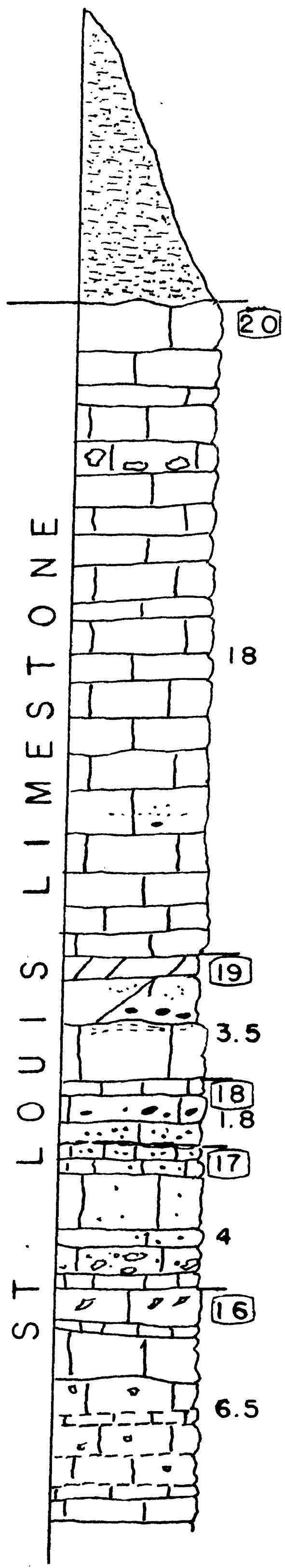
Sh.

Dol, sl cal w/calcite xls and intercalated sh w/small pyrite grains;v lgt, lgt to dk-gy and lgt olive gy w/pores or vugs, dk gy at top, lgt color below;f- to c-gnd, sh partings, med-bedded; scattered gn sh spots.

Dol, sl cal; v lgt to lgt gy, partly w'rd to wh or yell;med-gnd; med bedded w/lamination; thin bedded in places; sh partings.

Dol, lgt to med gy, yell or olive gy; med-gnd w/pores or vugs in middle prt; lwr prt is thin-bedded,upper prt is thick and w/sh on bedding planes.

Fig. 6. (continued)



Loess

Ls, v lgt gy med to f-gnd (sublithog); xln, med- to thick-bedded; fossiliferous.

Ls, sl chty, sl brecciated; lgt gy w/yell spots; f- to sl c-gnd; med-bedded.

Ls, v lgt gy; f-gnd grading to lithog; med-bedded.

Ls, lgt gy; f-gnd (lithog); med-bedded (6"-8" bed thickness); v sl sandy.

Dol in 1-1.5 ft. above, ls in lwr prt w/cht and sand grains; lgt gy to med lgt gy and lgt olive gy; med- to c-gnd; thick-bedded.

Ls, w/some cht nodules; lgt gy to lgt olive gy w/local occurrences of gyish-orange color; f-gnd (lithog) above; med-gnd and oolitic in lwr prt; med-bedded.

Ls, sl dol; lgt gy to lgt olive gy; med to c-gnd; thin- to med-bedded below, thick-bedded in middle to med-bedded above; sl brecciated especially in lwr prt, thin cht bed 2"-4" thick of red to pinkish color above; oolitic below.

Ls, sl dol; lgt gy to olive gy; med- to c-gnd thin- to med-bedded w/occasional calcite xls; sh partings on bedding planes 1"-2" thick; sh w'rd to lgt-yell or brn-gn-gy color. Lithostrotion zone close to top.

Fig. 6. (continued)

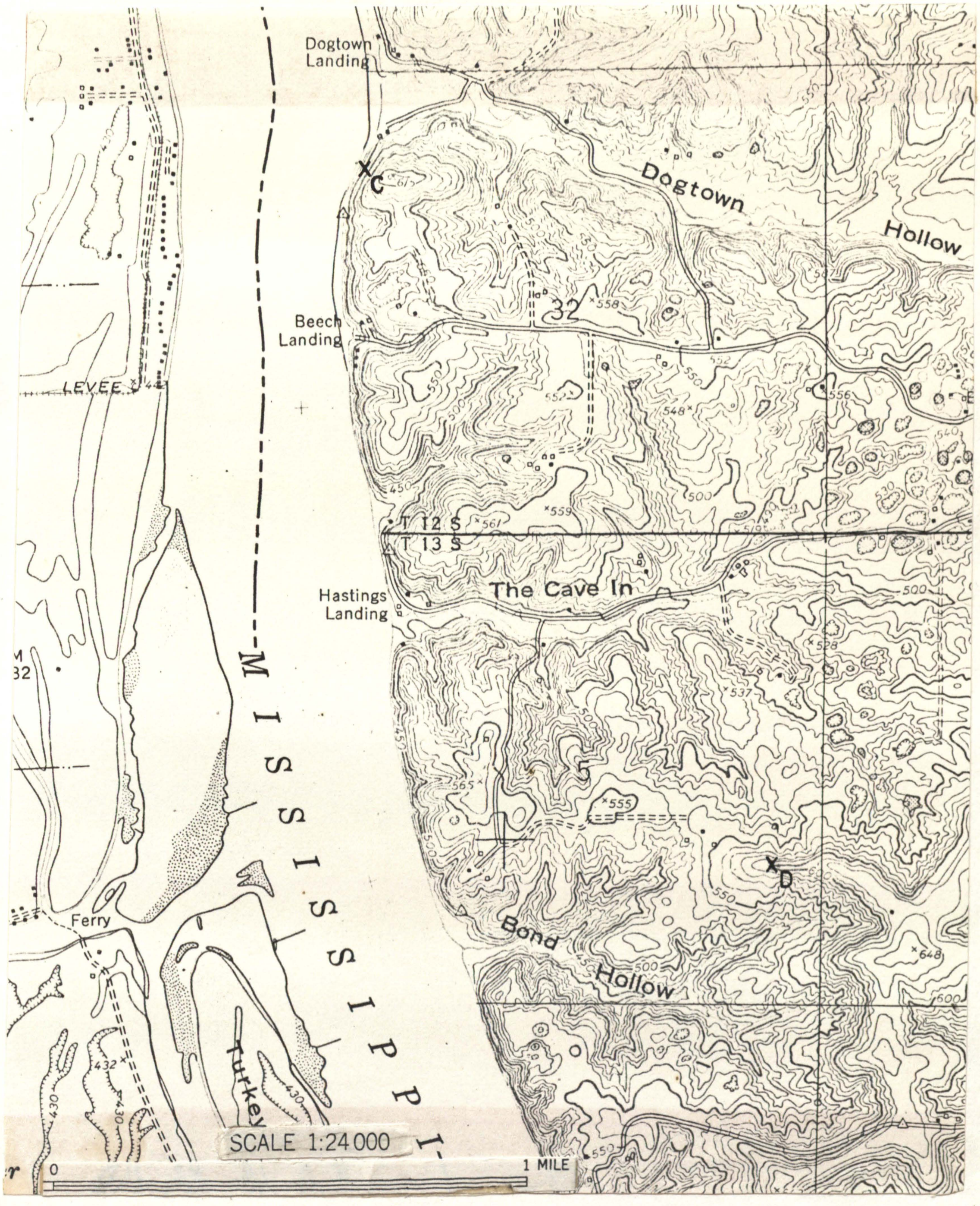


Fig. 7. Location map of the Mississippi River bluff stratigraphic section and location of drill hole number 5.

PLATE 3

Mississippi River bluff section. The photo is taken from the other side of the river at about 1.5 miles.

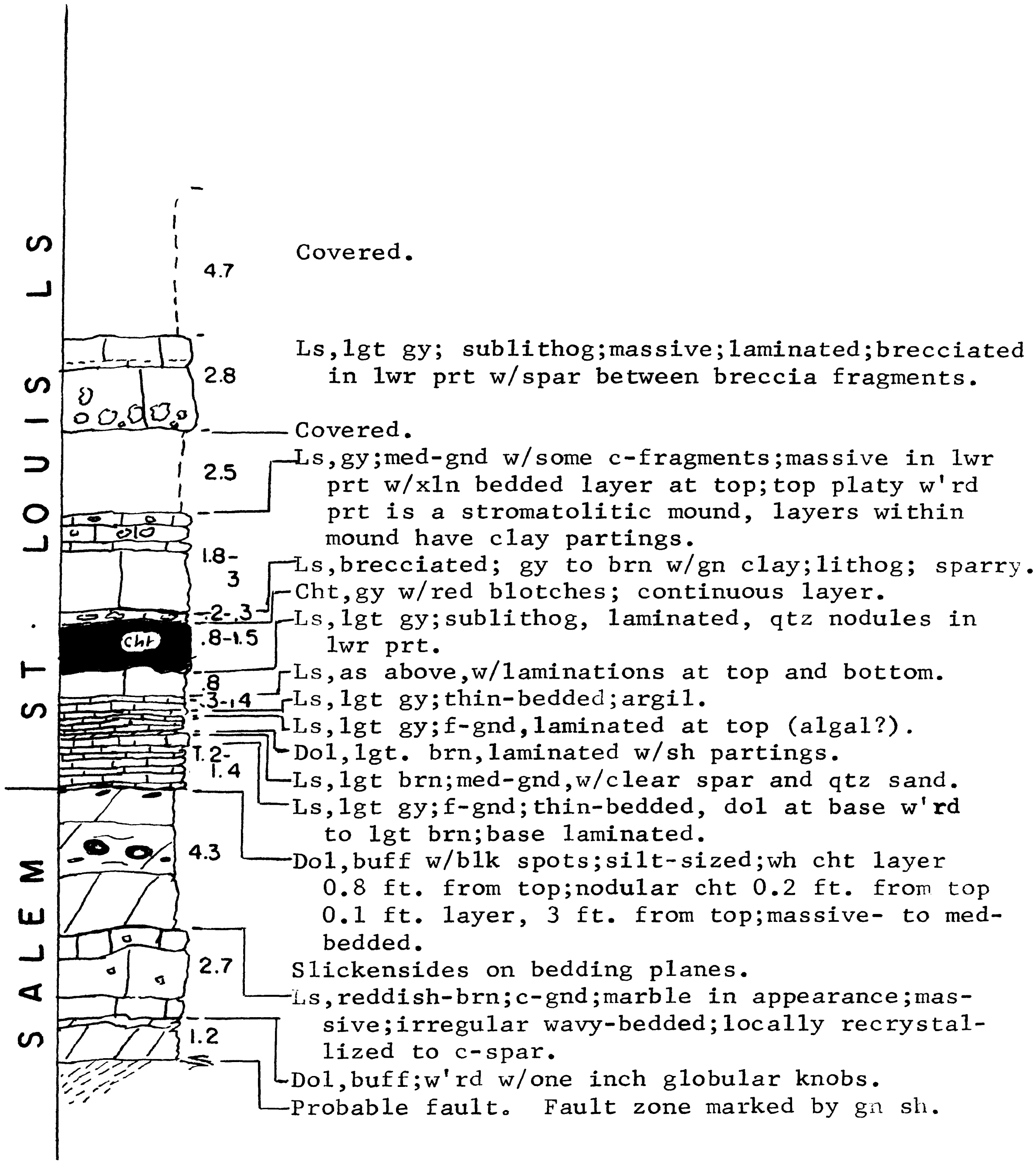


Fig. 8. Stratigraphic section along the Mississippi River bluff, Calhoun County, Illinois

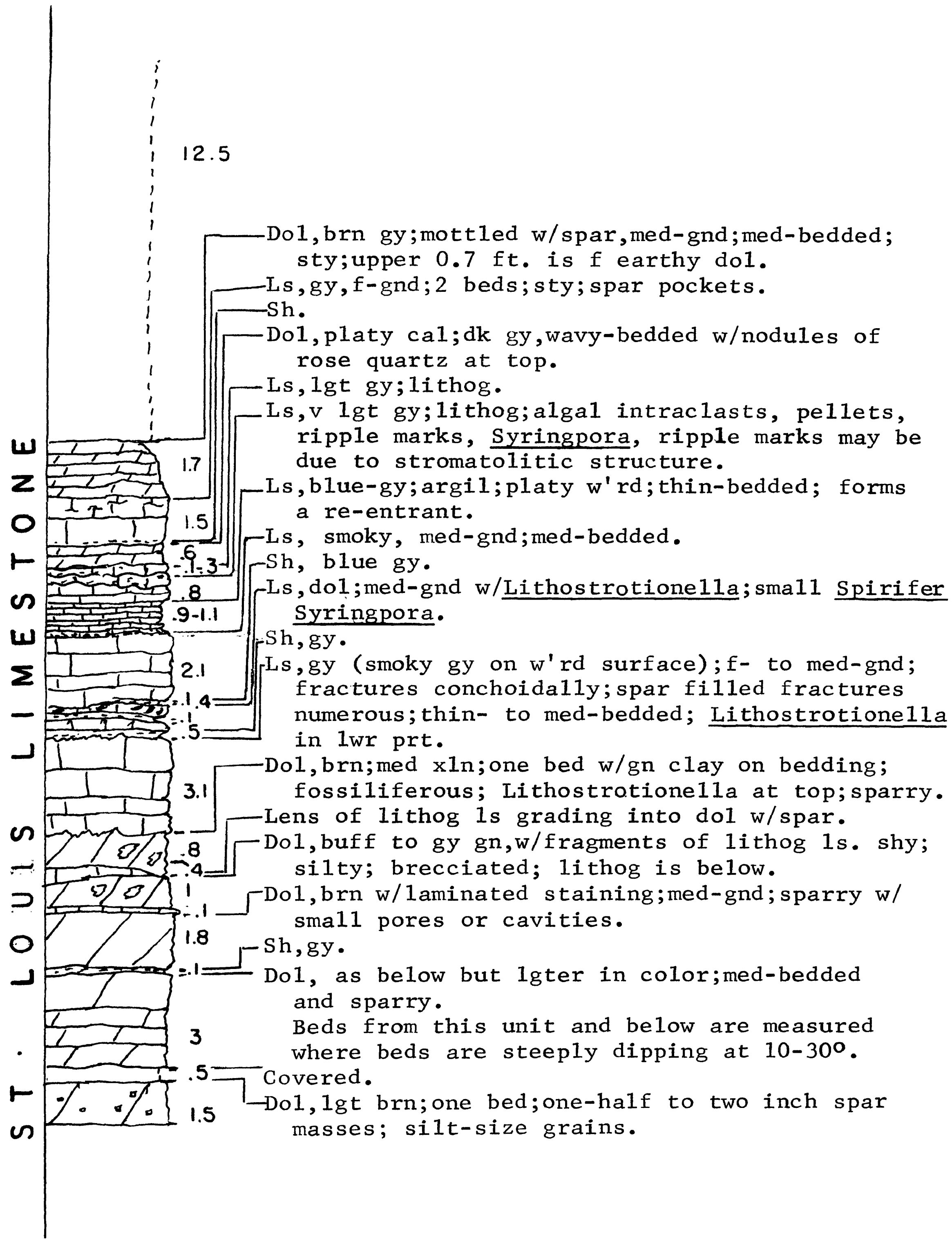
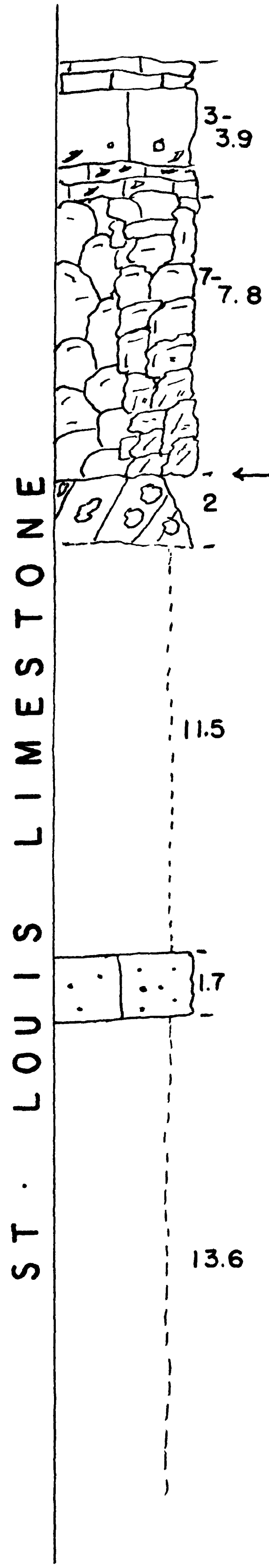


Fig. 8. (continued)



Ls,buff,med-gnd,similar to above but coarser-gnd,massive w/partings containing crinoid debris;bryozoans;Lithostrotionella, Syringopora, 2.5 ft. from top, pebble and cobbles of breccia at base; unit apparently thickens to north at expense of underlying breccia unit missing just to the north.

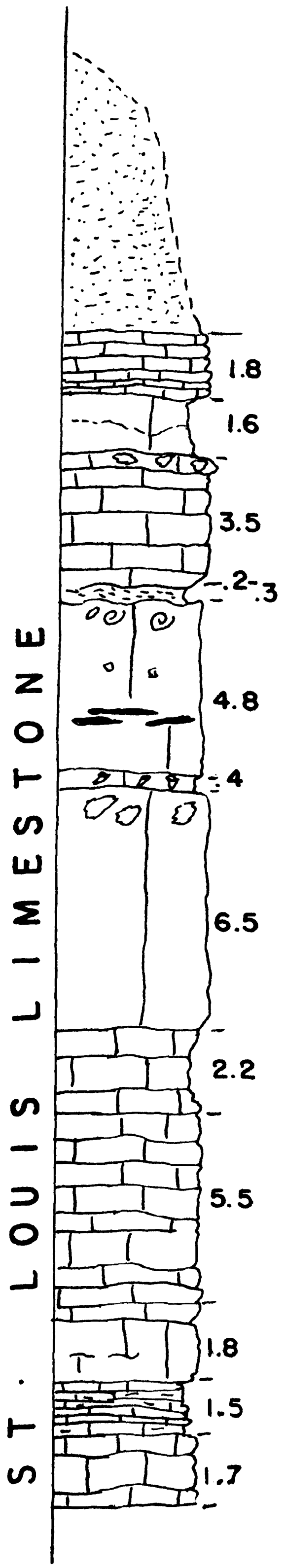
Ls,brecciated;gy,a little gn clay between fragments especially in lwr prt;breccia smaller and more easily w'rd at base; form prominent ledge.

Uneven contact.

Dol,brn;earthy;w/some lithog ls and dol breccia fragments embedded in upper prt in a gn sh matrix;form re-entrant under bluff.

Ls,nearly wh;biocalcarenite;partly oolitic; may be prt of large slump block.

Fig. 8. (continued)



Loess

Ls,lgt tan,f-gnd to v f-gnd;thin;wavy-bedded no apparent fossil debris.

Ls,as above but coarser-gnd;one bed w/vague partings,small crinoid columns (crino-arenite).

Ls,lgt brn gy;lithog w/fossil layers;thin-bedded to med-bedded at base; brecciated locally at top.

May be ripple marked surface.

Sh,gy,v cal.

Ls,tan;lithog,w/spar;locally coarser layers; chiefly biomicrite,w'rd to lgt gy;fossiliferous large (2") gastropod at top;red cht layer, 1.5 ft. from base.

Lithostrotionella biostrome.

Ls,lgt gy,f-biocalcarenite;massive, one bed; breccia in places near top,w'rd to c-hackly fractures;small Composita.

Ls,tan;f-gnd to sublithog;debris not conspicuous as below;crinoid debris at top.

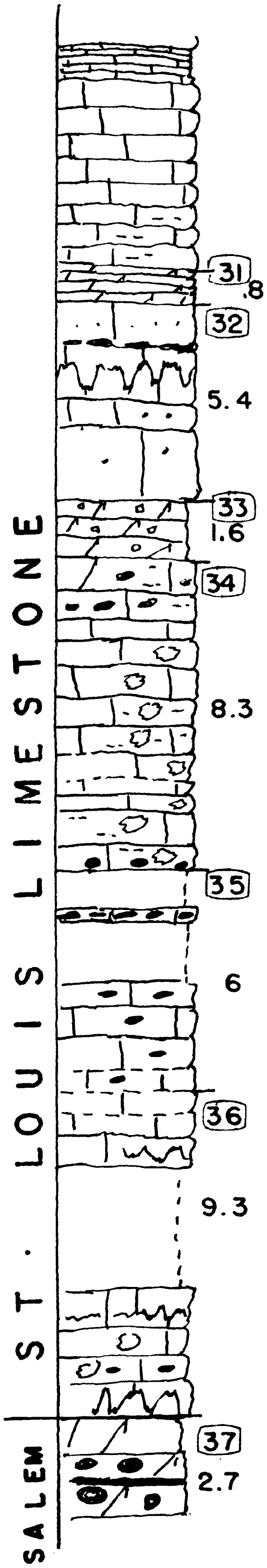
Ls,as below;but med-wavy bedded.

Ls, lgt gy;crinoid;echinoid spines;massive w/ local bedding and sty partings;biocalcarenite.

Ls;argil in prt;buff;f-gnd w/crinoid columnal; biocalcarnite; echinoid plates; bryozoans, horn corals; platy w'rd sh at base; linoproductids at base.

Ls,similar to 1.8 ft. unit above; med-gnd; fewer crinoid columnals;contains echinoid spines wavy-bedded.

Fig. 8. (continued)



gnd,med-bedded, laminated in middle prt,possibly fossiliferous w/corrosion surfaces and fractured and shaly at base.

Dol, cal;yell to lgt olive gy;f-gnd;thin-bedded.

Ls,as unit 30 but lgt to v lgt olive gy w/sl yell or red color;f-gnd (lithog) w/sty and fractured in upper 0.2 ft;about ½ inch red cht in xln possibly oolitic ls w/gn sh; med to thick bedded.

Dol,cal w/spar xls and pyrite gns; lgt olive gy med to f-gnd; med-bedded.

Ls, sl dol, med to lgt gy w/gn sh partings and spar surrounding fragments;f-gnd below, med-to c-gnd above;brecciated and/or fragmented; thin-to med-bedded;algal in upper prt, micritic-clastic fragments embedded in shaly ls matrix in lwr prt; 4 ft. from below is brn sh w/gn shaly sparry ls matrix; chty in upper prt, also cht nodules below; lwr prt is fossiliferous.

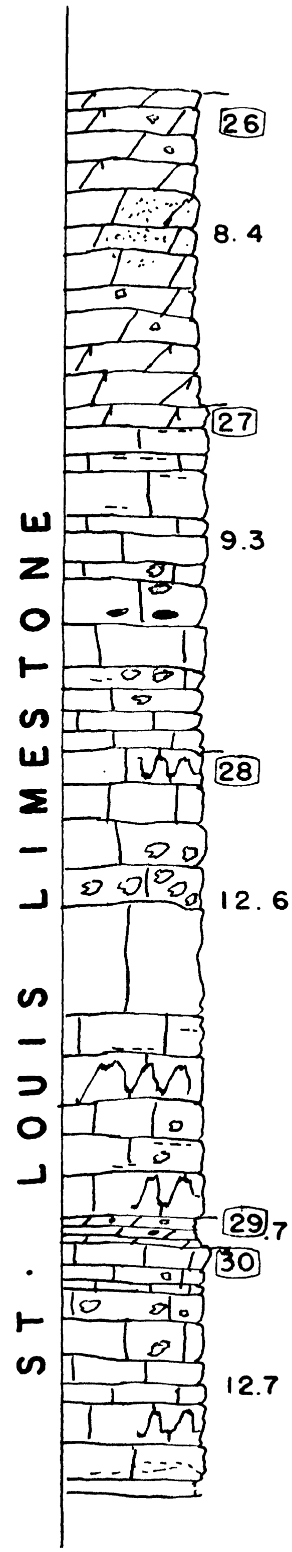
Cht,med lgt gy at top to v lgt gy below.

Ls, chty, ls is med gy to lgt olive gy,cht is cal and v lgt gy to wh;med-to f-gnd w/calcite xls filling fractures in lwr prt; med-bedded fossiliferous above base.

Ls, brecciated in lwr prt,xln in middle; fragments are med lgt gy,matrix is lgt olive gy; fragments are f-gnd w/spar xls;matrix and lwr prt is lithog;c-gnd in middle prt w/qtz and spar xls;med-bedded; sty or corrosion surfaces, and cht in lwr prt.

Dol,cal;lgt olive gy w/reddish or brnish stains; porous; med to f-gnd,chty w/geode structure above and xln qtz in lwr prt;med-bedded.

Fig. 9. Stratigraphic section of drill hole #5.



Dol,sl cal;vlgt gy to v sl yell-gy and/or pinkish;med- to f-gnd;med to thick-bedded;fractures filled w/spar in lwr prt;pyrite and qtz gns are present;porous.

Ls,v lgt gy (0.3 ft.),med lgt gy to lgt olive-gy (1.4 ft.);lgt gnish gy (1.0 ft.) and lgt olive gy for lwr prt,med- to c-gnd above, f-gnd (lithog) in lwr prt,fossiliferous w/scattered gn sh spots;algal(?) in med to lgt olive gy prt;med- to thin-bedded w/pyrite gns and cht nodules in lwr 4 ft;corrosion surfaces or small sty in lwr prt.

Ls,med gy for 1.2 ft. above,lgt gy to lgt olive gy below;f-gnd w/spar filling fractures and vugs at top;gn sh surrounding fragments in middle and lwr prts;brecciated above and lithog in lwr prt,breccia fragments are lithog. Lithog unit is sty w/corrosion surfaces, thin to med-bedded above,med- to thick-bedded below.

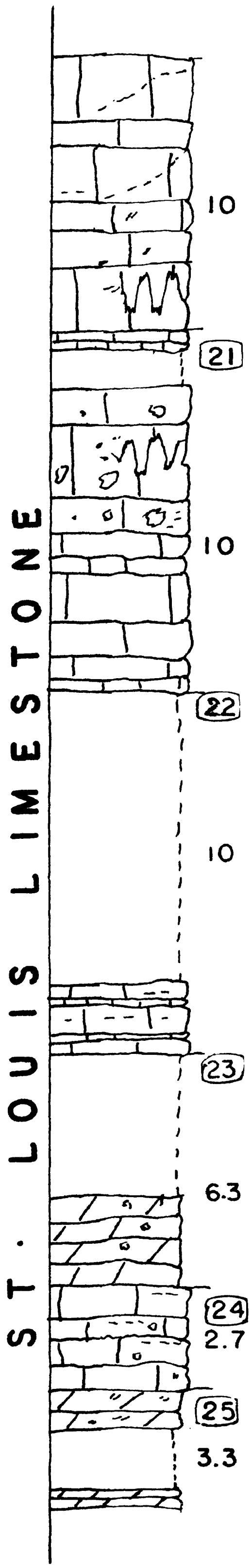
Ls;as base of above;med to lgt gy and lgt olive gy;f- to med-gnd,med-bedded; sty;w/crinoid stems and fossil fragments.

Dol,cal;sl yell to lgt olive gy, med-gnd w/spar xls filling vugs,dol in middle part.

Ls,med to lgt gy and lgt olive gy in lwr prt, shaly prts are gnish;med gnd;lithog in lwr prt,med to thin-bedded:,upper 0.2-0.3 ft. brecciated w/spar enclosing fragments; sty and shaly in lwr prt.

Ls,mostly as base of above, med to lgt gy or sl lgt olive gy w/local v lgt gy;med to f-gnd.

Fig. 9. (continued)



Ls,as above;v lgt to lgt gy and/or lgt olive gy w/gn or med gy sh partings;cht nodules-red to brn in upper part;few scattered minute gn sh spots in upper prt (0.2-0.4 ft. from top) med to f-gnd;(lithog) 2-4 ft. below top w/spar xls filling fractures;v few pyrite gns, 2-4 ft. above base is fossiliferous;med to thick-bedded above,med-bedded below;oolitic in upper prt; sh partings and solution surfaces in lwr prt.

Ls,lgt gy to lgt olive gy; gnish gy 3 ft. from top;med gnd above;f-gnd (lithog) in middle prt to med- to c-gnd in lwr prt; more gn sh in lwr half associated w/fractures and sh surrounding fragments; sl brecciated;0.3 ft. from below is mottled probably algal,spar xls mostly in lithog prt;med- to thin-bedded; solution surfaces and sty in lwr prt.

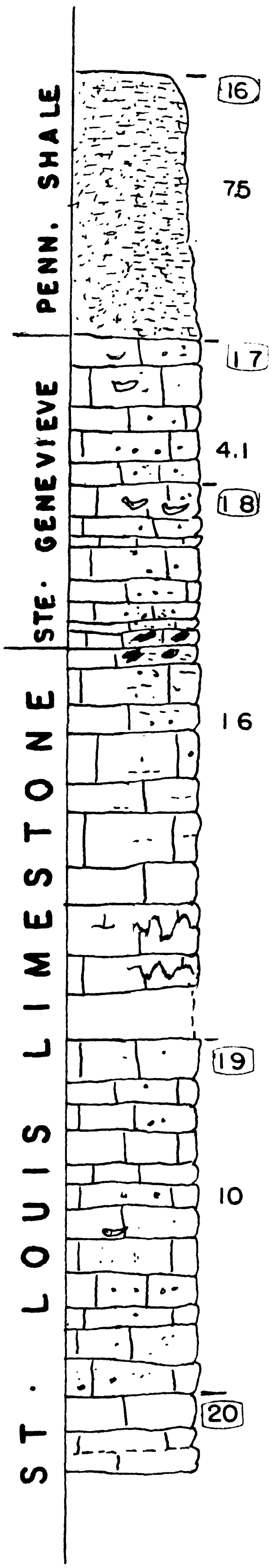
Ls,lgt gy to lgt olive gy;sl yell in lwr prt; f-(lithog) to med-gnd in lwr prt; algal(?), thin-bedded(?); sh surrounding fragments in lwr prt.

Dol,sl cal; v lgt gy;med- to f-gnd (cal matter as cement) w/med-to c-qtz gns and minute pyrite particles.

Ls,lgt gy to lgt olive gy;f-gnd (lithog) w/c-xln spar filling fractures or vugs in lwr prt; gn sh partings in upper prt;thin- to med-bedded w/corrosion or solution surfaces on bedding planes.

Dol,sl cal;dense; med dk gy to lgt olive gy; pinkish gy in lwr prt;f- to med-gnd; few scattered gn sh spots and pyrite gns;thin-bedded.

Fig. 9. (continued)



Sh,sandy and/or silty.

Ls,v lgt to lgt olive gy;mostly oolitic above, less oolitic below;med- to c-gnd;f-gnd in middle prt;fossiliferous (brachiopod);sty; med-bedded w/occasional lgt gn sh partings and pyrite gns above;fossils filled w/oolites; few scattered qtz gns.

Ls,v lgt to lgt gy and sl wh in lwr prt,fossiliferous prt is gy,f-gnd (sublithog) to med-gnd w/few oolites,med-to thick-bedded; chty and shaly for 0.5 ft. w/c-qtz xls and probably conglomeratic(?) and some clastic ls fragments w/pyrite;sty;fossiliferous above.

Ls,lgt gy to gnish gy 0.6 ft. below top,v lgt gy in lwr prt w/sh partings of bluish color; f-gnd (lithog to sublithog) w/spar xls and a few scattered pyrite gns;sty in lwr prt; thin to med-bedded above;med- to thick-bedded below.

Ls,lgt gy for 0.3 ft.,generally v lgt gy;lgt olive gy for 6.6 ft. below;f- to med-gnd above, lithog for one ft. in middle prt w/some med- to c-spar xls in lithog unit; few pyrite gns; sty;med- to thin-bedded(?) w/lamination in lwr prt; few oolites; few quartz gns.

Fig. 9. (continued)

CHAPTER III

PETROGRAPHY

A. Introduction

Carbonate rocks constitute from 15 to 20 percent of all the sedimentary rocks and they are widely distributed in time and space. They range in age from Precambrian to Recent and cover many parts of the earth's surface. Carbonate rocks are economically important, especially after the discovery of the large oil reservoirs in them. Of the large oil reservoirs in carbonates are the Devonian reefs of western Canada, the Pennsylvanian limestone of Texas and most of the large oil reservoirs in the Middle East. The traditional uses of carbonates are important too. Due to all of these, an urgent need has arisen among interested workers in this field to classify carbonate rocks.

B. Classification of Carbonate Rocks

The need for a classification of carbonate rocks was recognized in the early work of Grabau (1904) who introduced the two-fold classification of sedimentary rocks, the "exogenetic" and "endogenetic" or clastics (detrital) and the chemical precipitates respectively. Also, he introduced these terms regarding the texture of limestones: calcilutite for fine-grained, calcarenite for medium-grained and calcirudite for coarse-grained. Following Grabau some other workers here and abroad made some helpful contributions to the problem of classification. Particularly there should be mentioned: Cayeux (1935) of France, who described many carbonate types by use of thin sections; Black (1938) of England who introduced the organic aspects which modify limestones;

and Sander (1936) of Austria. Pettijohn (1947 and 1957) suggested a two-phase classification: "autochthonous" - biochemical accumulation in situ, and "allochthonous" - transported and redeposited or detrital limestone.

In spite of these contributions, limestone classification has been much delayed in comparison with the other types of sedimentary rocks. This is largely due to the complexity or the polygenetic character of limestone rocks; it is also due to the modifications that can occur in these rocks after deposition.

There is no one single type of limestone classification which will satisfy all the requirements needed by workers and which will also cover the widely variable characteristics of limestones. In general there are two main types of classification: descriptive and genetic. A combination of them can also be made using the important features of each to satisfy the particular needs required. The descriptive is the more desired one.

The different parameters which are normally used in carbonate classification include:

1. Mineralogical constituents: calcite, aragonite, and dolomite.
2. Chemical composition.
3. Identity of carbonate grains: clastic and biotic constituents. These are much related to the genesis of the grains.
4. Depositional texture: for clastic carbonates the size and sorting are the main features.
5. Textural maturity: abrasion and sorting; difficult to apply.
6. Diagenetic factors: the various modifications after deposition.

7. Clastic and non-clastic: transported or formed in situ.

8. Organic versus inorganic.

9. Energy levels: turbulent or quiet water deposition. Interrupted as high or low energy levels or ranges between.

10. Depositional environments: lagoon, barrier, or patch reef; shelf platform or basin.

1. Review of Some Recent Classifications of Carbonate Rocks

Mentioned here is a brief review of some of the recent carbonate classifications. This review is summarized from Ham and Pray (1962b).

a. Feray, Heuer and Hewalt classification: essentially a genetic classification, dividing carbonates into two major families: limestones of detrital origin, formed by mechanical weathering; and limestones of biochemical origin, formed by influence of organisms. These two main families are further subdivided into smaller units.

b. Leighton and Pendexter classification: primarily descriptive classification, but using genetic criteria. The classification is made by differentiating between two types of genesis; clastic and formed in place. The clastic limestone is produced by use of varying amounts of four textural elements, they are:

1. Grains: coarser clastics.
2. Void.
3. Micrite: lime mud (less than .03 mm.).
4. Cement: chemically precipitated.

The main rock types according to them are: detrital, skeletal pellets, lumps, and coated or encrusted grains. Thin sections are necessary.

c. Plumley, Risley, Graves and Kaley classification: genetic type of classification depending mainly on energy levels (energy index). Five major limestone types are introduced, whose origin varies from quiet to turbulent water conditions:

1. Quiet water sediments.
2. Intermittently agitated water sediments. 1 and 2 contain more than 50 percent microcrystalline matrix.
3. Slightly agitated aqueous sediments: contain less than 50 percent microcrystalline matrix.
4. Moderately agitated aqueous sediments: medium to very coarse clastic carbonate grains.
5. Strongly agitated aqueous sediments.

d. Dunham classification: this classification deals with the depositional fabric of carbonate rocks, depending mainly on which size is the framework supporter, whether it is mud or coarser clasts. The clastic carbonates are subdivided into four classes. Grainstone: grain supported, no mud. Packstone: grain supported, less mud. Wackestone: mud supported, more than 10 percent grains. Mudstone: mud supported, less than 10 percent grains. He also introduced the term "boundstone" applied to most reef biostromes and bioherms and crystalline carbonate for non-recognizable depositional texture.

e. Additional contributions made by other workers: these include Powers (1962) working on Arabian carbonates; Thomas (1962); Nelson, Brown and Brineman (1962); and Embrie and Purdy (1962). All of these classifications are discussed in detail in Ham (1962a).

C. Folk Classification

As pointed out before, there has been a fairly large number of classifications of carbonate rocks, each depends on one or more of important parameters thought to be of particular value by the classifier(s). In the case of the St. Louis Limestone, it seems that the kind of classification to be most suitable, is that of Folk (1959), because this classification is intended to be applied to all carbonate rocks. Although Folk's classification is essentially descriptive, it has the merits that genetic features may be deduced from the description. The main features of Folk's classification are briefly reviewed here. The classification is to be applied mainly for clastic carbonates (not formed in situ by organisms). Thin sections must be used. The classification mainly differentiate two major divisions; allochems and orthochems.

1. Allochems

The word is a collective one to include the carbonate sediments that are not the result of direct or ordinary chemical precipitates. It is composed of "allo" meaning "out of ordinary" and "chem" meaning "chemical precipitates." These sediments have undergone some degree of transportation, no matter how short it is, and also, must have certain degree of sorting. Under the allochems are included four main subdivisions. These are: intraclasts, fossils, oolites and pellets. A brief description is given for each.

a. Intraclasts: according to Folk (1959), intraclasts are "fragments of penecontemporaneous, generally weakly consolidated, carbonate sediments, that have been eroded from adjoining parts of the sea bottom and redeposited to form new sediments." The intraclasts may be produced as a result of submarine erosion, mild tectonic upwarp of the sea floor or by wave attack on carbonate rocks as a result of low tide. The size ranges from fine sand size up to boulders; it is well rounded and has equant to discoidal forms. Fragments of previously consolidated carbonates are excluded.

b. Pellets: Folk uses the term pellets for "rounded, spherical to elliptical or ovoid aggregates of microcrystalline calcite devoid of any internal structure." He puts an upper size limit for pellets as 0.15 mm., the term is used here as defined, but the limit of the upper size is extended from 0.15 mm. to include sand size particles as long as the other pelletal characteristics are present. Folk follows the belief that these aggregates may be invertebrate fecal pellets.

c. Oolites: the term is self-explanatory, designating all spherical to elliptical or ovoid particles that are internally characterized by either concentric or radial structure. There is no implication on size limits.

d. Fossils: Folk includes fossils and fossil fragments whether transported or sedentary (but not formed in situ as corals or algae) as allochem.

Folk includes with the above four categories a fifth one which he gave the name "pseudo-allochems" to cover all objects that have the same features as intraclasts, pellets, oolites and fossils but are formed by recrystallization. These features are not included in his classification on the basis that they are "rare exceptions."

2. Orthochems

This major subdivision includes all the carbonates that formed essentially as normal or ordinary chemical precipitates within the basin of deposition or within the rock itself, without significant transportation. This is further subdivided into two main classes: microcrystalline calcite ooze (micrite) and sparry calcite cement. In addition, minerals formed by replacement or recrystallization are also included.

a. Microcrystalline calcite ooze (micrite): This includes all the fine-grained particles (size limits being 1 to 4 microns) formed as direct precipitation by either chemical or biochemical processes in sea water and settling down to the sea bottom. No distinction is made between particles of the same size formed by abrasive action, such as dust or those formed by chemical or biochemical means, the reason being that the former (dust) is "quantitatively negligible" and also hard to identify in thin section.

b. Sparry calcite cement (spar): sparry calcite cement is a name used for the calcite that fills pores or spaces after the sediments are laid down. Folk puts a boundary line between micrite and sparry calcite on grain size at 4 microns. Sparry calcite crystal average in size from 0.02 to 0.1 mm.

3. Main Limestone Families

The three end members, micrite, sparry calcite and allochems (fossils, oolites, pellets and intraclasts) form the major limestone families. A wide range of proportions of each can be mixed with the other. Any of the allochems and the micrites can form the rock framework, but the sparry calcite cannot form a rock of its own. The main types of limestone families are:

a. Sparry allochem rocks: the main constituents are allochemical particles cemented together by sparry calcite. This type forms in high energy conditions as on a beach or bar where the wave action is strong enough to winnow the micrite from the allochems and prevents its deposition as matrix. These rocks are well-sorted and show abrasion of grains.

b. Microcrystalline allochemical rocks: here also the allochemical aggregates are deposited but with different percentages. The current is weak, so micrite can be deposited as matrix between the grains. Sparry cement can accumulate depending on whether the micrite ooze filled all spaces or not. If sparry calcite is deposited with micrite a transitional boundary is present, designated by descriptive terms such as "poorly washed biosparite" where one-third to two-thirds of interallochems is micrite.

c. Microcrystalline rocks (micrite): this type of limestone is formed entirely by deposition of microcrystalline calcite ooze either in calm water or rapid chemical or biochemical precipitation with the lack of any strong currents. Allochems may or may not form a small part of the rock. Microcrystalline calcite rocks are usually known as a lithographic limestone which is the most characteristic lithology of the St. Louis Limestone. Although micritic rocks are generally formed in place, with little or no transportation, they may be confused with others formed organically such as corals or algal limestones.

The major types mentioned above are further subdivided according to whether the allochem constituents are oolites, fossils, pellets or intraclasts, and also whether the other major rock type is micrite or sparry calcite. If 25 percent or more of the rock is intraclast, then the rock is called intraclastic, but if intraclasts are less than 25 percent and oolites are 25 percent or more, the rock is oolitic. If intraclasts and oolites are less than 25 percent and the fossil to pellets ratio is 3:1, the rock is biogenic, if this ratio is less than 1:3, the rock is pelletic. If the ratio is in between, the name is biogenic-pellet rock.

4. Rock Names

The rock name is composed of two main parts with a third at the end indicating the rock texture. The first is related to the type of allochem present, the second part is for either sparry calcite cement or microcrystalline calcite ooze whichever is dominant. The following abbreviations are used for the different allochem constituents; oo- for oolite, intra- for intraclast, pel- for pellets and bio- for fossils. The name sparry calcite cement is abbreviated to spar and microcrystalline calcite is micrite. If the rock contains more than 25 percent intraclast, the name of the most dominant allochem type can be used as a modifier before the rock name.

The textural part of the name is derived from Grabau: "calcilutite" for fine, "calcarenite" for medium and "calcirudite" for coarse. As may be noticed, these size terms apply only to the first part of the name, i.e., for the allochem. Coarse is considered above one mm., fine is less than 1/16 mm. and medium is for values between these.

D. Classification of the St. Louis Limestone

About 100 slides were used for this purpose. These slides were chosen mainly to show as many different features as possible. This choice may in one way or another affect the attempt to arrive at a more general rock name for the formation based on quantitative estimates from the study of thin sections. The detailed analyses of the chosen thin sections are given in Table 3 which is followed by a brief discussion of the main rock components and at the end an attempt is made to name the most dominant rock types in the St. Louis Limestone based on Folk's names. The percentages of the different categories in Table 3 are based on visual estimation, except the percentage of the insoluble residues which is the actual value as given by the analyses. This means that a possible variation in the estimation between one person and another will exist. But in any case, the names based on these percentages are not going to change due to the range of each component which is not critical as may be noticed from Table 3.

1. Characteristic of the Main Rock Components

A brief discussion of the main features, textures and other characteristics of the main rock components as shown in Table 3, is given here. The first part is devoted mainly to the allochem constituents and especially the fossil types, but without much elaboration. The rest of this section will be concerned with the orthochem and the miscellaneous features. The part of the table covering the insoluble residue analyses will be discussed later and is not included in this section.

a. Allochems: the components of allochems are: fossils, fossil fragments, oolites, pellets and intraclasts. Fossils are the most important of these in the St. Louis Limestone, followed in importance by oolites. The intraclasts were found to be the least important allochem. This implies that strong currents and wave action were not significant in the environment of deposition of the St. Louis. The discussion is based mainly on thin section study.

i. Fossils: the different kinds of fossils recognized in the thin section study include: brachiopods, crinoids, foraminifers, corals, bryozoans and gastropods. Although algae are present, their recognition is difficult. The total percentage of all the different kinds of fossils is given instead of the percentage of each, as one thin section may not be exactly representative of a large area. Also, the way in which the thin section is cut may have an effect on the presence of a specific kind of fossil, but taken at random, for a large number of thin sections, the average may come close enough to the actual state in the field. Again, the presence of a specific kind is not so important in this paper, as it is not the aim of this report to present a statistical or quantitative study of the different kinds of fossils. In addition, no attempt is made to identify the species or genus as this requires the whole complete specimen which actually was not easy to find. On the other hand, S. Weller (1920) made identifications of all the previously mentioned kinds of fossils, except for the foraminifera, in eastern

Missouri, western Illinois and Iowa. E. L. Clark (1939) also recognized most of the species mentioned by Weller (1920) in southwestern Missouri. It might be worth mentioning that the occurrence of these fossils is rather confined to specific localities or zones than distributed through the formation.

Another kind of fauna that has been reported from the St. Louis Limestone is conodonts, which are considered biostratigraphically useful fossils by some paleontologists. Collision, Scott and Rexroad, (1962) mentioned the occurrence of conodonts in the Alton bluffs, Madison County, Illinois; Rexroad and Collinson (1963) reported this fauna in the St. Louis area, south-central Indiana, southern Illinois and central Kentucky; Rexroad and Furnish (1964) in south-central Iowa; and Thompson and Goebel (1963) and Thompson (1965) in western Kansas. Thompson (1966) made a study of the conodonts in the Missouri Portland Cement Company Quarry at Fort Bellefontaine and Vigus North quarries; he listed 12 genera and 29 species in the Missouri Portland Cement quarry and 12 genera and 20 species in the Vigus North quarries. Rexroad and Collinson (1963) pointed out that the fauna is common in the upper part of the St. Louis Limestone and sparse in the lower part. They recognized two genera which can be used for biostratigraphic zonation. These are: Taphrognathus, common in the lower part and absent in the upper part, the second is Cavusgnathus, common in the upper part and absent in the lower part. They concluded that the conodont fauna of the St. Louis Limestone is transitional from the Warsaw and Salem Formations, but change occurs abruptly from the St. Louis to the Ste. Genevieve.

In thin sections studied in this report, conodonts were found only in one thin section (slide 10-A) from stratigraphic section A (see

Plate 7, Fig. 5). No other conodonts were found in thin sections or noticed either in hand specimens or insoluble residues. Because of this, conodonts will not be further considered and they are not used for correlation in this report.

Brachiopods

Although brachiopods have been reported by many writers to be present in the St. Louis Limestone, e.g., Weller (1920), Clark (1939) and Rubey (1952), it is difficult to find specimens that can be freed easily from the limestone. Different species and genera have been recognized, the most dominant of which are Spirifer and Composita which occur throughout the formation.

During the field work, only one complete specimen was found embedded in limestone matrix in stratigraphic section A. No complete brachiopod fossil was found elsewhere. In other St. Louis Limestone outcrops along the Mississippi River in Calhoun County, Illinois, some complete fossils were found mostly in the shale partings. Since brachiopods are megascopic fossils, it was not easy to encounter complete ones in thin section, except in the case where the animal is small. Larger specimens were found in some thin sections studied as well as some fragments thought to be parts of brachiopods on the basis of their fibrous structure parallel to the shell wall. The occurrences of brachiopods and brachiopod fragments are indicated in Table 3, where it will be noticed that the brachiopods occurrence is generally less than other fossils except gastropods. Fewer brachiopods occur in the lower part of the sections than in the middle or in the upper parts. The interior of the shell generally contains other fossils such as foraminifera, crinoid fragments, oolites, and calcite crystals. Plate 6, Figure 5, shows a segment of brachiopod shell. Thin sections that showed brachiopods as dominant are 7-C, 12-A, 20-1 and 21/2; many others showed no indication of brachiopods.

Crinoids

Included under crinoids are crinoid stems, columnals, arm plates and calyz plates. All of these are exclusively fragmental, with many of them angular in shape. They were undoubtedly transported, but for a short distance. Some seem to be laid down with no evidence of transportation, as indicated by poor sorting with no abrasive action. On the other hand, a few showed current-worn edges indicating some transportation. Crinoids are the dominant kind of fossils observed in thin sections, and they are present almost without interruption from the lower to the upper part of the formation. They are reported to be dominant in the Ste. Genevieve Formation (Reinhard, 1964) and probably they are present in the lower Warsaw and Salem Formations too. They are indicated as dominant in most of the sections tabulated in Table 3, except in the lower part of section B, where they are lacking, probably due to dolomitization. The upper part of the formation showed more crinoids than the lower part. In thin sections, crinoids were easily recognized; the stems by their longitudinal, fine, fibrous pattern and the plates by their perforated structure and reticulate shape (see Plate 6, Figures 1, 2, and 3). The crinoid stems and plates vary widely in shape and size, and fragments up to 2 or 3 mm. are observed. In the zones of oolites, the crinoids, especially the stems, act as a core or nucleus around which the oolite grains grew (Pl. 7, Figs. 1 and 3). In many thin sections, it has been noticed that crinoids are generally associated with other fossils such as bryozoans and foraminifera, as indicated in Table 3.

Foraminifers

The foraminifers observed in thin sections seem to need more detailed study and identification since such a study may help establish reasonable criteria for knowing more about St. Louis zonation. As shown on Table 3, the foraminifera were dominant in many thin sections. The number of different species in the St. Louis Limestone appears to be limited (about 2 to 4). The dominant kind is the planispiral form (see Pl. 4, Figs. 1, 2, 3, 4 and 5). Table 3 shows the presence of foraminifers through the stratigraphic sections from the base to the top of the St. Louis Limestone, and they occur continuously from the lower Salem to Ste. Genevieve Formations. Some thin sections did not show any foraminifers, especially in the lower part of stratigraphic section B. This is partly due to dolomitization. The cores of the oolite grains in the upper part of the formation are sometimes foraminifers. Because of the lack of strong current action during deposition, the sorting was poor. In most of the cases, the foraminifers are embedded in micrite matrix.

Corals

The most dominant coral genera in the formation are: *Lithostrotionella* and *Lithostrotion*. The presence of corals in the formation is a good indicator of the environment of deposition. On the other hand corals are found in widely different stratigraphic positions, both vertically and laterally, which limits their use for correlation purposes. Corals can be identified in hand specimens, and in most of the cases they are associated with the shaly part of the formation. Corals were not given a special column in Table 3, and they are included under "others" in the category of "fossils". Corals were observed in a few thin sections, of which slide 7-B of stratigraphic section A, showed the highest percentage (see Pl. 4, Fig. 6 and Pl. 9, Fig. 1).

Bryozoans

Bryozoans of a wide variety in shape ranging from branching, bead-like, net-like to leaf-shaped have been observed in thin sections. They seem to be important in the St. Louis Limestone and they are reported throughout all but the lower part of stratigraphic section B, where it was hard to recognize them due to dolomitization. Some slides showed bryozoans that can be of correlative value (see Pl. 5, Figs. 1, 2, 3, 4, 5 and 6). Bryozoans seem to be associated with micrite which means that these organisms required a calm water to grow.

In Table 3, it is seen that in many thin sections, bryozoans are dominant and in many slides they are associated with other fossils, especially foraminifers and crinoids (see Plate 5, Figs. 3 and 5). From the thin sections study, it is noticed that less bryozoans are associated where spar forms the matrix rather than micrite. Refer to slides 7-D, 20-A, 21-A, 14-4 and 20/3 as indicated in Table 3. It is seen that most of these slides are from the upper part of the formation.

Gastropods

Gastropods are the least abundant kind of fossils observed in thin sections. Only one thin section (12-A of stratigraphic section A), showed a complete section of a gastropod (see Plate 6, Fig. 6 and Plate 9, Fig. 2). On the other hand, gastropod casts can be seen well exposed in the upper part of the St. Louis Limestone cropping out along the Mississippi River bluff in Calhoun County, Illinois, south of stratigraphic section C.

Other fossils

Under this part of the discussion of fossil are included algea and ostracodes. Algae are mentioned in the description of the stratigraphic sections, but were hard to identify definitely in thin sections due to the fact that they are replaced in many cases by calcite crystals and also have a wide variety of shapes. Whenever the presence of algae is suspected in thin sections, this is indicated in Table 3, where it may be noticed that in many slides its existence is questioned. In general, if algae are present, the matrix is micrite.

Ostracodes have been observed in very few slides in which the shell is complete. They are included under "others" in the fossil category in Table 3 as their sparcity does not warrant a special column.

ii. Oolites

Second in importance to fossils are the oolites. This is not actually because of their dominance in the formation, but because of their sedimentological significance and their close similarity to the oolites described by Reinhard (1964) in the Ste. Genevieve Formation. The oolites of the St. Louis Limestone have been found in the upper part of the formation in all of the stratigraphic sections. The size ranges from 0.1 to 0.5 mm on the average and the shape varies from spherical to ellipsoidal to oval.

The matrix of the oolites in nearly all thin sections is spar. The oolites in many cases show growth after deposition (superficial oolites). The core around which the oolites grow may be fossil fragments such as a part of brachiopod shell, crinoidal plates or frequently crinoid stems and foraminifers (see Plate 7, Figs. 1, 2 and 3). The thin section that showed the largest percentage of oolites is slide number 21-A of stratigraphic section A, which shows 40 percent oolites in a spar matrix. No lower percentage limit is given as most slides have no oolites.

The significance of oolites in the St. Louis Limestone may be considered as an indication of the end of St. Louis time and the beginning of the Ste. Genevieve time, i.e., the transition from the St. Louis to the Ste. Genevieve Formation.

iii. Pellets and Intraclasts

Of the allochems, pellets and intraclasts are the least abundant components in the St. Louis Limestone. They are sparsely present both laterally and vertically, so they are of least correlative value. For all these reasons, they are included here together. Generally, if intraclasts make more than 25 percent of the rock, the matrix is spar. No slides showed more than 25 percent intraclasts in a micrite matrix. Some slides showed fragments of micrite cemented by spar (calcite crystals), but these fragments are not intraclasts because fragmentation occurred after lithification of the rock and not contemporaneously with deposition. Thin section 14-4 shows the highest percentage of intraclasts, 40 percent.

Pellets* were not significant in St. Louis Limestone. If they are present, they are associated with other fossils, mostly crinoids, and the matrix is either micrite or spar. In thin sections, they appear brownish in color, sometimes darker than micrite under transmitted light. The shape is inclined to be spherical, but other shapes, especially oval are present as well. The slide that showed the largest percentage of pellets is 20/3 which has a 30 percent pellets. See Plate 7, Figure 4 which shows pellets associated with oolites and crinoid fragments.

b. Orthochems

Of the direct precipitates, the microcrystalline calcite ooze

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* The upper size limit of 0.15 mm. of pellets may be higher than suggested by Folk (1959).

(micrite) seems to be more important and abundant than the sparry calcite cement (spar) in the St. Louis Limestone. Except for a few slides, most of the thin sections studied showed micrite in variable amounts. In the dolomitized units, it was not easy to determine whether micrite or spar was originally the main rock matrix especially when the whole slide is dolomite. In the following both micrite and spar will be discussed briefly.

i. Micrite

The term micrite is used here in the same way Fold (1959) used it in regard to its size limits of 1-4 microns. Micrite in thin sections appear to be subtranslucent, having a faint brown cast. It is believed that this micrite is formed on the sea floor by chemical and biochemical precipitates where the water current is quiet with a minimum of agitation. In St. Louis time it seems that the conditions must have been favorable for chemical and biochemical action, so that the dominant rock constituent is micrite which had been described in literature as lithographic. This texture is the most characteristic property of the St. Louis Limestone.

From thin section examinations, it has been noticed that micrite is present and is the main constituent in almost all slides in all the stratigraphic sections except in few cases where oolites, dolomite or alteration of micrite to pseudospar is present. The largest percentage of micrite observed in thin sections is up to 87 in thin section 12-A of stratigraphic section A. Many other slides, in all stratigraphic sections, gave values of more than 50 percent micrite (see Pl. 6, Fig. 5). The occurrence of micrite in the thin sections studied is given in Table 3.

ii. Spar

Spar formed as calcite filling pore space present at the time the sediments were laid down, is the least abundant rock constituent present in the St. Louis Limestone. It is recognized that clear crystalline calcite forming the shells of the fossils and that formed by recrystallization of micrite are not actually spar in the sense defined above. In spite of this, some of the spar given in Table 3 includes that formed by recrystallization. Also, as mentioned in the description of the stratigraphic sections, the spar which occurs as large calcite crystals filling pores or vugs, is not true spar as this spar is formed after deposition and lithification of the rock to fill vugs or pores formed by dissolution of previously existing matter (believed to be carbonates).

In the oolite beds, especially close to the top of the formation, the given spar percentage is believed to be representative of a true spar. Spar also was noticed to be associated with intraclasts if present. Table 3 gives all the spar percentage as noticed in thin sections, and if that spar is believed to be formed by alteration processes, this is indicated under the "name" column as pseudosparite.

c. Miscellaneous

Under this title in Table 3, is included: percentage of pores, stylolite structures, percentage of chert, percentage of quartz, percentage of dolomite and others which includes either pyrite or clay or both. All of them have been discussed somewhere in this text except the pores, so a brief review is given here concerning the pores.

i. Pores

The term "pores" is preferred here rather than porosity because from

EXPLANATION OF PLATE 4

Fig. 1. Foraminifers and fossil fragments (crinoids) in micrite matrix. Slide 10-A, from the lower part of stratigraphic section A,x34.

Fig. 2. Foraminifer (center) and crinoid fragments in spar matrix. Slide 17-4, from the upper part of stratigraphic section B,x34.

Fig. 3. Foraminifer and crinoid fragments in micrite matrix. Notice that the chambers are filled with pseudospar. Slide 16-5, from the upper part of stratigraphic section B,x34.

Fig. 4. Foraminifer and crinoid fragments, matrix is pseudospar (recrystallized from micrite). The gray color is micrite. Slide 1-14, from the upper part of stratigraphic section C,x34.

Fig. 5. Foraminifer and crinoid plates and stems in micrite matrix. The light color is due to alteration of micrite to pseudospar. Slide 11-4, from the middle of stratigraphic section B,x34.

Fig. 6. Segment of coral (probably <u>Lithostrotion</u>) in micrite matrix. The pseudospar filling the corallite is recrystallized from micrite. See Plate 9, Figure 1 for complete section of the specimen. Slide 7-B, from the lower part of stratigraphic section A,x44.

PLATE 4

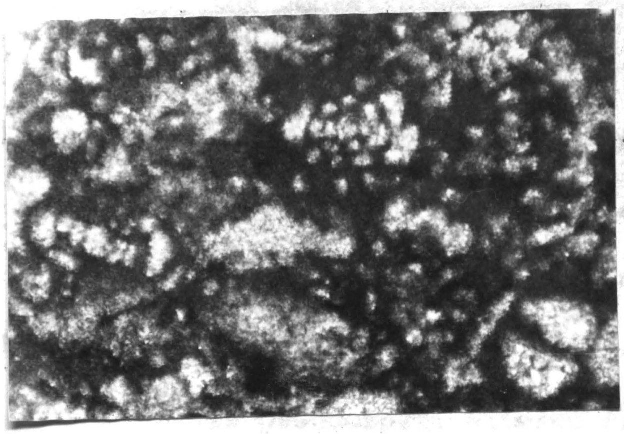


Fig. 1

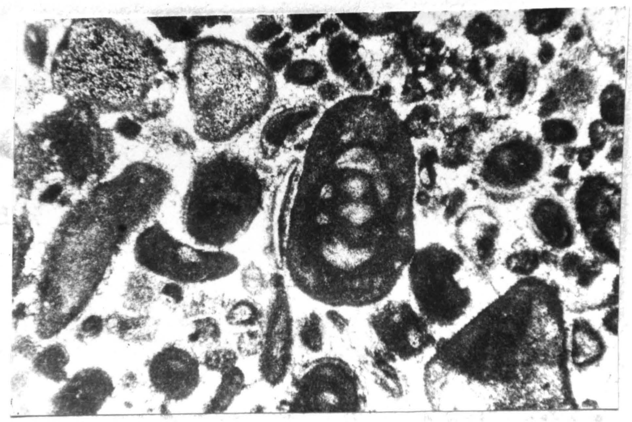


Fig. 2

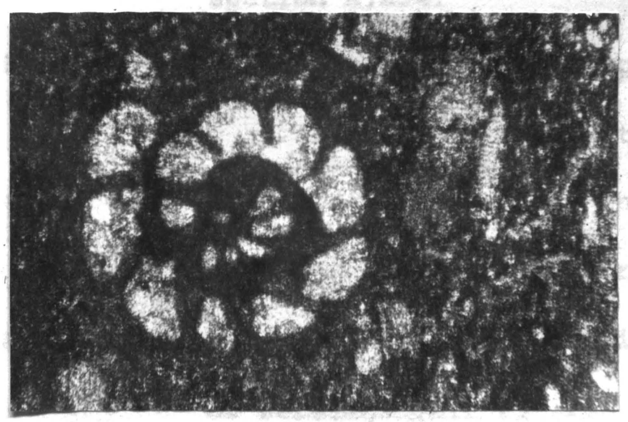


Fig. 3

Fig. 4

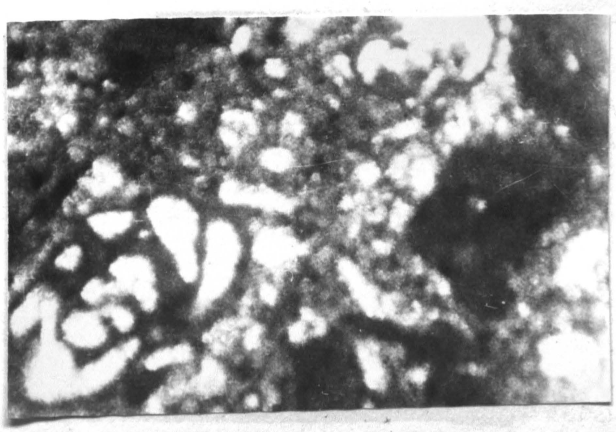


Fig. 5

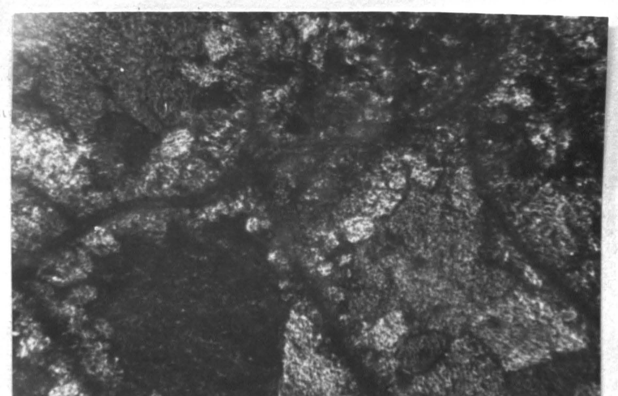


Fig. 6

EXPLANATION OF PLATE 5

Fig. 1. Bryozoan notice the inclusions of micrite and pseudospar in the fenestrules. The matrix is micrite. Slide 16-5, from the upper part of stratigraphic section B,x34.

Fig. 2. Bryozoan and crinoid stems in micrite matrix. The bryozoan material is recrystallized to pseudospar. Slide F-C, from the lower part of section A,x44.

Fig. 3. Bryozoan. The light colored material in the upper right corner is pseudospar, altered from the bryozoan material. The matrix is micrite. Slide 12-A, from the middle part of stratigraphic section A,x34.

Fig. 4. Bryozoan and crinoid fragments in micrite matrix. Slide 17-D, from the upper part of stratigraphic section A,x34.

Fig. 5. Bryozoan, crinoid fragments and foraminifer in micrite matrix. Slide 5-A, from the lower part of stratigraphic section A,x44.

Fig. 6. Bryozoan in micrite matrix. Slide 17-D, from the upper part of stratigraphic section A,x34.

PLATE 5

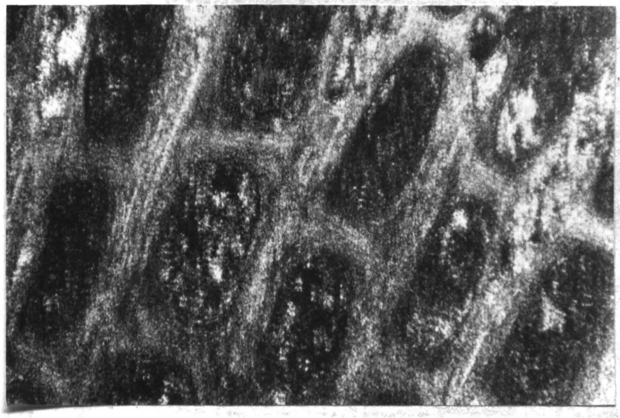


Fig. 1

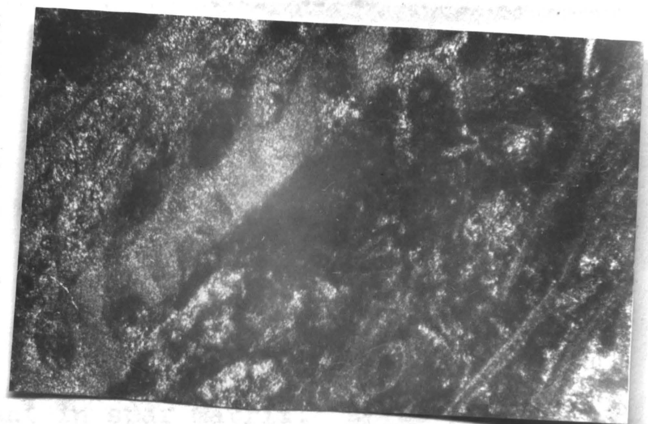


Fig. 2

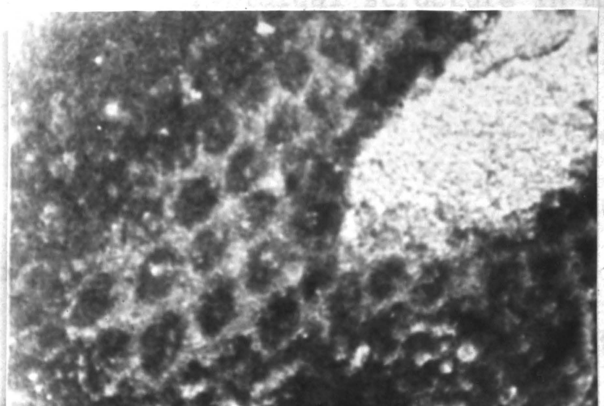


Fig. 3

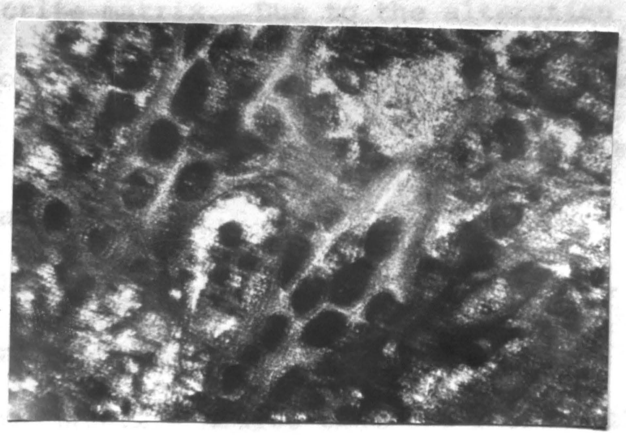


Fig. 4

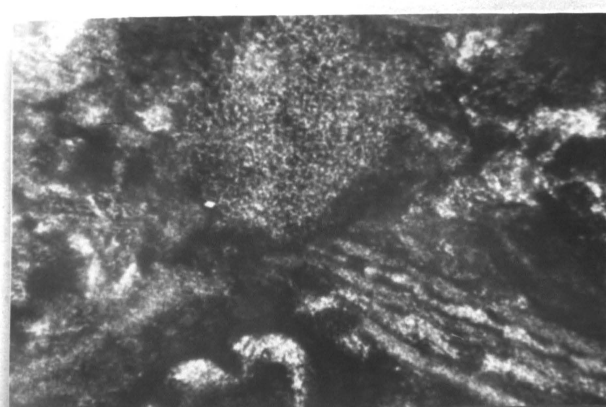


Fig. 5

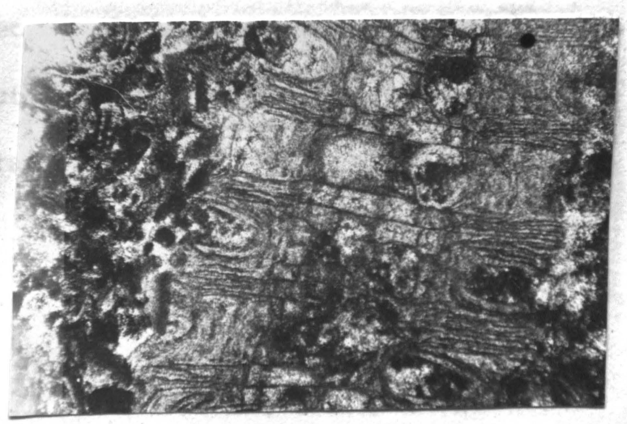


Fig. 6

Explanation of Plate 6

Fig. 1. Crinoid columnal and stems, foraminifer and a segment of coral (probably Lithostrotion). The matrix is micrite recrystallized to pseudospar. Slide 7-B, from the lower part of stratigraphic section A,x44.

Fig. 2. Crinoid columnal (center) and crinoid fragments. The matrix is spar. Slide 17-D, from the upper part of stratigraphic section A,x34.

Fig. 3. Crinoid columnal and fragment in spar matrix. Slide 20-A, close to the top of stratigraphic section A,x34.

Fig. 4. Cryptalgal structure in micrite matrix. Due to the alteration of the original material to pseudospar, it is hard to recognize any specific feature. The matrix is micrite. Slide 14-1, from the upper part of stratigraphic section B,x34.

Fig. 5. Brachiopod segment (upper left) in micrite matrix. Slide 12-A, from the middle part of stratigraphic section A,x34.

Fig. 6. Gastropod segment in micrite matrix. Notice that the shell wall is recrystallized to pseudospar and the inner part of the shell is filled with partially recrystallized micrite. See Plate 9, Figure 2 for a complete section of the shell. Slide 12-A, from the middle part of stratigraphic section A,x34.

PLATE 6

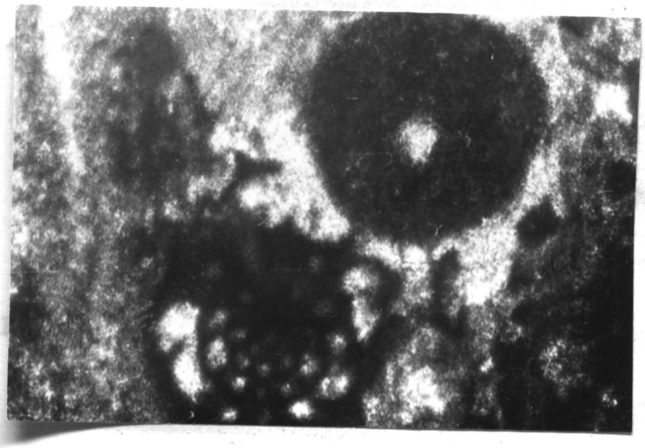


Fig. 1

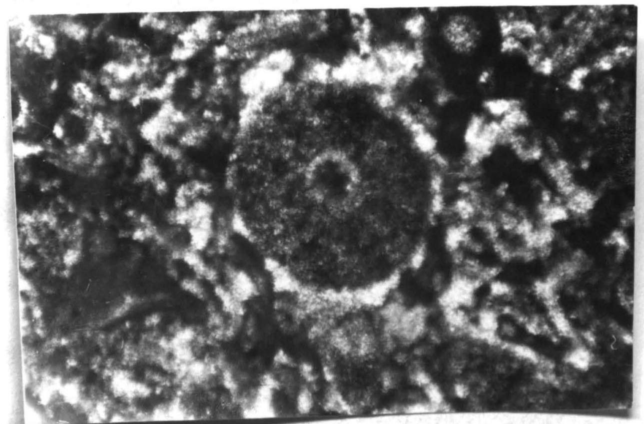


Fig. 2

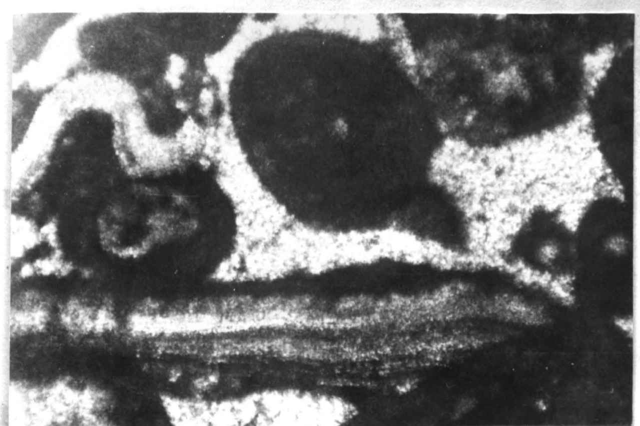


Fig. 3

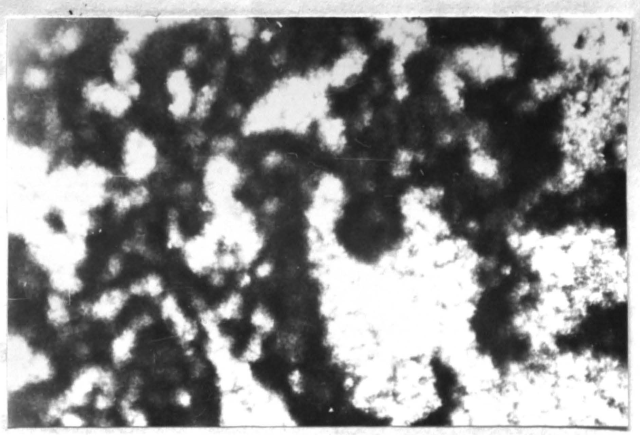


Fig. 4

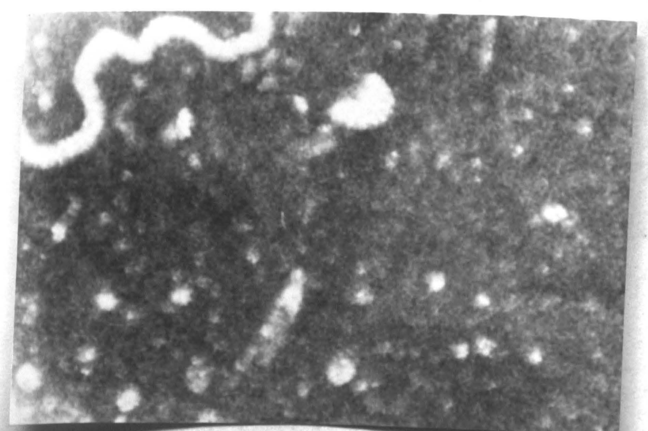


Fig. 5

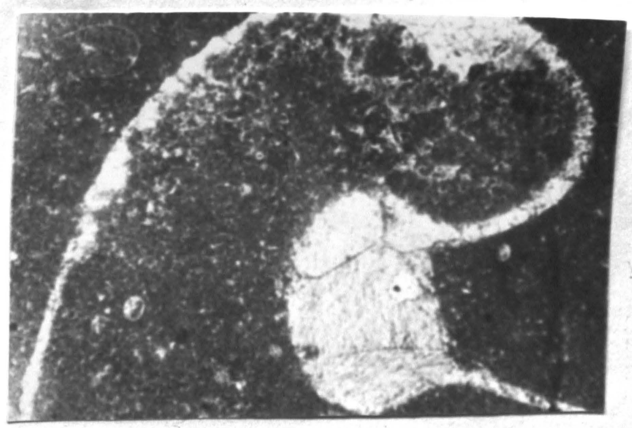


Fig. 6

EXPLANATION OF PLATE 7

Fig. 1. Oolites; both spherical- and elliptical-shaped in spar matrix. Slide 21-A, close to the top of stratigraphic section A,x34.

Fig. 2. Oolites and fossil fragments (especially crinoids). Notice that the nucleus of the oolite grain to the right of center is a fragment of a bryozoan. The matrix is spar. Slide 20-A, close to the top of stratigraphic section A,x34.

Fig. 3. Oolites. Notice the overgrowth around crinoid columnals which form the nuclei. The matrix is micrite. Slide 17-3, from the upper part of stratigraphic section B,x34.

Fig. 4. Oolites and pellets (notice the change in size), the matrix is spar. Slide 10-B, from the lower part of stratigraphic section A,x34.

Fig. 5. Conodont in micrite matrix. The conodont material has the typical dark brown color. Slide 10-A, from the lower part of stratigraphic section A,x34.

Fig. 6. Pseudospar (recrystallized micrite), the cloudy character is due to clay and micrite inclusions. Slide 1-1, at the base of stratigraphic section C,x34.

PLATE 7

Fig. 1

Fig. 2

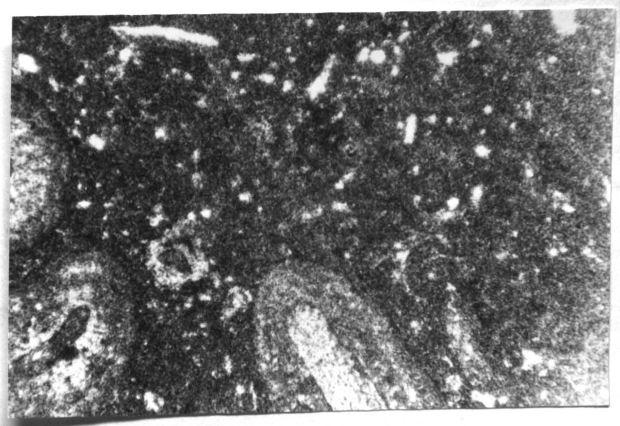


Fig. 3

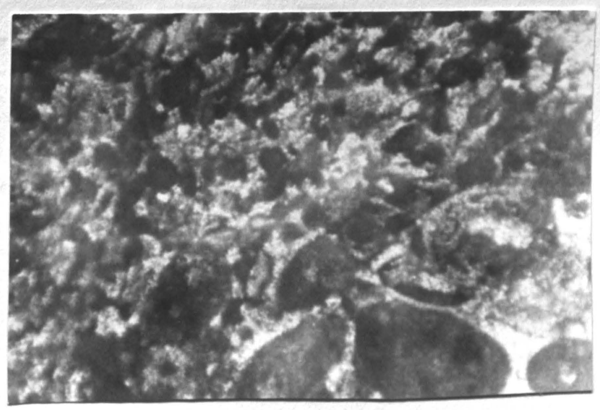


Fig. 4

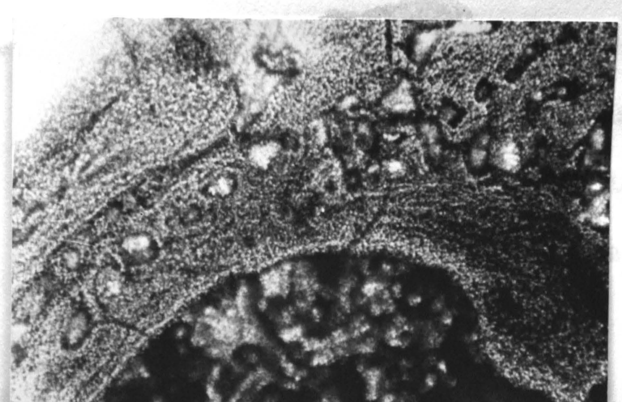


Fig. 5

Fig. 6

EXPLANATION OF PLATE 8

Fig. 1. Dolomite. The light color is due to quartz grains and the black areas are pores. Crossed nicols. Slide 26/3 of the dolomitic unit, from the middle part of stratigraphic section D,x34.

Fig. 2. Pyrite and quartz grains. The gray grains are dolomite. The pyrite is formed authigenically. Slide 26/3, from the middle part of stratigraphic section D,x34.

Fig. 3. Fractured dolomite. Fractures are filled with calcite. Slide 13-3, from the middle part of stratigraphic section B,x34.

Fig. 4. Fracture in limestone. The channel is filled with calcite. The effect of solution is evidenced by the dissolution of crinoid fragments and the presence of clay rim. The matrix is spar. Slide 21-A, close to the top of stratigraphic section A,x34.

Fig. 5. Stylolite structure adjoining foraminifer and crinoid stem, showing the effects of solution in the process of stylolite formation. Matrix is micrite. Slide 5-A, from the lower part of stratigraphic section A,x44.

Fig. 6. Geode structure, notice the increase in the size of quartz crystals towards the geode core (lower part). The dark color in the upper part is chert. Crossed nicols. Slide 37/1, at the base of stratigraphic section D,x34.

PLATE 8

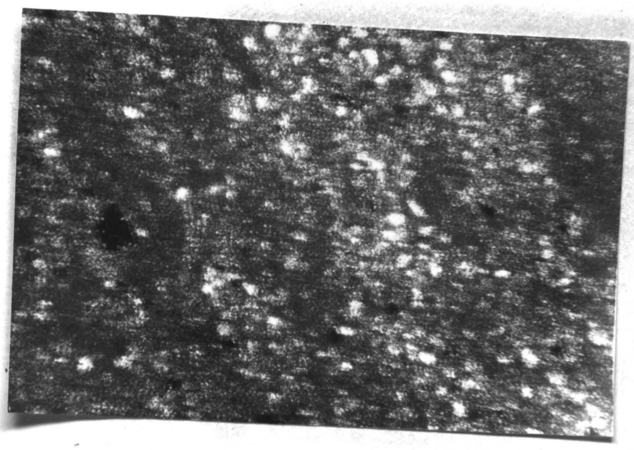


Fig. 1

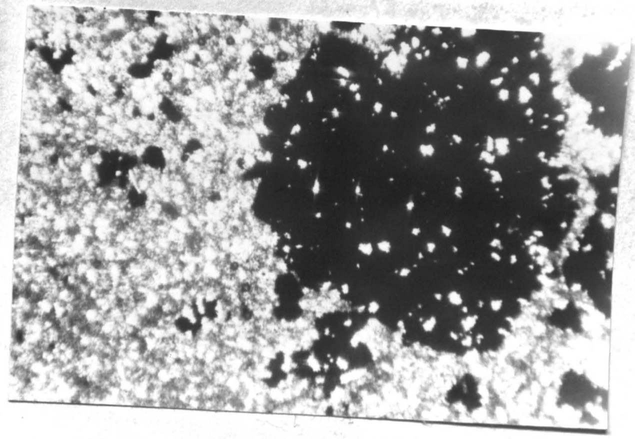


Fig. 2

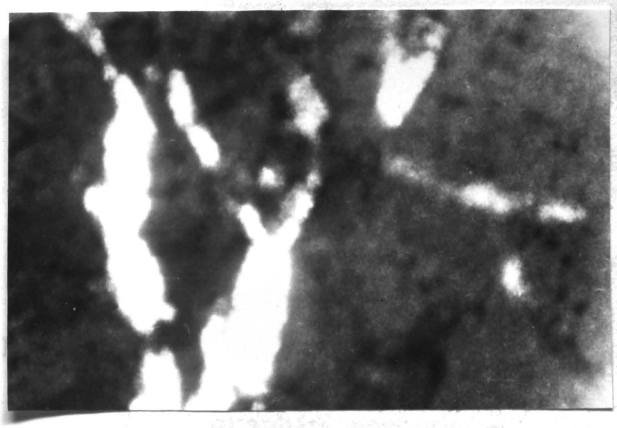


Fig. 3

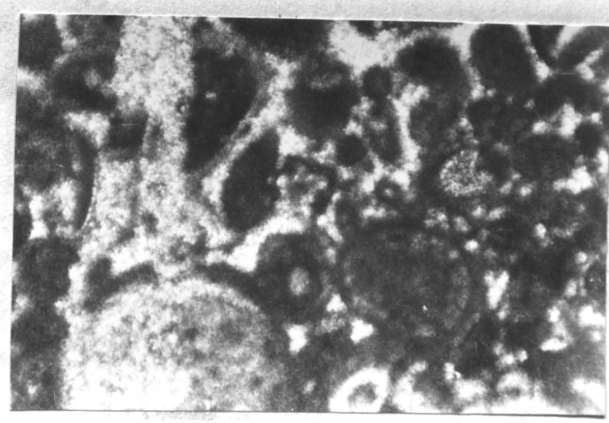


Fig. 4

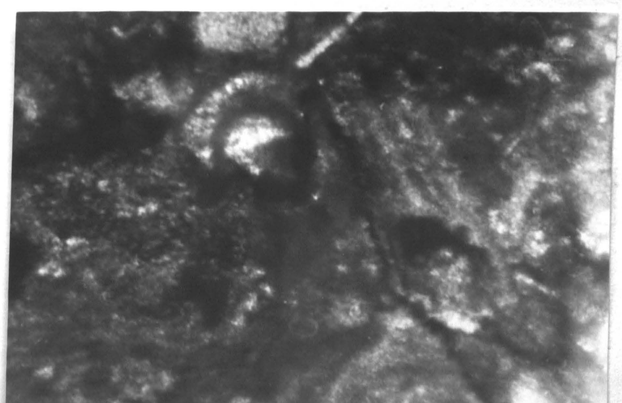


Fig. 5

Fig. 6

EXPLANATION OF PLATE 9

Fig. 1. Coral (probably *Lithostrotion*). Complete section through the specimen. Matrix is micrite. Slide F-B, from the lower part of stratigraphic section A,x3.8.

Fig. 2. Gastropod. Complete section of the specimen. Matrix is micrite. Slide 12-A, from the middle part of stratigraphic section A,x7.

Fig. 3. Stylolite. The photo is for a polished specimen. The sample is 5-A of stratigraphic section A.

Fig. 4. Geode. The photo is a polished specimen. The sample is 37/1 from the base of stratigraphic section A.

Fig. 5. Breccia. Notice the difference in sizes and shape. The cementing material is calcite which is introduced after brecciation. Slide 0-A, at the base of stratigraphic section A,x3.

Fig. 6. Breccia. The photo is for the breccia at the base of stratigraphic section A. The knife is 10.4 cm long.

PLATE 9

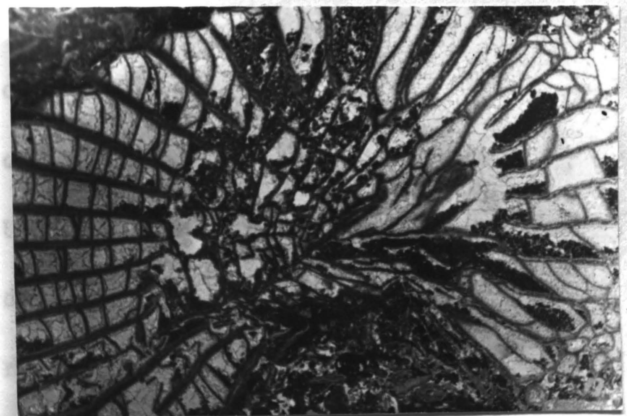


Fig. 1

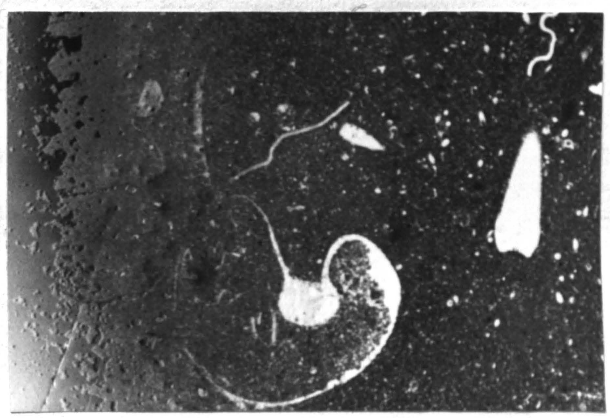


Fig. 2

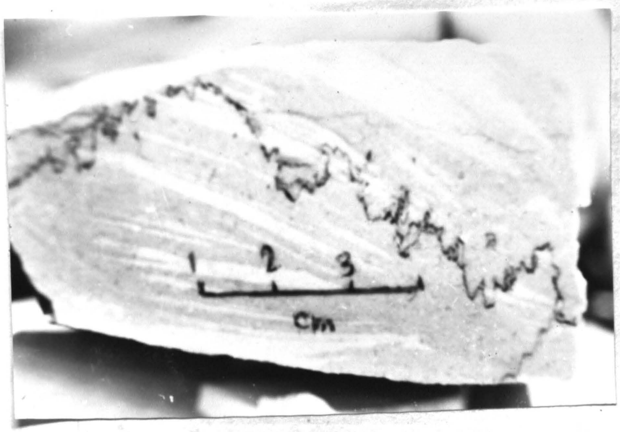


Fig. 3

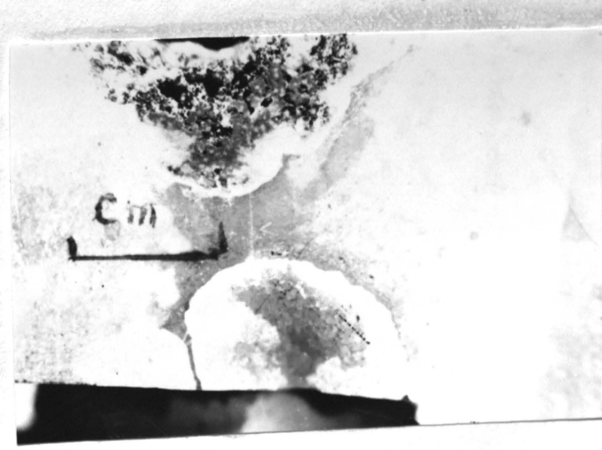


Fig. 4

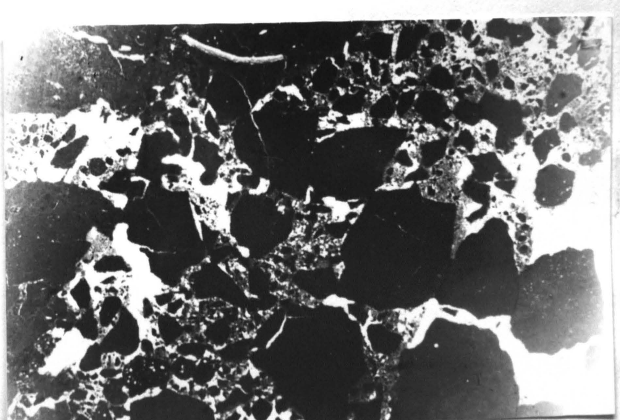


Fig. 5

Fig. 5

EXPLANATION OF TABLE 3

Table 3 is divided into three major parts. The first is general information, the second is for the summary of the petrographic examination of the thin sections and the third is for the insoluble residue analyses of the same samples for which the corresponding thin sections were cut. Under "general" there are three columns: the first is for the sample designation as described under "method and procedure" in Chapter I. The next column is the designation for the stratigraphic section from which the specimens for the thin sections have been obtained (see Table I, p.4). The symbols given to each stratigraphic section are used here. The third column is for the stratigraphic location of the sample within the section, the position of the sample being measured in feet from the base of the stratigraphic section considered. The second and major part of the table, "Summary of petrographic study", is subdivided into four main subdivisions: allochems, orthochems, miscellaneous, and rock name according to Folk. Allochems and orthochems are used as defined in this Chapter (pp. 54 and 56) under "miscellaneous" are given all other descriptive, compositional and structural features. The last major part tabulates the results obtained from the insoluble residue analyses; the different columns included in this part are self-explanatory.

Some of the symbols used require explanation:

1. Under fossils:

   D represents the most dominant kind of fossils, where more than one kind are equally dominant, the same letter is used for each. This designation of the amount of that kind of fossil does not imply any specific percentage.

L represents the less dominant kind of fossil.

E represents the least abundant fossil, or material indefinitely identified.

The column dealing with "other" in the fossil subdivision, has the following symbols used as indicated below:

C stands for corals

G stands for algae

O stands for ostracode

N stands for conodonts

2 Under "others" in miscellaneous, the following terms are used:

F for ferruginous stains

T for pyrite

3 C for clay or shale

The presence of stylolites are indicated by x; also the same designation is used for pyrite in the insoluble part.

Blank space indicates that this particular item is not present.

The percentage given in the table is to the closest two figures, and it is based on visual estimation, except in the insoluble part the values given are the actual percent as revealed by the analyses.

GENERAL			SUMMARY OF PETROGRAPHIC STUDY																					INSOLUBLE RESIDUE				
			ALLOCHEM											ORTHOCHEM			MISCELLANEOUS								KIND			
			FOSSILS																									
SAMPLE DESIGNATION	LOCATION	POSITION	BRACH.	BRY.	CRINOID.	FORAM.	GASTROP.	OTHERS	% TOTAL	OOLITES	PELLETS	INTRACLAST	% TOTAL	MICRITE	SPAR	% TOTAL	% PORES	STYLOLITE	CHERT	QUARTZ	DOLOMITE	OTHERS	NAME ACCORDING TO FOLK (1959) CLASSIFICATION	%	% FINE	QTZ. & CHT.	PYRITE	OTHERS
0-A	A	0.0												73	16	89	1			1	9		brecciated-micrite	1.8		1		
0-A'	A	1.0	L						1					81	10	91	2			2	4		brecciated-micrite	3.1		3		
1-B	A	8.5		D				G?	30			7	7	45	10	55	1			7		CT	biomicrite	12.	8	4	X	
1-D	A	11.0	E	L	D	D			15		3	7	10	53	17	70	2			3			biomicrite	2.6		3		
2-A	A	12.5	L		L	D			16			8		55	16	71	1			4		C	biomicrite	3.7	1	3		
2-B	A	14.0	L	E	L	D		G?	12			13	13	55	15	70	2			3		C	sparry-micrite	1.1		1		
2-C	A	15.3	E		D	D		C	45		8	10	18	20	15	35	1			1		C	biomicrite	1.9	1	1		
3-A	A	17.0	L	L	D	D			20	20		10	30	8	40	48	1			1		C	biosparite	1.9	1	1		
5-C	A	26.2	L	D	D	D		G?	48			13	13	24	12	36	1			2		C	biomicrite	2.9	1	2		
5-A	A	28.5	L	D	D	L	E		55			10	10	28	6	34		x		1		C	biomicrite	1.6	1	1		
7-A	A	34.0	L	D	D	L	E	G?	25			5	5	65	3	68				2		T	biomicrite	6.5		6	X	
7-B	A	38.5	E	L	L	D		C	58					30	10	40				1		C	biomicrite	4.4	2	2		
7-C	A	40.5	D	D	L	L		0	30					60	7	67		x		3		TF	biomicrite	6.9		5	X	F
7-D	A	41.0			L	D		G?	30	25		5	30		38	38	1			1		T	biosparite	1.1		1	X	
8-A	A	47.5													15	15				5	80	TF	calc-dolomite	9.9	2	7	X	F
10-A	A	52.5		L	L	D		N	31			7	7	60		60		x		2		C	biomicrite	3.5	1	3		
10-B	A	53.7	E	L	D	D			45	5	15		20	13	20	33		x		2		T	biosparite	2.0		2	X	
10-C	A	55.0													3	3	1			5	90	T	dolomite				X	
11-A	A	56.5													7	7	1			2	92	C	dolomite	2.3		2		
12-A	A	64.0	D	L	L	E	D		12					87		87				1		C	biomicrite	5.6	1	5		
13-B	A	80.0	L	L	D	D	D	G?	25	2	3	6	11	58	5	63		x		1		C	biomicrite	3.	1	2		
17-A	A	94.0	L	D	L				32			5	5	60	3	63				1			biomicrite	1.		1		
17-B	A	99.0		D	L	L			30	2		5	7	60	2	62		x		1		C	biomicrite	2.1	1	1		
17-C	A	103.0	L	D	L				35		8		8	15	40	55				1		FT	biosparite	1.3		1	X	F
17-D	A	108.0	E	D	D	E			55					11	35	46				1		T	biosparite	2.		1	X	
18-A	A	112	E	D	D	L			32					57	8	65	1	x		1		T	biomicrite	2.4		2	X	
19	A	113			L	L			7			18	18	50		50	1			23		CT	quartz-micrite	25.	2	23	X	

TABLE 3

GENERAL			SUMMARY OF PETROGRAPHIC STUDY																					INSOLUBLE RESIDUE				
			ALLOCHEM											ORTHOCHEM			MISCELLANEOUS								KIND			
			FOSSILS																									
SAMPLE DESIGNATION	LOCATION	POSITION	BRACH.	BRY.	CRINOID.	FORAM.	GASTROP.	OTHERS	% TOTAL	OOLITES	PELLETS	INTRACLAST	% TOTAL	MICRITE	SPAR	% TOTAL	% PORES	STYLOLITE	CHERT	QUARTZ	DOLOMITE	OTHERS	NAME ACCORDING TO FOLK (1959) CLASSIFICATION	%	% FINE	QTZ. & CHT.	PYRITE	OTHERS
20-A	A	117	E		L	E			7	25	18		33		58	58	1			1			oosparite	1.1		1		
21-A	A	120	E		D	L			7	40	7		47		45	45		x		1		C	oosparite	2.5	1	2		
24-A	A	126	E		L	L			7			30	30		21	21				42		C	quartz-intrasparite	43.	1	42		
25	A	129			D				5	27			27		30	30				29	8	CF	oosparite	29.	1	28		F
26	A	135	E		D				5	45				10	20	30				20			oosparite	21.		20		
-1-A	B	2.5												8	11	19	1			5	75	TC	calc-dolomite	5.4		5	X	
-1-B	B	5.										15	15		20	20	2			3	55	C	calc-dolomite	4.	1	3		
-1-C	B	7.5	L	L	D	D	L		35			20	20		30	30	2			4	9	C	biosparite	4.4		4		
1-2	B	22.5	L		L				5						12	12				8	75	T	calc-dolomite	8.2		8	X	
1-5[1]	B	29.															2	x		8	90	C	dolomite					
3-2	B	40.5															1			15	83	CT	dolomite	17.	2	14	X	
4-2	B	44.5	L		D			G?	15					65	15	80				5		CT	biomicrite	4.6	1	4	X	
5-3	B	49.5													62	62			3	5	30	C	pseudosparite	5.8	1	5		
6-2	B	51.5													90	90				2	8	C	pseudosparite	6.0				
8-1	B	53.4	L	L	L			G?	13					83	3	86		x		1		CT	biomicrite	1.7	1	1	X	
9-2	B	57.5		D		L		G	12		25		25	32	18	50	1			10	2		pelmicrite	7.7		8		
10-2	B	61.															4			10	86	C	dolomite	7.7	C			
10	B	62.2		L	L	D			12		4		4	58	6	64			20			CF	cherty biomicrite	21.	1	20		F
11-1	B	63	L	D	D	L			55		4		4	30	8	38				3			biomicrite	2.4		2		
11-3	B	66	E	E	D		L		8					70	3	73	1			3	15		dolmicrite					
11-4	B	67.3		E	L	D	L		20			25	25	13	40	53	1			1			intrasparite	2.		2		
11-7	B	71.5		E	D	L			15	32		25	57	3	30	33				2			intrasparite	2.2		2		
12-5	B	80															3			8	89	C	dolomite	8.3		8		
13-1	B	89		E	D				8		5		5	70	12	82	1	x		3		TC	dismicrite	2.4		2	X	
13-3	B	92													5	5				6	89	TC	dolomite	5.5	1	5	X	
13-4	B	93.5													5	5	2			8	85	CT	dolomite	9.7	2	8	X	

TABLE 3 CONT.

GENERAL			SUMMARY OF PETROGRAPHIC STUDY																					INSOLUBLE RESIDUE				
			ALLOCHEM											ORTHOCHEM			MISCELLANEOUS						NAME ACCORDING TO FOLK (1959) CLASSIFICATION	%	KIND			
SAMPLE DESIGNATION	LOCATION	POSITION	FOSSILS							OOLITES	PELLETS	INTRACLAST	% TOTAL	MICRITE	SPAR	% TOTAL	% PORES	STYLOLITE	CHERT	QUARTZ	DOLOMITE	OTHERS			% FINE	QTZ. & CHT.	PYRITE	OTHERS
			BRACH.	BRY.	CRINOID.	FORAM.	GASTROP.	OTHERS	% TOTAL																			
14-1	B	99.5												58	37	95	1			2	2	C	sparry-micrite	1.5	1	1		
14-3	B	102.	L		L	D		G	5					50	15	65	1			14	15	CT	dolmicrite	13	1	12	X	
14-4	B	104.	L		D	D	L		13	3	5	36	44		43	43							intrasparite	2.4				
15-3	B	110	E	E	D	E			22			20	20	15	30	45	1	x		2	9	CF	biosparite	2.8	1	2		F
16-1	B	113	L	D	D		L		51		8	5	13		36	36						FC	biosparite	0				F
16-3	B	115	L	D	D	L			35			10	10	39	10	49		x		6		CT	biomicrite	9.7	2	7	X	
16-4	B	116		L	L	D		C	15			12	12	60	10	70				3		FC	biomicrite	6.2	1	5		F
16-5	B	117	L	L	D	D			20					61	10	71	1			8		F	biomicrite	9.2		9		F
16-6	B	118	L	D	L	L		G?	50					210	5	45	1			4		FC	biomicrite	4.4		4		F
17-3	B	120			E				4	28			28	63		63				5		C	oomicrite	5.7	1	5		
17-4	B	121			L	D			22	13	10		23		50	50	2			3			biosparite	3.6		3		
18-3	B	125	L	D	L		E		13					72	5	77				10		CT	biomicrite	9.7	1	8	X	F
19-2	B	128													2	2	2			6	90		dolomite	8.8		9		
20-1	B	130	D	D	L				14			7	7	74		74	2	x		3		CF	biomicrite	5.8	1	4		F
20-3	B	138							2					88		88	1			4	5		micrite	7.7		8		
20-5	B	145	E	D	L				15		32		32	50		50				3			pelmicrite	4.8		5		
1-1	C	1.													90	90	1			2	7	C	pseudosparite	2.		2		
1-3	C	8.7												85	5	90	2	x		1	7	TC	micrite	1		1	X	
1-7	C	22.3			L	E			7		32	15	47		41	41	2			3			pelsparite	1.4		1		
1-9	C	30.6		?					5					20	8	28	1			8	58		calc. dolomite	8.1		8		
1-11	C	74.8	E	L			?		14					85		85				1			biomicrite	.7		1		
1-12	C	79.3	E	L	D	D			27					66	5	71				2			biomicrite	1.9		2		
1-14	C	89.1	E	D	D	L			35		8		8	21	35	55	1			1		CF	biosparite	2.4	1	1		F
1-16	C	98.7		C	D	L			15	30			30	25	30	55							oosparite	0.4				
1-17	C	105.		L	D	L	?		20					60	18	78	1			1		CT	biomicrite	1.5		1	x	
1-19	C	113.	L	D	L	L			20		8		8	65	5	70	1			1			biomicrite	1.6	1	1		

TABLE 3 CONT.

GENERAL			SUMMARY OF PETROGRAPHIC STUDY																					INSOLUBLE RESIDUE				
			ALLOCHEM											ORTHOCHEM			MISCELLANEOUS						NAME ACCORDING TO FOLK (1959) CLASSIFICATION	%	KIND			
			FOSSILS																									
SAMPLE DESIGNATION	LOCATION	POSITION	BRACH.	BRY.	CRINOID.	FORAM.	GASTROP.	OTHERS	% TOTAL	OOLITES	PELLETS	INTRACLAST	% TOTAL	MICRITE	SPAR	% TOTAL	% PORES	STYLOLITE	CHERT	QUARTZ	DOLOMITE	OTHERS			% FINE	QTZ. & CHT.	PYRITE	OTHERS
37/1	D	2.2																	85	15		FC	chert					
36/1	D	3.2	E	D	D			G?	50		5	25	30	4	15	19		x		1		C	biosparite	2.2		2		
36/3	D	10.7								3			3		50	50	2		25	20		C	cherty pseudosparite					
35/2	D	14.7	E					G?	8			7	7	35	5	40			35	10			cherty micrite	21		21		
33/1					L	L			5					4	25	29				5	60		cal-dolomite	8.7		5		
32/2	D	31.5	E		D	D	E	G	35	5		7	12	42	8	50	1			3		C	biomicrite	2.2		2		
30/1	D	35.0	L	D	L	D		G?	25		18		18	55		55				1		T	biomicrite	1.5		1	X	
30/4	D	41.8								40			40	59		59				1			oomicrite	1.5		1		
28/2	D	51.3													88	88	1			5	6	T	pseudosparite	4.5		4	X	
28/6	D	55.2	L		D	E			7				7	10	80	90	2	x		1		C	biosparite	1.2		1		
27/2	D	60.0	L		L	D			17					80		80	1	x		2			biomicrite	2.7		2		
27/5	D	65.3			L			C	8					70	8	78	6			8			biomicrite	9.3		9		
26/3	D	75															2			14	80	T	dolomite	18		18	X	
24/1	D	82.0												93		93	1	x		4	2	CT	micrite	3.2		3	X	
21/2	D	102.	L						2	28			28	68		68		x		2			oomicrite	2.6		2		
21/3	D	104.	D	E	D	D			44					50	5	55				1			biomicrite	1.7		1		
20/2	D	113.	E	D	L	D			35	3			3	60		60		x		2		C	biomicrite	2.9		2		
20/3	D	116.			D	D			11	12	30		42		45	45				2		C	pelsparite	1.7		1		
18/2	D	135.	L	D	E	D		C	30		8		8	56	5	61				1			biomicrite	1.8		1		
18/3	D	136.	L	L	D	D	L		20	4			4	68	5	73	1	x		2		C	biomicrite	2.9		2		
17/1	D	150.	E	L		L		G	12	26	10		36		46	46	2			4		C	oosparite	10.	1	9		

TABLE 3 CONT.

the definition (both absolute and relative porosities) must imply total volume of pores compared to total volume of sample. From the study of thin sections, it is questionable whether these pores will be, on the average, indicative of the total volume of pores in the sample or not, as these pores are seen only in two dimensions; moreover, the way the thin section is cut may have an effect on the porosity estimation. No effort was made to determine whether the porosity is primary or secondary, although all the pores associated with the dolomitized units are believed to be secondary. Though the main rock constituent is micrite, which may have a high original pore space, the pores observed constitute only 1 to 2 percent in most of the slides, which may suggest a high degree of compaction after the sediments were laid down. It may be mentioned that some pores have been produced due to grinding of the slides.

The highest percentage of pores in micrite is 3, in thin section O-A' and in dolomite, it is 4, in thin section 10-2. The pore space estimation based on thin section alone is not conclusive. It is seen in Table 3 that slide 27/5 has 6 percent pores, but this high percentage is due to grinding.

2. Main Rock Names

Attempted here will be to determine names for the most dominant rock types. To achieve this purpose, a count for each rock name as given in Table 3 was made. The resulting statistics are as given in Table 4. It might be mentioned here that, when choosing slides studied in Table 3, it was not intended for quantitative estimate, but the reason for the choice was mainly to show as many features as possible; this led to excluding many slides that were essentially micrite and this is reflected clearly on the resulting number of micritic rock types.

Stratigraphic section	Number of thin sections used	Micrite	Biomicrite	Intramicrite	Oomicrite	Pelmicrite	Biosparite	Intrasparite	Oosparite	Pelsparite	Dolomite	Others
A	32	4	15				5	1	4		3	
B	37	5	10		1	2	4	3			10	2
C	10	1	4				1		1	1	1	1
D	21	2	8		2		2		1	1	2	3
Total	100	12	37	0	3	2	12	4	6	2	16	6

Table 4. Summary of the different rock types; data is summarized from Table 3.

The singular name micrite was given in the case where the allochems present in the slides do not exceed 10 percent of the total rock and the thin section is essentially composed of this microcrystalline calcite ooze, a boundary which is suggested by Folk (1959, p. 26). He also suggested using a modifying name with micrite. This modifier is based on the most dominant constituent of the allochems, which in this report, is fossils. Fraom Table 4 it is seen that the most dominant rock types present are "biomicrite", followed by "biosparite" and "micrite". This result is in agreement with the general lithographic character of the St. Louis Limestone. The next largest count of the rock types is the "oosparite", which in all stratigraphic sections appear in the upper part close to St. Louis-Ste. Genevieve contact. The dolomite was not regarded seriously in the counts as the main attention was given to the limestone rock types. The rock was called dolomite if it contained more than 50 percent dolomite, with a descriptive name for the other component, if they are present in amounts more than 5 percent and less than 50 percent. This other component is clacite in this formation, so the name is "calcareous dolomite". If the dolomite content is from 10 percent to less than 50 percent, and the calcite present is more than 50 percent, and the dolomite is of secondary origin, as considered here, the modifier name is "dolomitized" followed by the rock name.

E. Chemical Composition

Although it is not the main objective of this report to present chemical analyses of the St. Louis Limestone, available chemical analyses are briefly discussed here. The analyses are made from the limestone section of drill hole number 5, and is kindly provided by the Missouri Portland Cement Company. Table 5 gives the analyses of three composite

Stratigraphic Position	Thickness Inches	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Ignition Loss %	Total
Ste. Genevieve and upper St. Louis	834	3.84	0.30	0.59	52.35	1.25	41.03	100.26
Middle St. Louis	141	8.30	0.84	1.34	31.20	17.76	40.16	99.60
Lower St. Louis	763	6.90	0.34	0.82	48.15	1.57	41.95	99.73

Table 5. Chemical analyses of stratigraphic section D. The analyses is provided by Missouri Portland Cement Company. The middle St. Louis in the table, is only units 25 and 26 of stratigraphic section D.

stratigraphic intervals: lower St. Louis, middle St. Louis and upper St. Louis with the Ste. Genevieve contact. The thickness of each part is given in column two. Under ignition loss due to the evolution of CO_2 is included also H_2O and SO_2, if present. Also, if any FeO is present, is included with Fe_2O_3.

It will be noticed that the analysis of the middle part shows some variation with regard to the upper and lower parts. The increase in SiO_2, Fe_2O_3 and MgO and the decrease in CaO can all be attributed to the advent of dolomite in the middle part-mainly units 25 and 26 of Fig. 9. Most, if not all, Fe_2O_3 present is due to higher clay and shale content associated with the dolomite. It is clear that there is a higher percentage of SiO_2 in the upper part of the formation than in the lower part; a fact which is shown also by the insoluble residue analyses.

The chemical analysis of carbonate rocks has its significant value in industry where the Ca/Mg ratio is a most important factor. For that reason, Hinchey, Fischer and Calhoun (1947) gave complete chemical analyses of 105 samples taken from seven selected locations from the St. Louis Limestone. The chemical analyses, in general, have no geologic application especially in regard to the classification of limestone.

F. Insoluble Residue Analyses

Insoluble residue is a technique which has been used for 40 to 50 years ago, especially in the Ozark region by the Missouri Geological Survey and Water Resources to correlate subsurface formations where there are neither changes in lithology nor good fossil markers to depend upon. The method is of primary and vital value in subsurface correlation using well cuttings from carbonate formations, whether cherty or not. Besides the Missouri Geological Survey, there are other state surveys and mining and oil companies that use the technique.

The method involves the dissolution of a specified amount of a sample in dilute HCl acid, drying, determining the amount of residue and then identifying the kind of residue under the binocular microscope. The method used here involved taking a portion of each sample, crushing it to pea-sized fragments, then weighing it. The weighed part is allowed to be dissolved in a 10 percent concentration of HCl, and heated if necessary. After reaction ceases completely, the insoluble portion is filtered, then dried to room temperature and weighed. Then the percentage of the insoluble is calculated. Although the use of insoluble residue is not of primary importance in correlation here, it is included to see the extent of variation of insoluble residue from one unit to another and from one section to another and, also, if it is of any correlation value in determining the general relationship of the stratigraphic sections.

The insoluble residue has been determined for each sample from each stratigraphic section, then an average value for each unit is made, excluding the inconsistent values, i.e., these which have higher than normal residues due to the existence of chert nodules. The insoluble matter have been examined under the binocular microscope. From the examination it has been revealed that generally, the lower part of all the stratigraphic sections contains small quartz grains of fine sand to coarse silt size. These quartz grains are well crystallized (euhedral grains), and some of them are elongate. Some finer quartz grains were also present as well as some minor amounts of cubic crystalline pyrite. The insoluble residue of the upper part of the stratigraphic sections, on the average, showed quartz grains of sand-size, some of them are angular to subangular and others are sub-rounded with some pitted or

Section location	Unit no.	Thickness (ft.)	No. of samples	Average percent	Lithology of the unit
A	0	7.9	5	3.1	brecciated limestone
A	1	3.4	4	4.0	limestone
A	2	4.3	3	2.2	limestone
A	3	6.8	2	4.3	limestone
A	5	6.2	3	2.5	limestone
A	6	2.5	2	6.0	limestone
A	7	13.0	4	4.7	limestone
A	8	6.0	2	5.4	dolomite
A	9	1.4	1	4.7	limestone
A	10	3.4	3	2.8	limestone
A	11	6.0	3	8.1	dolomite
A	12	5.5	1	5.6	limestone, slightly dolomitic
A	13	20.0	2	4.9	limestone
A	17	21.0	4	1.6	limestone
A	18	2.2	1	2.4	limestone
A	19	4.0	2	14.0	quartzitic limestone
A	20	2.6	2	1.0	limestone
A	21	3.3	3	4.1	limestone
A	23	5.0	1	1.1	limestone
A	24	4.0	1	43.0	quartzitic limestone
A	25	3.4	1	29.0	quartzitic limestone
A	26	7.3	1	21.0	quartzitic limestone
B	-1	8.8	3	4.7	dolomite
B	-2	7.0	1	4.2	dolomite
B	-3	5.3	1	3.3	dolomite
B	1	11.0	8	8.6	dolomitic limestone to calc. dol.
B	2	6.2	2	17.0	dolomite, calc.
B	3	4.0	3	14.0	dolomite
B	4	3.0	2	7.6	limestone, dolomitic
B	5	4.8	3	7.4	dolomite, calc.
B	6	2.9	3	4.2	dolomite, calc.
B	8	1.8	3	2.8	limestone, dolomitic
B	9	4.3	3	3.9	limestone, slightly dolomitic
B	10	2.0	3	11.0	dolomite, slightly calc.
B	11	9.9	7	5.0	limestone, dolomitic
B	12	15.0	11	7.6	dolomite
B	13	11.0	7	4.5	limestone, dolomitic below
B	14	7.6	5	4.0	limestone
B	15	6.0	4	6.3	dolomite, cherty
B	16	6.5	6	6.1	limestone, slightly dolomitic
B	17	4.0	5	5.0	limestone, slightly cherty

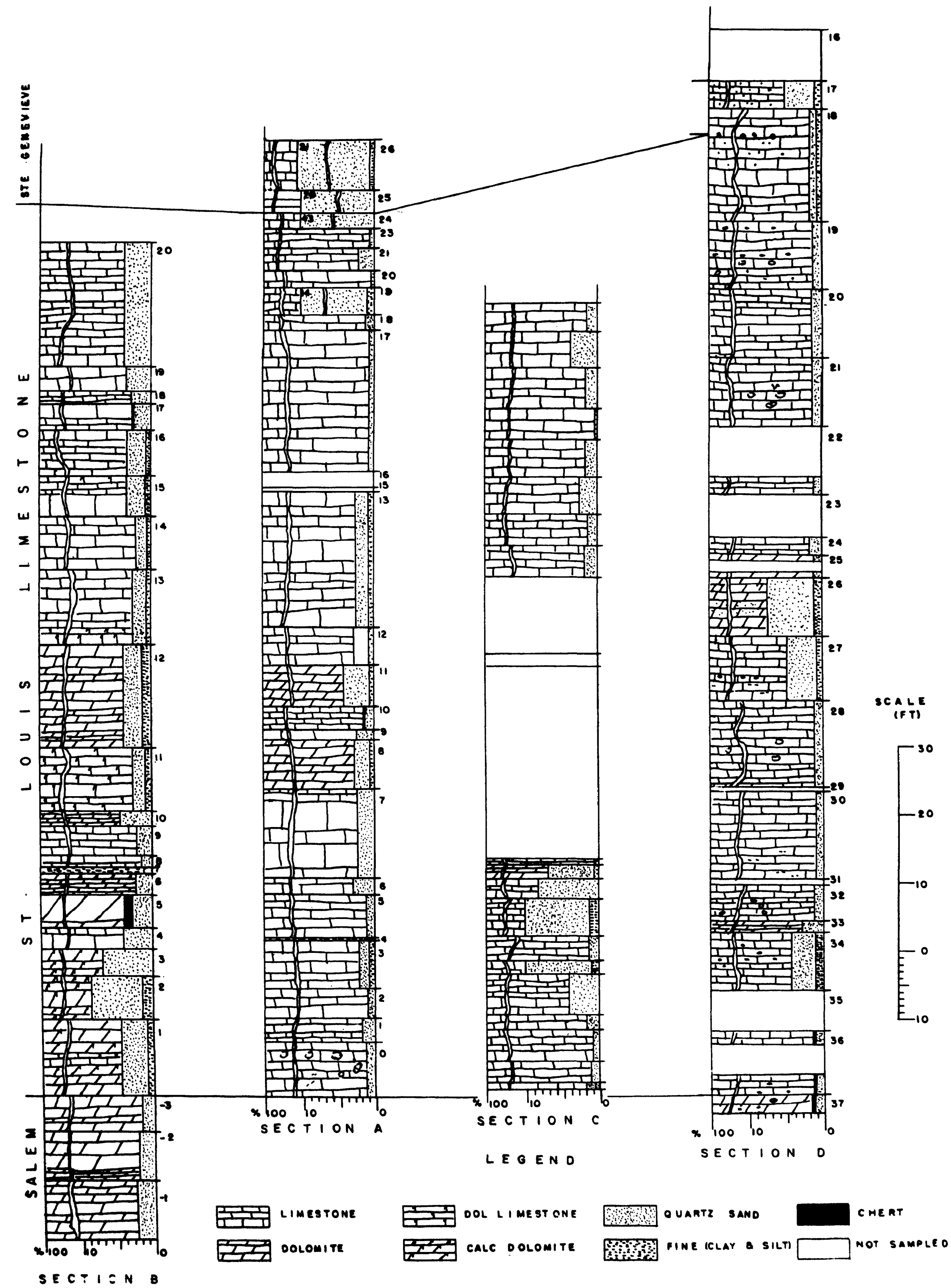
Table 6. Summary of insoluble residue data.

Section location	Unit no.	Thickness (ft.)	No. of samples	Average percent	Lithology of the unit
B	18	1.8	3	5.5	limestone, cherty
B	19	3.5	2	6.3	limestone, dolomitic, sandy
B	20	18.0	5	7.0	limestone
C	1	3.0	1	2.0	limestone
C	2	4.7	1	1.3	limestone
C	3	2.0	1	1.0	limestone
C	4	6.0	1	1.8	limestone
C	5	2.0	1	4.1	limestone
C	6	3.6	1	10.0	limestone
C	7	5.4	1	1.4	limestone
C	8	3.0	1	10.0	limestone
C	9	1.9	1	8.1	limestone, slightly dolomitic
C	10	2.1	1	6.9	dolomite
C	11	3.7	1	0.7	limestone, fractured
C	12	4.5	1	1.9	limestone
C	13	4.3	1	1.2	limestone
C	14	5.5	1	2.4	limestone
C	15	5.2	1	1.7	limestone
C	16	4.4	1	0.4	limestone
C	17	6.0	1	1.5	limestone
C	18	5.3	1	3.6	limestone
C	19	3.0	1	1.6	limestone
D	37	2.7	2	3.8	dolomite, one sample is used
D	36	9.3	3	3.4	limestone, brecciated below
D	35	6.0	-	---	cherty zone
D	34	8.3	2	8.5	limestone, slightly dolomitic
D	33	1.6	1	5.8	dolomite
D	32	5.4	2	2.5	limestone
D	30	13.0	5	2.0	limestone
D	28	13.0	6	2.1	limestone
D	27	9.3	7	9.3	limestone, dolomitic above
D	26	8.3	3	15.0	dolomite
D	25	3.3	2	2.3	dolomite
D	24	2.7	1	3.2	limestone
D	22	10.0	2	2.0	limestone
D	21	10.0	4	2.5	limestone
D	20	10.0	3	2.5	limestone
D	19	10.0	2	2.3	limestone
D	18	16.0	4	3.3	limestone
D	17	4.1	1	10.0	quartzitic limestone

Table 6. (continued)

CHART I

GRAPHIC REPRESENTATION OF THE INSOLUBLE RESIDUES



frosted surfaces, and no clear euhedral quartz grains were noticed. Cubic pyrite crystals were noticed in the dolomite beds (see Pl. 8, Fig. 2). The samples that gave less than 5 percent insoluble residues consisted of fine silt- to clay-sized grains, mostly quartz, whereas 5 to 10 percent insoluble residues show grain sizes ranging from silt- to sand-size.

The euhedral quartz grains in the lower part of the formation suggest overgrowth in place after the limestone has been deposited, whereas the occurrence of larger quartz grains, in the upper part of the formation, showing some evidence of transporation as evidenced by the pitted and frosted surfaces, may suggest that these quartz grains have been laid down at the same time the St. Louis Limestone was deposited. On the other hand, the pyrite must have been formed authigenically after deposition because of the presence of well developed cubic crystals. In some cases these crystals showed overgrowths.

Table 6 shows the general summary of the insoluble residue analyses. It may be mentioned that the average percentage given in column 5 is based on averaging the insoluble residue of each sample in the unit considered. Chart 1 shows the representation of these results in graphic form.

G. Sedimentary Structures in the St. Louis Limestone

Some sedimentary structures associated with the St. Louis Limestone are briefly discussed here. The primary or mechanical structures are mainly bedding and ripple marks. The secondary or chemical structures include: structures due to solution stylolites and vugs; structures due to accretionary action as nodules and other lesser structures such as geodes. Most of these structures are seen in the field. On the other hand, others, such as stylolites and geodes, are seen both in the field and in thin sections. The breccia problem is briefly mentioned too.

1. Primary Structures

a. Bedding

Details of the bedding in the St. Louis Limestone is given in the description of the stratigraphic sections in Chapter II. The different bedding terms used follow those used by the U. S. Geological Survey:

Massive if bed thickness is more than 3 feet

Thick-bedded if bed thickness is from 1 to 3 feet

Medium-bedded if bed thickness is from 4 to 12 inches

Thin-bedded if bed thickness is from 2 to 4 inches

Very thin if bed thickness is from ½ to 2 inches

Platy if bed thickness is from 1/16 to ½ inch

Fissile if bed thickness is less than 1/16 inch

From the stratigraphic sections, it is seen that the most common bedding type is medium (4 to 12 inches thick), although a complete range of the different types from massive to thin bedded is present. Most of the bedding surfaces are planar separating the different beds by shale partings, some bedding surfaces are wavy or irregular and others showed a corrosion effect somewhat similar to stylolites in appearance. In most cases these bedding surfaces are horizontal or very slightly inclined, except in the lower part of stratigraphic section C where the dip ranges from 10 degrees to 30 degrees. As pointed out elsewhere, this high dip is due to the Cap au Gres fault. Usually the bedding is uniform, but there are exceptions usually in and near the brecciated beds. The shale on bedding planes is generally green to slightly dark gray, ranging in thickness from few mm. up to 3 or 4 inches. This shale is generally calcareous.

b. Ripple Marks

Ripple marks, as primary structures, have been clearly seen only in stratigraphic section C, where the wave length is about 6 to 8 inches and the amplitude is about one-half to one inch. In section B it was hard to identify this feature, probably because the section is dolomitized. This writer has not seen any ripple marks in his visit to section A. Rubey (1952) in his description of the St. Louis Limestone in the same area of section C, noted these current ripple marks and described the largest as "perfect oscillation or symmetrical ripples ... perfect ripples have minor intermediate crests". Along the Mississippi River bluff south of section C, ripple marks are displayed clearly and can be followed for a long distance. Ripple marks are not necessarily an indication of closeness to shore; they can develop in broad shallow water bodies at some distance from shore.

2. Secondary or Chemical Structures

Of the secondary structures within the St. Louis Limestone, there are mainly two which are due to solution action, these are: stylolites and vugs. There are also geodes, but these are not as dominant as the first two. Actually geodes were found only at two localities; at the base of stratigraphic sections C and D. Included also here as a secondary structure are the brecciated beds, due to the fact that breccia has originated secondarily after deposition of the St. Louis Limestone.

a. Stylolites

The term "stylolites" is used here as defined by Pettijohn (1947 and 1955). It is applied to the kind of structure that has "interlocking or mutual interpenetration of the two sides". As might be noticed from the description of the stratigraphic sections, this structure is repeatedly found in nearly every section. It is seen both in the field and in thin sections (see Plate 8, Fig. 5 and Plate 9, Fig. 3). The material between these teeth-like patterns is dark brownish clay which sometimes is removed from the thin section, probably due to grinding, but in most of the cases this clay matter is present.

The idea of the origin of stylolites as being due to solution and pressure action is accepted here, and some slides showed the effect of solution as indicated by the removal of parts of fossils and crinoid stems (see Plate 8, Fig. 5). Although the evidence of the solution can be seen, the evidence of pressure cannot be substaintiated here. The relief varies from less than millimeter up to about 3 to 4 centimeters (see Plate 9, Fig. 3).

b. Vugs and Other Minor Features

As may be seen from the description of the stratigraphic sections, vugs occur in several places in the section. In most cases, they are associated with the brecciated and fractured beds, also within and close to dolomite beds. They are partially filled with crystalline calcite, some are empty. The origin is probably solution action by phreatic water or due to dolomitization.

Fine fractures ("hairline fractures") are generally associated with lithographic beds. Those which occur in these beds are filled with pure white crystalline calcite. Most of the fracture planes are vertical; some are inclined at different directions.

Green shale spots previously mentioned in the discussion of the stratigraphic sections occur in all sections. They are generally associated with dolomite beds, especially section B unit 11 which showed a remarkably large number of these spots. The clay is described as glauconite, and it is suggested to have originated secondarily by shale segregation during dolomitization.

The vugs vary in size from small pores to about an inch, and they have irregular shapes. The calcite filling these pores is considered here as a direct precipitate from solution, although it could have originated by recrystallization. Of course this refers to calcite present in the vugs and calcite filling fractures which must not be confused with other calcite formed by recrystallization.

Another secondary solution feature, corrosion zones due to intra-stratal solution is present. They are not as distinctive as stylolites, and are related to cessation of limestone deposition. Some of the small stylolites can be considered to be corrosion zones when distinct relief is not present. The corrosion zones are associated with bedding planes. Good examples are shown very clearly along the Mississippi River bluff south of the location of stratigraphic section C.

c. Geodes

As pointed out before, this structure was encountered at only two locations: in sections C and D (the core section). It occurs at the Salem-St. Louis contact in these two locations. Geodes are not as abundant as other structures. Plate 8, Figure 6 and Plate 9, Figure 4 show the main features of these geodes. It is noticed that the inner part has large, radiating, euhedral crystals of quartz; also, that the crystal size decreases outward so that at the outer rim the quartz becomes totally chert. Geodes have not been reported to be associated with the St. Louis Limestone.

d. Breccias and Brecciated Beds

Probably the most characteristic and diagnostic property of the St. Louis Limestone beside its distinctive lithographic texture and light gray color, is the existence of brecciated beds. As may be noticed from the description of the stratigraphic sections, this feature is present in all four sections and more than once in most of them. In section A, unit 0 (5 to 7 feet thick) and unit 19 (about 2 feet thick) are breccias, and unit 21 is slightly brecciated for about 2 feet.

In section B, the breccias occur in the lower 2 feet of unit -3, the lower 1.5 feet of unit 6, in unit 8 (about 1.8 feet thick is slightly brecciated), unit 9, unit 13 (about 9 to 10 feet of breccia), and unit 14 (lower part slightly brecciated and the upper part highly brecciated). About 1 to 2 feet of unit 17 is slightly brecciated.

In section C about 2.7 feet of the lower part are brecciated and about 8 separate breccia units occur higher in the section. In section D, breccia beds also occur at several horizons. The graphic sections of Figures 4, 6, 8 and 9, show the occurrence of these beds.

The breccia fragments are usually irregular in shape, angular to subangular (see Plate 9, Figures 5 and 6), and range in size from small pebbles to boulders. A size of 1 to 2 inches may be dominant. The fragments are in contact with each other, but shale may act as a coating or matrix in some cases. The fragments have no preferred orientation. In some cases calcite crystals, apparently formed after fragmentation or brecciation, fill voids between the brecciated particles.

In spite of this phenomenon which is characteristic of the St. Louis Limestone, and has been reported to be associated with this formation in every locality where the formation is present, there is no generally accepted agreement regarding its origin. There are three main suggested origins for the breccia in the St. Louis Limestone . They are:

1. Brecciation due to solution of evaporites.
2. Brecciation due to solution of carbonates.
3. Brecciation due to tectonic action shortly after deposition.

In regard to the first hypothesis, Collinson and Swann (1958, p. 13) suggested that the solution of underlying evaporites near Alton, Illinois was the cause of formation of caverns, leading to brecciation of the overlying St. Louis Limestone. The presence of evaporites, especially gypsum, was not confirmed within the study area. However, evaporites have been reported to be present in the formation in the subsurface in Illinios, confined to the lower part of the formation (Payne, 1940, p. 231). Spreng (1970, personal communication) found thin gypsum beds exposed in the lower part of the formation along the Mississippi River bluff south of stratigraphic section C in Calhoun County, Illinois. No one has strongly supported the second hypothesis. The presence of stylolites in the formation suggests solution of the limestone. Stylolites are present in all the stratigraphic sections and the evidence of carbonate solution has been observed and accepted. In addition to stylolites, there are corrosion structures and the presence of contorted surfaces which show good indication of carbonate solution. It is questioned, however, that the solution of carbonates would be enough to cause brecciation of the formation.

Smith (1961, p. 275) suggested "a submarine rock slump during St. Louis time which was triggered by tectonic activity that initiated early movement along the Mt. Carmel Fault". He added that brecciation had occurred after the limestone was lithified and accounted for the existence of breccia in different stratigraphic positions as due to tectonic pulses occurring at different time intervals during the deposition of the St. Louis Limestone.

Van Tuyl (1925, pp. 233-236) in his description of the St. Louis Limestone in Iowa, discussed the brecciation problem of the formation. He reviewed the suggestions of previous workers and presented his own view of the problem. Most of the previous suggestions, he mentioned, referred the brecciation of the formation to "systematic alternation of vigorous and quiet action of wind waves ..." and "deposit near the margin of some troubled sea". Van Tuyl presented his own suggestions regarding the formation of the breccia in the St. Louis Limestone. He suggested three different modes of formations. The first is small mounds or reefs broken by violent wave action; the second is due to differential movement along a bed and the third is "produced by mashing on a large scale and the brecciation is in many places associated with small overthrust faults and folds". He considered the last as the most important type of brecciation in the St. Louis Limestone.

The formation of breccia in the St. Louis Limestone by solution of carbonate is not likely to be accepted. Because no evidence of such brecciation is reported within the underlying Salem or the overlying Ste. Genevieve formations, the brecciation probably occurred during St. Louis time. It is not decided here whether the brecciation is due to solution of evaporites and/or due to tectonic activity of the type mentioned by Smith (1961) or by Van Tuyl (1925).

H. Metasomatic Changes

The name metasomatic is used here in wide meaning to include all the post-depositional changes that have affected the St. Louis Limestone.

In this part, only three changes will be discussed; namely dolomitization, silicification and recrystallization.

1. Dolomitization

Dolomite is found in all four sections. In section A, about 6 feet in unit 8, and 3 to 6 feet in unit 11 are dolomite. Section B is mostly dolomite except for the upper part. In section C there are about 18 feet of dolomite at different stratigraphic positions. This does not include the covered parts, which are also presumed to be mostly dolomites. In section D, units 26 and 25 are dolomites as well as some other thinner units.

The detailed description of these dolomitic units is given in the stratigraphic sections. The fresh color of dolomite ranges from smoky gray to mottled gray, with some occasional dark gray color (see section B unit 15). Scattered green shale spots are associated with dolomite (see section B, unit 12). Calcite filling fractures as well as vugs are occasionally present. The bedding associated with dolomite is not so much different from that of limestone, although the dolomitic units are somewhat thicker in some places. Although the breccia is present in dolomite in section B, the dolomite is generally less brecciated than the limestone. The dolomite units contain more pores than the limestone.

The thin section study of the dolomite did not reveal any character bearing on original features. In other words, under the microscope, the dolomite texture shows euhedral crystals of rhombohedral shape. These crystals were noticed to have the same size within the same slide. The crystals are generally in contact with well-defined clear boundaries (see Plate 8, Fig. 1). On the other hand, in some others, where pores are present, the boundaries are not clear. The size of the crystals ranges from 20 to 80 microns. If the whole slide is dolomite, no other features are present, such as fossils or fossil fragments, oolites, spar or micrite. Within dolomites, there has been a remarkable increase in the amount of shale, quartz and pyrite. Some slides showed mottled or "dirty" patterns which are probably due to clay concentrations.

The boundaries of the dolomite and limestone are not sharp or well-defined. There is a gradational change from either limestone or dolomite to the other. The transition is usually thus: dolomite, slightly calcareous dolomite, calcareous dolomite, dolomitic limestone, slightly dolomitic limestone to limestone. This gradation is well demonstrated by a study of successive thin sections in one stratigraphic section, and is shown clearly when the thin sections are stained.* It may be noticed here that the limestone constituents become obscure and it is hard to recognize each constituent in the dolomitized part.

The dolomite units of each stratigraphic section cannot be correlated. As may be observed, section B is mostly dolomite while section A, is mostly limestone. In regard to the origin of this dolomite, it seems likely from all the facts pointed out before that it has been formed metasomatically after the limestone was deposited by the replacement of the Ca ion by the Mg ion. The source of Mg needed for the replacement of Ca is not clear.

2. Silicification

Under this name the silica occurrence within the St. Louis Limestone in the form of chert is briefly discussed. The chert present in the formation is either as chert nodules or in a bedded form. The nodules

*The staining chemical used is Alizarin Red S; the slide is dipped in the solution for 35 to 45 seconds, then washed with running water and dried. This procedure stains the calcite red leaving the dolomite unstained.

vary in shape from spherical to elliptical or oval. If not spherical, the long axis is parallel to the bedding plane. The size ranges from pebble to boulders with a two to six inch diameter being normal. The color of the nodules varies with its stratigraphic position from light (white) through gray and brown. The stratigraphic positions of the chert nodules and layers present are indicated in each of the sections described.

Internally the nodules show a conchoidal fracture and a color banding. In thin sections, no other feature of specific value has been noticed. From the writer's cursory field observation the origin of these chert nodules is considered to be metasomatic.

The second type of chert present in the formation is the bedded chert. Although this type is not abundant, it is mentioned here due to its use as a marker in correlation. This chert has been noticed clearly in section D too. Generally it is present as a thin bed a few inches thick almost continuous in section B and in separate bands in section C. The color is light pinkish to light reddish.

3. Recrystallization

This term is used here to describe the kind of spar crystals (pseudospar) that have been formed by the alteration of original carbonate material. Where these spar crystals are associated with micrite, it is believed that the original carbonates were micrites. This belief is substantiated by the fact that micrites do not form the main rock matrix, which must have been the case before the alteration process. The base of stratigraphic section C shows examples of such alteration (see Plate 7, Fig. 6).

I. Quartz

From the insoluble residue analyses as well as the thin section study, quartz grains of fine-sand to coarse-silt size, mostly euhedral were noticed to be present in the lower part of the St. Louis Limestone. In the upper part, however, the quartz grains are larger in size, generally of medium sand-size; the grain surfaces are not planar but rather irregular with some pitting and frosting or partial frosting. The percentage of quartz is less in the lower part than in the upper part (in section A, unit 24, at about the St. Louis-Ste. Genevieve contact, gave 42 percent quartz of sand-size).

A remarkable increase in the amount of quartz was noticed generally in the dolomite more than the limestone, except in the upper part of the formation, where much more quartz is present in the limestone.

The euhedral shape and smaller size of quartz in the lower part of the stratigraphic sections may suggest secondary origin "formation after deposition", or at least quartz overgrowth around minute quartz grains as nuclei. The coarser size and angular to subangular quartz grains in the upper part of the formation, especially where a high quartz percentage is present may suggest primary origin, i.e., quartz deposited contemporaneously with the limestone.

CHAPTER IV

CORRELATION

It has been difficult to make stratigraphic correlations between the four sections studied here. In the first place, local alteration processes, mainly dolomitization, complicated the problem. Secondly, the nature of the breccia and brecciated zones which change, both laterally and vertically, make their value in correlation seemingly useless. The paucity of fossils within the formation does not help. Corals, which are very diagnostic in the St. Louis Limestone, as a whole, are not sufficiently confined at certain horizons to serve as good correlation markers. Add to that the sparseness of other fossils and the difficulty in freeing the fossils from the rock which makes their recognition uncertain.

In spite of all these limitations, the writer tried to make tentative correlations between these four stratigraphic sections. That correlation is made by the use of some other features of the formation. These features are: color similarities, bedding, cherty zones, especially the reddish brown bedded chert nodules in the upper part of the formation, the occurrences of similar oolitic beds close to the top of the formation, use of the insoluble residue percentage, the existence of dolomitic beds in the lower part of the formation and similarity of rock textures.

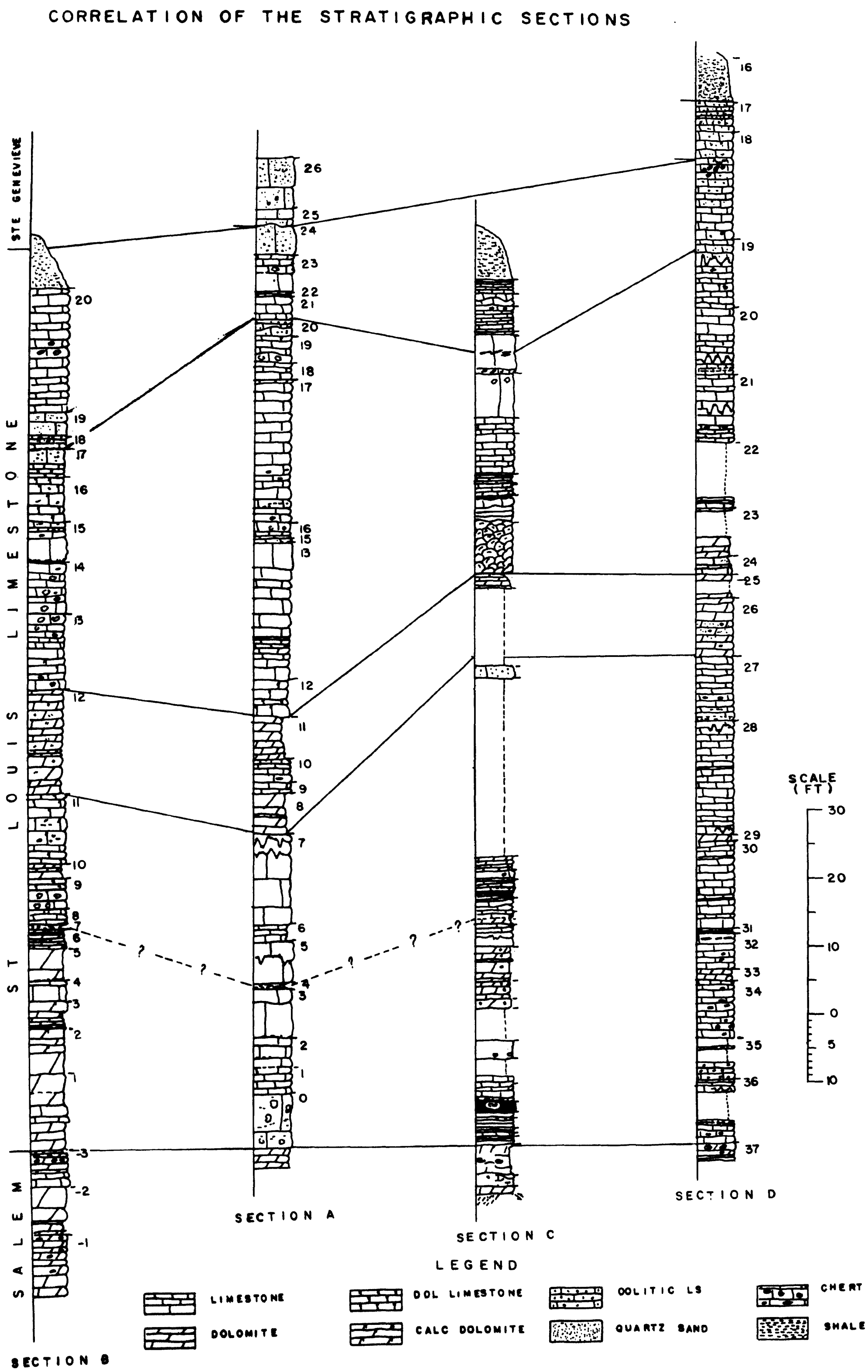
Due to the difficulties mentioned above, the correlation was delayed until the other studies were completed, so that a use of all data could be made.

From chart 2 it is seen that the stratigraphic sections can be divided into three major stratigraphic units: lower and upper limestones with a dolomite unit separating the two. This dolomitic unit, in the middle of the formation, is persistent not only in the stratigraphic sections presented here but also has been reported elsewhere: Van Tuyl (1925) in Iowa, Weller (1940) in Illinois and Marcher (1962) in Tennessee. Of course this dolomite varies in thickness from one section to another due to the variance in the favorability of dolomitization. The variance in thickness of dolomitization implies that the correlated dolomitic units may not have been deposited at essentially the same time, especially in section B, where the thickness of this unit is larger than in the other sections. Van Tuyl (1925) mentioned that the lower and upper units of the St. Louis Limestone are separated by an unconformity Southeast Iowa. The lower St. Louis here may correlate with his Croton Member and the upper St. Louis with his Verdi Member.

It is not intended here to introduce any subdivision of the St. Louis Limestone and the formation is treated as one unit. But the association of the middle dolomite unit in all sections suggests this subdivision.

The other minor correlation is within the upper part of the formation close to the top. The presence of oolite in that stratigraphic horizon suggests such a possible subdivision. This oolite unit has been noticed in all the sections presented in this paper, and from the thin section study, the oolite grains are very similar

CHART 2


CORRELATION OF THE STRATIGRAPHIC SECTIONS
STE GENEVIEVE
ST LOUIS LIMESTONE
SALEM
SECTION B
SECTION A
SECTION C
SECTION D
SCALE (FT)
LEGEND
LIMESTONE
DOLOMITE
DOL LIMESTONE
CALC DOLOMITE
OOLITIC LS
QUARTZ SAND
CHERT
SHALE

from one section to another. There is a very thin chert nodule unit overlying the oolitic unit. The chert is bedded and light red or yellowish-brown in sections B and C. It occurs as brown chert nodules in section D. This chert was not noticed in section A. Lines are drawn to include these oolitic beds in one stratigraphic unit with the red chert at the top.

No further subdivisions can easily be made, especially in the lower part of the formation as the dolomitization effect in section B makes such a thing difficult. In the lower part of the formation, however, close to its base there is a shaly unit in sections A, B and C, roughly at about 24 to 30 feet from the base. If this very thin-bedded shaly unit is taken into account, another tentative correlation may be possible.

In conclusion, the middle unit may subdivide the formation into lower and upper St. Louis. The upper St. Louis is subdivided into smaller units at the occurrence of the oolites and the overlying red chert and the lower St. Louis, may tentatively, be subdivided at the main lower shale unit. It should be mentioned that the oolites and shale, although they are present in the sections studied here, are not, by any measure, persistent in the formation. Chart 2 shows the subdivisions. Major subdivisions are indicated by solid lines; whereas the division in the lower St. Louis is shown by a dashed and questioned line.

CHAPTER V

ENVIRONMENT OF DEPOSITION

The limestone deposition from the Salem through the St. Louis and Ste. Genevieve seems to be continuous without clear evidence of a structural or depositional break. Stuart Weller (1908, pp. 88-90) and J. Baxter (1960, pp. 29-30) pointed out the fact that the limestone deposition continued from the Salem through the St. Louis. Although N. Short (1962, pp. 1931-1932) mentioned a questionable unconformable relationship between the St. Louis and the overlying Ste. Genevieve no such structural break was observed in the two stratigraphic sections of this study where the Ste. Genevieve is present. However, the evidence concerning the nature of the St. Louis-Ste. Genevieve contact should not be considered conclusive if based only on the two locations used in this study.

The lithologic characteristics of the St. Louis Limestone reflect the conditions under which this limestone was formed and deposited. The main rock component of the St. Louis Limestone was micrite. The deposition of this micrite would necessitate deposition under quiet water conditions where the effect of current winnowing is absent. The quietness of water could be either very deep, far below wave action, or under protected, shallow water conditions. If micrite was laid down under deep water conditions, the rock color and the kind of living organisms would be indicative of such conditions.

As indicated in the description of the rock color, it is generally light to very light gray, the presence of fossil shells, especially corals, would suggest shallow water conditions. In addition to these, there are other evidences of shallow water conditions such as the presence of gypsum, the reported cross-bedding (Fenneman, 1909), and ripple marks. The presence of the ripple marks is not necessarily an indication of closeness to depth the wave action can reach. It can be concluded that the micrite of the St. Louis Limestone was laid down in shallow and quiet water or low energy conditions. The water depth could be in the range of 20 and perhaps up too 100 feet. The temperature required for the survival of the living organisms, especially corals, should be warm.

In regard to the origin of micrite, there are various suggestions. The most general and most accepted suggestion is that this micrite is formed as a chemical or biochemical precipitate (Folk, 1959). On the other hand, Fenneman (1911, pp. 41-42) considered the micrite to be formed by "slight emergence of the calcareous bottom from another portion of the St. Louis sea..... its finer parts being carried to this area by suspension". The idea of land-derived carbonate dust could be considered as a minor source of micrite, but is is questionable whether this will be sufficient to account for the micrite in the formation. It is suggested here that micrite has been formed by chemical or biochemical precipitates augmented by minor amounts of derived fine grains.

The deposition of micrite was not continuous. Some interruptions occurred as indicated by the shale partings. This interruption occurred between deposition of almost every bed, but was of very short duration. There are some other phases of interruption as indicated by the oolite beds which are formed close to the end of the St. Louis time. The matrix or cementing material of the oolites is generally spar. The presence of spar and absence of micrite in the oolites is an indication of strong currents, capable of winnowing any micrite laid down. The presence of such oolite beds in the St. Louis Limestone, which are identical in many respects to the oolites in the Ste. Genevieve Formation (Reinhar, 1964; N. Short, 1962) represent pulses towards St. Genevieve conditions. Also the presence of a high percentage of quartz grains, mostly of sand-size at the top of the formation shows that some changes in the surrounding land must have occurred, perhaps slight uplift accompanied by strong currents capable of carrying these quartz grains. Where such quartz grains are present, no micrite is noticed and the cementing matrix is spar.

During St. Louis time it seems that the surrounding lands were not very high and were relatively stable as indicated by the lack of terrigenous constituents derived from erosion of source land, except close to the end of the St. Louis time.

CHAPTER VI

ECONOMICS

Here, under economics, is discussed the use of limestone. Man has used limestone for his needs since far back in history. Cavemen realized their need for limestone for their own daily use. The Ancient Egyptians built their magnificent and outstanding tombs of limestone. The Pyramids of Gize, built some 4500 years ago in Egypt (the United Arab Republic) are another example of the use of limestone.

At the present time, limestone has widely different uses. Lamar (1961) mentioned some 70 different uses of limestone and dolomite in Illinois. In this paper only the actual use of the St. Louis Limestone in the two quarries is considered. It must be pointed out that for each use of the rock, there are some standard specifications which the properties of limestone or dolomite must possess for that particular use of the rock.

The Missouri Portland Cement Company quarry limestone is used for the manufacture of cement, whereas in the Vigus North quarry the limestone and dolomite are used for road construction. The specifications of limestone used in the cement industry are briefly reviewed here, the source of data being Lamar (1961). The rock must have at least 75 percent calcium carbonate, less than 3 to 5 percent magnesium carbonate, phosphorous pentoxide (P_2O_5) should be less than 0.5 percent, and the alkali content (Na_2O and K_2O) should be less than 0.6 percent. If white cement is required, the iron oxide content (Fe_2O_3) should not exceed 0.01 percent. The limestone in the Bellefontaine quarry can safely pass these specifications for gray cement. There is a dolomitic unit within the middle part of the formation, but the upper and lower parts are free of dolomite and a mixture of dolomite and limestone can be made in such a manner not to exceed the specified percentage. The limestone is mixed with clay and/or shale at a ratio of four parts limestone to one part clay or shale. Then the raw materials, blended in the right proportions, are finely ground, and burned in a kiln. The product is ground and a small amount of gypsum is added to produce the portland cement.

The limestone and dolomite quarried from the Vigus North quarry is used for road construction as aggregate and road stone. There are certain requirements needed for such uses regarding aggregate size and resistance to wear. The size is coarse if the aggregate is retained on sieve number 4 and fine if retained on sieve number 200. The weathering resistance (soundness) and resistance to wear (abrasion) have standard methods for their measurements.

There are other purposes for which St. Louis Limestone can be used. Because the rock is generally lithographic, it could be used to make lithographs, but this method of printing has been superseded by more efficient methods. Where it is high in its calcium carbonate content and has no dolomite the rock can be used for lime manufacture. It could also be used for agricultural limestone. In short, it seems that the St. Louis Limestone can be used for most of the common limestone and dolomite uses, if not all of them.

CONCLUSION

The study of the St. Louis Limestone has been carried out within its type area. The study has been concerned mainly with the petrographic character of the formation, from which it is revealed that the main rock types, according to the Folk (1959) classification, are micrite and biomicrite. The other rock types present are: biosparite, oosparite, intrasparite, oomicrite and to a lesser degree pelmicrite and pelsparite. The dominant kinds of fossils in the formation are: bryozoans, foraminifers, crinoid plates, columnals, and stems, algae and corals. The minor fossils present in the formation are brachiopods and gastropods. Corals, especially Lithostrotionella and Lithostrotion are diagnostic of the formation but of little obvious correlative value. The most diagnostic feature of the St. Louis Limestone is the occurrence of breccia. This breccia is not confined to a single horizon and its position varies both laterally and stratigraphically. The formation is oolitic in its upper part. Some chert nodules and lentils occur in the formation. Dolomite is present in the formation especially in the lower part and the degree of dolomitization varies widely from one section to another.

The variance in degree of dolomitization, the occurrence of stratigraphically unconfined breccia and the sparseness of well-recognized fossil markers makes the correlation between the different stratigraphic sections a difficult task. However, the formation can be divided into three subdivisions on the basis of the occurrence of a dolomite unit in the middle of the formation. The deposition of limestone was continuous from the Salem through the St. Louis. The environment of deposition was quiet under shallow water condition.

It is the writer's belief that more study is needed, especially in the following fields:

1. Determination of the exact nature of the St. Louis-Ste. Genevieve contact within the study area.

2. More study regarding the breccia problem. Such study is needed to cover the breccia problem both geographically and stratigraphically to determine the origin of brecciation.

3. In spite of the fact that this thesis contains illustration of the foraminifers present in the formation, further study is required, however, to identify them.

4. The difficulty in recognizing and the limited discussion regarding the algae does not mean that algae are not important in the formation. It is believed, consequently, that a specific study of algae may be helpful.

If such studies are carried out, better understanding of the St. Louis Limestone, undoubtedly, will result.

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VITA

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