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Stratigraphy of the Captain Creek Limestone
(Missourian) of Eastern Kansas

by

William P. Eastwood

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Kansas Geological Survey
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047-3726

STRATIGRAPHY OF THE CAPTAIN CREEK LIMESTONE (MISSOURIAN) OF EASTERN KANSAS

William P. Eastwood
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ABSTRACT

The Captain Creek Limestone is the basal member of the Stanton Formation (Missourian) of eastern Kansas. In northern Kansas, the member is divisiable into three units. The lower limestone is a medium-grained, olive-gray, massive bed and averages from 1.5 to 2 feet thick. In northern Kansas, it contains a biota dominated by mollusks and Osagia with minor elements of small brachiopods and fusulinids. In central Kansas, this fauna mostly disappears and is replaced by "Marksia". This lower limestone unit grades into shales in southern Woodson or northern Wilson County. The upper limestone unit is fine-grained, light blue-gray, and medium-bedded. It is, generally, much thicker than the lower unit. In northern Kansas, the upper unit ranges from 6 inches to about 8 feet and the biota is dominated by Composita, at the base, and calcareous algae, at the top. Both of these forms become less abundant toward the south. The "mottled" limestone at the top of the Captain Creek in Johnson and Franklin counties is a local facies of the Eudora Shale. A thin limy shale parting separates the upper and lower limestone units in most of northern Kansas.

The Captain Creek of southern Kansas belongs to a different sedimentary facies than that of northern Kansas. From southern Woodson County, southward, only the upper unit can be recognized. In northern Wilson County, the Captain Creek is a medium- to coarse-grained, medium- to thin-bedded limestone 5 to 6 feet thick. Locally, it contains abundant Osagia The Captain Creek thickens southward to 64 feet in Montgomery County.

The thick limestone of northern Montgomery County thins southward to about 15 feet in central Montgomery County and to about 2 to 3 feet a few miles south of there. The member grades into shales and disappears in southern Montgomery County. An oolitic limestone in southern Montgomery County, which has been included in the Captain Creek, is part of the Lane-Vilas Shale.

The thick Captain Creek Limestone of Montgomery County exhibits features suggestive of a reef. Except for the Merriam, all limestone units of the Lansing Group are abnormally thick in southern Wilson and/or northern Montgomery counties. If the Captain Creek is a reef, the other thick Lansing limestones probably are also reefs. The relative positions of the outcrops leads to the conclusion that the reefs of the Lansing exhibit regressive and transgressive characteristics.

The Merriam and Captain Creek, while occupying similar positions in two different Missourian megacyclothems, are comparable only in northern Kansas. In southern Kansas, the sedimentary facies of the two members is different from each other and from that of northern Kansas.

INTRODUCTION

Purpose of Investigation

The purpose of this investigation is to study the Captain Creek Limestone member of the Stanton Limestone formation of Kansas with special attention to its local and regional variation and to the environment of deposition.

Previous Work

Hinds (1912, p. 3 & 7) defined the Lansing Formation as extending from the top of the "lower Lane Shale" (Island Creek Shale of the present terminology) to the base of the Weston Shale. The Stanton Limestone at that time was considered to be the topmost member of the Lansing Formation. In a later publication (Hinds & Greene, 1915, p. 28-30 & 155-169), Hinds further described the Lansing Formation, stating that its type area was in the vicinity of Lansing, Kansas, and that it was the same as the Garnett Limestone as defined by Haworth & Kirk (1894). Hinds also recognized three limestone and two shale units in the Stanton of Missouri.

Subsequent work showed that these divisions of the Stanton could be traced over a wide area. Moore (1931) raised the Lansing to the status of a group; the Stanton being regarded as a formation of the Lansing Group. However, Moore also defined the Lansing as extending from the base of the Wyandotte formation to the base of the Iatan Limestone (Wilmarth, 1938, p. 1147). Moore's reason for including the beds above the Stanton in the Lansing was the non-recognition of an erosional unconformity at the base of the Stranger Formation and the miscorrellation of the Iatan Limestone in northeastern Kansas with the Haskell Limestone in east central Kansas.

The following year, Moore (1932, p. 92 & 97) excluded the beds above the Stanton from the Lansing and Moore & Condra (1932) further restricted the Lansing to include only the Plattsburg, Vilas, and Stanton formations. This definition of the Lansing Group has been used to the present.

The name Stanton was first used by Swallow & Hawn (1865, p. 6) for beds in the vicinity of the old village of Stanton in northwestern Miami County, Kansas. However, they referred the name to beds which have since become known as the Plattsburg formation.(Newell, 1935). The first reference to the Stanton as it is defined today is by Haworth & Bennett (1908, p. 104) who applied the name to the uppermost limestone unit of rocks then assigned to the Garnett formation. Hinds & Greene (1915, p.29) recognized the Stanton as the uppermost limestone unit of the Lansing. Moore (1935, p. 132), following field work by Newell, indicated a typical exposure of the Stanton in a roadcut near the SE cor. sec. 3, T. 13 S., R. 21 E., Douglas County, Kansas.

The Stanton of Kansas was first studied in detail by Newell (1935a). He proposed the name Captain Creek for the lowermost limestone member of the Stanton and stated that the type area was in the vicinity of the stream called Captain Creek in Douglas and Johnson counties, Kansas. Moore (1935, p. 132) designated the type section as a roadcut on the east bank of Captain Creek near the SE cor. sec. 3, T. 13 S., R. 21 E., Douglas County, Kansas.

Newell (1935a) and Jewett & Newell (1935) described the Captain Creek of Miami, Johnson, and Wyandotte counties, Kansas, and Moore, Elias, & Newell (1936) described a portion of the Captain Creek Limestone of Anderson County, Kansas. Descriptions of the paleontology of the Stanton formation and the Captain Creek member may be found in Newell (1931b), 1934),(1937), and (1942). Zinser (1950) described a portion of the microfauna of the Lansing Group in northern Kansas.

Short descriptions of the Captain Creek Limestone may be found in Moore (1935), (1949), and Moore, et. al. (1951). A part of the stratigraphy of the Captain Creek Limestone of southern Kansas has been described by Chelikowsky & Burgat (1947), Wagner & Harris (1953), F. Wilson (1957), and Winchell (1958). McManus (1956) described the stratigraphy of the Merriam member of the Plattsburg formation and Mann (1957) described the Plattsburg formation of northeastern Kansas.

Before 1935, the lower limestone member of the Stanton formation was erronously correlated with the Meadow Limestone of Nebraska (Newell, 1935).Field work by Newell and other Kansas and Nebraska geologists showed that the Meadow Limestone of Nebraska is properaly correlative with the lower limestone member of the Plattsburg formation. The name Meadow has since been dropped and the name Merriam has been subsituted for the lowermost Plattsburg unit.

Location of Area

The Captain Creek Limestone is recognized throughout northern Kansas and northwestern Missouri and has been identified in Iowa and Nebraska.

The Captain Creek Limestone can be traced southward across Kansas into northern Montgomery County and, with question, to within a few miles of the Kansas-Oklahoma boundary. The Captain Creek has never been identified with certainty in Oklahoma, but certain limestone beds in Oklahoma have been correlated with other units of the Stanton formation (Oakes, 1940, p. 90).

This report is concerned only with the Captain Creek Limestone of Kansas, where it crops out in a general northeast-southwest direction from Leavenworth County on the north to Montgomery County on the south. (see Plate 1)

Acknowledgements

The writer wishes to thank Dr. C. W. Pitrat of the Department of Geology, University of Kansas, and Dr. J. M. Jewett, State Geological Survey of Kansas, for supervision and aid in the preparation of this report. Thanks are also due the State Geological Survey of Kansas for field expenses and access to unpublished stratigraphic sections, to Dr. H. A. Ireland and Dr. Elliot Gillerman for use of their laboratory equipment, to Dr. R. H. Benson for aid in photographing some of the thin sections, to Russell Runnels for making the chemical analysis, to Dr. Kenji Konishi for identification of certain of the algae, and to Stanton Ball for assistance in part of the field work.

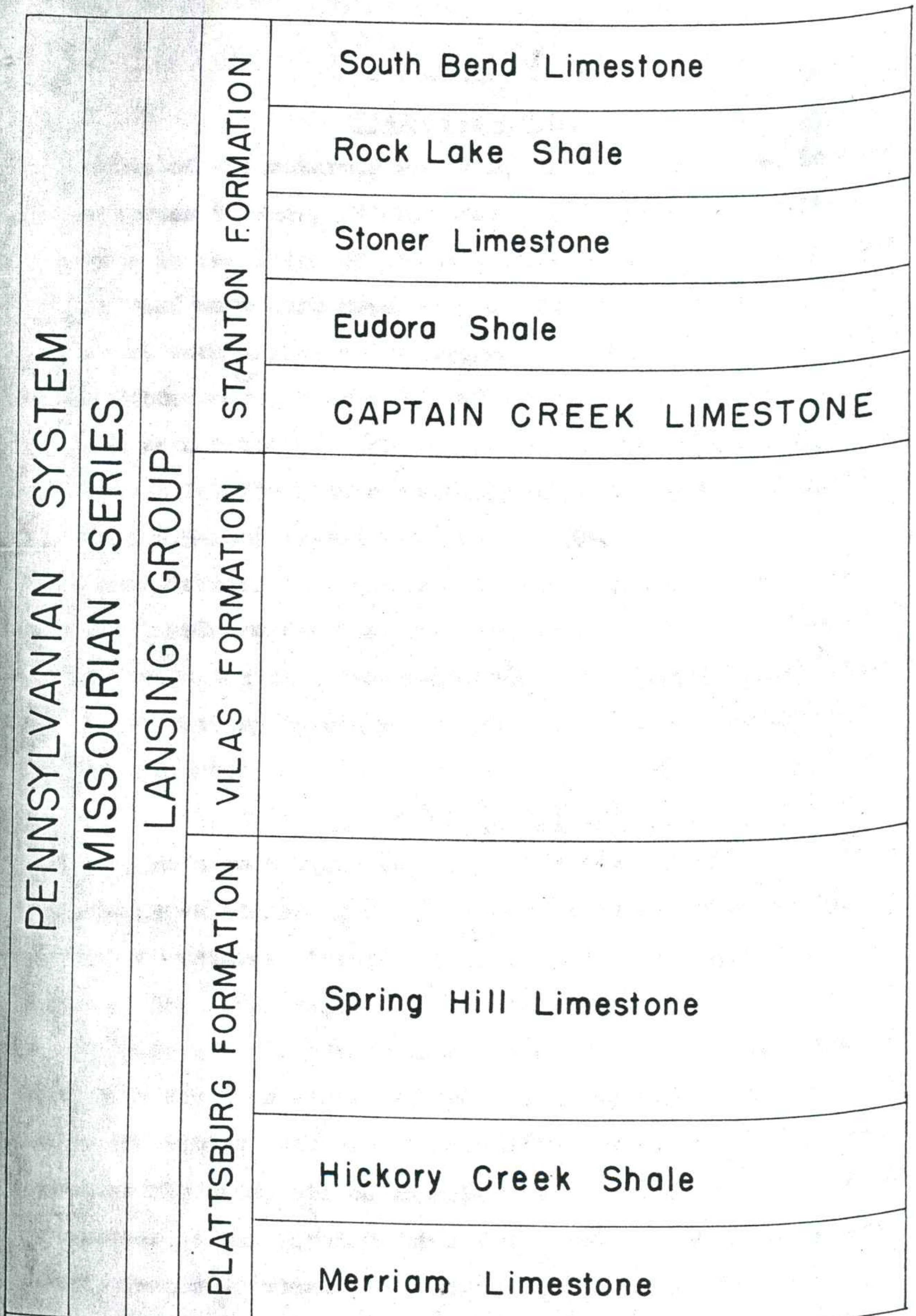

FIG. 1. Stratigraphic position of the Captain Creek Limestone.

TECHNIQUES

Field Techniques

Most of the outcrops measured by the writer were located by reference to the published and unpublished stratigraphic sections in the files of the State Geological Survey of Kansas. County road maps were used to plot the locations of the outcrops. At each exposure the member was measured and field notes were written describing the Captain Creek and adjacent beds. Samples were taken at each significant lithological change. The very thick limestones in Montgomery County were sampled at every 5.5-foot (eye-level) interval.

Hand samples were taken and fragments for the thin sections and the insoluble residues were chipped off in the laboratory. Any colors which were considered to be diagnostic were determined in the laboratory by use of the Rock Color Chart of the National Research Council.

Laboratory Techniques

The main techniques used in the laboratory study of the Captain Creek Limestone were acetate peels, thin sections, and insoluble residues. Acetate peels were made following the technique of Sternberg and Belding (1942). A face perpendicular to the bedding was cut and polished on a specimen of the limestone. This face was then etched in 10 percent hydrochloric acid for about 15 seconds. The limestone specimen was then gently washed toremove the acid, dipped in acetone, and pressed upon a sheet of acetate. After drying for a few minutes, the acetate was gently removed, trimmed to desired size, and mounted between glass plates. A negative print of the peel can then be made simply by projecting an image onto a sheet of photographic paper. The writer found that the 0.05 mm. thickness of acetate was best for use in this study and the F-5 photographic paper was the best for making the prints.

Bissell (1957) has recently described a technique of using the dichromate method of staining the etched specimen before making the peel. A modification of this method was used to determine the possible presence of dolomite in the "mottled" limestone. The polished and etched specimen was stained with silver nitrate solution ($AgNO_3$) for about 5 minutes, washed, and then treated with potassium chromate solution (K_2CrO_4) for about one minute. The acetate peel was then made in the ordinary manner.

The thin sections were made by the usual method. A small chip of the limestone was mounted on a glass slide and then ground to the desired thickness. No particular effort was made to grind the specimen exactly to standard thickness (0.03 mm.) because mineralogical determinations can be made if the rock specimen is slightly thicker than this. Also, the thin sections were ground mainly to observe certain small structures which did not show well on the acetate peels. Many of these structures disappear or become faint if the specimen is ground to standard thickness.

For study of the insoluble residues, chips were broken off the hand specimen and crushed in an iron mortar until all pieces were smaller than about 1/4 inch. About 50 grams were then placed in glass beakers and digested in 10 percent hydrochloric acid. After digestion ceased, the spent acid was decanted and concentrated hydrochloric acid was added to the beaker. This acid was then boiled to remove iron oxide. After boiling, the acid was again decanted, and the residue was washed in tap water and distilled water. Only the coarse fraction of the residue was used in this study; the fine and medium fractions were poured off during the washing.

Only three samples of the Captain Creek Limestone were prepared as etched blocks. They were prepared by polishing the surface to be etched, then placing the specimen (polished face up) in a pan containing enough 10 percent hydrochloric acid to completely cover the block. The specimen was left in the acid for about 3 minutes, then removed and very gently washed.

A chemical analysis of the "mottled" limestone was made by Russell Runnels of the Geochemistry Division of the State Geological Survey of Kansas.

The samples of the shale parting in the Captain Creek were soaked in water for a few hours. They were then washed through a nested set of 20-, 60-, and 100-mesh sieves, dried and examined under a binocular microscope.

STRATIGRAPHY

Plattsburg Formation

Introduction

The lower formation of the Lansing Group consists of two limestone members and an intervening shale member. They are, from the base upwards, the Merriam Limestone, the Hickory Creek Shale, and the Spring Hill Limestone.

Merriam Limestone

The lower member, the Merriam Limestone, was described by McManus (1956). He found that it was a typical "middle" limestone of a Missourian megacyclothem, averaging 2 to 3 feet thick and disappearing in northern Montgomery County. The Merriam is divisable into three distinct unit; a lower limestone unit, a thin shale bed, and an upper limestone unit.

The lower limestone unit is conglomeratic at the base, aphanitic just above the base, and oolitic at the top. In northern Kansas, zones of Composita and Osagia-Myalina occur in the lower unit. The lower limestone is variable in thickness, ranging up to 8 feet, with an average of about 2 feet. It is absent in one place in Johnson County and at another in Miami County. The lower limestone unit disappears south of Allen County.

The shale bed averages about 0.2 feet in thickness and ranges up to 0.5 feet. It is a limy, yellowish or olive, clayey shale and in a few places contains limestone nodules. Brachiopods and crinoid columnals constitute most of the fauna. They are associated with bryozoans, fish remains, rare ostracodes, and rare calcareous foraminifers.

The upper limestone unit of the Merriam is fairly constant in thickness, averaging about 1 foot and ranging from 0.4 to 1.5 feet in thickness. The unit is aphanitic and contains worm borings, fusulinids, and algae at various localities. In southern Kansas, it is yellow and slabby and contains many sponges. In general, however, it is less fossiliferous than the lower limestone unit. In northern Kansas, the unit contains common crinoid stems, rare brachiopods, rare horn corals and echinoid spines, and common _Osagia_ and fusulinids.

Hickory Creek Shale

The Hickory Creek contains, at the base, a 0.2 to 0.4 foot thick impure limestone which is overlain by a black carbonaceous shale and a limy or clayey shale. Thickness averages about one foot in northern Kansas, it averages 8 to 16 feet and locally is as much as 30 feet in thickness. The southern Kansas shale is more fossiliferous than that of northern Kansas, containing many sponges, crinoid stems, and brachiopods. Zinser (1950) reported six species of conodonts, four species of Foraminifera, and two species of ostracodes from the Hickory Creek of northern Kansas.

Spring Hill Limestone

The Spring Hill exhibits relatively regular lithology and thickness in northern Kansas. In that area, it consists of about 5 feet of thin-bedded, fine-grained, bluish-gray limestone overlain by about 7 feet of light gray, oolitic or argillaceous limestone (Moore, 1949, p. 116). Large robust _Composita_ are found in a conspicuous zone near the top of the member.

Southward from Allen County, the three divisions of the Spring Hill can not be distinguished. The member averages about 20 to 25 feet of light-gray to buff, medium-bedded limestone as far south as central Wilson County. In Wilson and Montgomery counties, the Spring Hill undergoes drastic changes in thickness and lithology within comparatively short distances. The thickness increases to over 80 feet in the southern part of Wilson County and the Spring Hill then pinches out about 5 miles to the south in northern Montgomery County. All of the limestone units of the Plattsburg formation pinch out in northern Montgomery County and none of the units of the formation have been recognized in southern Montgomery County or in Oklahoma.

Vilas Formation

The Vilas Shale, the middle formation of the Lansing, is a gray to buff, clayey and sandy shale, with fossils only locally abundant. Generally this sequence is all shale but a sandstone bed occurs near the top of the Vilas in the area near the Kansas River and a few lenses of impure limestone are found in this interval in southern Franklin County. The Vilas Shale contains many thin limestone beds in southern Wilson County in the area where the Spring Hill is thick.

Extreme variations in thickness are a characteristic of the Vilas throughout its area of exposure. Where the Vilas is thin, it contains little sand, but where it is thick, it is quite arenaceous (Newell, 1933, p.56). Near Ottawa, in Franklin County (Loc. 11), the Vilas ranges in thickness from 0.6 to 6 feet within the distance of about a quarter mile. Newell

(1933, p. 58) felt that there was a change in facies of the Vilas at Ottawa. Southward from Ottawa, the Vilas is more sandy and contains a zone of the gastropod Hypselentoma perhumosa. The thickness ranges from 7 to 25 feet in Franklin and Anderson Counties.

At the type section, in northern Wilson County, the Vilas is over 100 feet thick. It thins southward and in the southern part of the county, where the Spring Hill is so thick (Loc. 24), the Vilas is only about 17 feet thick and contains many thin limestone beds. Southward from there, the Vilas thickens as the limestones of the Plattsburg thin and disappear. Newell (1933, p. 63) reported that in sec. 16, T. 31 S., R. 15 E., Montgomery County, the Vilas is 140 feet thick and the Plattsburg is only 5 feet thick. Newell believed that some of this thick Vilas Shale may be a time equivalent of the thick Spring Hill Limestone in southern Wilson County.

The Vilas cannot be differentiated from underlying shales in southern Montgomery County and the interval from the top of the Iola Limestone to the base of the Stanton is known as the Lane-Vilas Shale. In this area, the formation contains a limy sandstone or an oolitic limestone bed near the top. This bed is present only in the Southern Area. It ranges from 1 to 7 feet in thickness in the northern part of that area, is absent in the central part, and is about 20 feet thick in the southern part of the Southern Area.

Fossils are not common in the Vilas Shale. Newell (1933) believed that the Vilas was essentially barren of fossils except for the gastropods in Anderson and southern Franklin counties. The top of the Vilas at Locality 26 contains abundant crinoid stems. Wagner & Harris (1953) reported the ostracode Bairdia from the Vilas of Wilson County. Zinser (1950) found six genera of ostracodes in the Vilas of northern Kansas.

Stanton Formation

Captain Creek Limestone

Introduction- As has been stated, the type section of the Captain Creek is in a roadcut in Douglas County. Some twenty years have passed since this cut was made and all but the upper foot of the Captain Creek Limestone is covered by vegetation and slumped material.

Outcrops of the Captain Creek were examined one mile to the southwest of the type section (Cen. south side sec. 10, T. 13 S., R. 21 E.) and in a quarry about 1.5 miles northwest of the type section (SW cor. sec. 34, T. 12 S., R. 21 E.) and were found to conform to Newell's (1935a) description. For the purpose of this report, the Captain Creek Limestone in the quarry in the SW cor. sec. 34, T. 12 S., R. 21 E., Douglas County, Kansas, (Loc. 7) is considered to be the type.

The stratigraphy of the Captain Creek Limestone can be best discussed by dividing the outcrop area into three parts. These are; the Northern Area (Leavenworth County to central Anderson County), the Central Area (Allen County to central Montgomery County), and the Southern Area (southern Montgomery County.

Northern Area- In most of this area, the Captain Creek Limestone can be divided into three units on the basis of fossil content and gross lithology. The upper unit can be further subdivided into a Composita phase at the base and an algal phase at the top.

Lower Limestone Unit- The lower 1.5 to 2 feet of the Captain Creek Limestone is an olive-gray (5Y4/1) to light olive gray (5Y6/1), medium-grained limestone. It is a single massive bed at most localities but at Localities 9 and 11, it is divided into two beds separated by thin calcareous shale stringer (Fig. 3 and 4). At Locality 10, this lower unit is not well exposed and may be made up of two beds there also.

This unit exhibits little variation in thickness or lithology. It is about 1.5 feet thick in the central part of the area and increases to about 2 feet both to the north and to the south. At the northernmost measured outcrop (Loc. 1), the basal part of this unit is slightly oolitic. In central Anderson County.(Loc. 14), the unit is more coarse-grained than to the north.

The characteristic fossils of this unit are mollusks and Osagia. Small high-spired gastropods are the most common mollusks and fragments of myalinid shells were found at scattered outcrops. Osagia occurs as a coating around the snails or shell fragments or as spherical or oval masses with no discernable nucleus (Fig. 3-8). At Locality 14, in central Anderson County, the Osagia is absent and an alga (?), informally called "Marksia" is present (Fig. 9).

The balance of the fauna is composed of Triticites, rare small Composita (?), and crinoid stems. Triticites, while never abundant in any part of the Captain Creek, is more common in the lower limestone unit. The brachiopods were seen

FIG. 2. Lower Stanton at Locality 4.
(sec. 18, T. 11 S., R. 23 E.)
L- lower limestone unit of the Captain Creek
S- middle shale unit of the Captain Creek
U- upper limestone unit of the Captain Creek
E- Eudora Shale
St- Stoner Limestone

FIG. 3. Captain Creek Limestone at Locality 9 (sec. 10, T. 14 S., R. 21 E)
L- lower limestone unit
S- middle shale unit
U- upper limestone unit
"Mottled" limestone is present at this outcrop but has been eroded back.

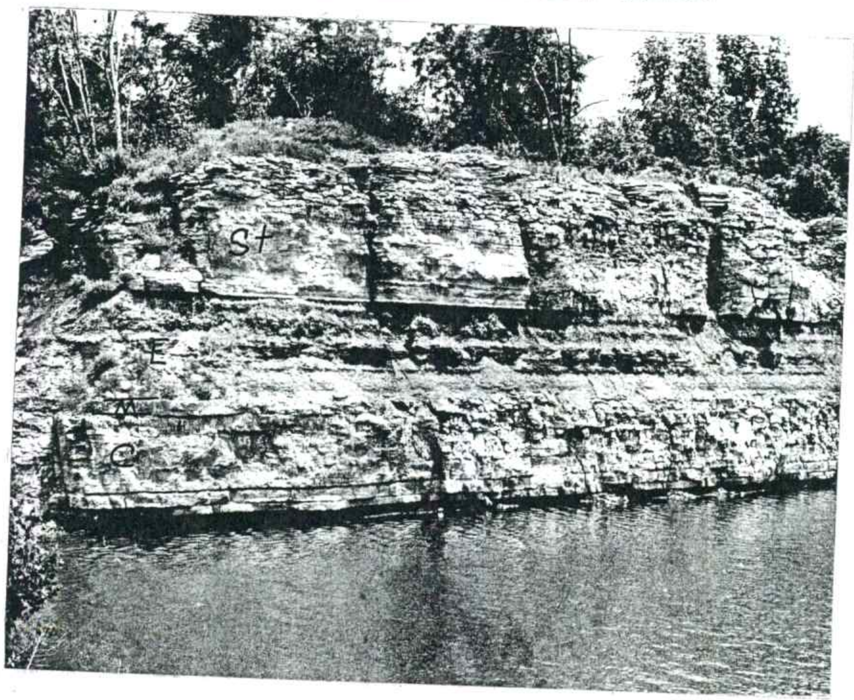

FIG. 4. Lower Stanton at Locality 11 (sec. 6, T. 17 S., R. 20 E)
C- Captain Creek Limestone
M- "Mottled" limestone
E- Eudora Shale
St- Stoner Limestone

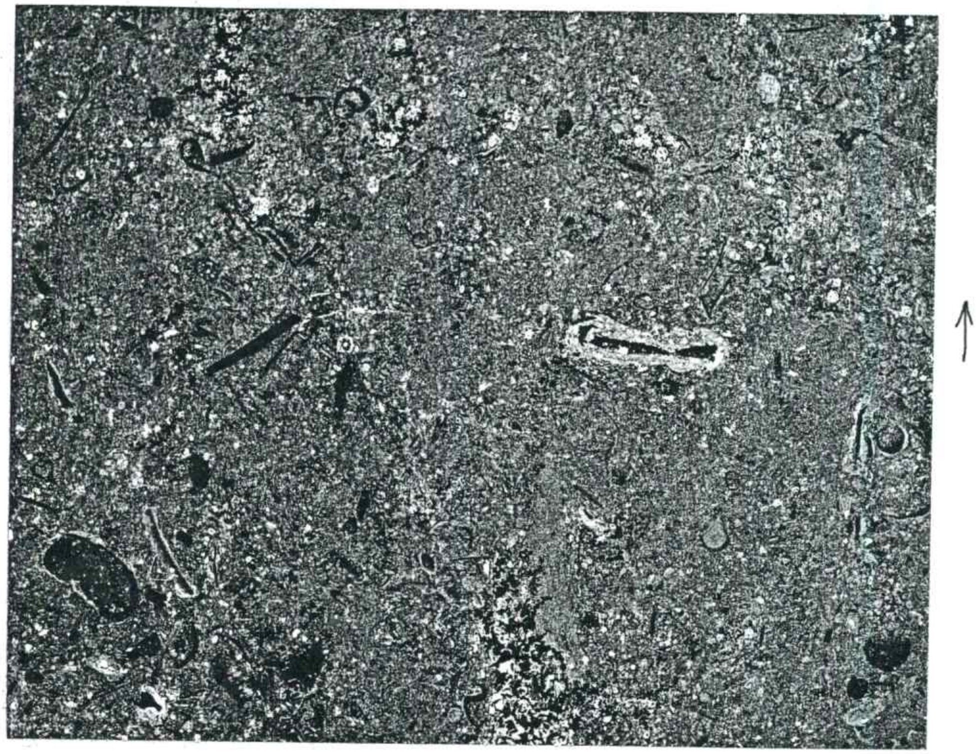

FIG. 5. <u>Osagia</u> and small gastropods, lower limestone unit, Loc. 6 (sec. 13, T. 12 S., R. 21 E.). Peel print, X-4. <u>Note</u>- In all peel prints, the arrow points toward the top.

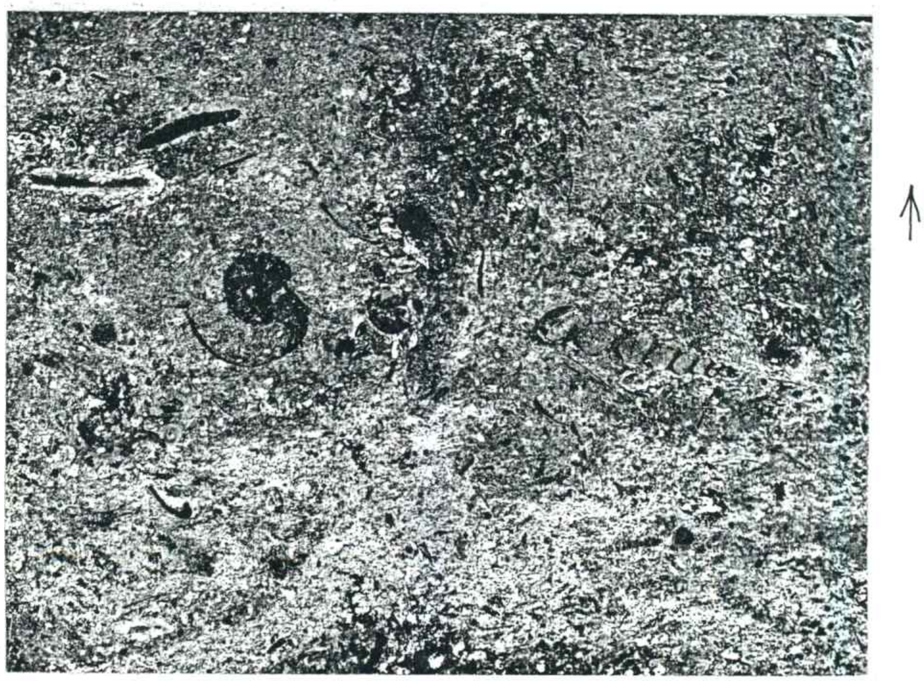

FIG. 6. Small gastropods, lower limestone unit, Loc. 6 (sec. 13, T. 12 S., R. 21 E.). Peel print, X-4.

FIG. 7. Fusulinids, gastropods, clams, and algae, lower limestone unit, Loc. 2 (sec. 27, T. 10 S., R. 23 E.). Peel print, X-4.

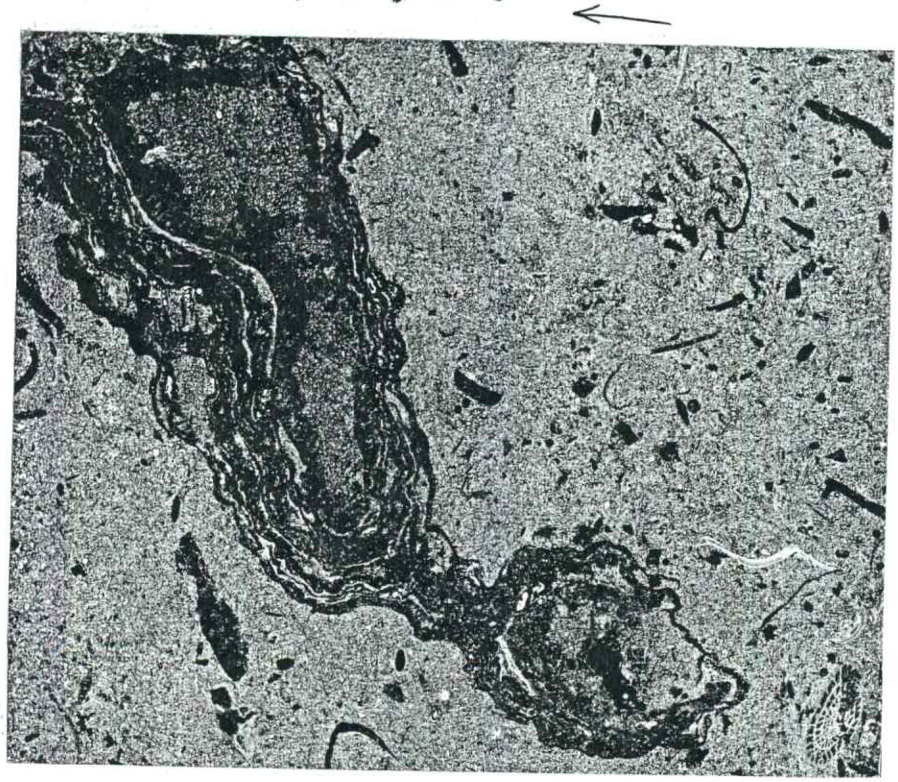

FIG. 8. Algae and fusulinids, lower limestone unit, Loc. 11 (sec. 6, T. 17 S., R. 20 E.) Peel print, X-4.

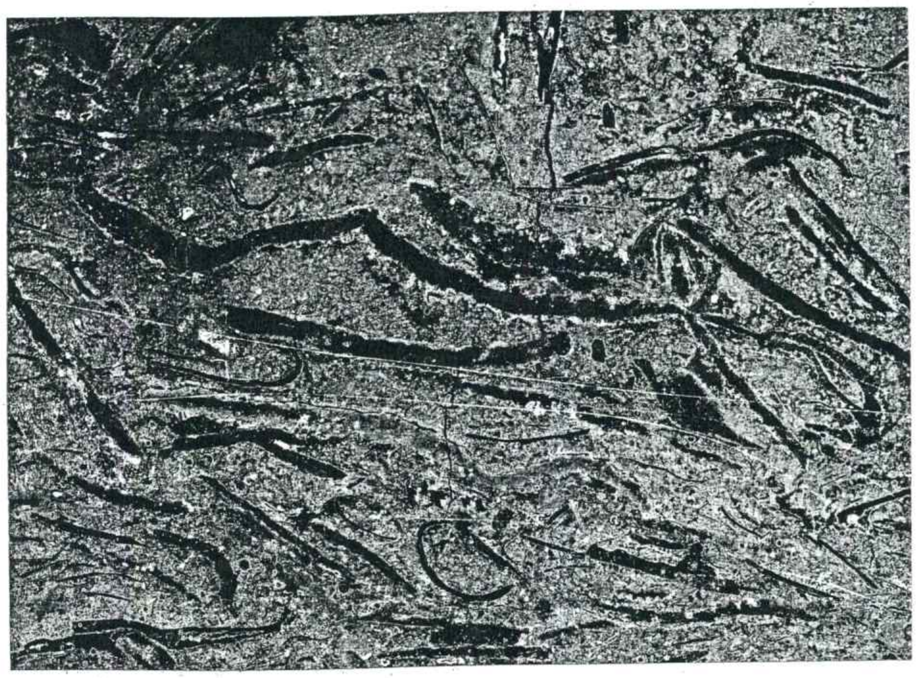

FIG. 9. "Marksia", lower limestone unit, Loc. 14, (sec. 12, T. 20 S., R. 19 E.). Peel print, X-4.

only on the acetate peels or in the thin sections and not at the outcrops. The crinoid fragments are not common but become more numerous toward the southern part of the Northern Area. Bryozoans were not seen in the lower limestone unit.

Middle Shale Unit- A thin (1-2 inches, buff- to light-gray, limy shale parting separates the lower limestone unit from the overlying limestone in the central part of the Northern Area. At one outcrop (Loc. 10), the parting is represented by a thin zone of shaly limestone. The shale is not present in southern Franklin County and Anderson County, but the two limestone units can still be distinguished. The shale is also absent in central Leavenworth County (Localities 1 and 2), and in this area there is no sharp division between the two different limestone lithologies.

The fauna of the shale bed consists of fusulinids, crinoid stems, and a few specimens of small Composita. This fauna is similar to that of the overlying limestone. Zinser (1950) reported the Foraminifera Tetrataxis and Cornuspira from the Captain Creek. He probably obtained these from this shale parting.

Upper Limestone Unit- The upper part of the Captain Creek is a light bluish-gray (5B7/1) limestone. It is fine-grained to aphanitic, and medium-bedded. Prominent vertical joints are present in this part of the member which usually weathers into medium-sized gray blocks. The thickness of this unit is not as constant as that of the lower limestone, being 8 to 9 feet in Anderson and Franklin counties and gradually decreasing northward to 5.4 feet in the type area and about 6 inches at Locality 1.

In Franklin and Anderson counties, small (1-3 inches), gray chert nodules are sparsely distributed 1-2 feet above the base of the upper limestone unit. These nodules contain rare fusulinids and brachiopod shell fragments. Newell (1933, p. 70) reported that the Captain Creek was "exceedingly" cherty in southwestern Miami County and eastern Anderson County. The writer did not find enough chert in the Captain Creek to warrant that description.

In many places in the Northern Area, the topmost part of the Captain Creek is stained red or pink, probably as a result of the weathering of iron minerals, the distribution of which seems to be controlled by the linear algae which are very abundant in the upper part of the member.

The dominant fossils of the upper limestone unit are Composita and a linear algae. Each of these forms is distributed throughout most of the unit but Composita is more abundant near the base and the algae are abundant at the top of the member (See Figs. 10-13).

Composita is not easily seen on the weathered surface of the rock but can be found if a fresh piece of the limestone is broken off the outcrop. The writer has a triangular block of limestone, about 4 inches on a side, from the Camp Naish section (Loc. 5) which, on its top surface, contains 10 specimens of Composita and the external molds of 5 more specimens. Most of the specimens are oriented in the living position (Robert Grinnell, personal communication).

The main line of the measured sections extends in a north-south direction, but three outcrops were examined that lie on

FIG. 10. *Composita* phase, lower part of upper limestone unit, Loc. 5, (sec. 27, T. 11 S., R. 23 E.). Peel print, X-4

FIG. 11. *Composita* and algae, middle part of upper limestone unit, Loc. 4, (sec. 18, T. 11 S., R. 23 E.). Peel print, X-4.

FIG. 12. Linear algae, top of upper limestone unit, Loc. 10, (Sec. 27, T. 16 S., R. 20 E.). Peel print, X-4.

FIG. 13. Linear algae, top of upper limestone unit, Loc. 6, (sec. 13, T. 12 S., R. 21 E.). Peel print, X-4.

an east-west line. They are; Loc. 7, Loc. 5, and an unmeasured outcrop north of Kansas City, Missouri. Comparison of the faunal content of these three outcrops leads the writer to believe that the Composita are more abundant toward the east. In Kansas, the Composita are most abundant along the Kansas River and become less common toward the southern part of the Northern Area. The abundance of Composita seems to remain about the same north from the Kansas River as it is near that area. At Locality 1, Composita is concentrated in pockets on top of the Captain Creek Limestone.

Associated with Composita are Enteletes, Marginifera, Dictyoclostus, Triticites, crinoid stems, and rare linear algae. Newell (1931, p. 53) reported Enteletes pugnoides from the Captain Creek Limestone of Johnson County. He stated that it was found associated with rare specimens of Enteletes hemiplicatus in a zone "about one quarter of the distance from the top of the member". The writer could find no evidence of any definite zone of Enteletes except that they are found only in the upper limestone unit and are rare in the upper one foot of the member. Enteletes is not as abundant as Composita. Newell (1933, p. 69) reported that Enteletes is absent from the Captain Creek Limestone in Kansas north of T. 11 S., and is not found in the Captain Creek of Missouri or Iowa.

Dictyoclostus was seen in the Northern Area only at Locality 1 where it is associated with abundant specimens of Composita. Enteletes was not found at this outcrop. Marginifera is is not especially common in the Captain Creek Limestone and was found only at scattered outcrops.

Newell (1931a) described a member of the Triticites irregularis group of fusulinids from the Captain Creek. Subsequently, he (Newell, 1935b, p. 422) split the T. irregularis species and named the form in the Captain Creek T. neglectus, stating that it was concentrated on bedding planes of the member.

The linear algae are especially abundant in the upper 1 to 2 feet of the Captain Creek where they constitute almost all of the biota. Johnson (1946, p. 1098) identified the algae from the Bert Ross quarry (Loc. 11; sec. 6, T. 17 S., R. 20 E.) as Anchicodium gracile and reported that it was associated with other algae, small foraminifers, and fragments of bryozoans. The writer found rare small brachiopods in the topmost part of the Captain Creek and arenaceous Foraminifera in the insoluble residues from that part of the member, but did not find any bryozoans. Archaeolithophyllum has been identified in association with Anchicodium in the Captain Creek (Kenji Konishi, personal communication). This genus has been reported from the Pennsylvanian deposits of Texas and Missouri (Johnson, 1956), but this is the first record of its occurrence in Kansas.

Algae are present in all of the upper limestone unit but are most abundant at the top. They are found in the upper unit throughout the Northern Area, but are not so abundant north of the Kansas River.

A few miles north of the Kansas River, the shale unit disappears and there is no sharp dividing line between the two limestone lithologies. At the northernmost outcrop of the Captain Creek (Loc. 1), the member is only 2.6 feet thick. The lower part is slightly oolitic and contains fusulinids and *Osagia*. It grades upward into about 6 inches of light-gray limestone at the top. Large specimens of *Dictyoclostus* are present at the top of the Captain Creek and small *Composita* are concentrated in pockets on top of the member. The upper limestone unit seems to have thinned out here and the lower limestone unit makes up most of the member.

FIG. 14. "Mottled" limestone ("M") and Captain Creek (CC) at Loc. 11, (sec. 6, T. 17 S., R. 20 E.).

In Johnson and Franklin counties (Locs. 9-11), an extra bed of limestone is present just above the Captain Creek (Fig. 14). 14). It is a very distinctive unit, being mottled very light gray (N8), light bluish gray (5B7/1), and grayish black (N2). Iron oxide produces a red or pink tinge on parts of weathered specimens. There is an irregular distribution to the mottling over the whole rock but the three different colors show a definite cyclic arrangement. At the base of a cycle is a very thin (1/8 inch) stringer or line of the black which is overlain by a thicker layer (1/2 to 1 inch) of the bluish gray. This is followed by about the same thickness of the light gray material, which is in turn overlain by another thin black stringer. Examination of thin sections and acetate peels leads the writer to believe that the black stringers are algae, possibly of the same type as in the Captain Creek Limestone below. The thin lines or stringers, which appeared to be black in the hand specimens were found to be composed of clear calcite upon examination in thin section.

The "mottled" limestone is 0.7 feet thick in Johnson county and about 1.8 feet thick in Franklin county. Where thickest, the "mottled" limestone occurs in two irregular layers separated by a very thin shale parting. In Johnson County, it is one single bed.

This "mottled" limestone has been noted previously (Newell, 1935a; Moore, 1935). It has usually been described as being "siliceous", probably because it is not as brittle as the underlying limestone. However, the chemical analysis showed that the silica content is only about 3 percent.

The "mottled" limestone is separated from the Captain Creek Limestone by a 1- to 2-inch tan, limy shale parting.

The contact between the "mottled" limestone and the Eudora could be seen only at the two outcrops in Franklin County. In those two places, the limestone is overlain by the black carbonaceous part of the Eudora Shale. Good exposures of the contact between the normal Captain Creek and the Eudora Shale are hard to find, but, where seen, the Captain Creek is separated from the black part of the Eudora by a 2- to 5-inch bed of tan, limy shale. The writer believes that this shale is the same as that below the "mottled" limestone and that the "mottled" limestone is a local facies of the Eudora Shale.

Another line of evidence leading to this conclusion is obtained by comparing the thicknesses of the Captain Creek in the three outcrops containing the "mottled" limestone with the thickness of the Captain Creek in the outcrops immediately to the north and to the south of these. The Captain Creek is 6.9 feet thick at Locality 7 in Douglas county. No "mottled" limestone lies above it there or at Locality 8. Total thickness of the Captain Creek could not be measured at Locality 8 because most of the outcrop is covered. Toward the southeast, in Johnson County, the Captain Creek is 6.5 feet thick at Locality 9. At that place, there is a thin limy shale bed and o.7 feet of "mottled" limestone above the Captain Creek. The member thickens toward the southwest from Locality 9 and is 6.7 feet thick at Locality 10. There the "mottled" limestone is 1.4 feet thick. At Locality 11, the Captain Creek is 8.2 feet thick and the "mottled" limestone is 1.7 feet thick. About six miles south of this place, at Locality 12, the

Captain Creek is 8.4 feet thick and the "mottled" limestone is absent.

Thus there is a general southward and westward thickening of both the Captain Creek and the "mottled" limestone. The "mottled" limestone is an extra bed above the Captain Creek and does not affect the thickening of that member. Plate 4 shows the relationships of the Captain Creek Limestone and the "mottled" limestone.

Fossils of the "mottled" limestone consist almost exclusively of the linear algae mentioned above. Only a few arenaceous foraminifers were seen in the insoluble residues.

Central Area- No outcrops of the Captain Creek Limestone were found in southern Anderson or northern Allen counties. This area is occupied by a smooth divide between the drainage systems of the Osage and Neosho rivers. The divide is a gently undulating plain formed on the dip slopes of the Plattsburg and Stanton formations with low hills of Weston Shale outliers. The highest portion of the divide is capped by Tertiary chert gravels (Frye, 1955).

A roadcut at the SE cor. sec. 25, T. 24 S., R. 17 E., Allen County (Loc. 17), exposes about 11 feet of the lower part of the Captain Creek. At the base is 3.2 feet of dark-gray limestone containing, at the top abundant linear algae of the type called "Marksia" (Fig. 15). These are short, straight algae and are not the same type as seen at the top of the Captain Creek in the Northern Area. U.S. 54

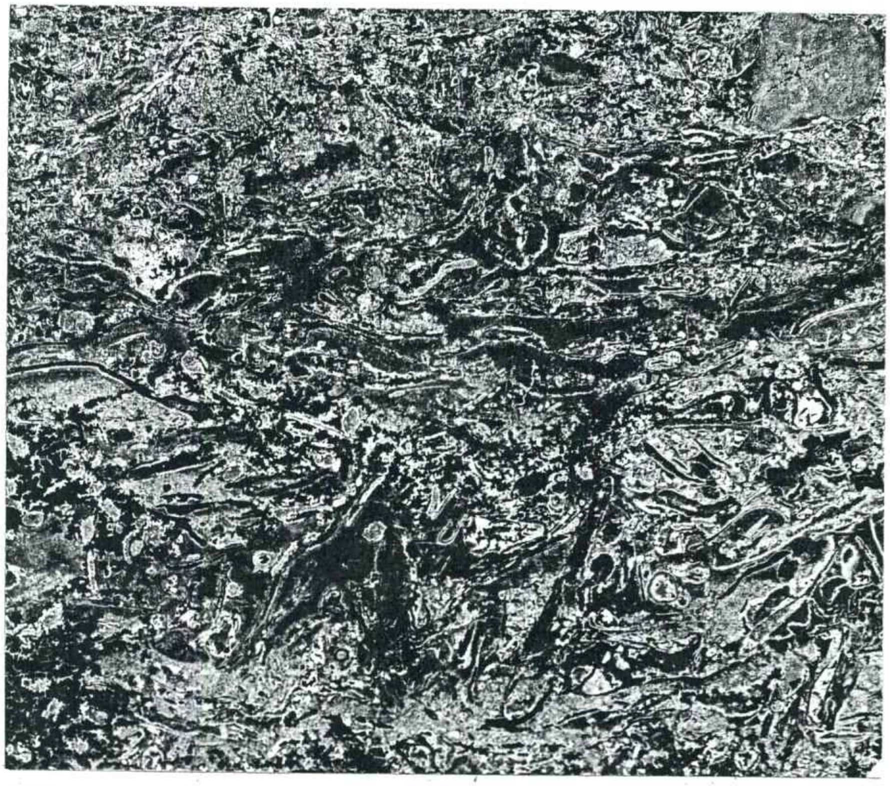

FIG. 15. "Marksia" and an echinoderm fragment, lower limestone unit, Loc. 17, (sec. 25, T. 24 S., R. 17 E.). Peel print, X-4.

The dark-gray limestone grades upward into about 8 feet of light-gray, wavy-bedded, medium-grained limestone. Fossils are sparse and consist of Composita, Echinochoncus, crinoid stems, and rare linear algae.

The top of the Captain Creek cannot be seen in this road-cut but it is exposed about 2 miles to the north in a quarry in the NW cor. sec. 19, T. 24 S., R. 18 E., Loc. 16. About 4 to 5 feet of light-gray, very fine-grained to aphanitic limestone can be seen in the bottom of the quarry (Fig. 16). This limestone is thin-bedded with slight wavy bedding. Rare Composita, Enteletes, and rare linear algae make up the biota.

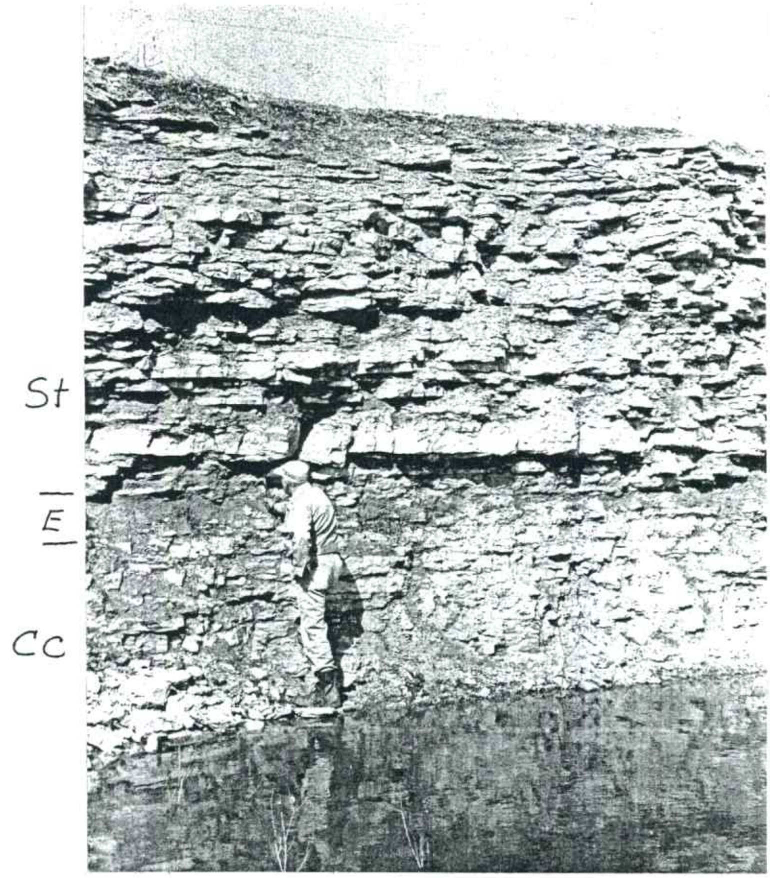

FIG. 16. Loc. 16, (sec. 19, T. 24 S., R. 18 E.).
CC- Captain Creek Limestone
E- Eudora Shale
St- Stoner Limestone

The limestone is overlain by 0.8 feet of dark-gray limy shale. Crinoid columnals, small low-spired gastropods, Neo-spirifer, Composita, and ramose bryozoans make up the fauna. Small pockets of black shale are present on top of the Captain Creek. Above the gray shale is a 5-foot sequence of coarse-grained, thin limestone beds interbedded with dark-gray limy shale, all of which is overlain by 5 feet of coarse-grained limestone.

Newell (unpublished stratigraphic section, Kan. Geol. Survey) measured a poorly exposed section of the Stanton in sec. 14, T. 24 S., R. 17 E. He stated that the Captain Creek is 16 feet thick (ranging from 11 to 16 feet thick in the surrounding area) and that the Eudora consisted of 5 feet of limy shale and impure limestone. The thickness of parts of the sequence that he describes is similar to that seen in both the roadcut and the quarry. The writer believes that only the 0.8 feet of shale overlying the Captain Creek should be called the Eudora because the limestone beds intercalated with the shale above it are not essentially different from the 5 feet of limestone at the top of the quarry.

The few outcrops seen in Woodson County show a sequence similar to that seen in the roadcut at Locality 17 in Allen County. There is, at the base, a dark-colored limestone containing "Marksia" (Fig. 17), followed by a sequence of buff-colored, thin- to medium-bedded, medium- to coarse-grained limestone. The top of the Captain Creek and the Eudora Shale were not seen in Woodson County.

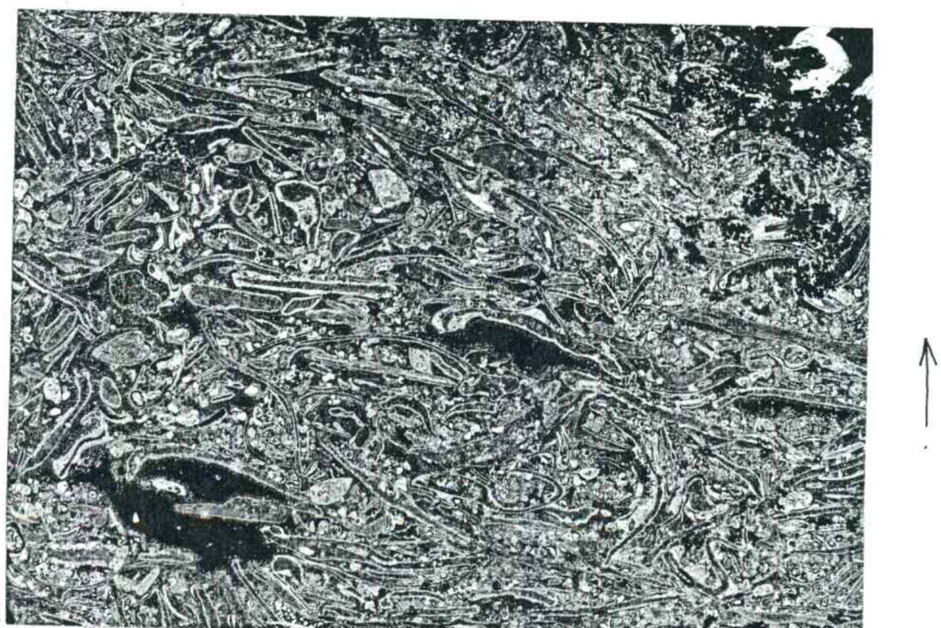

FIG. 17. "Marksia", lower limestone unit, Loc. 18, (sec. 32, T. 25 S., R. 17 E.). Peel print, X-4.

Wilson and Montgomery counties are the area of extreme variation in thickness and lithology of all parts of the Lansing Group. The thickness of the Captain Creek ranges from 3 to 20 feet in Wilson County and it has been reported absent north of Fredonia in west central Wilson County (Wagner & Harris, 1953). In central and northern Wilson County, the Captain Creek consists of 3 to 10 feet of light-gray to dark-gray, medium- to coarse-grained limestone. It is massive to medium-bedded and weathers pitted and vuggy. A 0.5-foot bed of Osagia-bearing limestone occurs 0.5 to 2 feet below the Captain Creek in northern Wilson and southern Woodson counties. (Fig. 18). In northern Wilson County, the base of the Captain Creek also contains abundant Osagia. Enteletes and fusulinids are present, and Wagner & Harris (1953) reported large clams from a local shaly limestone at the top of the Captain Creek. Clams (Myalina) were found in only one locality and these were in a limy shale and shaly limestone sequence believed to be the Eudora.

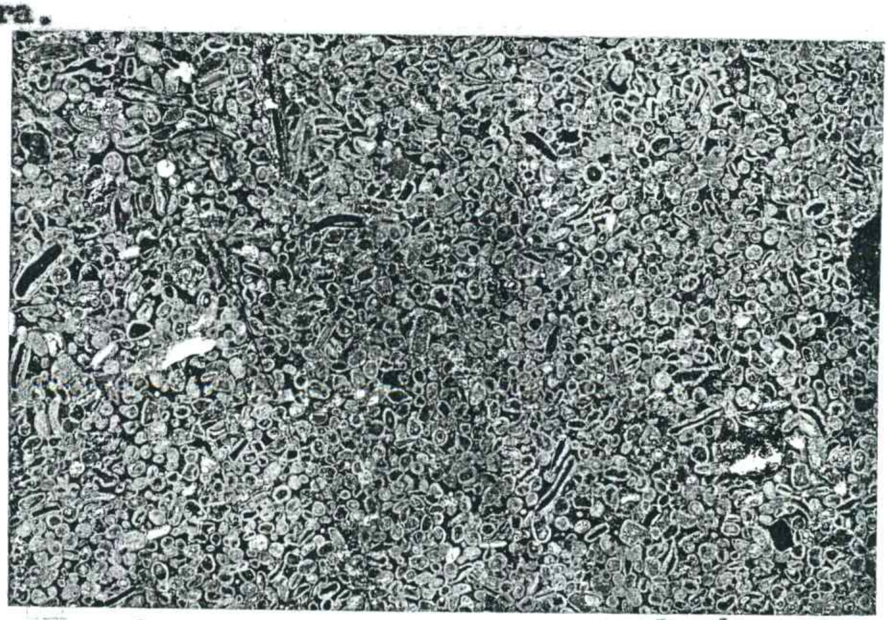

FIG. 18. Osagia limestone, Locl 18, (sec. 32, T. 25 S., R. 17 E.). Peel print, X-4.

Interesting exposures of the Stanton are found in the southwest and south part of sec. 7, T. 29 S., R. 16 E., Wilson County (Locs. 22-23). On the north-south road at the southwest corner of the section, the Captain Creek comprises 7.5 feet of massive light-gray limestone. It is medium- to coarse-grained and contains abundant masses of clear calcite. The fauna consists mostly of Enteletes, Composita, crinoid stems, and fenestrate bryozoans. The Eudora Shale consists of 2.5 feet of shaly limestone and limy shale and contains small myalinids and bryozoans (Fig. 19).

FIG. 19. Loc. 22, (sec. 7, T. 29 S., R. 16 E.).
CC- Captain Creek Limestone
E- Eudora Shale

Approximately one-quarter mile to the southeast, in a roadcut on the south side of the section (Loc. 23), the Captain Creek is not more than 5 feet thick. The base is very irregular (Fig. 20-21) and in places the thickness is only about one foot.

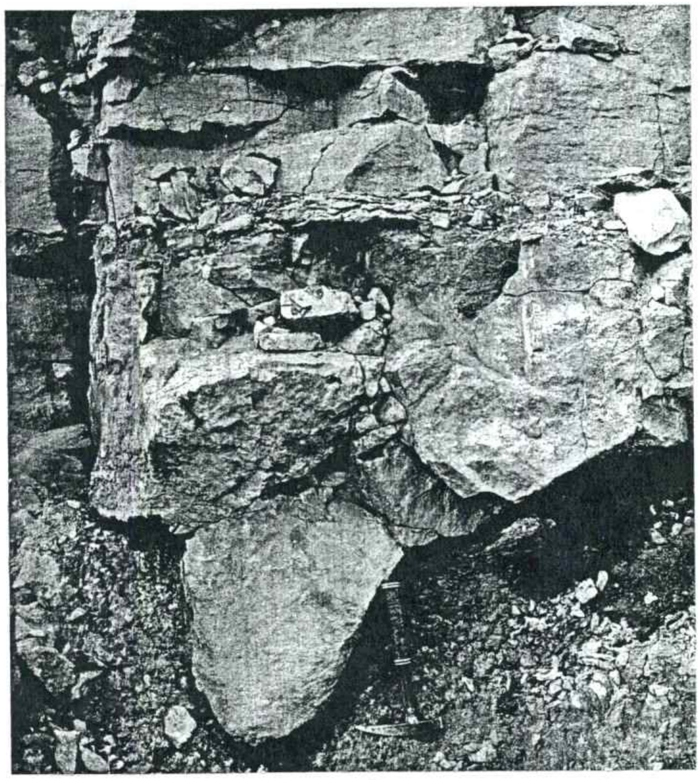

FIG. 20. Loc. 23, (sec. 7, T. 29 S., R. 16 E.) Base of Captain Creek.

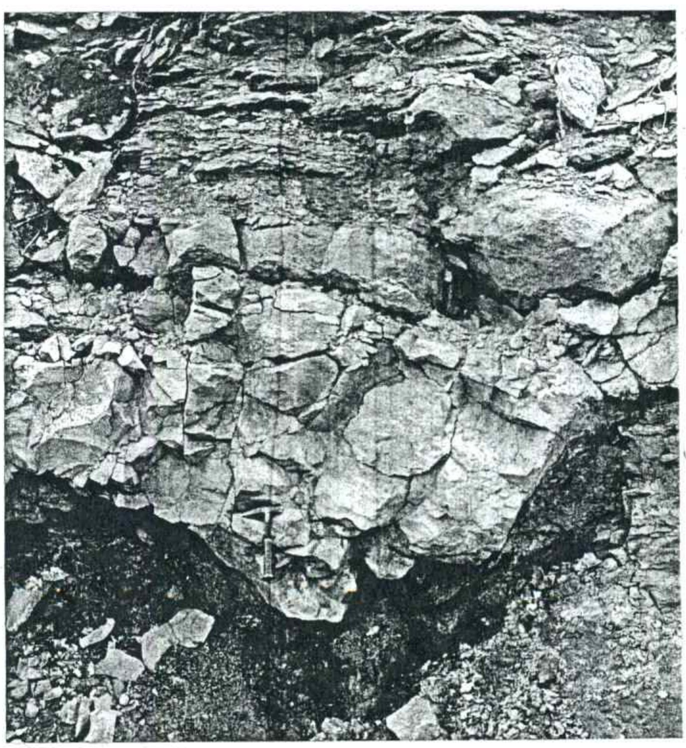

FIG. 21. Loc. 23, (sec. 7, T. 29 S., R. 15 E.). Base of Captain Creek.

The rock is fine-grained, massive, and is dark blue gray in color. Composita and Osagia associated with rare nautiloids make up most of the fossils. The Eudora here is about 5 feet thick and consists of limy shale and shaly limestone with a 0.5 foot bed of black shale at the base. The black shale bed is present only on the north side of the cut and was not seen on the south side.

The thickness of the Captain Creek increases to the south and west from this locality. Wagner & Harris (1953) reported that the Captain Creek is 20 feet thick in a quarry near Fredonia. At the NW cor. sec. 26, T. 30 S., R. 15 E., Wilson County (Loc. 24), the Captain Creek is 10+ feet thick above about 17 feet of limy Vilas Shale and approximately 80 feet of Spring Hill Limestone (Fig. 22).

FIG.22. Loc. 24, (sec. 26, T. 30 S., R. 15 E.).
CC- Captain Creek Limestone
V- Vilas Shale

The greatest thickness of the Captain Creek was measured in a roadcut at the cen. sec. 31, T. 31 S., R. 15 E., Montgomery County (Loc. 25), where it is 64.1 feet thick. The lower 19 feet is thick- to massive-bedded, light-gray with abundant masses of clear crystalline calcite. The next 17 feet is light tan to gray, iron-stained, massive, contains numerous masses of clear calcite and weathers very vuggy. The rest of the limestone is light gray to tan, medium- to fine-grained, and thin- to medium-bedded. Calcite masses are much less common than in the lower limestone. About 20 square feet of the upper surface of the Captain Creek is exposed at this locality. The top is a fairly level surface with small pits and undulations.

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The lower two limestone units contain *Enteletes*, productids, horn corals, crinoid columnals, fusulinids, and algae. The fossils are not very abundant and most specimens are crushed or broken and are concentrated in local pockets or stringers. The upper thin-bedded limestone contains fusulinids and crinoid stems but contains fewer brachiopods than the underlying limestones. Very few *Enteletes* were seen in the upper limestone and they seem to have been replaced by *Neospirifer*. The Captain Creek is overlain at this locality by 8 feet of limy fossiliferous Eudora Shale and only 2 feet of the original Stoner Limestone.

Three miles to the southeast (sec. 9, T. 32 S., R. 15 E., Loc. 26), 36 feet of the Captain Creek is exposed in an old quarry on the east side of Table Mound. The Captain Creek here overlies about 80 feet of the Vilas Shale (unpublished stratigraphic section, Kan. Geol. Survey). The lower foot of the member is a dark-gray, fine-grained limestone with a fauna composed of crinoid stems and a few Enteletes. The next 10 feet is a massive, brecciated bed with light-gray angular pieces of limestone and masses of clear calcite. The fauna consists of Enteletes, Marginifera, crinoid stems and rare fusulinids. The top surface has a thin crust of crushed brachiopods.

The next 3 feet of limestone above this last bed is a persistant (in this quarry) layer of medium-bedded, fine-grained, light-gray limestone containing Enteletes, crinoid stems, and very abundant fusulinids. The limestone is in 3 even-bedded layers and show little or no variation throughout the quarry.

Above this bed is 22.4 feet of massive, vugular-weathering, iron-stained limestone which is very similar to the limestone in the middle of the thickest section of the Captain Creek to the northwest. The fauna is composed of Enteletes and fusulinids. The top of the Captain Creek could not be identified here because the Stoner Limestone and the Eudora Shale have been eroded away.

A third thick limestone section of the Captain Creek was measured at sec. 14, T. 32 S., R. 14 E., (Loc. [illegible]27) beneath a bridge over the Elk River. The limestone is 15.5 feet thick, is light gray, and contains numerous calcite masses. The upper two feet is thin- to medium-bedded and contains numerous fusulinids. The fauna of the massive portion at the base consists of Enteletes, Marginifera, Neospirifer, and crinoid stems. At this locality, the Captain Creek is overlain by about 18 feet of Eudora Shale, and underlain by about 6 feet of shale, containing an impure limestone bed near the top, and 7+ feet of limy, fine-grained sandstone below the shale. F. Wilson (1957, p. 12) classified the shale and sandstone as part of the Captain Creek Limestone because of similarity to beds to the south of this locality. This conclusion will be discussed below.

Southern Area- There is a rapid change in the thickness and lithology of the Captain Creek Limestone immediately south of the Elk River. This change is caused by reef conditions in the member and will be discussed under the Environment of Deposition. At the cen. north side sec. 36, T. 32 S., R. 14 E., (Loc. 28), the Captain Creek is a 2.3-foot layer of thin-bedded dar-gray and light-tan, impure limestone. It is underlain by 3 feet of silty, limy shale and 2.2 feet of limy, fine-grained sandstone. A similar sequence can be seen on Walker's Mound (Loc. 29) about 2 miles to the southeast, except that there is a bed of oolitic limestone at the stratigraphic position of the sandstone.

F. Wilson (1957) correlated the oolite and the sandstone of this area with the thicker sandstone below the Captain Creek at Locality 27. Examination of the insoluble residues leads the writer to believe that this conclusion is correct. However, Wilson classes the oolite and the sandstone, and the and the overlying shale as part of the Captain Creek Limestone. The writer does not agree with this classification. The sandstone was not seen at any place to the north of the Elk River, nor is the base of the Captain Creek expecially sandy. The writer believes that this sandstone and oolitic limestone should be placed in the Vilas or the Lane-Vilas Shale. (See Plates 2 and 3).

The two outcrops of the Captain Creek immediately south of the Elk River (Loc. 28 and 29) occur below thick (60-70 feet) sections of the Eudora Shale (F. Wilson, 1957). At the base of the Eudora there is 1 to 2 feet of black shale containing phosphatic nodules.

At the SW cor. sec. 7, T. 34 S., R. 15 E., (Loc. 30) there is a buff, marly, crinoidal limestone about 2 feet thick. This bed occurs below about 50 feet of shale which, at the base, contains a bed of black shale with phosphatic nodules. The limestone is correlated with the Captain Creek of the area near the Elk River by its position below a similar shale interval. The Captain Creek here overlies a covered interval which Newell (unpublished stratigraphic section, Kan. Geol. Survey) measured as 40 feet of Lane-Vilas Shale. Newell gave no evidence and the writer saw no evidence of the oolitic limestone bed at this locality.

The oolitic limestone is present again in sec. 30, T. 34 S., R. 15 E. (Loc. 31) where it has locally thickened to about 18 feet. No bed which could be correlated with the Captain Creek Limestone of the area to the north was seen at ?

this locality. F. Wilson (1957) by using cores, was able to find the oolitic limestone about a mile south of Loc. 31 where it is divided into two beds separated by about 3 feet of shale.

Eudora Shale

The shale next above the Captain Creek Limestone is named the Eudora Shale from exposures in the same locality as the type section of the Captain Creek (Moore, 1935, p. 133). At that place, the Eudora is 6.3 feet thick and is composed of, from the base upwards, 0.5 feet of light-gray limy shale, 4.2 feet of black, subfissile to fissile shale, and 1.6 feet of maroon to tan, silty and limy shale.

The Eudora is between 5 and 6 feet thick throughout most of the area near the Kansas River, but thins northward. Moore (1949, p. 118) reported that the Eudora is only a foot thick in some localities in the northern part of the state. The greatest thickness of the Eudora in the Northern Area is in Franklin County where it is between 8 and 10 feet thick.

In exposures where the contact between the Captain Creek and the Eudora can be seen, there is a thin, tan to olive, limy shale at the base of the Eudora. This is not the case in those exposures containing the "mottled" limestone at the top of the Captain Creek. In those outcrops, the black shale part of the Eudora rests directly upon the "mottled" limestone and, in places, the limestone seems to grade upward into the black shale. The "mottled" limestone is separated from the Captain Creek by a thin, buff to tan, limy shale stringer. This relationship can be seen best in the quarries near Locality 11.[1]

In most of the Northern Area, the Eudora is essentially as described from the type locality. Three to four feet of black, fissile shale occur in the middle of the Eudora and are separated from the underlying and overlying limestones by thinner limy shale beds. The Eudora of this area is not especially fossiliferous. Zinser (1950, p. 11) described 7 species of conodonts (most belonging to the genus *Streptognathodus*) and one species of the foraminifer *Ammodiscus* from the Eudora of northern Kansas. Rare inarticulate brachiopods and plant fragments have also been found in the Eudora of the Northern Area.

As the outcrop of the Stanton is traced southward from Franklin County, the Eudora thins and the black, fissile part begins to disappear. In Anderson and Allen counties, the Eudora is about one foot thick and contains a thin, discontinuous layer of black shale at the base. As the black shale disappears, the rest of the Eudora becomes more fossiliferous. Newell (1933, p. 80) states that almost all of the black part of the Eudora is absent south of T. 22S.

The Eudora comprises about 1 to 2 feet of limy, fossiliferous shale in northern Wilson County and increases to about 2 feet (locally 5 feet) in central and southern Wilson County. Wagner & Harris (1953) state that, in the Fredonia Quadrangle, the Eudora seems to grade laterally into a shaly limestone. The thickening of the Captain Creek below and the Stoner above make exposures of the Eudora in Wilson County difficult to find. Those in Wilson County were seen only in local areas where the Captain Creek is thin.

In northern Montgomery County, the Eudora is about 8 feet thick but the thickness increases rapidly to the south. The member is approximately 18 feet thick at the Elk River in central Montgomery County (Loc. 27), and F. Wilson (1957, p. 14) estimated over 70 feet of the Eudora Shale a few miles s south of there. He also reported that the Eudora thins to 10 to 20 feet near the Oklahoma boundary with all or parts of it cut out during a hiatus represented by an unconformity at the base of the Stoner Limestone.

Stoner Limestone, Rock Lake Shale, and South Bend Limestone

The remaining members of the Stanton received only cursory study during this investigation and the following descriptions are taken from Newell (1933; 1935a), Moore (1949), Wagner & Harris (1953), F. Wilson (1957), and Ball (1958).

The Stoner is, throughout most of eastern Kansas, the thickest member of the Stanton. It is 11 to 15 feet thick in most of Kansas but increases to about 30 to 40 feet in partso of southern Kansas. It is fine-gto medium-grained (locally coarse-grained), light gray in color, and is characterized by thin, wavy limestone beds separated by limy shale partings.

Through Allen and Woodson counties, The Stoner breaks down into whitish limy, nodular shales and intercalcated irregular limestone lenses. Newell (1933, p. 81-82) could not distinguish between the Eudora, Stoner, and Rock Lake of this area.

Wagner & Harris (1953) describe the Stoner of the Fredonia, Kansas, area as about 30 feet thick but thinning westward to only 5 feet. It is fine-grained with a blotchy appearance caused by segregations of clay and iron.

Newell (1937) and Moore & Dudley (1944) found that the thick Stoner of the Fredonia area contained an exotic fauna which was characterized by the brachiopod Shizophoria texana?, the bryozoan Meekoporella dehiscens and abundant gastropods. The writer found the first two forms in the Stoner in association with abundant crinoid stems composed of pentagonal columnals. Newell (1937, p. 101) felt that this fauna had affinities with faunas described from the Pennsylvanian of Texas and interpreted it as evidence of an environment cut off, in some way, from the faunal elements and environmental conditions of the Stoner Limestone to the north. F. Wilson (1957, p. 31) believes that this fauna represents a lagoon enclosed by a reef.

The thick phase of the Stoner persists southward to the Elk River where it has been measured as approximately 30 feet thick. Newell (1933, p. 88) reported that in the hills just west of Table Mound in Montgomery County the Stoner is more than 40 feet thick.

The Stoner begins to thin a short distance south of the Elk River and in southern Montgomery County is quite variable in thickness and lithology. F. Wilson (1957, p. 15-17) describes the Stoner of this area as consisting variously of light-gray, calcite-cemented sandstone, coarse clastic limestone, or of fossil breccia and ranging in thickness from 4 feet to a few inches. He further states that the Stoner is unconformable upon the underlying strata.

The contact between the Stoner Limestone and the Rock Lake Shale is a disconformity (Moore, 1949, p. 119). There was emergence sometime shortly after the deposition of the Stoner and the Rock Lake represents a time of near-shore and lagoonal deposition (Peabody, 1952, p. 38).

This member is quite variable in lithology throughout all of eastern Kansas. Ball (1958) found that the Rock Lake of northern Kansas ranges from 1 to 10 feet thick and consists of a lower portion of gray to green clay shale, overlain, in some localities, by thin-bedded calcareous siltstones and, in other places, by impure limestone. Nodular limestone and arenaceous shale characterize the upper part of the Rock Lake. Coal stringers and land plants may be found in some localities and a terrestial reptile was found at a locality in Anderson County.(Peabody, 1952). The marine fauna of the Rock Lake is dominated by mollusks. Brachiopods and bryozoans are not common.

Wagner & Harris (1953) found that the Rock Lake of the Fredonia area averages 2 feet in thickness and consists of a gray and orange clay shale or a very calcareous and fossiliferous clay shale. Just east of the Fredonia Quadrangle, at Loc. 23, the Rock Lake is missing and the South Bend lies unconformably upon the Stoner Limestone.

F. Wilson (1957, p. 17-18) described the Rock Lake of northern Montgomery County as ranging in thickness from a few inches to about 5 feet and consisting of gray-green, silty shale containing abundant fusulinids. The Rock Lake of southern Montgomery County is 15 to 30 feet thick and consists of unfossiliferous shale or a series of thin shales and thin, ripple-marked sandstone beds. A thick, reddish, current-bedded sandstone is found in certain outcrops at the stratigraphic position of the Rock Lake (Loc. 31). F. Wilson (1957, p. 18) believes this to be a channel or deltaic deposit correlative with the Rock Lake Shale, but admits that it closely resembles the Tonganoxie Sandstone.

The South Bend Limestone of northern Kansas averages 7 feet in thickness and consists of a blue-gray to brown limestone. A highly arenaceous lower part with a molluscan fauna grades upward into a less arenaceous limestone at the top which contains a molluscoid-fusulinid fauna. A locally-developed conglomerate is found at the base. The most characteristic fossil is the brachiopod Meekella.

The South Bend of the Fredonia area is predominately a sandy, oolitic limestone. In some areas, it is disconformable on the underlying beds and, in those areas, the basal part is a sandy conglomerate containing fragments of the underlying Rock Lake Shale and Stoner Limestone. In certain areas, the oolitic limestone is interbedded with white or iron-stained calcareous sandstone. Both the limestone and the sandstone are cross-bedded. The South Bend is commonly about 6 feet thick in the Fredonia Quadrangle but varies from 3 to 15 feet.

F. Wilson (1957, p. 18-21) found that in the thick limestone sequence of northern Montgomery County, the South Bend is 27 feet thick with an oolitic phase at the top and a current-bedded sandstone at the base and the middle part being composed of thick-bedded, porous limestone. The fauna consists of abundant large crinoid stems associated with fusulinids and the brachiopod Meekella.

The thickness of the South Bend decreases abruptly as it is traced southward in Montgomery County. In that area, the South Bend consists of a basal lime-cemented sandstone and conglomerate which is overlain by about 3 feet of blue-gray, fine-grained limestone containing crinoid stems and numerous sponges. This topmost bed changes to an impure, nodular limestone and disappears near the Oklahoma boundary.

The Birch Creek Limestone of Oklahoma has been correlated with the South Bend Limestone by similarity of position in the column and because both exhibit an unconformity at or near the base (Oakes, 1940, p. 90).

SEDIMENTARY ANALYSIS

Acetate Peels and Thin Sections

Introduction

Acetate peels were made from specimens of the Captain Creek selected from nearly all the localities of the measured sections. Peels are a quick and easy method of determining the microstructure of limestones but any study utilizing this method should be supplemented by the use of selected oriented thin sections. Mineralogical determinations cannot be made readily with peels; and small fossils, such as fusulinids, and certain small sedimentary structures, such as oolites, are better studied in thin section. The information gained from these two different methods of investigation is either similar or supplementary and, accordingly, will be discussed under one heading.

Northern Area

In the Northern Area, the lower limestone unit is typically a medium-grained limestone containing shell fragments and small snails, all generally coated with Osagia. The fossil content is about the same throughout the Northern Area and only at Loc. 1 is there any significant difference in the lithology. There the lower part of the lower limestone unit is slightly oolitic. The nuclei of the oolites are small quartz sand grains, shell fragments, or opaque material of unknown origin (Fig. 23). At Loc. 14, in Anderson County, the lower limestone unit also contains short, straight, calcite-filled structures which are interpreted as algae, probably similar to the "Marksia" of Allen and Woodson counties (Fig. 24).

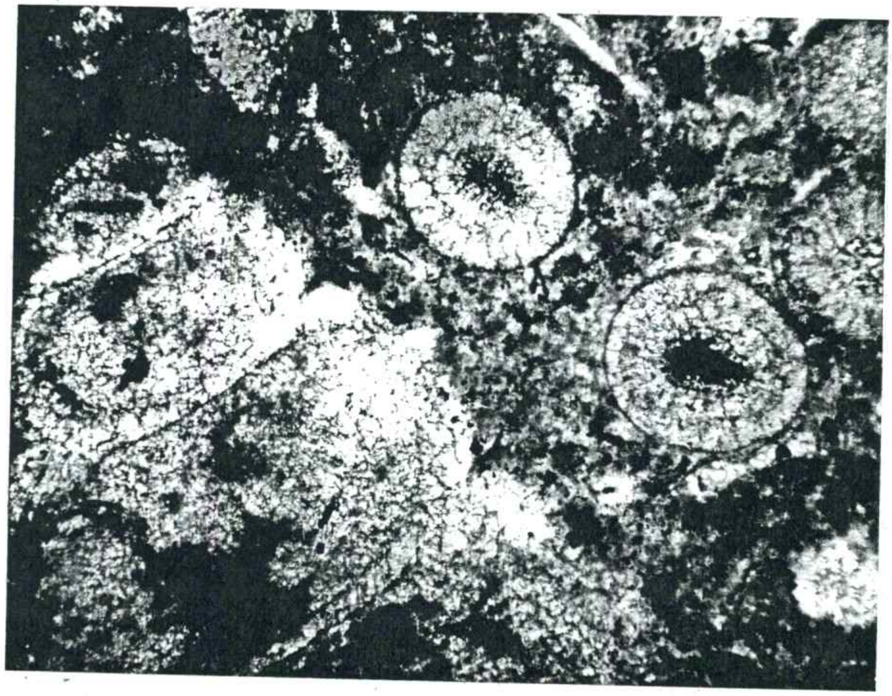

FIG. 23. Lower limestone unit, Loc. 1,(sec. 36, T. 9 S., R. 22 E.). Oolites and a gastropod. Photomicrograph, X-40.

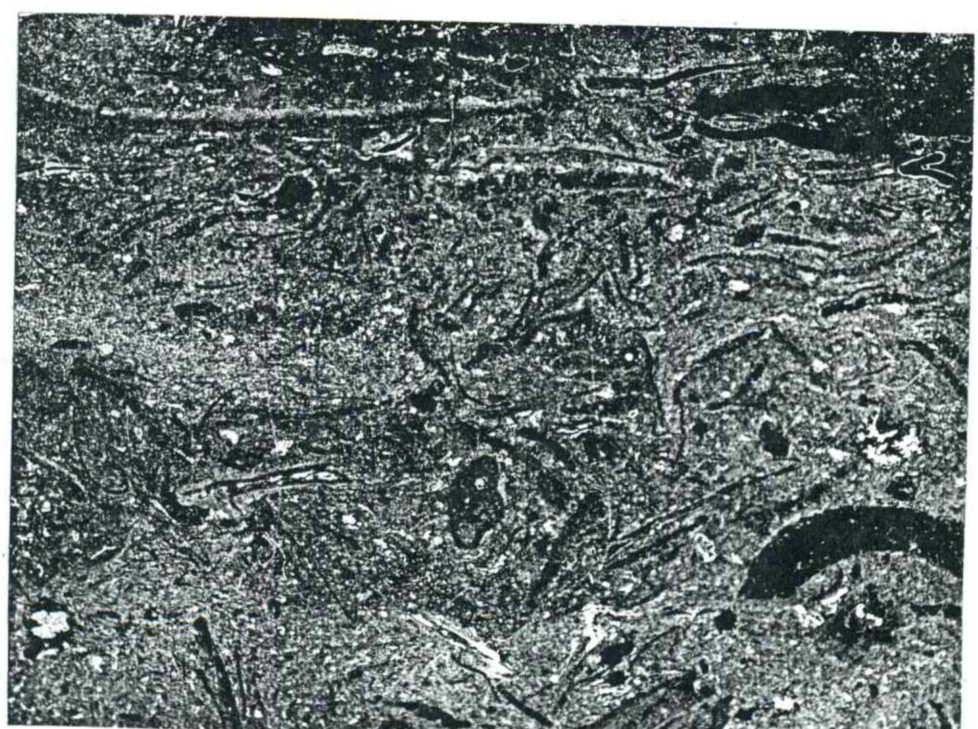

FIG. 24. "Marksia", lower limestone unit, Loc. 14, (sec. 12, T. 20 S., R. 19 E.). Peel print, X-4.

The upper limestone unit of the Captain Creek of the Northern Area is fine-grained. The two faunal divisions can be easily discerned in the peels and thin sections. The linear algae are rare at the base but constitute nearly all the biota of the upper part of the unit. Small concentrations of silt were seen beneath some of the algal stringers in specimens from the top of the Captain Creek. In weathered specimens, these silt concentrations were stained red by the weathering of iron minerals.

The "mottled" limestone contains abundant linear algae which have concentrations of silt grains immediately below them (Fig. 25). The blue-gray part is fine-grained and contains short fragments of linear algae and many algal (?) pellets which may be Osagia. The light gray part of the "mottled" limestone is also fine-grained but contains less algal material and becomes progressively more silty toward the top.

In certain slides (Fig. 26), small dark spots can be seen in the rock of the upper limestone unit. These are interpreted as faecal pellets because of resemblance to descriptions and pictures by Beales (1956).

At both Locality 15 in Anderson County and Locality 16 in Allen County, the upper part of the Captain Creek is fine-grained to aphanitic. Fossils are rare, pyrite masses are common, and short, straight algae are common.

FIG. 25. "Mottled" limestone, Loc. 11, (sec. 6, T. 17 S., R. 20 E.). White silt accumulations immediately below dark gray algal limestone. Peel print, X-4.

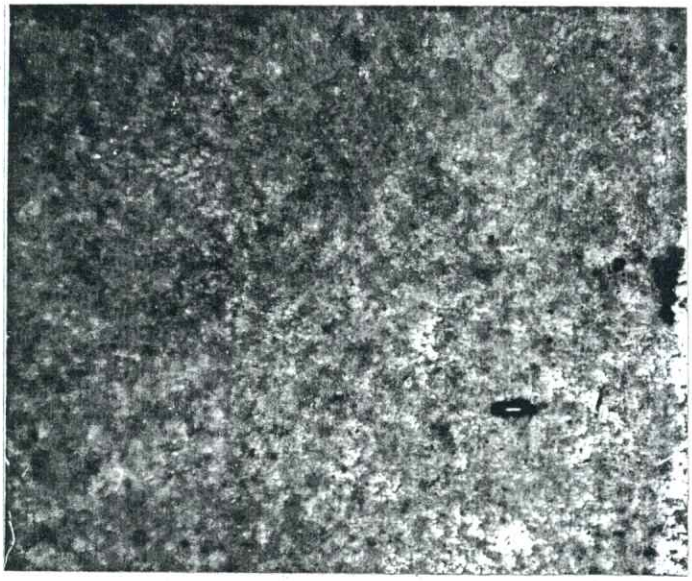

FIG. 26. Faecal pellets (?), upper limestone unit, Loc. 15, (sec. 12, T. 20 S., R. 18 E.). Photomicrograph, X-40.

Central Area

The thick limestone of the Captain Creek of Montgomery County exhibits an entirely different type of lithology from that of the Northern Area. Angular pieces of light gray, dense, algal (?) limestone, fossil fragments and coherent masses of small rounded bodies are distributed through a clear calcite matrix.(See figs. 27-29.) Two sequences of filling of the interstices with calcite can be distinguished in the thin sections (Fig. 30). Local concentrations of broken or crushed fusulinids and <u>Enteletes</u> are distributed throughout the limestone. Many of the angular pieces of light gray limestone show no type of structure but others seem to be made up of small rounded bodies which are interpreted as faecal pellets. Seemingly coherent masses of elliptical or subspherical bodies are interpreted as concentrations of <u>Osagia</u> and/or faecal pellets (See fig. 27). Locally,(Loc. 26), the basal part of

FIG. 27. Masses of Osagia and/or faecal pellets, algal(?) limestone and clear calcite. Loc. 26, (sec. 9, T. 32 S., R. 15 E.). Peel print, X-4.

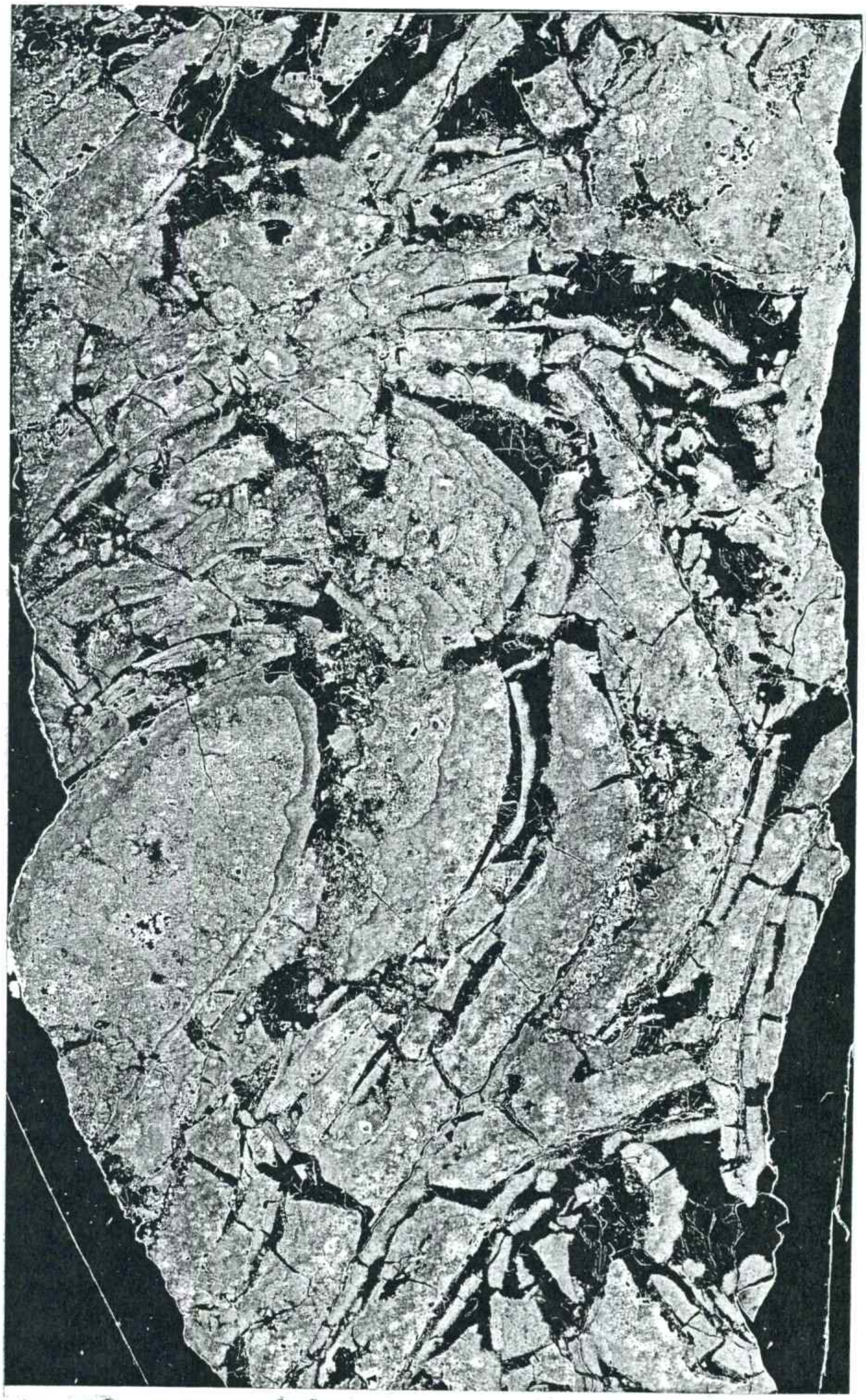

FIG. 28. Algal (?) structure, voids filled with clear calcite, Loc. 27, (sec. 14, T. 32 S., R. 14 E.). This is the base of a specimen so there is no arrow showing the top. Peel print, X-4.

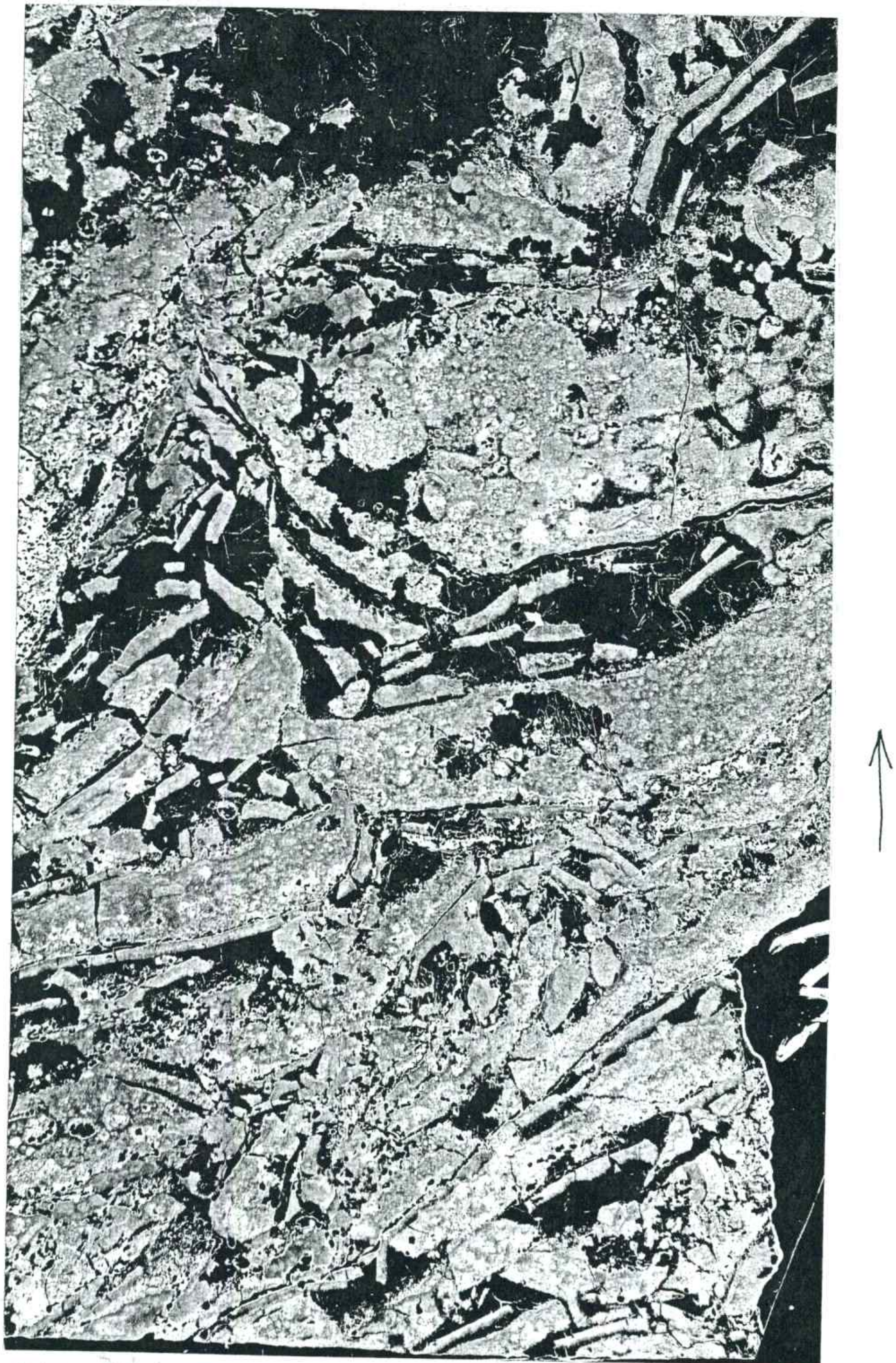

FIG. 29. Algal (?) limestone, Loc. 27, (sec. 14, T. 32 S., R. 14 E.). From same specimen as Fig. 28. Peel print, X-4.

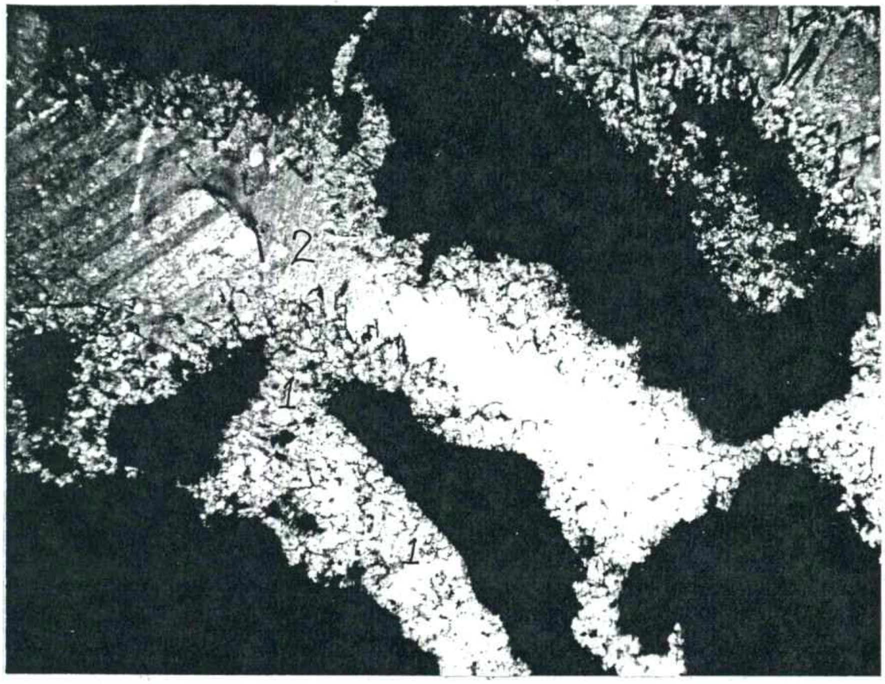

FIG. 30. Captain Creek Limestone, Loc. 27, (sec. 14, T. 32 S., R. 14 E.).
1.- small calcite crystals lining a primary void.
2.- clear, coarsely crystalline calcite.
Photomicrograph, X-40.

the Captain Creek contains pyrite replacing some of the shell material. At Locality 25, the upper 28 feet of the Captain Creek contains less abundant algal material and more dense, light-gray limestone fragments. None of these limestone fragments were seen to exhibit any structure. Voids filled with clear calcite are still common, however (Fig. 31).

A similar type of lithology prevails in the Captain Creek throughout most of southern Wilson County. In northern Wilson County, the Captain Creek is a fine- to medium-grained limestone with abundant <u>Osagia</u> at the base. Except for <u>Osagia</u>, the member is a medium-grained, relatively structureless limestone. Rare fusulinids, crinoid stems, and shell fragments constitute the fauna.

FIG.31. Upper part of Captain Creek Limestone, Loc. 25, (sec. 31, T. 31 S., R. 15 E.). Peel print, X-4.

Southern Area

The Captain Creek Limestone of the Southern Area exhibits a different type of lithology from that of the member in the Central Area. The rock is fine-grained but silty, and the amount of non-calcareous material increases toward the south. The limestone contains a great amount of fossil material. Algal masses are abundant; gastropods, bryozoans, and unidentified shell fragments are common (Fig. 32). At the southernmost exposure of the Captain Creek (Loc. 30), crinoid stems are very abundant.

The oolitic limestone near the top of the Vilas Shale is composed almost exclusively of calcareous oolites(Fig. 33). The oolites have a nucleus composed of subangular quartz grains. Certain specimens show that small pits have been

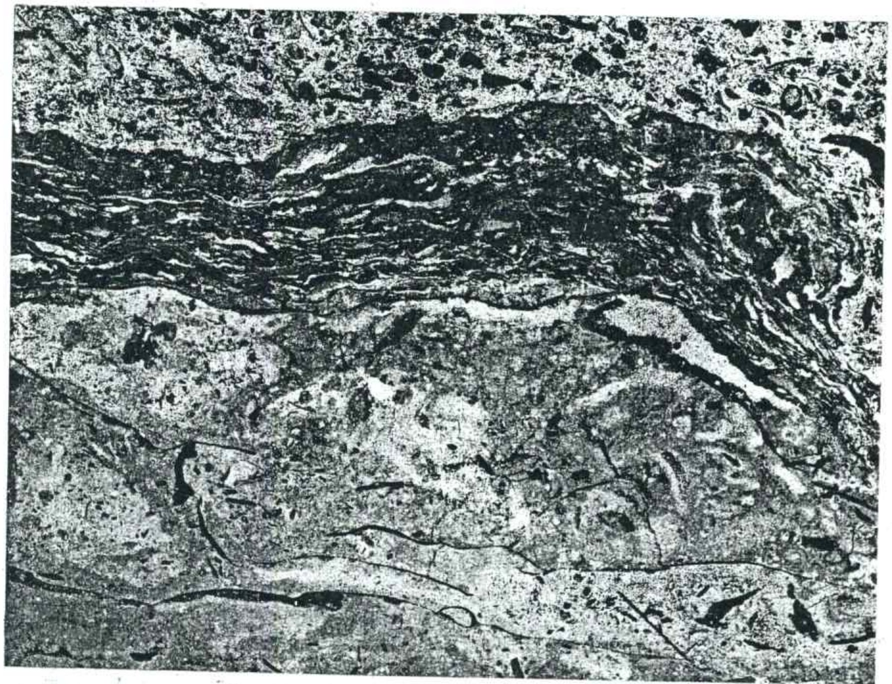

FIG. 32. Algal mass, Captain Creek Limestone, Loc. 29, (sec. 5, T. 33 S., R. 15 E.). Peel print, X- 4.

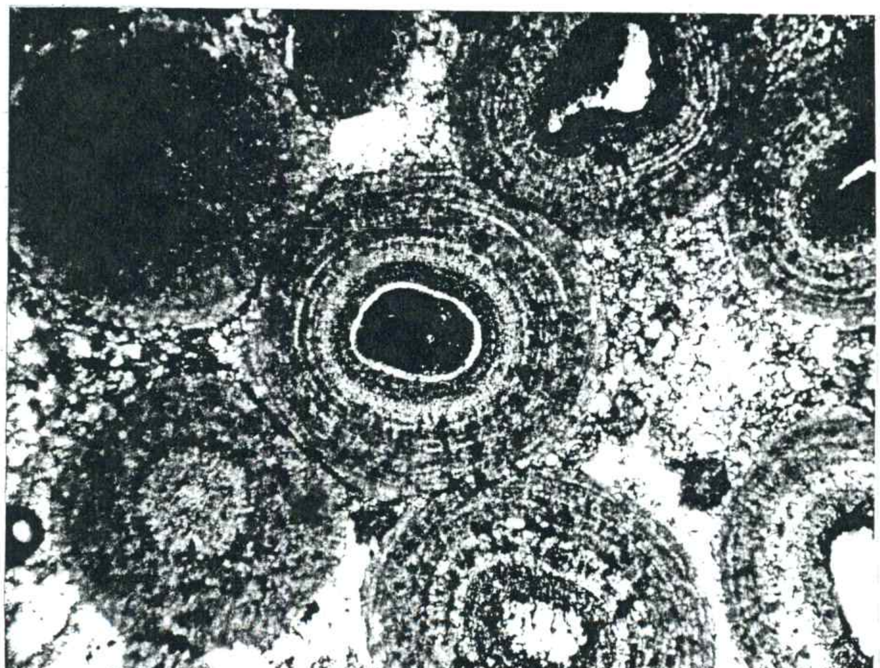

FIG. 33. Vilas oolitic limestone, Loc. 29, (sec. 5, T. 33 S., R. 15 E.). Photomicrograph, X-40.

etched into the quartz grains and filled with calcite. The calcite is in concentric layers around the nucleus. No radial structure was observed in the oolites. Rare small shell fragments are the only fossils seen in the oolitic limestone.

Insoluble Residues

Introduction

The insoluble residues of the Stanton formation and the Captain Creek member received preliminary study by Schoewe, Keroher, & Keroher (1937) and by Keroher (1939). A comparison of their conclusions and the results of the present report will be made later.

The fine- and medium-sized fractions of the residue were saved and examined in a few selected samples and were found to be non-diagnostic. Accordingly, these were not saved for the rest of the samples, and only the coarse feaction will be discussed in this report. Table 1 is a classification of the insoluble residues of the Captain Creek Limestone based on the outline by Ireland (1939). A detailed description of the samples will be found in Appendix A. The terminology used is that of Ireland, et. al.(1947). Only the general type of residue will be discussed here.

Table 1. Classification of insoluble residues of the Captain Creek Limestone member.

I. Allogenic- Constituents derived from previous sediments

1. Sand, quartz and minor amounts of mica
2. Silt, usually in aggregates

II. Authigenic- Constituents formed contemporaneously with or subsequently to the deposition of the sediments.

A. Syngenetic-Constituents formed contemporaneously with the deposition of the sediments.

1. Fossils
2. Glauconite

B. Epigenetic-Constituents formed subsequent to the deposition and lithification of the sediments

1. Silicified fossils
2. Interstitial silica
3. Secondary quartz

C. Syngenetic or Epigenetic

1. Pyrite
2. Chert

Allogenic

Sand- Fine sand grains are common in the Captain Creek of the Northern Area, where, along with silt aggregates, they make up the major percentage of the residue of the lower limestone unit. The sand becomes more abundant in the southern part of the Northern Area, especially in Franklin County. Sand grains make up over 50 percent of the residue at Locality 1 where the lower limestone unit of the Captain Creek is oolitic. In the upper limestone unit, fine sand grains rarely make up more than 10 limestone unit, fine sand grains rarely make up more than 10 percent of the coarse fraction of the residue.

Fine sand grains are more abundant in the Captain Creek of the Central area, sometimes making up as much as 90 percent of the coarse fraction. The Captain Creek of the Southern Area has only minor amounts of sand. Medium-sized sand grains are very abundant in the residues from the oolitic limestone in the Vilas Shale.

The quartz grains are subangular and white to very light tan. Etched pits can be clearly seen on the larger grains and can be faintly seen on the smaller grains. It is interesting to note that in both of the oolitic limestones (Loc. 1, Loc. 29, and Loc. 31) many of the pits etched into the quartz grains contain small pyrite particles. Rare rounded and frosted sand grains also were found in the residues.

Small flakes of muscovite and biotite mica are rare in the residues. No constant distribution of the biotite could be discerned but the muscovite seemed to be the most common in those samples containing the greatest percentage of sand grains.

<u>Silt</u>- Silt aggregates are abundant in the coarse residues of the Captain Creek of the Northern Area, especially in the lower limestone unit where they commonly make up 50-60 percent of the residue. These aggregates range in color from tan to brown to black. They are associated with rare mica flakes and rare arenaceous foraminifers. Silt aggregates are

less abundant in the upper limestone unit, although locally they may comprise as much as 80 percent of the sample. Such is the exceptional case; they usually make up only 30-40 percent of the residue. The color of the silt in the upper unit is tan or brown and rarely black.

The basal dark-gray bed of the Captain Creek Limestone in Allen and Woodson Counties contains very abundant (80-90 percent) dark gray to black silt aggregates and rare arenaceous foraminifers and about 10 percent pyrite aggregates. Silt is not as abundant in the upper part of the Captain Creek in that area as it is in the lower part. The silt averages about 40 percent of the residue in the upper part and is tan to brown in color.

Silt aggregates are not common in the rest of the Captain Creek of the rest of the Central Area except in the very southern part. At Locality 27, the Captain Creek contains 30-60 percent brown silt aggregates associated with fine quartz sand and 10-20 percent arenaceous foraminifers. The thin shaly limestone about 2 feet below the Captain Creek at this locality contains the same type of residues in association with about 20 percent pyrite aggregates.

The Captain Creek Limestone at Locality 28 contains 70 percent tan silt aggregates, 15 percent fine sand grains, and 15 percent arenaceous foraminifers. It does not contain pyrite. The remaining two outcrops of the Captain Creek in the Southern Area (Loc. 29 and 30) contain about 70 percent tan or light brown silt in the coarse fraction of the residue.

Syngenetic

Fossils- Arenaceous foraminifers are the most abundant fossils seen in the residues. In the Northern Area, they are rare in the lower limestone unit but are much more common in the upper limestone unit where they sometimes comprise as much as 90 percent of the coarse fraction. Abundance varies from 10 to 50 percent in the residues from the Southern Area, except for the medium-bedded middle limestone unit at Table Mound (Loc. 26) where they constitute all of the coarse fraction of the residue.

Foraminifera present include abundant Tolypammina and Ammonvertella and less abundant Ammodiscus, Psammosphaera, and Textularia. No attempt was made to define the relative distribution, if any, of the foraminifers in the Captain Creek.

Glauconite- Glauconite is an extremely minor constituent of the coarse fraction of the insoluble residues. Only scattered small grains were found.

Epigenetic

Silicified fossils- Common silicified spines, shell fragments, and rare bryozoans are found in the upper limestone unit of the Captain Creek of the Northern Area, especially in Franklin and Anderson counties. Associated with them are a few sponge spicules. Silicified fossils are rare in the Central Area and are absent from the Captain Creek of the Southern Area.

Interstitial Silica- Interstitial silica was found only in the residues from Franklin and Anderson counties. It is com-

composed of clear, dolomoldic silica and quartz in irregular masses. It is interesting to note that the only place where interstitial silica is found is also the area where silicified fossils are the most common.

Secondary Quartz- Secondary quartz is a common minor constituent of the Captain Creek Limestone in the Northern Area. The grains are clear and subhedral to anhedral. It is most common in Franklin and Anderson conties. These large, clear grains are rare in the Central Area and were found only in the thick limestone section of northern Montgomery County. They were not found in the Captain Creek Limestone of the Southern Area.

Syngenetic or Epigenetic

Pyrite- Pyrite is a common minor constituent of the residues from the lower limestone unit of the Northern Area. It is generally in the form of small cubes or aggregates that have no discernable crystal form. Distribution of the pyrite in the upper limestone unit is irregular. It is not common, but may make up as much as 50 percent of the residue. It is found in the form of small aggregates and as a replacement of spines and shell material in the upper limestone unit.

In Allen County, pyrite occurs as aggregates in the dark-gray "Marksia"-bearing bed at the base of the Captain Creek and as a replacement of spines and shell material at the top of the member.

Distribution of pyrite is very irregular in the rest of the Central Area. It is generally found at or near the base of the Captain Creek. At one outcrop (Loc. 22), the pyrite is in the form of small round pellets which may be faecal pellets.

Pyrite is a very minor constituent of the Captain Creek of the Southern Area. However, it occurs in the oolitic limestone below the Captain Creek where it is associated with the quartz nuclei of the oolites.

Chert- Rare chert nodules were seen on the outcrops in Franklin and Anderson counties. However, no chert was seen in the insoluble residues.

Summary

The most abundant part of the coarse residues of the lower limestone unit is silt aggregates. These are supplemented by fine sand grains, arenaceous foraminifers, and small pyrite aggregates.

The upper limestone unit has less silt, more arenaceous foraminifers, and generally less fine sand grains than the lower limestone unit. Pyrite is sparse in the upper limestone unit. Also occurring in the upper limestone unit are silicified fossil fragments, rare sponge spicules, interstitial silica, and secondary quartz crystals.

Keroher (1939) reported gray micaceous shale, sandy shale, organic remains, and pyrite from the Captain Creek of eastern Kansas. None of these were considered as being diagnostic of the Captain Creek Limestone.

Chemical Analysis

In an effort to determine a possible cause for the mottling of the distinctive limestone bed above the Captain Creek in Johnson and Franklin counties, a search of the literature was made for a description of various mottled or spotted limestones. Those articles which dealt with this subject (Beales, 1953; Osmond, 1956) attributed most of the mottling of limestones to selective or incomplete dolomitization. Accordingly, it was felt that a chemical analysis of a specimen of the "mottled" limestone would be helpful in determining the amount, if any, of dolomite that was present. Also, this bed has been described as "siliceous" and the amount of silica present could also be determined from the chemical analysis. Table 2 is a chart of the results of the chemical analysis of a specimen of the "mottled" limestone from the Bert Ross Quarry (Loc. 11) together with the average of 7 analyses of the Captain Creek Limestone in eastern Kansas computed from Runnels & Schleicher (1956). The findings of the chemical analysis wil be discussed under the section on Environment of Deposition.

Etched Blocks

Only three specimens of limestone were selected for acid etching. These are a piece of the "mottled" limestone from the Bert Ross Quarry (Loc. 11), and two specimens from the thick limestone of Montgomery County (Localities 25 and 27).

The only important fact added by examination of the etched piece of the "mottled" limestone was that the top of the light-gray limestone, immediately below the algal stringer, contained abundant light-gray silt. The rest of the rock is

Table 2. Analysis of Captain Creek Limestone and the "Mottled" Limestone

	1	2	3
Calcareous $CaCO_3$	91.41	90.93	94.98
Calcareous $MgCO_3$	2.98	2.59	0.81
Total	94.39	93.52	95.79
	Chemical Analysis (%)		
CaO	51.39	51.15	53.43
MgO	1.42	1.62	0.81
L.O.I.(1)	41.96	41.51	42.01
SiO_2	2.53	3.29	1.65
Al_2O_3	0.73	0.98	0.46
Fe_2O_3	1.13	1.24	1.14
TiO_2	-----	-----	0.03
K_2O	-----	0.10	0.03
Na_2O	-----	-----	-----
SO_3	0.14	0.12	0.25
S	0.03	0.10	0.25
P_2O_5	0.04	0.09	0.02
Total	96.37	100.20	99.83

Column 1- Average of 7 analyses of the Captain Creek Limestone (Runnels & Schleicher, 1956)

Column 2- "Mottled" limestone from Locality 11.*

Column 3- Dark blue-gray part of "mottled" limestone.*

(1)- Loss on Ignition

(*)- Analysis by Runnels, Kan. Geol. Survey.

aphanitic; arenaceous foraminifers are common in the blue-gray limestone. Figure 34 is a diagrammatic sketch of an etched surface of the "mottled" limestone.

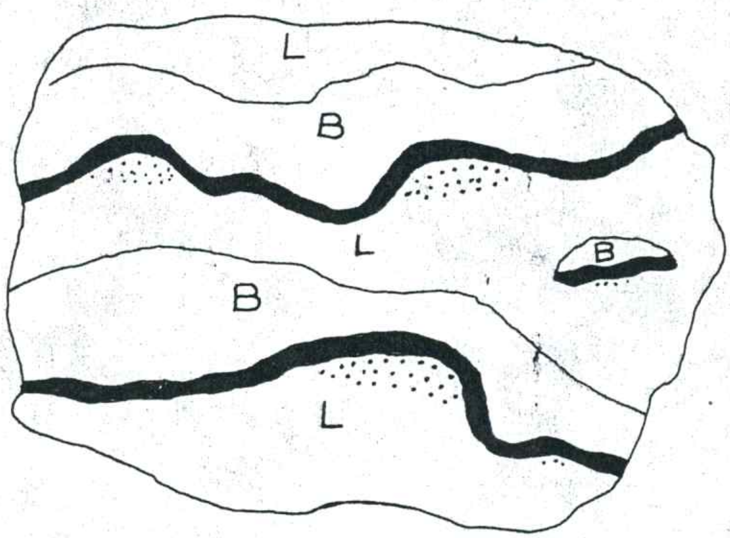

FIG. 34. Sketch of a typical specimen of the "mottled" limestone.
L- light gray
B- dark blue-gray

The two specimens from the thick limestone of Montgomery County (Localities 25 and 27) added little information to that already known. Angular pieces of dense, light tan limestone with interstices filled with Osagia (?) and other algal (?) fragments all cemented by clear crystalline calcite.comprise the structure of the limestone. Two stages of matrix filling can be seen. Limonite or hematite particles are concentrated in pockets or occur as scattered particles along the boundaries between the limestone particles and the calcite matrix. No fossils except the algal particles and rare arenaceous foraminifers were seen on the etched surfaces.

Shale Study

Only two outcrops (Localities 4 and 6) were fresh enough to provide good samples of the thin shale parting between the lower and upper limestone units of the Captain Creek. The major part of the shale consists of tan to yellow-orange silt particles which are associated with angular fragments of quartz and rare chert. Black shale particles were present in the sample from Loc. 4 but were not seen in the sample from Loc. 6. Fusulinids (*Triticites*), crinoid stems, and shell fragments are the dominant part of the fauna. *Tetrataxis*, brachiopod spines, and a few ostracodes and immature brachiopods were noted under the microscope.

THE CAPTAIN CREEK CYCLOTHEM

The Pennsylvanian rocks of Kansas are well known for the cyclic sequence presented by the various strata. Such sequences have been named cyclothems by Weller (1930).

Moore (1935, p. 24) has defined the members of an ideal Kansas cyclothem (Table 3). The actual cyclothems are rarely as fully developed as the ideal and may themselves show a cyclic arrangement. The word "megacyclothem" has been coined by Moore (1935, p. 29) for a cycle of cyclothems. The megacyclothems of the Shawnee Group, Virgilian Series, are unusually well-developed. These megacyclothems are characterized by a sequence of 4 well-developed and persistant limestone (lower, middle, upper, and super) and a fifth less well-developed limestone bed. All of these limestones are separated from one another by shale beds. The cyclothems in the megacyclothems are lettered A to E from the base upwards as a systems of reference.

The megacyclothems of the Missourian Series are similar to those of the Shawnee Group but the succession is not so complete. Units of the B (middle limestone) and C (upper limestone) cyclothems are definitely recognized in the Missourian but the D cyclothems (super limestone) are rarely present and the A (lower limestone) and E cyclothems are missing.

The Captain Creek Limestone is a "middle" limestone (B.5) of the Stanton megacyclothem. Following Moore's (1935, p. 23) proposal to name the cyclothems and the megacyclothems after the named limestone unit contained within them, this B cyclothem is called the Captain Creek cyclothem.

The Captain Creek cyclothem extends from the base of the sandstone in the Vilas Shale to the base of the black part of the Eudora Shale. The relation of this sequence to the ideal cyclothemic units can be seen in Figure 35. A study of this figure shows that the sequence near the Kansas River is fairly complete. The absent units are the upper molluscan shale (B.8), the upper molluscoidal shale (B. 6), and the nonmarine shale and coal (B.1). An anomaly is introduced in those areas where the "mottled" limestone is present. Apparently, this was formed under the same general conditions as the limestone immediately below. If so, it represents a reversal in the cycle back to deposition of limestone after the B.9 unit was deposited. It definitely is not a normal part of the overlying Stoner cyclothem.

As has been stated, the Captain Creek cyclothem can be best seen in the area near the Kansas River, specifically in Franklin, Johnson, Douglas, Wyandotte, and southern Leavenworth counties. Northward from this general area, the Captain Creek thins and several phases are missing. Southward from Franklin County, the Captain Creek generally thickens but differences between the various phases become obscure. None of the subdivisions of the Captain Creek cyclothem were recognized in southern Kansas.

Table 3. Members of an ideal cyclothem (Moore, 1935)

.9	Shale (and coal)
.8	Shale, typically with a molluscan fauna
.7	Limestone, algal, molluscan, or with mixed molluscan and molluscoid fauna
.6	Shale, molluscoids predominant
.5	Limestone, contains fusulinids, associated commonly molluscoids
.4	Shale, molluscoids
.3	Limestone, molluscan, or with mixed molluscan and molluscoid fauna
.2	Shale, molluscan fauna
.1c	Coal
.1b	Underclay
.1a	Shale, land plants
.0	Sandstone

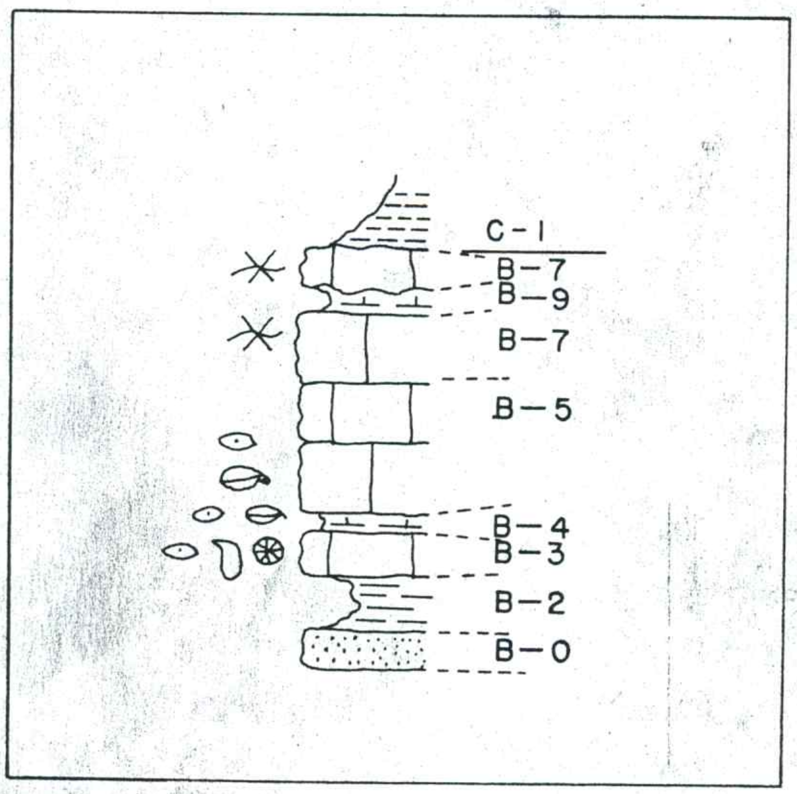

FIG. 35. Subdivisions of the Captain Creek cyclothem.

ENVIRONMENT OF DEPOSITION

Introduction

One of the main purposes of any study of a sedimentary rock is to determine the environment of deposition. This determination requires an interpretation and integration of several factors such as paleogeography, stratigraphy, sedimentation, lithology, paleontology, and paleoecology. The data presented in the first part of this report will be interpreted in the light of these several factors. Since the depositional environment of the Captain Creek is related to that of the underlying and overlying strata, the genesis of these beds will also be discussed.

Plattsburg Formation

McManus (1956) presented a study of the lower part of the Plattsburg. The Merriam Limestone, lower member of the Plattsburg, was deposited in the eulittoral zone in a depth of water of a few feet to about 165 feet and is indicative of a transgressing sea. The upper limestone bed represents a time of deeper water than the lower limestone unit. The major shoreline was to the south and there may have been another shore, or a shallow area, to the northeast. Generally, the central part of eastern Kansas was an area of quiet water with the deposition of fine-grained to aphanitic limestone. Local areas of strong currents in the south were associated with areas of quiet, clear water. The top of the Merriam in northern Kansas is a rubbly limestone indicative of the shallowing of the sea before the beginning of Hickory Creek time.

The Hickory Creek Shale is a black shale of the type present near the middle of many of the Kansas megacyclothems. These shales contain a black, fissile layer at or near the base and grade upward into calcareous, gray to buff shale. The fauna of the black shale consists mainly of conodonts, inarticulate brachiopods, and fish spines. Weller (1957, p. 351) feels that this fauna does not contain bottom-dwelling forms; the brachiopods and rare foraminifers may have lived near the surface attached to seaweeds.

Most authors are agreed that black shales are deposited in a restricted, anerobic environment. Moore (1929, p. 465) suggests that this type of black shale was formed in a shallow sea containing such abundant plant growth (seaweeds, etc.) that circulation was restricted.

Whatever the exact conditions of origin, they were not widespread during Hickory Creek time, and McManus (1956, p. 32) reports that the black shale is only locally developed at the base of the member. It is overlain by a "punk" bed of argillaceous limestone which in turn is overlain by the main limy or clayey part of the shale. These beds indicate that the environment changed from reducing to oxidizing conditions (McManus, 1956, p. 101). The thicker Hickory Creek of southern Kansas with its contained limestone beds probably represents a near-shore environment and a beginning of the development of the thick limestone of the Spring Hill member.

Transgression of the sea during late Plattsburg time brought an end to the deposition of the clastics of the

Hickory Creek Shale and a return to quiet water conditions allowing the deposition of the Spring Hill Limestone. This bed was probably deposited on an uneven surface in northern Kansas inasmuch as the thickness is quite variable. As an "upper" limestone of a megacyclothem, the Spring Hill represents a time of deposition farther from shore and in deeper water than the other limestone of the megacyclothems (Moore, 1935). In southern Kansas, the Spring Hill thickens considerably and then pinches out between thick shales. The thick part may represent a reef which was formed during Spring Hill time.

Vilas Formation

The Vilas Shale is one of the shales deposited at the end and beginning of the megacyclothems of the Missourian Series. As such, it represents an environment ranging from subaerial to near-shore marine. Moore (1929, p. 476) regards these shales as representing a type of deltaic deposit built out into the shallow sea by the coalescence of the deltas of several low-gradient streams. Such a deposit would have the normal topset beds of a delta, but, if the sea were as shallow as it is postulated to have been, the normal fore-set beds would not develop. McManus (1956, p. 84) believes that the Bonner Springs Shale, a deposit analogous to the Vilas, was deposited in water of a depth of somewhat more than three fathoms. The topset beds would not be destroyed by wave action because the force of the waves would have been reduced and dissipated during their travel over the wide, shallow sea.

The ripple-marked sandstone in the upper part of the Vilas near the Kansas River records a time of local strong currents. Locally, in Franklin County, small embayments permitted the development of thin limestone lenses. Some of these limestones are of the fine-grained, marly, unfossiliferous type that are interpreted as "freshwater". If this interpretation is correct, these limes were formed in small fresh- or brackish-water lakes or embayments upon the deltaic plain.

A great thickness of the Vilas is present in northern Wilson County just north of the place where the Spring Hill is also thick. It is possible that some of the Spring Hill Limestone and the Vilas Shale are contemporaneous deposits (Newell, 1933). Thick limestone sections in the overlying Stanton have been called reefs (F. Wilson, 1957) and the upper part of the Spring Hill in southern Wilson County may represent continued reef growth from Plattsburg time into Vilas time (see Plate 3). The great thickness of the Vilas in northern Wilson County may represent only the normal southward thickening of the shales in this part of the column. This thickening was interrupted in southern Wilson County by the growth of a reef.

In the places in southern Wilson County where the Spring Hill is thick, the Vilas is relatively thin and contains many thin limestone beds (Loc. 24, Fig. 22). The reef growth which began in Spring Hill time continued into Stanton time. The writer believes that the thick limestones of the Lansing in Wilson and Montgomery counties are vertically connected. The area (Loc. 24) where the Vilas Shale is thin and limy is probably near one of the places where there was continuous reef growth from Spring Hill time to Captain Creek time (see Plate 3).

Southward into Montgomery County, the Plattsburg thins and disappears and the Vilas Shale thickens and grades into the thick clastic sequence of the Missourian Series of Oklahoma.

Near the top of the Vilas in southern Montgomery County a sandstone and oolitic limestone bed is locally developed. The exact method of formation of oolites has been a matter of debate. Brown (1914) gives a good review of the various theories of origin of oolites which had been proposed up to that time. Even then the different theories could be grouped under two main headings: theories calling for formation of oolites by the direct precipitation of mineral matter from sea water, and theories in which the development of the oolites is postulated to have been caused directly by organic activity, usually algae.

Brown (1914) favored the chemical precipitation theory because he felt that various changes of structure observed in oolites could be best explained by changes in the solutions which precipitated the oolites. The algal material observed in some oolite grains were the remains of algae which had selected the oolites as places of attachment and had then been imprisoned by further precipitation of calcium carbonate.

Certain features, such as ripple marks and cross-bedding, found in oolite deposits and the occurrence of these deposits only along the shore were believed by Eardley (1938, p. 1372) to show that the origin of the oolites is correlated with vigorous wave action. Constant agitation of the oolites caused them to be rolled over and over, exposing new surfaces for accretion of carbonate and causing layers of uniform thickness to be built up.

Illing (1954, p. 43) also found that the oolites of the Bahamas occur only where the sediment is subjected to strong currents. He found no evidence that algae, whose remains are found in the oolites, have anything to do with the formation of the Bahamian oolites.

Many oolite-like bodies, such as Osagia, are algal in origin but most calcareous oolites seem to have been formed by the direct precipitation of carbonate on nuclei in a turbulent environment (Pettijohn, 1957, p. 96). Organic activity may influence the pH, and thus the rate of precipitation of the carbonate, but has no direct influence on the formation of calcareous oolites.

According to Brown (1914, p. 750), Sorby in 1879 was the first to point out that all Recent oolites are composed of aragonite while older calcareous oolites are composed of calcite. Brown (1914, p. 773), from work on Recent and fossil oolites, concluded that calcareous oolites were first precipitated as aragonite which, being unstable, soon changed to calcite. He believed that the aragonite was precipitated as a result of chemical reaction between the calcium sulphate of the sea-water and the sodium carbonate and ammonium carbonate generated by decay of organic matter.

Zeller & Wray (1956) and Wray & Daniels (1957) believe that the presence of small amounts of strontium, barium, or lead ions in solution influences the precipitation of either calcite or aragonite. These cations are larger than the calcium ion and, when incorporated into the carbonate lattice, cause the formation of the more open aragonite unit cell.

At the instant of precipitation, the large ions are incorporated into the small colloidal particles that form. If sufficient time passes before crystallization of the colloidal material, the large ions will diffuse out into the solution and calcite will be formed. At higher temperatures the rate of crystallization is accelerated and the large cations are incorporated into the carbonate lattice causing the formation of aragonite. Wray & Daniels (1957, p. 2133) found that the temperature range was very critical. At 50°C the precipitate was mostly aragonite, but at 40°C it was nearly pure calcite. Zeller & Wray (1956, p. 151) state that colder waters seem to favor the precipitation of calcite, whereas warmer waters tend to favor the precipitation of aragonite.

The large cations do not precipitate readily at low pH values and calcite tends to be formed under these conditions. At high pH values (8-10) the larger ions are precipitated with the calcium carbonate and aragonite is formed (Wray & Daniels, 1957, p. 2033).

Zeller & Wray (1956, p. 146) concluded that the presence of magnesium ions favored the precipitation of calcite rather than aragonite. The ionic radius of magnesium is smaller than that of calcium and thus tends to favor the more compact arrangement of the calcite unit cell. Monaghan & Lytle (1956, p. 114), however, concluded that the presence of magnesium ions in the sea water caused the precipitation of aragonite rather than calcite. Their findings may have been influenced by impurities in the reagents.

The oolitic limestone in the Vilas is believed to have formed in shallow water, probably very near the shore. Illing (1954) reported that the Bahamian oolites are formed by the currents only where the water has been warmed sufficiently to be supersaturated with calcium carbonate. Most chemists, however, doubt that a supersaturated solution could exist in the presence of a crystal of the solute; the Vilas oolite deposit was probably shallow enough for the sun to warm the water to the saturation point with respect to calcium carbonate. Waves and currents rolled the quartz grains about and calcium carbonate was precipitated around them. In the deeper water to the north, the currents were not as operative and the sea not so saturated with calcium carbonate; hence only quartz sandstone was formed. If the oolites were precipitated as aragonite, as it is assumed they were, the pH was probably about 8.

Areas of oolite formation normally would be expected to have strongly oxidizing conditions. The presence of pyrite in the insoluble residues from the Vilas oolite is therefore quite surprising. Some of the pyrite is in the form of cubes and probably was formed below the depositional interface. However, small grains of pyrite are present in etched pits on the quartz grains and must have been present before the calcium carbonate was deposited around the grains. On the basis of laboratory experiments, Monaghan & Lytle (1956, p. 118) state that sulphate-reducing bacteria might be important in the origin of calcareous oolites. Environments containing sulphate-reducing bacteria would be highly localized and would be characterized by a deficiency of oxygen, increased pH, and the presence of hydrogen sulphide or sulphide salts.

As the area of eastern Kansas continued to subside, local strong currents were developed in the northern part of the state and the limy, ripple-marked sandstone near the top of the Vilas was deposited. A return to conditions more normally marine is indicated in northern Montgomery County where the top of the Vilas contains abundant crinoid stems and plates.

Stanton Formation

Captain Creek Limestone

Captain Creek of Northern Kansas- The deepening of the sea caused an end to the deposition of the clastics of the Vilas Shale and the beginning of the deposition of limestone in the Northern Area. Fine clastics were still being deposited in the Central Area and parts of the Southern Area. Some of these clastics were carried northward into the area of limestone deposition. In the most northerly part of the area, a turbulent zone allowed the development of oolites. The biota of the lower limestone unit consists of small snails and shell fragments encrusted with *Osagia*. Lane (1954, p. 58) concluded that *Osagite* limestones were formed in water approximately 60 feet deep and under generally quiet conditions. The water was clear and shallow enough for the growth of plants, and gentle currents rolled the shell particles around so that algae accumulated on all sides. The fossil fragments were probably derived from a shallow water zone which was characterized by rolling and breaking by waves.

The general small size of the fossils and fossil fragments in the lower limestone unit of the Captain Creek is probably caused by sorting by the gentle currents. The fossil fragments could have been derived from the south, however, the upper part of the Vilas Shale in southern Kansas is generally barren of fossils. Also, there is no apparent increase in the size of the fragments toward the south. If anything, there is a decrease both in size and in the amount of organic fragments, other than algae, toward the southern part of the area.

These factors and others, such as the presence of oolites and sand grains in the northernmost part of the area, lead to the conclusion that the fragments were derived from a shallow area to the north or northeast. Whether this was a near-shore area or a shallow bank is not known. In any case, the sea floor was sufficiently near the surface for wave action to break the shells and for rip currents to carry the fragments into deeper water. Small fossils and fragments along with very fine sand grains were carried southward by currents. Locally, these currents produced small oolites. Some of the oolites may have been derived from the shallow area. Illing (1954, p. 43) has shown that oolites can form where currents sweep over the edges of shallow banks. The oolites in the Captain Creek, how- ever, are larger than most of the fossil fragments and, being more compact, would have a higher effective density than the small shells. The oolites could have been transported into the area by storm currents but there are no large fragments of shells associated with them. It would seem that any current competent to carry oolites would also be able to carry large pieces of shells. It is also possible that the shells have been chewed up by bottom-dwelling scavangers. The oolites are considered to be indigenous and were formed in a shallow area with a slightly stronger current than the surrounding areas.

The presence of fusulinids has usually been taken as indicative of the deepest water phase of a cyclothem. By comparing fusulinids with modern large Foraminifera, Elias (1937, p. 418) concluded that the fusulinids of the lower Permian were benthonic forms (with the possible exception of _Pseudoschwagerina_) and lived in waters less than 30 fathoms deep. A deep-water fauna in association with the shallow-water _Osagia_ would seem anomalous. The fusulinids in the Captain Creek are not fractured or broken and so do not seem to have been reworked or carried in a current for a long distance. Moore (1929, p. 467) states that the presence of large well-preserved Foraminifera indicates a relatively quiet environment, unagitated by strong currents or waves. This does not necessarily mean that the water was deep. The sea floor beneath broad areas of shallow water would be subjected to little disturbance by waves because shallow-water waves are never very large. Consequently, depths ranging from 5 to 50 feet may offer environments similar, at least in the amount of turbulence, to those at a depth of 400 to 500 feet.

The lower limestone unit of the Captain Creek in northern Kansas was deposited in an oxidizing environment. This statement is not contradicted by the occurrence of small grains of pyrite in the unit. Krumbein & Garrels (1952, p. 20) point out that reducing conditions may develop below the depositional interface even though oxidizing conditions exist above it.

Southward, the lower limestone unit becomes more silty and finally grades into shales. The biota is reduced until only "Marksia" is present at the top of the unit. These forms are most common in central Allen County and in Woodson County and may represent a local area in which water was clear enough for the growth of the algae.

The shale bed represents a time of introduction of a greater volume of clastics into the Northern Area. The shale bed is calcareous and thus may be considered to be a masking of calcium carbonate deposition by more abundant clastic material. In local areas, the sediment supply was not great enough for complete masking and silty limestone was deposited. The sediment supply was not rapid enough nor was the water turbid enough to prevent the development of a normal marine fauna.

Fusulinids are the most numerous part of the fauna in the two shale samples examined. They are associated with other

Foraminifera, crinoid stems, brachiopods, and rare specimens of bryozoans. This fauna indicates a slightly deeper water environment than the molluscan-Osagia biota of the lower limestone unit (Elias, 1937; Lane, 1954).

The increased amount of clastic material may have been caused by an increased competency and capacity of streams draining the land area to the south. This increase could be related to either uplift in the land mass and/or downwarping of the basin with regression of the sea. Climatic change could cause an increase in the clastic supply either by increased rainfall which would produce a greater amount of runoff or by a rise in temperature and a decreased amount of precipitation which would remove the plant cover.

The upper limestone unit of the Captain Creek is more widespread than the lower unit and indicates a return of limestone deposition throughout all of eastern Kansas and a wider transgression of the sea than during the time of the lower limestone unit.

The upper limestone unit is fine-grained to aphanitic. The finess of grain size has usually been taken as denoting deposition in quiet water. However, the importance of grain size in limestones should not be overemphasized because the original carbonate is usually recrystallized during diagensis.

Brachiopods are the most abundant faunal element in the upper unit of the Captain Creek. In the Northern Area, the most abundant brachiopod is Composita, followed by Enteletes and Marginifera, with rare specimens of Dictyoclostus. Menard

& Boucort (1951, p. 144-145) state that the more spherical brachiopods are the ones best adapted to live in the faster currents. This spherical shape may be related to a secondary characteristic of fast currents such as increased oxygen and food supply. Enteletes, a very spherical form, is common in the Captain Creek everywhere except in the extreme southern and northern parts of the outcrop area. The less spherical Composita is abundant only in northern Kansas and the non-spherical Dictyoclostus is found only in the extreme north. If the shape of the different genera is indicative of the water turbulence, it would seem that there were currents throughout all the area of eastern Kansas with faster currents in the southern part of the state. Enteletes is present in the thick limestone of Montgomery and Wilson counties which is believed to be a reef. The reef was built above the wave base and the region of growth was characterized by very turbulent water. The assumption that Enteletes could live in very turbulent water seems to be born out at least in this case. The theory that more turbulent water was in southern Kansas is also indicated by the general southward increase in grain size of the Captain Creek Limestone.

Composita is common in the lower part of the upper unit and is locally very abundant. This abundance in local areas may also be caused by the sorting actions of currents. The local abundance of Composita and Dictyoclostus at Locality 1 may represent current sorting or may be a lag deposit. Only about 6 inches of the upper limestone unit was deposited here.

The top of the Captain Creek may have been very near the base-level of deposition and the abundant brachiopods could represent the accumulation of several generations.

Chert is present in the Captain Creek In Anderson and Franklin counties. The presence of silicified fossils in the chert together with the rarity and local occurrence of the chert indicates that it is secondary. Rare sponge spicules were found in the insoluble residues from this area. The chert was probably formed by precipitation from ground water. The ground water could have obtained the silica from some other area or it could have dissolved most of the sponge spicules and/or other siliceous fossils and redeposited the silica as chert.

The upper part of the Captain Creek in northern Kansas is characterized by the presence of the calcareous algae, Anchicodium and Archaeolithophyllum. They are abundant to the exclusion of other elements of the biota. Illing (1954, p. 17 & 21) has shown that the calcareous algae of the Bahamas are most abundant at a depth of about 60 feet. This figure agrees with the 60-180 feet depth for calcareous algae arrived at by Elias (1937, p. 419 & 426) and the 60-90 feet depth for the molluscan-Osagia phase of the lower limestone unit of the Captain Creek. Clear water conditions must have prevailed to allow the profuse growth of the algae. A local area in western Anderson County and northern Allen County was characterized by very quiet water in which very fine-grained limestone was deposited.

Captain Creek Reef Complex-

Introduction- The lithological differences between the Captain Creek of the Northern Area and the Captain Creek of the Central Area are accentuated by the fact that no outcrops were found between the two. The changes in lithology noted between the two areas could be only gradational changes related to the southward thickening to the Captain Creek. However, Newell (1933) describes differences in the lithology of the Upper Missourian beds which seem to suggest a division of these beds into a Northern and a Southern facies along a line running through northern Allen County. Moore (1949, p. 80) ascribes the southward change of facies and variability of the Kansas City beds to slight movements in the Chautauqua Arch area of southeastern Kansas. The Chautauqua Arch is a pre-Mississippian structure and probably had little influence on the deposition of the Upper Missourian rocks. Jewett (1951, p. 121) states that the Bourbon Arch of Bourbon, Allen and Coffey counties, Kansas, was a positive area between the Cherokee and Forest City Basins in Pennsylvanian time and probably was an area of meeting and overlap of sediments from the north and the south. The thick Captain Creek Limestone in Montgomery County, which is believed to be a reef, does seem to have influenced the development of the Captain Creek of the northern part of the Central Area. This influence becomes more pronounced as the Captain Creek is traced southward.

The Captain Creek of the Northern Area shows no particular influence of this thick limestone development and may have originated from a source area other than the one to the south. McManus (1956, Plate 3) illustrates a subaerial region in northern Missouri and southern Iowa during Bonner Springs time. The oolites in the Captain Creek of northern Kansas suggest a shallow area somewhere nearby.

Definition of terms- W. B. Wilson (1950, p. 181) defined a reef as a sedimentary rock aggregate composed of a generally non-stratified rigid framework formed from the remains of colonial organisms. The organisms lived near the surface of the water and the general direction of growth of the reef was upward. W. B. Wilson felt that this definition was in accord with the definition of bioherm as given by Cumings (1932). Bioherm means any mound-like or dome-like organic mass and may or may not be a thanatocoenose. A reef is composed of the remains of colonial and/or sedentary organisms which lived and died in the same locality and thus constitutes a biocoenose. The word bioherm is a more inclusive term than the word reef and Johnson (1953, p. 22) sums this up by saying "thus while all reefs are bioherms, all bioherms are not reefs.".

Other writers (Link, 1950, p. 263) believe that reef and bioherm are synonomous. MacNeil (1954, p. 399) considers a bioherm to be that part of a reef that consists of the remains of organisms while a reef is made up of a bioherm and the detrital material derived from the bioherm.

Since the word reef has other meanings which do not imply an organic origin, many authors believe that the term organic reef should be used so as to not confuse methods of origin.

The Glossary of Geology and Related Sciences (Howell, 1957) places W. B. Wilson's (1950) definition of a reef under the term organic reef but does not include it under the term reef. The essential difference between a bioherm and a reef as defined by Cumings and W. B. Wilson seems to be that a reef is built near the surface and is a wave-resistant structure.

Henson (1950, p. 216) has used the term "reef-complex" to mean the aggregate of reef limestones and the calcareous rocks "genetically (?)" associated with them. MacNeil (1954, p. 391) does not like this term because it has been used as an ecological designation and suggests "reef rock complex" as a generic term for all types of rock that form reefs or are directly derived from reefs. Henson's term sould seem to be the better, however, because it can include rocks whose deposition is influenced by thr growth of a reef as well as those that are derived from the reef.

The "back-reef" is that area between the reef and the shore while "fore-reef" means the steeply dipping talus slope on the seaward side of the reef (Howell, 1957). "Reef talus" is used by Newell, et. al. (1953, p. 67) to denote the beds in the fore-reef slope. "Reef detritus" is the material derived from the erosion of a reef (MacNeil, 1954, p. 400). "Basin", as used in this report, means the area in front of the reef beyond the fore-reef slope.

Link (1950) has illustrated the theory of the formation of transgressive and regressive reefs. Given a reef growing along a shoreline with a transgressing strand line, the reef would grow in a vertical direction and, if the rise of the sea level were not too fast, the top of the reef would maintain itself in the same relation to the sea level and the distance from the shore.

An alternate hypothesis would be that if the rise in sea level was rapid enough to drown the reef, other reefs might still develop in shallower waters near the shore. The drowned reef and the newer reef might or might not be connected by a biostrome-like bed. Link (1950) would call the reef development associated with a rising or trangressing sea a transgressive reef. Continued submergence would drown the reefs and they would be overlain and surrounded by marine shales and/or limestones.

The typical back-reef evaporite facies of the regressive type of reef is lacking in the transgressive reefs so that there is no essential difference between the shoreward, basinward, and overlying sediments. The reefs deposited during the first part of the transgression may, if the wave base is low enough or transgression slow enough, undergo submarine denudation and degradation, causing the tops of the reefs to be beveled off before the deposition of the overlying clastics. This would give rise to what might be mistaken for a large unconformity. Link (1950, p. 273) considers the D-3 zone of the Leduc, Alberta, field and the producing zone of the Norman Wells, Northwest Territories, to be examples of the transgressive type of reef development.

A regressive reef would be built in the case of a stable land mass and a receding sea or in the case of a rising land mass. In either case, the strand line would recede and the reef would be built out into the sea and over its own fore-reef talus slopes. Back-reef and fore-reef sediments associated with a regressive reef are different. The back-reef sediments would, according to Link (1950) be composed of evaporites and clastics and would consist of anhydrites, gypsum, red shales, sandstone, and rare limestones and dolostones.

Link (1950, p. 283) considers the Capitan Reef of New Mexico and Texas to be an example of a regressive reef and discusses the basinward sediments associated with it as examples of the fore-reef sediments of a regressive reef. The Delaware Basin was a bay having restricted circulation during Permian times. Ventilation of the basin was incomplete throughout much of the Permian and there was complete stagnation during the late Guadalupian (Newell, et. al., 1953, p. 193). The black shales and limestones of the basin or pontic facies of the Capitan Reef were, therefore, deposited in an abnormal marine environment. There is no reason why the basin facies of a regressive reef cannot be the same as the normal marine sediments characteristic of the basin facies of a transgressive reef.

Also, Link's (1950) reason for the development of the back-reef evaporite facies of the regressive reef is that these reefs would constitute a barrier reef and the lagoonal water trapped behind it would gradually dry up and deposit evaporites. If the regressive reef were large, it probably would produce a restricted environment in the back-reef lagoon. However, a small regressive reef would not necessarily have a hypersaline lagoon behind it because the lagoon could be ventilated by circulation from the sides of the reef or over the reef. The sediments deposited in this back-reef area of normal salinity would probably be thin limestone beds and shale beds which, toward the shore, would intertongue with terrigenous sands and shales.

During the regression of the sea, some destruction of earlier reefs would take place, giving rise to brecciation of the reef by wave action and subaerial solution. The destruction of the regressive reefs would probably be much more pronounced than the submarine erosion of the transgressive reefs. The regressive reefs would be overlain by back-reef deposits and terrigenous sediments. Link (1950, p. 276 & 283) believes that the D-2 zone of the Leduc field and the Capitan Reef of New Mexico are examples of regressive reefs.

Captain Creek Reef- The Captain Creek Limestone of northern Montgomery County is a thick, massive-bedded, coarse-grained limestone containing much clear, crystalline calcite and weathering very vuggy. Examination of thin sections and acetate peels show that the limestone is composed of brecciated, fine-grained, algal (?) limestone fragments with the interstices filled with calcite. Fossils found in the Captain Creek are poorly preserved and are concentrated in pockets or lenses. The thickness decreases rapidly to the north and to the south.

The brecciated appearance of the massive limestone suggests erosion and breaking by waves. All of these features imply the existence of a reef in the Captain Creek of Montgomery County.

Except for the Merriam Limestone, all of the limestone members of the Lansing Group show pronounced thickening in northern Montgomery County and southern Wilson County. This thickness decreases rapidly to the north and to the south. If the Captain Creek Limestone of this area is a reef, it is logical to assume that the thick limestones in the other units of the Lansing are also reefs.

It is possible that the Lansing Reefs of Wilson and Montgomery counties are transgressive and regressive reefs.(see Plate 3). The thickest section of the Spring Hill Limestone is in southern Wilson County, the thickest part of the Captain Creek Limestone is in north-central Montgomery County, the Stoner Limestone is 25-40 feet thick throughout southern Wilson and northern Montgomery counties, and the South Bend Limestone is thickest in west-central Montgomery County. The shales between the thick limestones are thinner than in surrounding areas and, in places, contain many thin limestone beds. These features suggest that the Lansing Reefs are vertically connected and that they have a regressive and transgressive relationship. This is the conclusion arrived at through a surface study of the Lansing limestones. An investigation that utilized subsurface data might lead to a different conclusion.

The main reef-former of the Captain Creek Reef seems to have been a type of algae (see Fig. 28). This is in agreement with the evidence obtained from studies of modern and fossil reefs. Ladd (1950, p. 204) says that calcareous algae are important in both building the reef and in binding the detritus together. Newell, et. al., (1953, p. 152) list a number of algal species from the lagoonal phase of the Capitan Reef and Newell (1955, p. 306) says that stromatolites (blue-green algae) are the most abundant of the main frame builders of that reef. Most of the massive phase of the Captain Creek Reef is composed almost exclusively of brecciated algal (?) limestone. Brachiopods and Triticites are other common fossils. Crinoids and horn corals are conspicuous by their rarity. At Locality 25, Enteletes is present in the massive, brecciated limestone and Neospirifer occurs in the medium-bedded limestone on top of the massive unit. The massive, brecciated limestone apparently was formed in more turbulent water than the finer-grained, medium-bedded limestone. The distribution of the two genera of brachiopods would seem to bear out the findings of Menard & Boucort (1951) on the correlation between brachiopod shell shape and water turbulence. However, the massive limestone is in a brecciated unstratified condition and may be a slope d deposit derived from the main reef. The growing part of a reef is subjected to incessant attack by waves and currents. Most of the material eroded from the reef is deposited as a fore-reef talus slope. Some of the eroded detritus is carried over the reef, by high tides or storm waves, and deposited in the back-reef lagoon. The fossils in the massive limestone, although poorly preserved, are not sufficiently broken to lead one to think that they had been transported very far. The material would not have to be transported far and, in fact, may only have been broken and not moved. Newell (1955, p. 302) states that the in situ reef limestone forms only a very small portion of the reef complex and Sollas (in Newell, 1955) ventured the opinion that the actual reef limestone forms only a thin outer crust or veneer on the reef which binds the looser brecciated deposits making up the greater part of the reef.

The interstices of the massive, brecciated limestone are filled with clear, crystalline calcite. Examination of thin sections shows that this coarsely crystalline calcite is not the only material occurring between the particles of algal (?) limestone. The pieces of algal (?) limestone themselves are covered by a thin layer of small prismatic calcite crystals arranged radially with respect to the depositional surface. Partially filling some of the voids are faecal pellets (?), pieces of fossil material, and small fragments of limestone. Some of the fragments have a crust of prismatic calcite. The rest of the void is filled with the coarsely crystalline calcite mentioned above.

Newell (1955) has described the sequence of filling of the primary voids of a reef. The first of the deposits in the primary pores is fibrous calcium carbonate which is usually deposited as aragonite. This aragonite soon undergoes conversion to calcite. After the void is coated by the encrusting calcium carbonate, reef detritus enters the cavities. This relationship led Newell (1955, p. 304) to believe that the chemical precipitates as well as the detritus were deposited while the pores were still in free communication with the sea and that the primary voids were largely filled with secondary deposits at shallow depths. Newell (1955, p. 305) suggested that the calcium carbonate deposited so early in the primary voids came from the surface waters on top of the reef. These waters, which are "supersaturated" with calcium carbonate, are warmed in the daytime over the shallow reef flats and the solubility of the carbonate is further reduced by the photosynthesis of plants. During times of ebb-tide, the surface waters form a hydrostatic head a few inches above the surrounding ocean. Part of the water moves to the sea through the voids of the reef, depositing calcium carbonate in transit.

The voids which had not been filled by the fibrous calcium carbonate and the detrital material are finally completely closed by the precipitation of transparent calcite. Newell (1955, p. 309) felt that the deposition of the clear calcite took place relatively late in the history of the reef, after free communication of the voids with the sea had been terminated. The clear calcite may have been deposited by ground water.

Newell (1955) established this sequence of pore-filling from a study of the Capitan Reef and cores of Recent Pacific reefs. He concluded that the primary porosity so characteristic of reef rock is filled with secondary deposits soon after the formation of the rock. He felt that the reef porosity which so interests petroleum geologists is secondary porosity formed by leaching aragonite constituents from calcite and the calcite constituents from dolomite. Where this leaching had not taken place, the reef would have a very low porosity.

Link (1950), however, believes that primary porosity is a characteristic of the transgressive types of reefs. The primary voids are partially filled by a thin crust of calcite crystals but complete filling could not take place on a large scale, because the transgressive reef would be sealed off by the marine shales overlying and surrounding the reef. The deposition of the clear calcite, which occurs late in the history of the reef, would not take place.

A regressive reef, such as the D-2 zone of Leduc or the Capitan Reef, shows a different sequence of secondary deposits. The regressive reefs are overlain by evaporites and clastics. Waters could percolate down through these and completely obliterate the primary porosity by secondary deposition of calcite or dolomite.

Link (1950, p. 292) feels that it is the primary porosity of a reef which is of importance in petroleum geology. The primary voids of a transgressive reef would become filled with hydrocarbons derived from the reef animals and the deposit would become an oil reservoir. Secondary porosity is developed only when a large reef is uplifted near the surface and ground water begins to dissolve cavities. If this uplifted reef were then buried, it could also act as an oil or gas reservoir. However, the hydrocarbons would not be indigenous but would be derived from another reservoir. Such an accumulation would be close to an unconformity and Link (1950, p. 292) cites as an example of this type of pool, the Kevin-Sunburst field of Montana where oil is present in large chambers in the Madison Limestone at the Jurassic-Mississippian unconformity.

The sequence of pore-filling which Newell (1955) described can be discerned in the Captain Creek Reef. All of the voids are filled, and Link (1950) believs that this is a characteristic of regressive reefs (see Fig. 30, p. 59). Newell (1955) said that the final pore-filling was by ground water action, which according to Link, does not take place in transgressive reefs because they are sealed off by marine shales. The Lansing reefs are not completely sealed from one another, however. They all occur within a north-south distance of about 10 miles. The shales separating the reefs are very thin and may be absent in places. The Lansing reefs are small compared with most reefs described in the literature and the height from the base of the Captain Creek Reef to the surface of the water was probably never more than about 100 feet during Lansing time. Also, in certain localities, there is evidence of subaerial erosion above the Stoner Reef so the surface may have been even closer to the Captain Creek Reef at times. If the Captain Creek Reef was never completely sealed off from the entry of calcite-bearing waters, the pores could have been completely filled whether the Captain Creek is a regressive or a transgressive reef. There is, of course, subaerial solution going on in the Lansing reefs at the present time. Davis (1955) describes small caves in the Lansing limestones of southern Wilson County.

The Lansing reefs exist within a very small area and are almost stacked one on top of the other. Link (1950, p. 278) has suggested that a concentration of reefs would take place along a steep slope in the sea floor. The sea floor during Pennsylvanian time in Kansas has usually been considered to have been fairly level or only gently undulating, even near the shore. Regressive and transgressive reefs could be concentrated in a small area if the rise or fall of the strand line were only slight.

The reef which was in existance at the beginning of Captain Creek time began growing southward with the rise of the sea level which initiated Captain Creek time in northern Kansas. At Locality 26, a local lagoon was formed on top of the reef allowing deposition of medium-grained, fusulinid-bearing limestone. This bed, or a deposit of similar nature, can be seen at the top of the Captain Creek at Locality 27. Somewhere between Localities 27, 26, and 25 the reef began growing back to the north in response to another change in the strand line (see Plate 3). At Locality 26, the regressive portion covered the thin lagoonal deposit. No lagoonal beds were formed between the regressive and transgressive phases of the Captain Creek Reef at Locality 25 so there is a very thick section of reef limestone at that place. As the reef grew farther to the north, mediu-grained, medium-bedded limestone was deposited on top of the former reef detritus, at Locality 25, behind the reef front.

Reef growth was probably continuous from Captain Creek time through Eudora time somewhere in southern Wilson County. No outcrops showing a continual limestone section from the Captain Creek, through the Eudora, into the Stoner Limestone were observed. However, indications of this were seen in the thinning of the Eudora toward southern Wilson County from both the north and the south and in the presence of limestone beds in the Eudora Shale of central Wilson County.

Back-reef Facies- During the time of growth of the Captain Creek Reef, shales were being deposited in southern Montgomery County. A thin limestone bed was formed during middle Captain Creek time when the Captain Creek Reef was at its southernmost position. The limestone is fine-grained but very silty. Algae and small gastropods dominate the biota. This bed was deposited in the lagoon or bay between the Captain Creek Reef and the shore. The lagoon was shallow enough so that sunlight could produce photosynthesis in the algae. Even though silt and fine sand blew or were washed in from the land area, the water near the reef was clear enough for the algae to grow. Farther south, the influx of clastics was greater than near the reef and the algae disappear and crinoids become the main part of the fauna. The area of limestone deposition was only about 5 or 6 miles wide. At the southernmost exposure of this limestone (Loc. 30), the Captain Creek is only about 1 foot thick and is quite silty. It probably pinches out between the thick Lane-Vilas and Eudora.

Some of the shale called Eudora in southern Montgomery County was probably deposited at the same time that the Captain Creek Reef was being formed. The basal black, phosphatic portion of the Eudora in that area may have been deposited in a resticted bay cut off from the normal circultation of the sea by the Captain Creek Reef to the north. In this case, the Captain Creek Reef would be a barrier reef.

The medium-bedded, non-clastic limestone at the top of the Captain Creek at Locality 25 is a back-reef deposit formed when the active growth of the reef was to the north, probably in Wilson County.

As has been mentioned before, Link (1950) believes that, by the nature of their development, regressive reefs have a back-reef facies different from the basinward facies while transgressive reefs have back-reef beds which are similar to those in front of the reef. Also, Link considers the Capitan Reef Complex of New Mexico to be typical of a regressive reef and its associated back-reef sediments.

Newell, et. al. (1953, p. 115) list five lithofacies on the shelf area behind the Capitan Reef;

1. coquina and calcarenite
2. pisolite
3. fine-grained dolostone (secondary)
4. evaporites
5. terrigenous phase- quartz sandstone.

The Lansing beds of southern Montgomery County are mostly shales with a few sandstone lenses and thin limestone beds. The Vilas oolitic limestone and the oolitic limestone in the South Bend may be analogous to the pisolite although Newell, et. al. (1953, p. 150) favor an algal origin for that lithofacies. The Stoner Limestone, in southern Montgomery County, contains a fossil breccia which may be analogous to the coquina. No evaporites or dolostones are associated with the Lansing in either Kansas or Oklahoma. Actually, there is not much relationship between the back-reef sediments as listed by Newell,et. al. (1953) and the Lansing of southern Montgomery County because so much of the Lansing interval in that area is shale. The Vilas Shale is the only Lansing shale unit which is thick north of the reef area. In southern Montgomery County, it cannot be distinguished from the underlying Lane-Bonner Springs Shale. Newell (1933) did not report any significant change in lithology between the Vilas in northern Wilson County and the Vilas just south of the area of the thick Plattsburg Limestone. The general similarity of the shales of southern Montgomery County with the shale units of the Lansing to the north would suggest that this is an area of transgressive reefs if Link's (1950) interpretation were followed. As we have seen, small reefs would not necessarily have a back-reef facies different from the basin sediments no matter what kind of reefs they were.

Fore-reef Facies- The reef phase of the Captain Creek Limestone is present in southern Wilson County and the thick Captain Creek near Fredonia reported by Wagner & Harris (1953) may also represent part of the reef. No definite fore-reef beds were recognized during the course of this investigation. Wagner & Harris (1953) reported that the Captain Creek is locally absent along a line of steep dips in western Wilson County. F. Wilson (1957) interprets this as evidence of a fore-reef slope. In central Wilson County, the Captain Creek, while thin, still shows some influence of reef development in its brecciated character. This may represent part of the fore-reef talus.

Basin Facies- At Locality 23, also in central Wilson County, the base of the Captain Creek is quite irregular. The thickness ranges from about 1 to 5 feet within very short distances and all the variation is caused by the very irregular base. The bedding planes of the Vilas Shale are conformable with the base of the Captain Creek (Fig. 20 & 21). The limestone is not part of the reef phase of the Captain Creek. In gross aspect the Captain Creek at this locality approximates the form of the *Collenia* colonies described by Fenton & Fenton (1939) except that the rounded protuberences are directed downward. However, the limestone shows little evidence of being of algal origin.

It may be that the Captain Creek was deposited here in small local channels cut in the top of the Vilas. However, many of the "channels" are too narrow and deep to be considered as having been eroded in the soft muds of the Vilas. The bedding planes are completely conformable to the base of the Captain Creek and show no evidence of being cut by erosion. These bedding planes may be fissility planes originating after the shale was compacted. The close conformability of these features and the base of the Captain Creek could be caused by the Captain Creek being forced down into the Vilas by the weight of the overlying Stoner Limestone. The Stöner is at least 14 feet thick in the roadcut. Its actual thickness cannot be determined by a surface study because it is exposed on the downthrow side of a fault.

The basal part of the Captain Creek and the uppermost part of the Vilas could have been deposited contemporaneously, but it is not known why there should be such a localized difference in conditions leading to the deposition of either limestone or shale. If this is the explanation, the conformity of the top of the Vilas with the base of the Captain Creek would have to be due to the formation of planes of fissility during compaction.

The upper part of the Captain Creek in Wilson and Woodson counties can be correlated with the upper limestone unit of the Northern Area. However, the two were not developed under the same conditions. The base of the Captain Creek in northern Wilson County contains abundant Osagia pellets. Johnson (1946) has shown that these are algal-foraminiferal intergrowths composed of the thread-like alga Girvanella and the foraminifer Nubecularia. The intergrowths probably owe their spherical or elliptical form to being rolled about on the ocean floor by currents. The water was clear enough and shallow enough to allow the growth of the algae. Conditions necessary for the growth of the Osagia did not persist long. The growth of the Captain Creek Reef to the south may have altered currents in this area or in some way influenced environmental conditions on the sea floor. The water may have become more turbid with the introduction of fine clastics from the south but this does not agree with the presence of reefs in Wilson and Montgomery counties. If the reefs were small or there were a break in the reefs, the silt could still be carried into the area in front of the reefs.

The Captain Creek of northern Wilson County and Woodson County was deposited in water slightly more turbulent and with more silt than the sea of Captain Creek time in the Northern Area. Enough silt was introduced into the ocean from the south to inhibit algal growth. *Enteletes* and *Composita* are the only common fossils; fusulinids are sparse. The brachiopods apparently could tolerate an environment different from the Northern Area but the fusulinids probably could not live here either because of the currents or because of the turbidity.

The Captain Creek Limestone of this northern part of the Central Area is light reddish-brown or buff in color, probably due to the presence of iron minerals. Krumbein & Garrels (1952, p. 26) state that calcite and the iron oxides could precipitate together in a slightly oxidizing environment with an Eh of +0.1 and a pH of about 8.

Eudora Shale

In Northern Kansas, Captain Creek deposition was ended by the shallowing of the sea and the influx of fine clastics which were deposited to form the Eudora Shale. The first clastics that were washed into the area contained some calcareous matter and were deposited in an oxidizing environment. Seaweed growth soon became so dense that circulation was restricted and the middle part of the Eudora was deposited under reducing conditions. In Johnson and Franklin counties, the seaweed growth was not as abundant as in surrounding areas. This area may represent a high or a tidal channel where conditions were not suited for the growth of the seaweeds. The quiet waters allowed the deposition of limestone and the growth of calcareous algae. The presence of the algae indicates that oxidizing instead of reducing conditions prevailed during the time of deposition of the "mottled" limestone. Fine silt was incorporated into the limestone. This silt was probably blown in because the abundant plant growth would prevent the development of any currents in the surrounding areas.

The "mottled" limestone has been called "siliceous" (Newell, 1935a; Moore, 1935) and recent articles dealing with the mottling of limestones (Beales, 1953; Osmond, 1956) have suggested that this effect is due to incomplete dolomitization. The percentage of dolomite ($MgCO_3$) in the "mottled" limestone is only 2.98 and the silica content is only 3.29 percent. These are both low values and neither one is significantly different from the average of the Captain Creek in eastern Kansas (see Table 2, p. 70).

The figures mentioned above for the "mottled" limestone are an average for that bed. The composition of the dark blue-gray portion of the rock, as regards the two compounds under discussion, is dolomite- 0.81 percent; silica- 1.65 percent.

The percentage of the two compounds in the light gray portion of the bed would be higher than the average value given in Column 2, Table 22, but still would not be high enough to warrent calling the bed either siliceous or dolomitic.

The dark color of parts of the rock may have been caused by bacteria producing reducing conditions below the depositional interface (McManus, 1956, p. 88) or by a slightly greater concentration of organic matter in the dark gray part than in the light gray part (Russell Runnels, personal communication). The presence of organic matter is indicated by the slightly greater figure for Loss on Ignition for the dark gray part of the rock than for the average of the bed. The color of the light gray part of the "mottled" limestone may be caused by the presence of light gray or white silt in that part of the bed or because the light gray part is oxidized. The slightly greater percentages of sulphates and sulphides in the dark blue-gray part of the rock indicate that reducing conditions still prevail there. The deposition of the "mottled" limestone ended when a greater amount of clastics was introduced into the area and seaweeds began growing there.

The black part of the Eudora Shale is thickest in northern Kansas. Toward the south, it thins along with the southward thinning of the whole Eudora. Only small pockets of black shale are present on top of the Captain Creek in Allen County. The Bourbon Arch, which extends through Allen County, may have served as a sill or a barrier to restrict circulation to the north and cause an euxinic environment.

The reducing conditions ended in northern Kansas and the limy and silty, fossiliferous upper part of the Eudora was deposited. This interval is much more fossiliferous from Allen County southward into Oklahoma. Brachiopods and crinoids are the most common elements of the fauna in Allen, Woodson, and Wilson counties. Near the Captain Creek Reef, in southern Wilson County, limestone beds were deposited during Eudora time and reef growth was continuous from Captain Creek time through Eudora time.

Marine conditions still prevailed during deposition of the Eudora Shale in Montgomery County. This is shown by the crinoid and brachiopod fauna of the Eudora at Locality 25. In central Montgomery County, restricted conditions were developed in the back-reef lagoon and the black, phosphatic lower part of the Eudora was deposited.

At Locality 30, the basal part of the Eudora contains a gastropod fauna which Newell (1933) considered to be similar to faunas in southern Oklahoma and northern Texas.

The Eudora grades into the thick shale section of southern Montgomery County and Oklahoma. This shale may have been deposited as deltaic beds in the same manner as postulated for the Vilas Shale.

Stoner Limestone

The sea floor gradually lowered after Eudora time and the Stoner Limestone was deposited. The Stoner is the "upper" limestone of the Stanton megacyclothem and, as such, represents deposition in deeper water or farther from shore than the

the other limestone beds of the Stanton (Moore, 1935). Over the Bourbon Arch, shales and thin limestones were deposited during Stoner time and exact differentiation between the Eudora, Stoner, and Rock Lake is difficult.

Reef conditions still prevailed in Wilson and Montgomery counties during Stoner time. The Stoner Reef is larger than any of the other Lansing reefs, cropping out from central Montgomery County to northern Wilson County and ranging in thickness from 25 to 40 feet. In Wilson County, local lagoons were formed on the Stoner Reef as shown by a fauna composed of gastropods, Schizophoria, Meekoporella and crinoids which lived in these lagoons.

Subaerial conditions prevailed behind the reef sometime prior to the deposition of the Stoner in southern Montgomery County and the top of the Eudora Shale was eroded. The clastic limestone and fossil breccia of the back-reef facies of the Stoner were deposited under strong current conditions. These strong currents in the back-reef area may represent a time of breaching of the Stoner Reef and development of long-shore currents.

Rock Lake Shale

Uplift brought the Stoner of northern Kansas near enough to the wave base to allow erosion of the top of the Stoner before the deposition of the Rock Lake Shale. In local areas this erosion may have been subaerial. The Rock Lake Shale throughout northern and central Kansas was deposited very near the shore. Portions of the deposition occurred under subaerial conditions and thin coal beds were formed.

The Rock Lake was deposited under more normal marine conditions in the reef area of Wilson and Montgomery counties as shown by the fusulinids found by F. Wilson (1957, p. 17-18) in the Rock Lake Shale. Reef growth either slowed or stopped during Rock Lake time. However, the Rock Lake is very thin over the Stoner in Montgomery County and a part of the top of the Stoner Reef may be contemporaneous with the Rock Lake Shale of northern Kansas.

South Bend Limestone

Normal marine conditions returned to northern Kansas with the subsidence of the sea floor and the deposition of the South Bend Limestone. The lower arenaceous, molluscan phase was deposited nearer the shore than the upper, less arenaceous, molluscan-fusulinid phase.

Reef growth may have stopped during Rock Lake time but it began again with the general subsidence of the area during South Bend time. The oolitic limestone on top of the South Bend Reef was formed in the currents and the shallow sea which were caused by the gradual regression of the seas preparatory to the beginning of Weston time.

COMPARISON OF THE CAPTAIN CREEK LIMESTONE AND THE MERRIAM LIMESTONE

The Captain Creek and Merriam Limestones are both fairly typical examples of the "middle" (B.5) limestones of the Kansas Pennsylvanian megacyclothems. These "middle" limestones are dark to light blue-gray, fine-grained to aphanitic, and occur below a black, carbonaceous shale. As compared with other limestones of the megacyclothems, the thickness and lithology of the "middle" limestones are persistant over wide areas. They are, however, generally less fossiliferous than the other limestone beds of the megacyclothems.

Although both the Merriam and the Captain Creek exhibit these features of the "middle" limestones, there are differences between them. The most conspicuous difference in the two limestones is thickness. The Merriam is rarely thicker than 3 feet while the Captain Creek, in nearly all exposures, is thicker. than this.

Like the Captain Creek of the Northern Area, the Merriam is divisable into three units. The lower unit of the Merriam is much more variable in thickness than that of the Captain Creek. The Merriam's lower limestone unit averages about 2 feet thick but in Franklin County it increases locally to about 8 feet (McManus, 1956, p. 140-141). The thickness of the lower limestone unit of the Captain Creek is fairly constant at 1.5 to 2 feet. The lower unit of the Merriam is absent at a few localities in Johnson and Miami counties while that of the Captain Creek is present at all localities examined in the Northern Area. Both lower units disappear south of Allen County.

The biota of the two lower units is also slightly different. McManus (1956, p. 21) describes a Composita zone and an Osagia-Myalina zone in the lower Merriam unit of northern Kansas. Specimens of Composita occur throughout the unit, but in northern Kansas, commonly are concentrated in a zone near or at the base of the unit. Overlying the Composita zone is an Osagia-Myalina zone. The myalinids are more or less restricted to this part of the Merriam but Osagia is present throughout the unit.

Composita is rare in the lower unit of the Captain Creek and the zone of Composita in this member is found at the base of the upper limestone unit. Myalina is much more abundant in the Merriam than in the Captain Creek. McManus (1956, p. 21) mentioned that gastropods are present in the lower Merriam but, apparently they are rarer than in the Captain Creek. The amount of Osagia seems to be about the same in the two lower units. McManus (1956) did not report the occurrence of "Marksia" or any other calcareous algae other than Osagia in the lower limestone unit of the Merriam.

The lower unit of the Captain Creek is medium-grained throughout its outcrop area and locally is slightly oolitic. It contains slightly more silt than the rest of the Captain Creek and becomes more silty toward the south. The basal part of the lower Merriam unit is commonly conglomeratic and contains shale pebbles. The rest of the Merriam is generally aphanitic but may be oolitic. In northern Kansas, the oolitic portion is slightly cross-bedded.

Overlying both lower units is a thin shale bed. The shale beds are similar in regard to fauna and mineralogy, although the Merriam shale contains spiriferid brachiopods near the Kansas River. The Captain Creek shale averages 0.2 feet in thickness and is present only from southern Leavenworth County south to central Franklin County. The Merriam shale averages about 0.2 feet thick and locally increases to about 0.5 feet. It is absent along a line extending from southern Johnson County to northern Anderson County but is present throughout the rest of the area where the lower limestone unit is present and may also be present in southern Kansas where the lower Merriam is absent (McManus, 1956, p. 25).

The greatest difference between the two members is seen in the upper limestone units. That of the Merriam is very constant in terms of thickness (0.4-1.5 feet, average- 1.0 foot) and crops out over a longer distance than the lower Merriam unit, being present from Leavenworth County south to southern Wilson County and possibly northern Montgomery County. Throughout most of eastern Kansas it is a single massive bed of aphanitic limestone, although in southern Kansas it is a yellow, irregular, slabby limestone. McManus (1956, p. 27) stated that this unit was oolitic at two localities.

The upper Captain Creek limestone unit is commonly 4 feet or more thick. It is fine-grained to aphanitic and medium-bedded in the Northern Area. In southern Kansas, it ranges up to 64 feet thick and is medium- to coarse-grained. In the reef complex the Captain Creek is massive-bedded. No oolites were seen in the upper limestone unit of the Captain Creek.

The upper limestone unit of the Merriam is less fossiliferous than the lower limestone unit of that member. _Osagia_ are common in the lower part and calcareous algae are common in Allen County. The rest of the fauna consists of rare small brachiopodd with some _Composita_, common crinoid columnals, and rare echinoid spines and horn corals. The most characteristic organic feature of the upper unit is worm borings filled with ferruginous clay. These borings are 3-5 mm. in width and up to 8 mm. in length.

The upper limestone unit of the Captain Creek is more fossiliferous than the lower Captain Creek unit, containing especially numerous brachiopods. _Composita_ are abundant at the base in the Northern Area and _Enteletes_ and _Marginifera_ are common throughout the lower part of the unit. _Dictyoclostus_ and other large productids are rare. _Osagia_ is present in the upper Captain Creek unit only in Wilson and Woodson counties. Calcareous algae are the characteristic fossils of the upper 1-2 feet of the Captain Creek in the Northern Area and may have been the main reef-formers in southern Kansas.

Generally, in spite of relatively minor differences, the Captain Creek and the Merriam are similar in northern Kansas. This similarity disappears in southern Kansas where the Merriam pinches out and the Captain Creek assumes reef characteristics. McManus (1956) did not report any reefs in the Merriam Limestone.

CONCLUSIONS

1. The Captain Creek Limestone member of the Stanton Limestone formation can be divided into three rock units in northern Kansas; the lower limestone unit, the middle shale parting, and the upper limestone unit. These units are distinct in lithologic and biologic characters.

2. The lower limestone unit is fairly consistent in thickness and lithology, but pinches out in central Kansas.

3. The shale parting is definitely identifiable only in northern Kansas.

4. The upper limestone unit is the most persistent and the most variable of the Captain Creek units. In southern Kansas this unit is the only recognizable part of the member.

5. The Captain Creek of southern Kansas exhibits reef characteristics. The main reef-former seems to have been a type of algae.

6. Most of the Lansing limestones of southern Kansas are abnormally thick. These limestones exhibit characteristics of regressive and transgressive reefs.

7. The Captain Creek exhibits several lithofacies and biofacies both vertically and laterally. These different facies are the result of different environments of deposition.

8. The Captain Creek Limestone of Kansas was deposited in the eulittoral zone of a shallow sea, at a depth of a few feet to about 40 to 60 meters. The shallowest deposition was in the reef comples area of southern Kansas and the Captain Creek of northern Kansas was deposited in deeper water.

9. The major shoreline during Captain Creek time was toward the south in Oklahoma. There may have been another shoreline, or a shallow bank, to the northeast in Missouri or Iowa.

10. The Captain Creek represents a fairly complete cyclothem in the area near the Kansas River, but farther southward and northeastward fewer cyclothemic units are identifiable.

11. The exceptionally mottled limestone at the top of the Captain Creek in Johnson and Franklin counties is a local facies of the Eudora Shale.

12. The oolitic limestone in southern Montgomery County is part of the Lane-Vilas Shale.

13. In northern Kansas, the Captain Creek and the Merriam Limestones are very similar. In southern Kansas, they are quite different.

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APPENDIX A

CONSTITUENTS OF THE COARSE FRACTION OF THE INSOLUBLE RESIDUES OF THE CAPTAIN CREEK LIMESTONE MEMBER

1-1 80% etched, subhedral, subrounded quartz grains
10% pyrite, some replacing spines or forams, some small pyrite grains in the etched pits of the quartz grains.
10% arenaceous foraminifers

1-2 60% arenaceous foraminifers
40% brown silt aggregates

1-3 40% light gray silt aggregates, some light green
10% brown silt aggregates
15% small pyrite grains
25% arenaceous foraminifers and silicified shell material

1-3b 90% light tan silt aggregates
5% arenaceous foraminifers
5% small quartz sand grains

2-1 50% etched, subrounded quartz sand grains
40% disseminated tan silt
10% arenaceou foraminifers
10% small pyrite aggregates

2-2 100% arenaceous foraminifers

2-3 60% fine and very fine pyrite aggregates
30% arenaceous foraminifers
10% tan silt aggregates
rare particles of maroon silt

2-4 50% pyrite, replacing spines and in aggregates
30% arenaceous foraminifers
10% brown silt aggregates
10% light gray silt aggregates
rare euhedral quartz grains

3-1 95% light gray and tan silt aggregates
5% arenaceous foraminifers
rare frosted quartz grains

3-2 50% arenaceous foraminifers
40% light tan silt aggregates
5% silicified spines
5% frosted quartz grains, clear and euhedral quartz

3-3	50%	arenaceous foraminifers
	40%	tan silt aggregates
	10%	silicified spines
		rare clear, subhedral quartz
3-4	80%	silt aggregates
	20%	arenaceous foraminifers
		rare frosted quartz grains
3-5	70%	tan silt aggregates
	20%	arenaceous foraminifers
	10%	silicified shell material
3-6	60%	tan silt aggregates
	30%	silicified shell material, some light green
	10%	arenaceous foraminifers
		rare euhedral quartz
4-1	90%	gray silt aggregates
	5%	arenaceous foraminifers
	5%	quartz sand grains
4-2	70%	light gray silt aggregates
	20%	arenaceous foraminifers
	10%	silicified shell material
4-3	60%	light gray silt
	30%	arenaceous foraminifers
	10%	silicified shell material
4-4	60%	light gray silt aggregates
	40%	arenaceous foraminifers
		rare anhedral quartz sand grains
4-5	100%	arenaceous foraminifers
		rare clear anhedral quartz fragments
4-6	80%	arenaceous foraminifers
	20%	light tan silt aggregates
		rare clear anhedral quartz fragments
4-7	80%	arenaceous foraminifers
	20%	light tan and light gray silt aggregates
		rare anhedral quartz fragments
4-8	40%	brown silt aggregates
	40%	silicified spines
	10%	arenaceous foraminifers
	10%	white silt grains, may be from crushed foraminifers
		rare small pyrite grains

5-1 50% etched fine quartz sand grains
30% fine to coarse pyrite aggregates
10% arenaceous foraminifers
10% maroon silt aggregates
large white silica plates
muscovite mica flakes

5-2 60% light gray silt aggregates
30% arenaceous foraminifers
5% etched quartz sand grains
5% brown silt aggregates
euhedral quartz fragments

5-3 70% light gray silt aggregates
30% arenaceous foraminifers
small pyrite aggregates

5-4 60% arenaceous foraminifers
30% light gray silt aggregates
10% euhedral quartz fragments
rounded quartz grains

5-5 60% brown silt aggregates
30% silicified shell material
10% arenaceous foraminifers
pyrite aggregates

5-6 60% light tan silt aggregates
20% silicified shell material
10% silicified spines
10% arenaceous foraminifers
rounded quartz sand grains

5-7 60% light tan silt aggregates
20% arenaceous foraminifers
20% silicified shell fragments and spines
euhedral quartz grains

6-1 80% very dark brown silt aggregates
15% fine pyrite aggregates
5% arenaceous foraminifers

6-2 70% brown silt aggregates
20% arenaceous foraminifers
10% fine pyrite aggregates

6-3 60% light to dark tan silt aggregates
40% arenaceous foraminifers and silicified shell material

6-4 60% arenaceous foraminifers
40% light gray silt aggregates

6-5 80% brown silt aggregates
15% arenaceous foraminifers
5% silicified shell material

6-6 80% light tan silt aggregates
20% arenaceous foraminifers and silicified shell material

6-7 60% arenaceous foraminifers
40% brown silt aggregates
euhedral quartz fragments

6-8 40% light tan silt aggregates
40% arenaceous foraminifers
10% pyrite aggregates
10% silicified shell material
euhedral quartz fragments

7-1 80% brown silt aggregates
20% arenaceous foraminifers and silicified shell material

7-2 70% brown silt aggregates
20% arenaceous foraminifers
10% silicified shell material

7-3 50% arenaceous foraminifers
50% subrounded quartz grains

7-4 60% arenaceous foraminifers
40% gray silt aggregates
frosted quartz sand grains

7-5 50% brown silt aggregates
20% light gray silt aggregates
20% silicified shell material
10% black chert
biotite flakes

7-6 90% small fine-grained pyrite aggregates
5% light gray silt aggregates
5% arenaceous foraminifers

8- No insolubles were prepared from Locality 8.

9-1 50% brown silt aggregates
30% fine pyrite aggregates
20% arenaceous foraminifers

9-2 80% brown silt aggregates
20% arenaceous foraminifers and silicified shell fragments

9-3 60% arenaceous foraminifers
40% pyrite aggregates
euhedral quartz

9-4 90% arenaceous foraminifers
5% maroon silt aggregates
5% pyrite aggregates
rounded, frosted quartz grain
biotite flakes

9-5 40% tan silt aggregates
40% arenaceous foraminifers
20% rounded, frosted quartz grains

9-6 50% arenaceous foraminifers
40% tan silt aggregates
10% rounded frosted quartz grains

9-7 100% arenaceous foraminifers
euhedral quartz grains

9-8 100% arenaceous foraminifers
euhedral quartz grains

9-9 100% arenaceous foraminifers
euhedral quartz grains

9-10 90% arenaceous foraminifers
10% tan silt aggregates

9-11 80% tan silt aggregates
10% silicified spines and arenaceous foraminifers
10% fine grained pyrite aggregates

10-1 60% light gray silt aggregates
40% silicified spines
arenaceous foraminifers
tan silt aggregates
one sponge spicule

10-2 80% dark gray silt aggregates
20% arenaceous foraminifers

10-3 60% silicified spines
20% light gray silt aggregates
20% clear anhedral quartz
sponge spicules

10-4 80% fibrous silicified shell material
10% silicified spines and bryozoans
10% euhedral quartz crystals

10-5	70%	fibrous silicified shell material
	10%	silicified spines
	20%	white silt grains
		euhedral quartz grains
10-6	90%	light gray fibrous silica and silicified spines
	10%	subhedral dolomoldic clear quartz
10-7	90%	light gray to tan fibrous silica
	10%	clear dolomoldic quartz
		pyritized foraminifers
		silicified spines
10-8	90%	silicified shell material
	10%	silicified spines
		arenaceous foraminifers
		small pyrite cubes
10-9	80%	light tan silicified shell material
	10%	light gray silt
	10%	silicified spines
		arenaceous foraminifers
10-10	80%	light gray to light tan silicified shell material
	10%	silicified spines and arenaceous foraminifers
	10%	gray silt aggregates
11-1	90%	fine sand grains
	5%	white interstitial silica
	5%	small silicified spines
		muscovite mica flakes
11-2	90%	fine quartz sand
	10%	silicified spines
		arenaceous foraminifers
11-3	90%	very fine quartz sand grains
	10%	arenaceous foraminifers and silicified spines
11-4	90%	very fine quartz sand grains
	10%	arenaceous foraminifers
		silicified spines
11-5	90%	silicified shell material
	5%	arenaceous foraminifers
	5%	euhedral quartz crystals
11-6	50%	tan silt aggregates
	30%	dark gray silt aggregates
	10%	arenaceous foraminifers
	10%	silicified spines

11-7	50%	dark gray silt aggregates
	50%	white interstitial silica
		arenaceous foraminifers
		silicified spines
		euhedral quartz
11-8	60%	arenaceous foraminifers
	30%	gray silt aggregates
	10%	white silica plates
11-9	90%	tan fibrous silicified shell material
	10%	arenaceous foraminifers
11-10	40%	white to tan silicified shell material
	60%	arenaceous foraminifers
11-11	50%	dark gray silt aggregates
	20%	tan silt aggregates
	20%	arenaceous foraminifers
	10%	subrounded quartz sand grains
		pyrite cubes
11-12	60%	tan silt aggregates
	30%	arenaceous foraminifers
	10%	subrounded quartz sand grains
12-1	50%	light tan quartz sand grains
	40%	dark brown silt aggregates
	10%	pyritized spines and foraminifers
		arenaceous foraminifers
		aggregates of small pyrite cubes
12-2	80%	fine quartz sand grains
	15%	dark brown silt aggregates
	5%	arenaceous foraminifers
		euhedral quartz grains
12-3	70%	large cark brown silt aggregates
	30%	fine sand grains
12-4	40%	light gray fine sand grains
	30%	dark brown silt aggregates
	30%	light gray silt aggregates
12-5	90%	dark brown silt aggregates
	10%	gray silt aggregates
		arenaceous foraminifers
12-6	50%	tan silt aggregates
	40%	euhedral quartz fragments
	10%	brown silt aggregates
		arenaceous foraminifers
12-7	50%	tan silt aggregates
	30%	brown silt aggregates
	20%	arenaceous foraminifers
		e

12-8	50%	dark brown silt aggregates
	30%	light gray silt aggregates
	20%	arenaceous foraminifers
12-9	50%	tan silt aggregates
	40%	light gray silt aggregates
	10%	black silt aggregates
13-1	80%	tan silt grains
	10%	green shale fragments
	10%	arenaceous foraminifers
13-2	80%	dark brown silt aggregates
	15%	brown silt grains
	5%	large silicified shell fragments
13-3	90%	brown silt aggregates
	10%	light gray silt aggregates
		arenaceous foraminifers
13-4	70%	dark brown silt aggregates
	20%	arenaceous foraminifers
	5%	large fragments of silicified shell material
	5%	fibrous porous silica
13-5	80%	arenaceous foraminifers
	20%	gray silt aggregates
		euhedral quartz grains
13-6	60%	arenaceous foraminifers
	30%	gray silt aggregates
	10%	silicified shell material
13-7	60%	tan silt aggregates
	20%	silicified shell fragments
	20%	arenaceous foraminifers
14-1	60%	tan silt aggregates
	30%	arenaceous foraminifers
	10%	brown silt aggregates
		muscovite mica flakes
		white silt aggregates
14-2	60%	tan silt aggregates and grains
	40%	arenaceous foraminifers
		fibrous porous silica masses
14-3	70%	dark tan silt aggregates
	20%	arenaceous foraminifers
	10%	light gray silt aggregates

14-4 80% silicified shell material
10% arenaceous foraminifers
10% tan silt aggregates

15-1 60% small tan silt aggregates
30% pyrite aggregates
10% arenaceous foraminifers
muscovite mica flakes
euhedral quartz

15-2 70% tan silt aggregates
30% arenaceous foraminifers

15-3 60% tan silt aggregates
30% dark brown silt aggregates
10% arenaceous foraminifers

15-4 70% porous silica masses and plates
25% silicified shell material
5% pyrite aggregates

15-5 50% dark brown silt aggregates
40% tan silt aggregates
10% pyrite replacing spines and shell material

16-1 80% brown silt aggregates
20% arenaceous foraminifers
silicified shell material

16-2 40% white silicified shell material
40% pyritized shell material
20% arenaceous foraminifers

16-3 50% gray silt aggregates
40% arenaceous foraminifers
10% pyrite aggregates
euhedral quartz grains

16-4 50% arenaceous foraminifers
30% silicified shell material
20% aggregates of pyrite cubes

16-5 50% arenaceous foraminifers
20% silicified porous plates of shell material
20% aggregates of pyrite cubes
10% gray silt aggregates

16-6 50% arenaceous foraminifers
40% light tan silt aggregates
10% pyrite aggregates
sponge spicules

17-1 70% dark brown silt aggregates
10% arenaceous foraminifers
10% pyrite aggregates and pyritized fossils
10% gray silt grains

17-2 40% light gray silt grains
60% arenaceous foraminifers

17-3 60% light gray silt grains
40% arenaceous foraminifers
euhedral quartz grains

17-4 60% light tan silt aggregates
20% arenaceous foraminifers
20% frosted and clear quartz fragments

18-1 80% large dark gray silt aggregates
15% arenaceous foraminifers
5% fine-crystalline small pyrite aggregates

18-2 50% fine subrounded quartz sand grains
40% brown silt aggregates
10% arenaceous foraminifers
angular quartz fragments
muscovite mica

18-3 80% fine subrounded quartz sand grains
20% arenaceous foraminifers
angular quartz fragments
muscovite mica flakes

18-4 60% small white silt aggregates
30% arenaceous foraminifers
10% fine subrounded sand grains
muscovite mica flakes

18-5 80% fine subrounded quartz sand grains
15% arenaceous foraminifers
5% muscovite mica flakes
angular quartz fragments

19- No insolubles were prepared for Locality 19.

20-1 90% fine subrounded quartz sand grains
10% silicified spines

20-2 50% tan silt aggregates
40% fine subrounded quartz sand grains
10% arenaceous foraminifers

20-3 50% fine subrounded quartz sand grains
40% tan silt aggregates
10% small fine-crystalline pyrite aggregates

21-1 60% fine subrounded quartz sand grains
20% light tan oomoldic silt aggregates
10% pyritized bryozoans
10% arenaceous foraminifers
muscovite mica flakes

21-2 50% fine angular to subrounded quartz sand grains
40% arenaceous foraminifers and silicified spines
10% brown silt aggregates
small pyrite aggregates
muscovite mica flakes

21-3 80% fine angular to subrounded quartz sand grains
20% arenaceous foraminifers
muscovite mica

22-1 40% tan silt aggregates
30% fine subrounded quartz sand grains
20% small pyrite aggregates
10% arenaceous foraminifers

22-2 80% small rounded pyrite pellets
20% fine subrounded to angular quartz sand grains
arenaceous foraminifers

22-3 50% arenaceous foraminifers
25% light gray silt aggregates
20% fine subrounded quartz sand grains
5% pyrite pellets

22-4 90% white silt aggregates
10% fine subrounded to angular quartz sand

23-1 90% fine crystalline pyrite grains and aggregates
10% silicified spines

23-2 70% fine subrounded quartz sand grains
20% arenaceous foraminifers
10% fine crystalline pyrite

23-3 60% fine subrounded quartz sand grains
20% arenaceous foraminifers
20% small fine-crystalline pyrite aggregates

24-1	30%	tan silt aggregates
	30%	arenaceous foraminifers
	40%	fine subrounded quartz sand grains
24-2	50%	tan silt aggregates
	40%	fine sand grains
	10%	arenaceous foraminifers
		small pyrite aggregates
25-1	30%	tan silt aggregates
	30%	arenaceous foraminifers
	20%	platy silica
	20%	fine angular to subrounded quartz sand grains
25-2	40%	tan silt aggregates
	40%	fine angular sand grains
	15%	arenaceous foraminifers
	5%	small pyrite aggregates
25-3	100%	tan fine sand grains
		arenaceous foraminifers
25-4	100%	tan fine sand grains
		arenaceous foraminifers
25-5	60%	fine angular quartz sand grains
	20%	arenaceous foraminifers and silicified spines
	10%	white angular chert
	10%	euhedral quartz grains
25-6	70%	fine angular to subrounded quartz sand grains
	20%	tan silt aggregates
	10%	arenaceous foraminifers
		frosted, rounded quartz sand grains
25-7	80%	fine angular to subrounded quartz sand grains
	20%	arenaceous foraminifers
25-8	90%	tan fine angular to subrounded quartz sand grains
	5%	arenaceous foraminifers
	5%	frosted subangular quartz grains
25-9	60%	fine angular quartz sand grains
	30%	arenaceous foraminifers
	10%	tan silt aggregates
25-10	100%	fine angular sand grains
25-11	90%	fine angular quartz sand grains
	10%	arenaceous foraminifers

25-12 90% fine angular quartz sand grains
10% white silica

26-1 80% pyritized fossil material
20% arenaceous foraminifers

26-2 50% arenaceous foraminifers
40% brown silt aggregates
10% fine subrounded quartz sand grains
small pyrite cubes

26-3 100% arenaceous foraminifers and silicified shells

26-4 70% light tan silt aggregates
25% white silt aggregates
5% silicified spines

27-1a 40% brown silt aggregates(1)
30% fine subrounded quartz sand grains
20% pyritized brysozoans
10% arenaceous foraminifers

27-1 60% fine angular quartz sand grains
35% brown silt aggregates
5% arenaceous foraminifers and silicified spines

27-2 60% brown silt aggregates
20% fine angular quartz sand grains
10% arenaceous foraminifers

27-3 60% brown silt aggregates
20% fine angular quartz sand grains
10% arenaceous foraminifers

27-4 60% fine angluar to subrounded quartz sand grains
10% brown silt aggregates
10% black silt aggregates
20% arenaceous foraminifers
silicified spines

28-1 70% light tan silt aggregates
25% fine angular quartz sand grains
5% arenaceous foraminifers

28-2 80% light tan silt
15% arenaceous foraminifers
5% fine angular quartz sand grains

(1) The impure limestone a few feet below the Captain Creek.

29-1 80% angular to subrounded quartz sand grains[1]
10% small pyrite aggregates
10% light tan silt aggregates
arenaceous foraminifers

29-2 90% light tan silt aggregates
10% arenaceous foraminifers

30-1 90% large gray silt aggregates
5% arenaceous foraminifers
5% small pyrite aggregates

31-1 95% medium-sized angular to subrounded, etched[1]
quartz sand grains
5% small pyrite aggregates and grains, some of
the grains are in the etched pits of the
quartz grains

31-2 95% angular quartz grains[1]
5% brown silt aggregates

(1) Vilas oolitic limestone.

APPENDIX B

MEASURED SECTIONS OF THE CAPTAIN CREEK LIMESTONE IN EASTERN KANSAS

Locality 1. Center east side, Sec. 36, T. 9 S., R. 22 E., Leavenworth County; measured on west bank of Nine Mile Creek.

	Thickness Feet
Stanton Limestone	
Stoner Limestone member	
Limestone, thin-bedded, wavy-bedded, top eroded, base covered........................	12+
Eudora Shale member	
Shale, covered, base is black and fissile....	6.4
Captain Creek Limestone member	
Limestone, massive, weathers thin-bedded. Upper six inches light gray, lower part dark gray. _Dicytoclostus_ and many small _Composita_ in pockets on top. Lower part has fusulinids, _Osagia_, and is slightly oolitic..................................	2.6
Vilas Shale	
Shale, dark gray, blocky.....................	unmeasured

Locality 2. Center north side NW 1/4, Sec. 27, T. 10 S., R. 23 E., Wyandotte County; measured on south side of road.

Stanton Limestone	
Stoner Limestone member	
Limestone, float............................	unmeasured
Eudora Shale member	
Shale, mostly covered, black shale as float. Three inches of reddish-brown, slimy and sandy shale at base.................	5+
Captain Creek Limestone member	
Limestone, medium-bedded, light blue-gray, fine-grained to dense. _Marginifera_, _Composita_ and linear algae. Algae abundant at top. Fusulinids locally abundant..................	1.6

Locality 2 (Cont'd)	Thickness Feet
Limestone, massive, blue-gray. Fusulinids locally abundant at base......................	2.5
Total Captain Creek member-	4.1
Vilas Shale	
Shale, covered............................	18.5
Plattsburg Limestone............................	unmeasured

Locality 3. Center south side, Sec. 36, T. 10 S., R. 22E., Leavenworth County; measured on U. S. 40 east of Wolf Creek bridge.

Stanton Limestone	
Stoner Limestone member	
Limestone, massive, wavy-bedded...............	11.2
Eudora Shale member	
Shale, mostly covered, bottom half black, upper half gray............................	6.0
Captain Creek Limestone member	
Limestone, massive, light blue-gray. Enteletes, Composita, Marginifera, shell fragments, fusulinids, crinoid stems. Linear algae abundant at top. Fusulinids common at base, less common above. At 1.2 and 2 feet below top are 2 inch bands of reddish-brown limestone......................	4.1
Vilas Shale...................................	unmeasured

Locality 4. Near center west side Sec. 18, T. 11 S., R. 23 E., Wyandotte County; measured on Kansas Turnpike between Bonner Springs Interchange and 142nd Street bridge.

Stanton Limestone	
Stoner Limestone member	
Limestone, medium- to massive-bedded, wavy-bedded, light gray. Fusulinids, crinoids, brachiopods. Zone of <u>Ottonosia</u> near top.................................	11.3

Locality 4. (Cont'd)

	Thickness Feet
Eudora Shale member	
Shale, dull black and subfissile at base, tan and limy at top..........................	3.6
Shale, black, fissile.........................	1.0
Shale, black, subfissile.....................	0.7
Shale, light gray, silty and limy............	0.5
Total Eudora member-	5.8
Captain Creek Limestone member	
Shaly limestone, coquinoid...................	0.1
Limestone, two beds, dense, linear algae at top and _Enteletes_ and _Composita_ below.....	1.4
Limestone, two beds, light gray, dense, _Composita_ at base, linear algae at base and at top..................................	2.4
Limy shale parting, yellow-brown, silty. Shell debris, echinoid spines, fusulinids....	0.1
Limestone, dark blue-gray, medium- to fine-grained. _Composita_, crinoid stems, horn corals, fusulinids. Myalinid shell in top....	1.4
Total Captain Creek member-	5.4
Vilas Shale	
Shale, light gray, sandy, blocky, a 2-feet siltstone bed about 6 feet below top.........	23.0

Locality 5. Center west side, Sec. 27, T. 11 S., R. 23 E., Wyandotte County; measured on road to Camp Naish

Stanton Limestone

Stoner Limestone member	
Limestone, thin- to medium-bedded, wavy-bedded, fusulinids, crinoid stems...........	11.4
Eudora Shale member	
Shale, dark gray to brown, fissile..........	5.3

Locality 5. (Cont'd)

	Thickness Feet
Captain Creek Limestone member	
Limestone, two beds, light blue-gray, fine-grained. Composita abundant at base. <u>Enteletes</u>, <u>Marginifera</u>.................	3.7
Limy shale parting...........................	0.1
Limestone, one bed, dark blue-gray, shell fragments and crinoid stems. Fusulinids in top.......................................	1.6
Total Captain Creek member-	5.4
Vilas Shale	
Shale, dark gray.............................	1.1
Sandstone, fine-grained, silty, ripple-marked, thin-bedded.........................	2.1
Shale..	unmeasured

Locality 6. SW 1/4, SE 1/4, Sec. 13, T. 12 S., R. 21 E., Leavenworth County; measured in roadcut between Linwood and Mt. Sidney cemetary.

Stanton Limestone	
Eudora Shale member	
Shale, black and fissile at base, tan and limy at top............................	5.8
Captain Creek Limestone member	
Limestone, three beds, light blue-gray, even-bedded, abundant linear algae...........	2.6
Limestone, one bed, light blue-gray to gray, <u>Composita</u> abundant at base, linear algae common at top, rare fusulinids, crinoid stems................................	1.7
Limy shale parting, light brown to tan.......	0.2
Limestone, massive, blue-gray, medium-grained rare brachiopods and crinoid stems...........	1.3
Total Captain Creek member-	5.8
Vilas Shale..................................	unmeasured

Locality 7. SW cor. Sec. 34, T. 12 S., R. 21 E., Douglas County; measured in quarry on east side of road.

	Thickness Feet
Stanton Limestone	
Eudora Shale member	
Shale, covered...............................	5.2
Captain Creek Limestone member	
Limestone, light blue-gray, fine-grained to aphanitic. Abundant algae, rare <u>Enteletes</u>..	1.0
Limestone, light blue-grey, fine-grained <u>Composita</u>, <u>Enteletes</u>. Zone of crinoid stems 1 foot below top..........................	2.7
Limestone, blue-gray, <u>Composita</u> common, linear algae rare..........................	1.7
Limy shale parting..........................	0.1
Limestone, fine-grained, massive, blue-gray, crinoid stems, Marginifera, fusulinids..	1.5
Total Captain Creek member-	6.9
Vilas Shale.....................................	unmeasured

Locality 8. Center south side Sec. 3, T. 13 S., R. 21 E., Douglas County; measured in roadcut on west bank of Captain Creek. Type section of Captain Creek and Eudora.

Stanton Limestone	
Stoner Limestone member	
Limestone, erosional remnant.................	6.0+
Eudora Shale member	
Shale, dark tan, clayey, blocky.............	0.5
Shale, light maroon, silty, blocky...........	1.1
Shale, black, fissile.......................	0.5
Shale, dark gray to black, subfissile........	1.2
Shale, black, fissile.......................	2.5

Locality 8. (Cont'd)

	Thickness Feet
Shale, light gray, limy......................	0.5
Total Eudora member-	6.3
Captain Creek Limestone member	
Limestone, massive, fine-grained, light blue-gray, algae abundant, base of member is covered..................................	2.1

Locality 9. NE 1/4, Sec. 10, T. 14 S., R. 23 E., Johnson County; measured in spillway of Olathe city lake.

Stanton Limestone

Stoner Limestone member	
Limestone, erosional remnant.................	6.0+
Eudora Shale member	
Shale, lower 3.5 feet black and fissile, upper part brown and clayey. Base covered....	6.5
Limestone, light blue-gray, mottled with reddish-brown, top uneven, abundant algae....	0.7
Limy shale parting..........................	0.1
Total Eudora member-	7.3
Captain Creek Limestone member	
Limestone, light blue-gray, fine-grained to dense, abundant algae....................	0.8
Limestone, light gray, dense, abundant algae, rare _Composita_, _Enteletes_, and crinoid stems................................	0.7
Limestone, light gray, dense, abundant algae, rare _Enteletes_ and crinoid stems......	1.3
Limestone, light blue-gray, dense, algae and _Enteletes_ rare, abundant _Composita_.......	1.6
Limy shale parting, fusulinids, horn coral...	0.2
Limestone, blue-gray, medium-grained, Composita, horn corals, productids, rare fusulinids, crinoid stems....................	1.1

Locality 9. (Cont'd)	Thickness Feet
Limy shale parting............................	0.1
Limestone, blue-gray, medium-grained, cinoid stems, shell fragments, fusulinids....	0.6
Total Captain Creek member-	6.4
Vilas Shale	
Shale, light gray, blocky....................	5.0+

Locality 10. SE 1/4, Sec. 27, T. 16 S., R. 20 E., Franklin County; measured in abandoned quarry.

Stanton Limestone	
Stoner Limestone member	
Limestone, erosional remnant..................	3.0+
Eudora Shale member	
Shale, olive to tan, silty, blocky, limy......	3.5
Shale, dark gray to dull black, subfissile....	1.9
Shale, black, fissile.........................	1.5
Shale, dark gray, subfissile..................	2.0
Limestone, mottled blue and gray, dense, algal, top uneven............................	1.4
Limy shale parting............................	0.1
Total Eudora member-	10.4
Captain Creek Limestone member	
Limestone, light blue-gray, dense, top slightly mottled. Abundant algae. Rare brachiopods in base..........................	2.4
Limestone, light blue-gray, dense, rare dark gray chert nodules. <u>Enteletes</u> and <u>Composita</u>. Common algae in top...............	2.1
Limestone, blue-gray, medium-bedded, <u>Composita</u> and rare <u>Marginifera</u>. Fusulinids in a shaly layer at top....................	1.2

Locality 10. (Cont'd)	Thickness Feet
Limestone, blue-gray, medium-grained........	1.0
Total Captain Creek member-	6.7
Vilas Shale	
Shale, covered...............................	5.5

Locality 11. SW cor. Sec., 6, T. 17 S., R. 20 E., Franklin County; measured in Bert Ross quarry.

Stanton Limestone	
Stoner Limestone member	
Limestone, light gray, wavy-bedded...........	10.0+
Eudora Shale member	
Shale, olive, silty...........................	2.0
Shale, dark gray to black, subfissile........	2.0
Shale, black, fissile.........................	1.0
Shale, dark gray, subfissile.................	3.5
Limestone, two beds separated by brown shale parting. Mottled dark blue and light gray. Abundant linear algae............	1.7
Limy tan shale parting.......................	0.2
Total Eudora member-	10.4
Captain Creek Limestone member	
Limestone, light blue-gray, dense, slightly mottled, abundant linear algae................	1.6
Limestone, three beds, _Composita_, _Enteletes_, crinoid stems, fine-grained. Top bed has linear algae locally abundant. Small chert nodules in lower beds.................	2.8
Shale parting, fusulinids....................	0.1
Limestone, two beds, light blue-gray, dense. Chert nodules near top. Fossils in the chert. _Fusulinids_ and _Marginifera_..........	1.8

Locality 11. (Cont'd)

Thickness
Feet

Limy shale parting.............................. 0.2

Limestone, blue-gray, medium-grained to dense. Osagia at top. Productids and fusulinids on top bedding plane.............. 1.0

Limy shale parting.............................. 0.1

Limestone, dark blue-gray, medium-grained, crinoid stems, fusulinids........... 0.6

Total Captain Creek member- 8.2

Vilas Shale

Shale, light gray, silty..................... 0.9

Plattsburg Limestone................................ unmeasured

Locality 12. SW 1/4, Sec. 5, T. 18 S., R. 20 E., Franklin County; measured in roadcut just east of Middle Creek bridge.

Stanton Limestone

Eudora Shale member

Shale, covered.................................. 6.0+

Captain Creek Limestone member

Limestone, light blue-gray, massive- to medium-bedded, fine-grained. Small horn corals, crinoid stems. Linear algae.......... 2.7

Limestone, light blue-gray, dense, medium-bedded. Enteletes, Composita, Marginifera, crinoid stems. Linear algae common. Rare small chert nodules near top................. 2.2

Limestone, light gray, massive, fine-grained. Fusulinids at base and top. Enteletes and Composita...................... 1.6

Limestone, blue-gray, medium-grained, massive. Rare fusulinids, myalinid shell..... 1.9

Total Captain Creek member- 8.4

Vilas Shale.................................... unmeasured

Locality 13. Center west side, Sec. 4, T. 20 S., R. 19 E., Anderson County; measured in roadcut at north end of North Pottawatomie Creek bridge.

	Thickness Feet
Stanton Limestone	
Stoner Limestone member	
Limestone, erosional remnant..................	3.0+
Eudora Shale member	
Shale, olive, silty............................	0.3
Shale, black, fissile..........................	1.4
Shale, olive, silty............................	0.2
Total Eudora member-	1.9
Captain Creek Limestone member	
Limestone, light blue-gray, dense, massive- to medium-bedded. Abundant linear algae......	2.1
Limestone, light gray, medium- to thin-bedded. Light gray and dark gray chert nodules near base. *Enteletes* abundant near top. Common linear algae in top.........	3.5
Limestone, light gray, fine-grained, medium-bedded. Small gray chert nodules near top. Abundant productids about 1 foot below top. Fusulinids in thin shaly partings. Rare *Enteletes*..................................	3.0
Limestone, dark gray, massive, medium-grained, algal(?), base covered..............	0.9+
Total Captain Creek member-	9.5+

Locality 14. Center east side Sec. 12, T. 20 S., R. 19 E., Anderson County; measured in quarry on east side of road.

	Thickness Feet
Stanton Limestone	
Captain Creek Limestone member	
Limestone, thin-bedded, wavy-bedded, light gray, medium-grained. Rare chert nodules at base. *Enteletes*, *Marginifera*, fusulinids, and a large echinoid spine........................	4.2+

Locality 14, (Cont'd) | Thickness Feet

Limestone, medium-grained, thin to medium-bedded and wavy-bedded. Dark blue-gray. Linear algae near top. Rare chert nodules near top. Marginifera, Enteletes, rare Composita, and crinoid stems........... 3.6

Total Captain Creek member- 7.8+

Vilas Shale
Shale, gray, flaky to blocky................. 7.1

Locality 15. Center south side, N 1/2, Sec. 12, T. 20 S., R. 18 E., Anderson County; measured in small quarry.

Stanton Limestone

Stoner Limestone member
Limestone, light gray, erosional remnant..... 4.0+

Eudora Shale member
Shale. From base upwards- 0.2' black and crumbly shale, 0.5 feet light gray shale, 0.4 feet tan and limy shale. Gradational contact between Eudora and Stoner, sharp between Eudora and Captain Creek. Thickness variable, black shale missing in places.. 1.1

Captain Creek Limestone member
Limestone, two beds, very fine-grained. Dark blue-gray. Styolites along base......... 0.6

Limestone, massive- to medium-bedded. Light blue-gray. Black shale partings between beds. Enteletes, fusulinids, small horn corals, rare bryozoans. Base covered. Member actually about 10 feet....... 4.6+

Total Captain Creek member- 5.2+

Locality 16. NE cor., Sec. 19, T. 24 S., R. 18 E., Allen County; measured in small quarry.

Stanton Limestone

Stoner Limestone member
Limestone, coarse-grained, impure, light gray, thin-bedded, wavy-bedded.............. 5.0+

Locality 16. (Cont'd)

	Thickness Feet
Limestone, thin-bedded, coarse-grained, interbedded with limy shale. Composita, Neospirifer, crinoid stems....................	5.8
Total Stoner member-	10.8+
Eudora Shale member	
Shale, dark gray, limy. Pockets of black shale at base. Small low-spired gastropods, crinoid stems, Composita....................	0.8
Captain Creek Limestone member	
Limestone, light blue-gray, wavy-bedded, thin-bedded, linear algae common.............	0.9
Limy shale parting...........................	0.1
Limestone, dark gray, linear algae and Composita.................................	0.6
Limy shale parting, dark gray................	0.1
Limestone, dark gray, medium-bedded, fine-grained. Enteletes, Marginifera, Composita, and rare linear algae........................	4.1+
Total Captain Creek member-	5.8+

Locality 17. SE cor., Sec. 25, T. 24 S., R. 17 E., Allen County, measured in roadcut on U. S. #54.

Stanton Limestone

Captain Creek Limestone member	
Limestone, light gray, impure, thin- to medium-bedded, medium- to coarse-grained. Echinochoncus near base. Rare linear algae... Top eroded..................................	8.6+
Limestone, massive, lower 1.5 feet dark blue-gray, dense, locally has linear algae ("Marksia") at top. Upper part is light blue-gray. Gradational contact with overlying limestone........................	3.2
Total Captain Creek member-	11.8+

Vilas Shale

Shale, dark gray..............................	unmeasured

Locality 18. NW 1/4, NE 1/4, NE 1/4, Sec. 32, T. 25 S., R. 17 E.

Woodson County; measured in roadcut.

	Thickness Feet
Stanton Limestone	
Captain Creek Limestone member	
Limestone, medium-bedded, wavy-bedded, light gray, medium-grained. Composita, large Enteletes, crinoid stems. Top eroded...	2.8+
Limestone, three beds, light gray. Linear algae, small Composita, Neospirifer..........	1.4
Limy shale, fusulinids......................	0.3
Limestone, thin-bedded, dark blue-gray, "Marksia" common...........................	0.8
Total Captain Creek member-	5.3+
Vilas Shale	
Shale, limy.................................	0.7
Limestone, dark blue-gray, abundant Osagia. Composita in upper part. Base irregular........	2.0
Shale, light gray...........................	unmeasured

Locality 19. Center south side, Sec. 33, T. 25 S., R. 17 E.,

Woodson County; measured in roadcut on county road.

Stanton Limestone	
Captain Creek Limestone member	
Limestone, light gray, thin-bedded, wavy-bedded, fine- to coarse-grained, top eroded..	5.0+
Limestone, light gray, thin- to medium-bedded, medium-grained, small Composita common at base, many thin calcite veins.......	5.5
Shale, limy, thin limestone beds, small Composita............................	1.4
Limestone, dark blue-gray, "Marksia"..........	0.7

Locality 19. (Cont'd)

	Thickness Feet
Limestone, fine-grained, dark blue-gray, conglomeratic with many siltstone pebbles, pinches out within about 5 feet..............	1.2
Total Captain Creek member-	13.8+
Vilas Shale..	unmeasured

Locality 20. Center west side, Sec. 36, T. 27 S., R. 16 E., Wilson County; measured in cut along railroad.

Stanton Limestone

Stoner Limestone member	
Limestone, light gray, erosional remnant.....	7.0+
Eudora Shale member	
Shale, gray, marly, crinoid stems............	1.5
Limestone, tan, medium-grained...............	0.8
Shale, gray, limy, fusulinids................	0.4
Total Eudora member-	2.7
Captain Creek Limestone member	
Limestone, light gray, fine-grained, medium-bedded, upper part slightly mottled, and algal. <u>Composita</u>, <u>Enteletes</u>, and fusulinids. Base covered......................	5.0+

Locality 21. Center north side, Sec. 26, T. 28 S., R. 15 E., Wilson County; measured in roadcut on K-32.

Stanton Limestone

Stoner Limestone member	
Limestone, light gray, erosional remnant.....	6.0+
Eudora Shale member	
Shale, tan to brown, limy....................	0.6
Captain Creek Limestone member	
Limestone, thin-bedded, light gray, shaly....	3.0
Limestone, light gray, <u>Osagia</u> at base, massive.....................................	3.2
Total Captain Creek member-	6.2

Locality 21 (Cont'd)	Thickness Feet
Vilas Shale	
Shale, olive, limy..............................	3.8
Limestone, dark blue-gray, dense...............	0.5
Shale, limy....................................	unmeasured

Locality 22. NW cor. SW 1/4. SW 1/4, Sec. 7, T. 29 S., R. 16 E., Wilson County; measured in roadcut.

Stanton Limestone	
Stoner Limestone member Limestone, light gray, thin-bedded. Crinoid stems and <u>Osagia</u>............................	8.0+
Eudora Shale member Limestone, light gray and interbedded gray limy shale. Small myalinids, <u>Composita</u>, crinoid stems, bryozoans..........	2.5
Captain Creek Limestone member Limestone, massive, medium- to coarse-grained. Abundant crystalline calcite. Enteletes, bryozoans, crinoid stems..........	7.4
Vilas Shale....................................	unmeasured

Locality 23. Center south side, Sec. 7, T. 29 S., R. 16 E., Wilson County; measured in roadcut on K-47.

Stanton Limestone	
Eudora Shale member Limestone and interbedded shale, small myalinids near base, top eroded..............	4.5+
Shale, lower half black and fissile, upper part tan and limy......................	0.6
Total Eudora member-	5.1+
Captain Creek Limestone member Limestone, fine- to medium-grained, nautiloids, <u>Composita</u>, dark blue-gray. Base is very irregular......................	4.8

Locality 23. (Cont'd)	Thickness Feet
Vilas Shale	
Shale, silty, a 2-feet sandstone bed about 3 feet above the base..................	26.0

Locality 24. NE cor., Sec. 26, T. 30 S., R. 15 E., Wilson County; measured in new roadcut.

Stanton Limestone	
Captain Creek Limestone member	
Limestone, massive, light gray, coarse grained, crystalline calcite. Top eroded.....	10+
Vilas Shale	
Gray limy shale and gray shaley algal limestone beds................................	10.2
Limestone, dark blue-gray, dense, medium-bedded, *Osagia*................................	4.4
Shale, gray, limy..........................	2.7
Total Vilas-	17.3
Plattsburg Limestone	
Limestone..................................	80.0+

Locality 25. Cen. Sec. 31, T. 31 S., R. 15 E., Montgomery County; measured in roadcut along county road.

Stanton Limestone	
Stoner Limestone member	
Limestone, erosional remnant..................	2.0+
Eudora Shale member	
Shale, tan, limy. *Derbyia*, *Marginifera*, crinoid stems..............................	8.7
Captain Creek Limestone member	
Limestone, light gray to tan, thin-bedded, fine- to medium-grained, fusulinids near base, *Neospirifer* in top....................	28.0

Locality 25. (Cont'd)	Thickness Feet
Limestone, light gray and light tan, massive. Fine-grained but with abundant masses of crystalline calcite. _Enteletes_, fusulinids, and crinoid stems in lenses......	16.8
Limestone, light gray, medium- to thick-bedded, medium-grained, abundant calcite masses. _Enteletes_, fusulinids, and rare small horn corals. Fossils especially common at the base...........................	12.3
Limestone, light gray, medium-grained, medium- to massive-bedded. _Enteletes_, fusulinids, rare crinoid stems and rare horn corals................................	7.0
Total Captain Creek member-	64.1
Vilas Shale..	unmeasured

Locality 26. SE cor., Sec. 9, T. 32 S., R. 15 E., Montgomery County; measured in old quarry on east side of Table Mound.

Stanton Limestone

Captain Creek Limestone member	
Limestone, massive, light gray, abundant clear and milky calcite. Weathers very vuggy and pitted. Common _Enteletes_, top 2 or 3 feet are slightly finer grained with less crystalline calcite and with fusulinids and crinoid fragments. Top eroded....................................	22.4+
Limestone, light gray to tan, three beds, medium-grained. _Enteletes_, crinoid stems, abundant fusulinids.........................	3.2
Limestone, massive, light gray, abundant crystalline calcite. Weathers very vuggy. Lower 1 foot is dark gray and fine-grained with a few crinoid stems. Rest contains _Enteletes_, fusulinids, and crinoid stems. Top has a crust of crushed fossils..........	10.9
Total Captain Creek member-	36.5+

Locality 26. (Cont'd)	Thickness Feet
Vilas Shale	
Shale, light gray, limy, crinod plates.......	unmeasured

Locality 27. SW cor., Sec. 14, T. 32 S., R. 14 E., Montgomery County; measured near bridge over Elk River.

Stanton Limestone	
Eudora Shale member	
Shale, covered...............................	18.0
Captain Creek Limestone member	
Limestone, upper 4 feet thin- to medium-bedded with abundant fusulinids. Rest of member massive, light gray, with abundant calcite masses. <u>Enteletes</u> common in base. <u>Marginifera</u>, <u>Neospirifer</u>, fusulinids.........	15.5
Vilas Shale	
Shale, light gray, silty, crinoid stems......	1.3
Limestone, dark tan to buff, impure, crinoid stems and <u>Neospirifer</u>...............	1.0
Shale, dark gray to olive....................	5.0
Sandstone, fine-grained, limy and silty. Base not seen..................................	7.2+

Locality 28. Center north side, Sec. 36, T. 34,S., R. 14 E., Montgomery County; measured in roadcut on K-160.

Stanton Limestone	
Captain Creek Limestone member	
Limestone, thin-bedded, wavy-bedded, dark gray with tan splotches. <u>Marginifera</u>, rare fusulinids...................................	2.3
Vilas Shale	
Shale, brown, silty, slightly limy...........	2.8
Sandstone, dark gray, silty and limy.........	2.2
Shale, dark gray, silty......................	unmeasured

Locality 29. NE cor., Sec. 5, T. 33 S., R. 15 E., Montgomery County; measured in roadcut on north side of Walker's Mound.

	Thickness Feet
Stanton Limestone	
Captain Creek Limestone member	
Limestone, medium-bedded, dark blue-gray, crinoid debris................................	2.6
Vilas Shale	
Shale, covered................................	3.0
Limestone, oolitic, blue-gray................	1.0

Platsbur

Locality 30. SW cor., Sec. 5, T. 34 S., R. 15 E., Montgomery County; measured in ditch at corner of road.

Stanton Limestone	
Eudora Shale member	
Shale, mostly covered. Black, phosphatic shale about 1 foot above the base............	unmeasured
Captain Creek Limestone member	
Limestone, lower 1.5 feet buff and marly and contains crinoid stems, <u>Enteletes</u>, and <u>Marginifera</u>. Upper part <u>less</u> crinoidal and <u>more</u> crinoidal ?	2.0
Lane-Vilas Shale................................	unmeasured

Locality 31. SE cor., Sec. 30, T. 34 S., R. 15 E., Montgomery County; measured in quarry northeast of Tyro.

Stranger Formation (?)	
Tonganoxie Sandstone member (?)	
Sandstone, reddish-brown, cross-bedded, disconformable on underlying shale. Top eroded....................................	10.0+
Weston Shale (?)	
Shale, light gray, silty, thickness variable..................................	7.8

Locality 31. (Cont'd)	Thickness Feet
Lansing Group	
Limestone, sandy, contains rounded pebbles, cross-bedded..	2.6
Shale, light gray and silty at base, upper part black and fissile. Pinches out in this quarry..	1.6
Limestone, oolitic, massive, faintly cross-bedded. Wilson (1957) measured 17.9 feet of this bed by the use of cores. Base cannot be seen in this quarry........................	14.0+