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STRATIGRAPHY OF BIONERMS AND OTHER DEPOSITS
OF THE UPPER PENNSYLVANIAN BEGGI LIMESTONE
IN EAST CENTRAL KANSAS

by Don E. Owen
B.S., Lamar State College of Technology, 1957

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Geology and the Faculty of the
Graduate School of the University
of Kansas in partial fulfillment
of the requirements for the degree
of Master of Science.

Instructor in charge

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For the department

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Summary: Accretive fossils best facilitate study of microlithologies of carbonatic rocks. The three members of the Bern formation, in ascending order, Burlington Limestone, Soldier Creek Shale, and Wabavron Limestone are divided into zones on the basis of microlithology and fauna. The insoluble residues of these zones are sufficiently distinctive and consistent to permit differentiation and correlation. Two Hirmeria-type cystoliths are contained in the beds studied. The Burlington Cystolith differs from the typical cystolith in that it contains an algal-fucoid phase rather than a fucoid phase. The Wabavron Cystolith differs in that it does not contain a basal straddler and that it has two fucoid phases rather than one. The units within the Burlington Limestone consist of a discontinuous molluscan limestone at the base, a persistent fucoid-cragite limestone in the middle, and a localized bryozoan limestone at the top. The Soldier Creek Shale contains a regressive molluscan bichora in the northern part of the area and a transgressive molluscan bichora in the northern part of the area along with marine and non-marine shales and a fossiliferous coal bed. The bichoras were formed on the southwestern flank of the Forest City Basin during regression of the sea to the northeast and again during transgression to the southwest. The units within the Wabavron Limestone consist of a fairly persistent fucoid limestone at the base, an extremely persistent coralline limestone in the middle, and a persistent fucoid bed at the top.

ABSTRACT

The stratigraphy of the Bern Limestone, an escarpment-forming formation of the Wabaunsee Group (Virgilian Series; Pennsylvanian System) was subjected to detailed study in Shawnee, Osage, and Lyon Counties, Kansas. Acetate peels best facilitate study of microlithologies of carbonate rocks. The three members of the Bern formation, in ascending order, Burlingame Limestone, Soldier Creek Shale, and Wakarusa Limestone are divided into zones on the basis of microlithology and fauna. The insoluble residues of these zones are sufficiently distinctive and constant to permit differentiation and correlation. Two Wabaunsee-type cyclothem are contained in the beds studied. The Burlingame Cyclothem differs from the typical cyclothem in that it contains an algal-fusulinid phase rather than a fusulinid phase. The Wakarusa Cyclothem differs in that it does not contain a basal sandstone and that it has two fusulinid phases rather than one. The units within the Burlingame Limestone consist of a discontinuous molluscan limestone at the base, a persistent fusulinid-osagite limestone in the middle, and a localized brecciated limestone at the top. The Soldier Creek Shale contains a regressive molluscan bioherm in the southern part of the area and a transgressive molluscan bioherm in the northern part of the area along with marine and non-marine shale and a localized coal bed. The bioherms were formed on the southwestern flank of the Forest City Basin during regression of the sea to the northeast and again during transgression to the southwest. The units within the Wakarusa Limestone consist of a fairly persistent fusulinid limestone at the base, an extremely persistent encrinural limestone in the middle, and a persistent fusulinid bed at the top.

INTRODUCTION

Location and Size of Area

This report is concerned with the stratigraphy of the Bern Limestone as it crops out in Shawnee, Osage and Lyon Counties of east central Kansas (See Fig. 1 for location). However, the outcrop of the formation is not confined to these three counties, but extends from southwestern Iowa, across northwestern Missouri, southeastern Nebraska, and eastern Kansas into northern Oklahoma (Condra, 1949, p. 18).

The combined area of Shawnee, Osage and Lyon Counties is 2130 square miles. The outcrop of the Bern Limestone however occupies only a small portion of this area. The straight-line distance from the northern-most outcrop to the southern-most outcrop is approximately 72 miles. The distance measured along the actual irregular outcrop is much greater.

Purpose of Investigation

This report was prepared to partially fulfill the requirements for the degree of Master of Science in Geology at the University of Kansas. The specific subject of this report was chosen because of the author's desire to make a very detailed stratigraphic study of thin limestone units with special emphasis on differentiation and correlation of lithologic zones within units commonly regarded as members of formations.

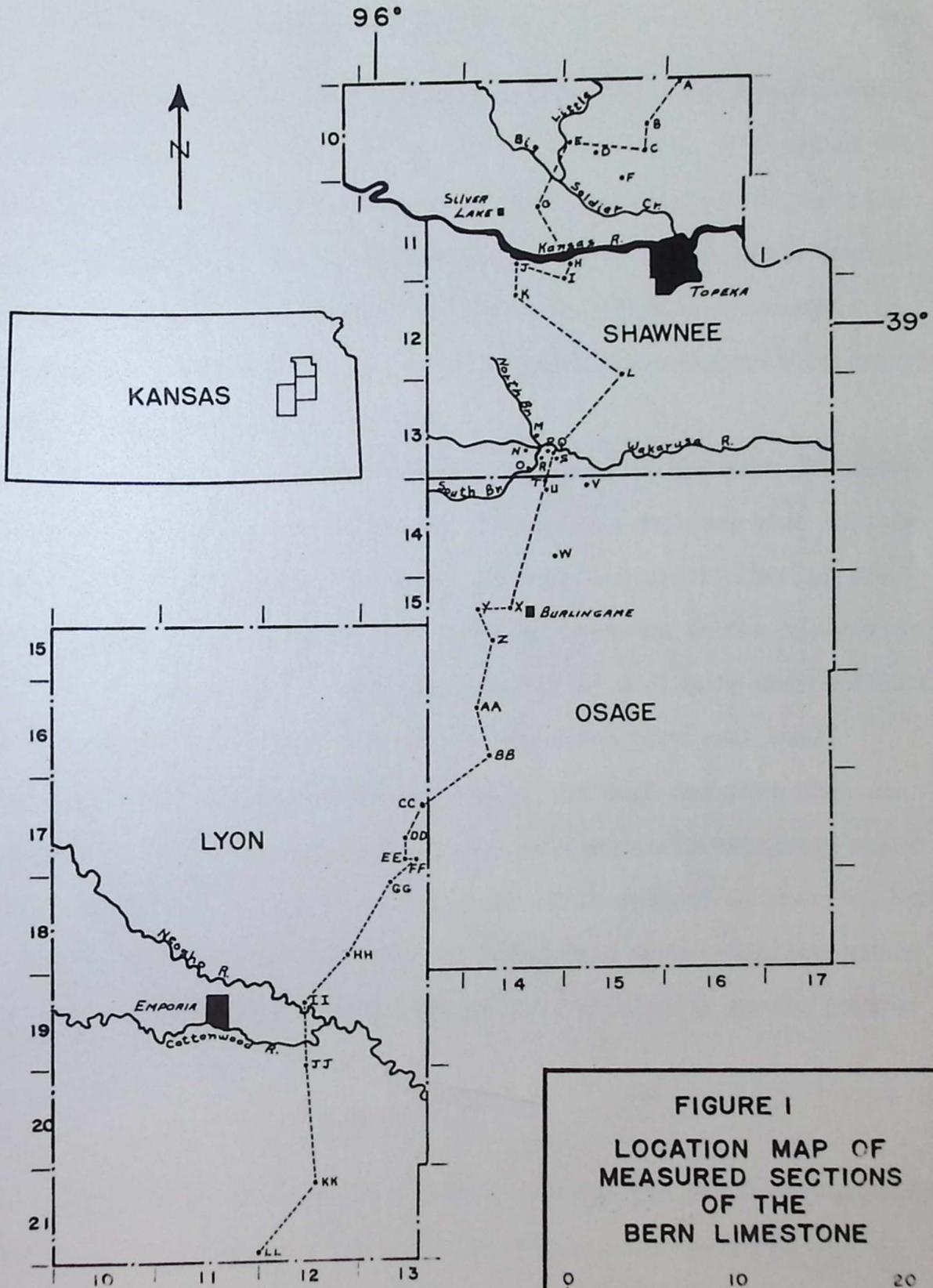


FIGURE 1
LOCATION MAP OF
MEASURED SECTIONS
OF THE
BERN LIMESTONE

0 10 20
SCALE IN MILES

Method of Investigation

Outcrops suitable for detailed stratigraphic measurement were located along the outcrop belt of the Bern formation as shown on the geologic maps and topographic maps of the area. Reference was also made to the stratigraphic sections in the files of the State Geological Survey of Kansas. The greatest number of sections were measured in roadcuts and roadside ditches; a large number were measured in quarries; a few were measured along streams.

All complete or nearly complete exposures of the Bern formation that could be found were measured. Incomplete sections that exhibit some special feature were measured. A detailed description of the Bern and adjacent formations was made and recorded in the field along with the measurements. Fresh hand samples of each unit were collected for laboratory analysis. One sample was taken from each small lithologic unit within limestones unless the unit was more than one foot thick, in which case a sample was collected approximately every foot. The limestone samples were oriented in respect to vertical and to north. Channel samples were collected from apparently homogenous shales. Nonhomogenous shales were sampled at closely spaced points.

Previous Work

The Bern Limestone and its three members, the Burlingame Limestone, Soldier Creek Shale, and Wakarusa Limestone, have been mentioned numerous times in publications dealing with Pennsylvanian rocks of the Mid-Continent. However, no detailed stratigraphic studies similar to those of this report have been published.

Brief outlines of the stratigraphy of the members of the Bern are found in publications on stratigraphy of the various state geological surveys of Kansas and surrounding states. The more important publications are by: Moore (1935), Moore (1949), and Moore and others (1951) in Kansas; Condra (1927), Condra and Reed (1943), and Condra (1949) in Nebraska; Tilton (1920) in Iowa, Gould (1925) in Oklahoma. Further references to earlier work can be found in these papers.

Wahrhaftig (1952) studied the insoluble residues of the limestones of the Bern formation along with the other limestones of the Wabaunsee Group. Ireland (1956) described the arenaceous foraminifera of the limestones of the Bern in his study of Shawnee and Wabaunsee Group foraminifera. Runnels and Schleicher (1956) analyzed several samples of limestone from the Bern in their study of the chemical composition of eastern Kansas limestones.

Recent work on the general stratigraphy of the Bern Limestone is found in the series of reports on the geology of a number of counties in eastern Kansas by the State Geological Survey. These reports include: Lyon County (O'Connor, 1953) and Osage County (O'Connor, 1955) within the area of this report; Elk County (Verville, 1958) to the south; Jackson County (Walters, 1953) to the north. The United States Geological Survey is presently preparing a report on the geology of Shawnee County. The geologic maps of Lyon and Osage Counties along with the geologic map of Shawnee County, when completed, will provide complete coverage of the outcrop belt of the Bern formation in the area of this report.

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The west-dipping Lincoln is well known from its characteristic trending, truncated escarpments and low, rounded hills to the east. The Barn Limestone is one of the more prominent members of the Lincoln Group. Throughout most of its extent the formation forms one escarpment with the west-dipping limb to the west and the east-dipping limb to the east. However, at certain places where the shale between the two Lincoln members is thinner and in other places, two escarpments are formed, one to the west and one to the east. Rounded hills and irregularly shaped areas that usually consist of the Barn Limestone are common.

The elevation of the Barn escarpment is fairly constant, being about 1100 feet above sea level throughout. Its average height is approximately 100 feet above an area that may be designated the dip

PHYSIOGRAPHY

Shawnee, Osage and Lyon Counties are in the Central Lowland physiographic province of Fennemen (1938). All Lyon and Osage and that part of Shawnee County south of Kansas River (Fig. 1) are in the Osage Plains section of the Central Lowland. That part of Shawnee County north of Kansas River is a portion of the Dissected Till Plains section of the Central Lowland. The boundary line between the Osage Plains and the Dissected Till Plains is the maximum extent of Pleistocene glaciation in this part of the country. This line follows approximately Kansas River, although isolated glacial deposits are found south of the River. North of the River the bedrock is extensively covered by Pleistocene glacial deposits, but escarpments formed by bedrock persist.

The west-dipping limestone beds in this area form north-south trending, crenulated escarpments that have their face slope on the east. The Bern Limestone is one of the most prominent escarpment-formers of the Wabaunsee Group. Throughout most of the area studied the formation forms one escarpment with two small benches held up by the two limestone members (Fig. 2). In most of Shawnee County where the shale between the two limestone members is thicker than in other places, two escarpments are formed, one by each limestone. Rounded hills and irregular-shaped mesas that contain outlyers of the Bern Limestone are common.

The elevation of the Bern escarpment is fairly constant, being about 1100 feet above sea level throughout. Its average height is approximately 100 feet above an area that may be designated the dip

slope of the Howard Limestone escarpment.

The area is maturely dissected by eastward-flowing major streams that are remarkably parallel. The drainage pattern is aherescent. Most of the streams flow in valleys partially filled with alluvium. This condition combined with a heavy cover of vegetation along the stream valleys is responsible for the rareness of natural exposures of bedrock.



FIG. 2. Bern Limestone Escarpment in Osage County. Note two small benches on escarpment held up by two limestone members.

TABLE 1

CLASSIFICATION OF THE WABAUNSEE GROUP
GENERAL STRATIGRAPHY

Permian System

Wabunsee Series

Admire Group

Pennsylvanian System

Wabaunsee Group

Virgilian Series

Wabaunsee Group

The Wabaunsee Group is the uppermost group in the Pennsylvanian System in Kansas. It rests conformably on the rocks of the Shawnee Group and is overlain by Lower Permian rocks of the Admire Group which seemingly, mostly are in conformity with the Wabaunsee rocks (Table 1). Average thickness of the Wabaunsee is about 500 feet.

Sacfox Subgroup

The Sacfox Subgroup, basal subgroup of the Wabaunsee Group, has an average thickness of about 200 feet. It is divided into three formations; listed in ascending order, they are: Severy Shale, Howard Limestone, and Scranton Shale.

Scranton Shale

The Scranton Shale (Haworth and Bennet, 1908) is the uppermost formation in the Sacfox Subgroup. In ascending order it is divided into these five members: White Cloud Shale (Condra, 1927), Happy Hollow Limestone (Condra, 1927), Cedar Vale Shale (Condra, 1930), Rulo Limestone (Condra and Bengtson, 1915), and Silver Lake Shale (Beede, 1898). Before Moore and Hudge (1956) reclassified the Wabaunsee Group, each of these members were recognized as separate formations.

TABLE 1

CLASSIFICATION OF THE WABAUNSEE GROUP

Permian System

Wolfcampian Series

Admire Group

Pennsylvanian System

Virgilian Series

Wabaunsee Group

Richardson Subgroup

Wood Siding Formation

Brownville Limestone

Fony Creek Shale

Grayhorse Limestone

Plumb Shale

Nebraska City Limestone

Root Shale

French Creek Shale

Jim Creek Limestone

Friedrich Shale

Stotler Limestone

Grandhaven Limestone

Dry Shale

Dover Limestone

Pillsbury Shale

Zeandala Limestone

Maple Hill Limestone

Wamego Shale

Tarkio Limestone

The St. Nemaha Subgroup

Willard Shale

Emporia Limestone

Elmont Limestone

Harveyville Shale

Reading Limestone

Auburn Shale

Bern LimestoneWakarusa LimestoneSoldier Creek ShaleBurlingame Limestone

The St. Sacfox Subgroup

Scranton Shale

Silver Lake Shale

Rulo Limestone

Cedar Vale Shale

Happy Hollow Limestone

White Cloud Shale

Howard Limestone

Utopia Limestone

Winzeler Shale

Church Limestone

Aarde Shale

Bachelor Creek Limestone

Severy Shale

Shawnee Group

Silver Lake Shale

The name Silver Lake Shale was proposed by Beede (1898) for the strata between the top of the Elmo Coal bed of the Cedar Vale Shale and the base of the Burlingame Limestone. Condra (1927) restricted the Silver Lake Shale to its present boundaries-- between the top of the Rulo Limestone and the base of the Burlingame Limestone.

The type locality of this unit was designated to be in the vicinity of Silver Lake, Shawnee County, Kansas (Fig. 1). No exact exposure was designated to be the type. It is here proposed that Locality G of this report (Appendix A) be regarded as the type section of the Silver Lake Shale. This is a good exposure in a roadcut about two miles east of the town of Silver Lake in the SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 11, T. 11 S., R. 14 E., Shawnee County, Kansas.

The Silver Lake Shale was measured completely at several locations for this report. A more complete discussion of this unit will be found under Detailed Stratigraphy.

Nemaha Subgroup

The Nemaha Subgroup is the middle division of the Wabaunsee Group. It can be traced southward only to about the Osage-Lyon County line, because its upper boundary, the Tarkio Limestone, is not present south of this line. The average thickness of the subgroup is about 160 feet. It is divided into four formations; in ascending order they are: Bern Limestone, Auburn Shale, Emporia Limestone and Willard Shale. Limestones are more predominant in the Nemaha Subgroup than in the underlying Sacfox Subgroup.

Branch, south of Taylor Bern Limestone

The basal formation of the Nemaha Subgroup was named the Bern Limestone by Moore and Hudge (1956) from the town of Bern, just south of the Nebraska state line in Nemaha County, Kansas. The type locality is in a roadcut in the SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 7, T. 1 S., R. 13 E., one mile west and one-half mile north of Bern. The Bern Limestone is divided into three members; in upward order they are: Burlingame Limestone, Soldier Creek Shale, and Wakarusa Limestone. Moore (1935, p. 215-220) lists other names that have been applied to these rocks.

The Bern Limestone is the main subject of this report. Thirty-eight stratigraphic sections of the formation were measured in the area covered. The stratigraphy is discussed fully under Detailed Stratigraphy.

Burlingame Limestone

The Burlingame Limestone is the basal member of the Bern formation. It was named by Hall (1896) from outcrops just west of the town of Burlingame, Osage County, Kansas (Fig. 1). It is proposed that the section measured at Locality X (Appendix A) for this report be regarded the type section for the Burlingame Limestone. It is located approximately one mile west of Burlingame in a ditch on the north side of Kansas Highway 31 in S $\frac{1}{2}$, SE $\frac{1}{4}$, Sec. 9, T. 15 S., R. 14 E., Osage, County, Kansas.

Condra (1935) divided the Burlingame Limestone (then classed as a formation) into three members. The basal member was named the Taylor Branch Limestone from the type locality in a clay pit south of Taylor

Branch, south of Table Rock, Nebraska. The middle member was named the Winnebago Shale from an exposure in Missouri River bluffs south of the mouth of Winnebago Creek, north of Rulo, Nebraska. The upper member was named the South Fork Limestone from a locality high in the hill about three-fourths of a mile southwest of DuBois, Nebraska, at the west side of South Fork Valley. Condra states, "the members of the....Burlingame formation have been traced through Kansas to Oklahoma". In a later publication, Condra (1949) points out that the two upper members of the Burlingame named by him, the Winnebago Shale and South Fork Limestone, are actually part of the Soldier Creek Shale and that the basal member, the Taylor Branch Limestone, is actually the entire Burlingame Limestone. The South Fork Limestone would therefore be a bed or beds in the middle part of the Soldier Creek Shale. A calcareous zone of limestone, mudstone, and shale was found in the middle part of the Soldier Creek Shale by the author throughout Shawnee County (Plate 1). This probably represents Condra's South Fork Limestone. However, this zone of limestones cannot be traced across Osage and Lyon Counties, and therefore not across Kansas into Oklahoma as stated by Condra. Plate 1 shows numerous sections in Osage and Lyon Counties where the Soldier Creek is composed entirely of shale. Verville (1958, p. 20) reported no limestones in the Soldier Creek of Elk County, in southern Kansas. The author proposes that the three members of the Burlingame named by Condra (1935) should be abandoned.

The Burlingame limestone is a very persistent unit. It can be traced from south central Iowa across Nebraska and Kansas into northern Oklahoma (Condra, 1949, p. 16).

Soldier Creek Shale

The Soldier Creek Shale is the middle member of the Bern formation. The name Soldier Creek Shale was first proposed by Beede (1898). The type locality was not designated, but it presumably is on Big and Little Soldier Creeks in Shawnee County, Kansas (Fig. 1). Localities E and G of this report (Appendix A) are in this vicinity and could be regarded the type locality, although both are rather poor exposures. According to Moore (1935, p. 218), Beede's Soldier Creek Shale corresponds to the present Auburn Shale directly above the Bern Limestone. Condra (1927) used the name Soldier Creek for the shale between the Burlingame and Wakarusa Limestones, its present boundaries. This definition of Soldier Creek has been accepted and Beede's earlier definition rejected (Moore, 1935, p. 218).

The Soldier Creek Shale also is a very persistent unit. It can be traced from southwestern Iowa, across Nebraska and Kansas, into northern Oklahoma (Condra, 1941, p. 18).

Wakarusa Limestone

The Wakarusa Limestone is the upper member of the Bern formation. The name Wakarusa Limestone was proposed by Beede (1898) from a type locality on Wakarusa Creek immediately south of Auburn, Shawnee County, Kansas (Fig. 1). The name was again used by Condra (1927) for the limestone above the present Soldier Creek Shale. This usage of the term appeared extensively in the literature but when Condra's Wakarusa is traced southward to the area of the type locality of Beede's Wakarusa, the two limestones do not correlate. They are separated by the present

Auburn Shale, and Beede's Wakarusa is the present Reading, a member of the Emporia formation. Because of the widespread use of Condra's definition of Wakarusa it has been accepted over Beede's prior definition (Moore, 1935, p. 220). Two sections of the Wakarusa were measured for this report in the vicinity of the type locality of the limestone originally called Wakarusa. Locality N (Appendix A) was measured just south of Wakarusa River in the SE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 27, T. 13 S., R. 14 E., Shawnee County, Kansas (Fig. 1). Locality M was measured near the North Branch of Wakarusa River in Sec. 23, T. 13 S., R. 14 E., Shawnee County, Kansas. Since the section at Locality N is better exposed, it will be regarded the type locality in this report even though the upper contact of the Wakarusa is not exposed. Moore (1935, p. 220) makes note of the fact that exposures of the Wakarusa Limestone are poor in the vicinity of the type locality and then states, "Much better exposures are to be found on Kansas Highway 10 west of Topeka in Sec. 35, T. 11 S., R. 13 E., and along the creek north of the highway near this place". These exposures designated by Moore are not the Wakarusa Limestone. They are the Zeandale Limestones. Either the wrong location was given or the limestones were misidentified.

Like the other members of the Bern Limestone, the Wakarusa is a very persistent unit. It can be traced from southwestern Iowa, across Nebraska and Kansas into northern Oklahoma. It is called the "Cryptozoon Limestone" in Oklahoma where it is a widely-recognized datum (Moore, 1949, p. 183).

Auburn Shale

The Auburn Shale immediately overlies the Bern Limestone. Beede (1898) named this formation presumably from outcrops near the Wakarusa River in the vicinity of Auburn, Shawnee County, Kansas (Fig. 1); he did not definitely state a type locality. Beede's original Auburn Shale corresponds to the present Harveyville Shale member of the Emporia formation according to Moore (1935, p. 222). Condra (1927) designated the shale between the present Wakarusa Limestone and the present Reading Limestone as the Auburn Shale. This definition is now accepted (Moore, 1935, p. 222).

The Auburn formation can be traced from southeastern Nebraska, across Kansas, into northern Oklahoma.

Although not the subject of this report, several partial stratigraphic sections of the Auburn Shale were measured.

The general results of the pool study were excellent. In the author's opinion, this is the simplest and most effective method for the study of carbonate lithologies. The pool prints may be enlarged any number of times to show as much detail as is desired. A number of small fossils, especially small pelecypods and fusulinids, and microstructures not observed in the field were readily found in the pool prints. The

SEDIMENTARY ANALYSIS

Acetate Peel Study

Approximately 320 acetate peels were prepared from limestone samples of the Bern formation. The oriented sample of limestone collected from the field was first sawed in a north-south direction at right angles to the bedding. Another cut was made parallel to the bedding in most samples. The cut surfaces were smoothed on a lap using a medium grade of grinding compound (#150). The surfaces were then polished by hand on a glass plate with a fine grade of grinding compound (#600). The polished surfaces were next immersed in a 10% solution of hydrochloric acid for 10 to 15 seconds, depending on the density of the limestone. After drying, the etched surface was submerged in acetone for about 30 to 60 seconds, depending on the permeability of the limestone, and quickly pressed upon the frosted surface of thin acetate paper. After drying, the acetate was peeled from the sample, trimmed to size, and mounted between two glass slides. Binding tape was used to seal the peel between the glasses. The glass-mounted peel was used as a photographic negative and enlarged positives were made from all the samples.

The general results of the peel study were excellent. In the author's opinion, this is the easiest and most effective method for the study of carbonate lithologies. The peel prints may be enlarged any number of times to show as much detail as is desired. A number of small fossils, especially small gastropods and fusulinids, and microstructures not observed in the field were readily found in the peel prints. The

peel prints used as illustrations in this report are enlarged four times unless otherwise indicated.

The vertical peels were found to be most useful. Horizontal peels were prepared in an effort to determine any preferred orientation of elongate material in the limestones. No such orientation was found. Regarding the peel prints utilized in this report, up is toward the top of the page in the vertical peel prints and north is toward the top of the page in the horizontal peel prints. All prints are elongate in a north-south direction.

Etched Block Study

The acid-etched blocks of limestone remaining after the peel study were used in this investigation. These samples were examined under a binocular microscope with special notice being given to the lithology, mineralogy, and paleontology. Any additional information gained from examination of the etched blocks was added to the description of measured sections (Appendix A).

The study of etched blocks supplemented the peel and insoluble residue investigations. Certain features that were unidentifiable from the peel prints were identified from the etched blocks. This was particularly true of certain mineral and rock materials present in the limestones. The orientation and distribution of insoluble residues can also be determined from etched blocks.

For a more complete discussion of the use of etched blocks in limestone investigations the reader is referred to Ives (1954).

Insoluble Residue Study

Insoluble residues were made of selected samples of the limestones of the Bern formation. Several samples were selected from each microlithologic zone within a member. Samples were selected in such a way that they represented the entire lateral extent of each zone within the area studied.

The procedure used in preparation of the residues is very similar to that of Fisher (1958, p. 10). Ireland (1951) also summarized the general procedure. The fresh limestone was crushed and thoroughly mixed. A 20 gram portion was weighed, placed in a beaker, and covered with water. Concentrated hydrochloric acid was added until digestion was complete. While the solution within the beaker was being boiled, stannous chloride solution was added to remove the limonite. The coarse residue remaining was thoroughly washed, dried, weighed, and placed in glass vials for later microscopic examination. The fine residue was decanted and discarded after being weighed. Percentages of total residue, coarse fraction and fine fraction were computed (Appendix B). The coarse fraction was examined and described using a binocular microscope (Appendix C). Standard insoluble residue terminology (Ireland, 1947) was used. Table 2 is the classification of insoluble residues used in this report.

TABLE 2

CLASSIFICATION OF THE INSOLUBLE RESIDUES OF THE BERN LIMESTONE

I. Allogenic: constituents derived from previously-existing rock.

1. Quartz Sand
2. Clay and Silt Material
3. Mica Flakes
4. Tourmaline

II. Authigenic: constituents formed contemporaneously with or subsequent to deposition of the sediments.A. Syngenetic: contemporaneous constituents.

1. Arenaceous Foraminifera
2. Carbonaceous Material

B. Epigenetic: subsequent constituents.

1. Silicified Fossils

C. Syngenetic or Epigenetic: either contemporaneous or subsequent constituents.

1. Pyrite
2. Gypsum
3. Chert

Wahrhaftig (1952, p. 46-47), in his study of the insoluble residues of the Wabaunsee Group, points out that the residues of both the Burlingame and Wakarusa Limestones are not distinctive or sufficiently constant enough to permit differentiation of these limestones from the other limestones of the group. The author agrees with this statement in that, as a whole, the Burlingame and Wakarusa can not be distinguished from other limestones. However, the author found that the residues of the individual microlithologic zones within the Burlingame and Wakarusa are distinctive enough and sufficiently constant to permit correlation of these units within the members. The distinctive characters of the residues of these individual microlithologic zones is presented under the discussion of these zones in Detailed Stratigraphy.

The difference in sampling technique used by Wahrhaftig and that of the author probably accounts for the difference in results. Wahrhaftig's sample was a channel sample of the entire member. The author sampled each microlithologic zone within the member. Because the development of these zones is very unequal from place to place, Wahrhaftig's samples from different localities were likely to be from different microlithologic zones or different combinations of these zones. For example, his sample of the Burlingame Limestone in Shawnee County was from the brecciated limestone bed of that member; his sample of the Burlingame in Osage County was from the fusulinid-osagite bed of that member. It is not surprising that the residues of these samples were quite different. Although, the residues do vary laterally within a single zone, the variation is much greater vertically where more than

one zone is present. In other words, the Bern Limestone or its members as a whole are not greatly different from other adjacent limestones, but individual zones within the formation can be correlated and differentiated from each other.

Only three sets of insoluble residues are abundant in the Bern Limestone---quartz sand, arenaceous foraminifera, and silt and clay aggregate. These residues make up about 90% of all coarse insoluble material in all the samples. As previously mentioned only the coarse residue was studied.

Quartz Sand: Quartz sand is very abundant in the Bern Limestone. It is present in about 50% of the samples and constitutes an average of about 45% of the residue where present. The grains generally are small and range from rounded to angular. Subangular grains, however, are the most common. Many of the grains are frosted but some are transparent.

Silt and Clay Material: Silt and clay matter is also very abundant in the Bern. This material probably composed most of the fine residue. Silt and clay aggregate is present in about 70% of the samples and composes an average of approximately 50% of the residue where present. Silt grains cemented with clay make up this residue. Even though all samples were boiled and a deflocculant added to some, this clay did not deflocculate.

Mica Flakes: Flakes of mica are common in the Bern Limestone. Mica is present in about 50% of the residues and composes an average of about 7% of the residue where present. Some small flakes were undoubtedly lost when the fine residue was decanted. Almost all of the mica

present is muscovite.

Tourmaline: Tourmaline is rare in the Bern. It was found only in about 7% of the samples and, where present, forms only a very small percent of the residue. All tourmaline observed is brownish red, translucent, and in elongate euhedral crystals with slightly rounded corners.

Arenaceous Foraminifera: Arenaceous foraminifera are very numerous in the Bern formation. They exist in about 80% of the residues and constitute an average of about 35% of the residue where present. Almost all of the tests are composed of white silt grains. Most were broken but many were not.

Carbonaceous Material: Carbonaceous material is common in the Bern Limestone. It is present in approximately 40% of the samples, comprising an average of about 5% of the residue where present. This material occurs as irregular-shaped black masses.

Silicified Fossils: Silicified fossil material is very rare in the Bern. It is present at only one locality in the Wakarusa Limestone where it composes about 20% of the residue. Most of the replaced fossils are fusulinids but some silicified shell fragments are present.

Pyrite: Pyrite is fairly rare in this formation. It is present in about 20% of the residues. Where present, it comprises an average of approximately 10% of the residue. Pyrite is quite variable in amount however. This mineral occurs in various forms. Amorphous masses, aggregates, cubes and foraminiferal fillings were noted.

Gypsum: Gypsum is rare in this unit. It exists in about 20% of the residues and, where present, constitutes an average of about 3% of

the residue. Alabaster is the most common variety, but selenite is present.

Chert: Chert is rare in the Bern Limestone. It is present in approximately 18% of the samples but, where present, constitutes an average of only about 4% of the residue. It is usually gray in color, irregularly shaped and angular.

Shale Study

The shales of the Bern formation were not subjected to as detailed a study as the limestones. They were simply examined with a binocular microscope with special attention being given to fossil and mineral content. The shales were found to be very pure in general with little silt or sand. Some were calcareous. In general, most of the shales were unfossiliferous although many exceptions were found. The shales of the different members of the Bern formation are discussed under Detailed Stratigraphy.

In the Mahanawan Group are classic cyclothems in which marine deposits dominate. No less than 15 distinct cyclothems and one rudimentary megacyclothem—the Howard cycle—have been distinguished in the Mahanawan Group.

The distinctive features of the Mahanawan type of cycle are: very rare black shale; extreme persistence of very thin coal beds; the sequence of shaly and limestone beds in the marine portion of the cycle beginning with near-shore transgressive deposits, progressing to near-offshore deposits, and then regressive deposits (modified from Moore, 1950, p. 9). The cycle begins and ends with non-marine deposits.

That part of the Mahanawan Group studied in this report includes

CYCLOTHEMS

A cyclothem, according to Weller (1932, p. 1003), is "a series of beds deposited during a single sedimentary cycle of the type that prevailed during the Pennsylvanian Period". Cyclothem may be only cyclic--repetition of conditions without reference to periodicity, or they may be rhythmic--repetition of conditions at regularly varying intervals of time. Lowman (1959) discusses this problem and presents evidence that cyclothem are rhythmic. There have been many theories for the origin of cyclothem. It is not the purpose of this report to analyze these theories. For such an analysis, the reader is referred to Weller (1956).

The Pennsylvanian sediments of the Mid Continent are well-known for their many and varied cyclothem. There are many kinds of cyclothem. Some are dominantly marine, others are dominantly non-marine. Some are simple cycles, others are cycles of cyclothem, called megacyclothem. The type present in the Wabaunsee Group are simple cyclothem in which marine deposits dominate. No less than 15 distinct cyclothem and one rudimentary megacyclothem--the Howard cycle--have been distinguished in the Wabaunsee Group.

The distinctive features of the Wabaunsee type of cycle are: very rare black shale; extreme persistence of very thin coal beds; the sequence of shale and limestone beds in the marine portion of the cycle beginning with near-shore transgressive deposits, progressing to maximum offshore deposits, and then regressive deposits (modified from Moore, 1950, p. 9). The cycle begins and ends with non-marine sediments.

That part of the Wabaunsee Group studied in this report includes

two cyclothem. The Burlingame Cyclothem extends from the central part of the Silver Lake Shale to the central part of the Soldier Creek Shale. The Wakarusa Cyclothem extends from the central part of the Soldier Creek Shale to the lower part of the Auburn Shale.

Moore (1935, p. 21-26) discusses the members of the ideal cyclothem and the members of the typical Wabaunsee type cyclothem. Where fully developed, the Wabaunsee cyclothem is essentially the same as the ideal cyclothem. It must be emphasized, however, that all members of a cyclothem are not necessarily present in any single locality. In fact the development of these individual units is very unequal from place to place. Some units may persist as a single thin bed for hundreds of miles, whereas others may be present only locally.

The following are members of a typical Wabaunsee type cyclothem according to Moore (1935, p. 25).

- .8-.9 Shale, mostly unfossiliferous, marine of nonmarine.
- .7 Limestone, light-gray, algal, in many cases sandy to conglomeratic, or coquina, locally oolitic, laminated to flaggy, may contain numerous mollusks, brachiopods and bryozoans or relatively unfossiliferous, marine.
- .6 Shale, commonly somewhat sandy, marine.
- .5 Limestone, blue to gray, weathers brown, granular to dense, massive, contains more or less abundant fusulinids with or without a varied assemblage of brachiopods, bryozoans, crinoid remains, and less commonly other fossils, marine.
- .4 Shale, clayey, in many cases with rich mollusoid fauna, marine.
- .3 Limestone, blue-gray, dense to shelly, contains numerous mollusks, especially pelecypods and some brachiopods, crinoid remains, etc., marine.
- .2 Shale, clayey, commonly contains Myalina and other pelecypods, Derbyia, Chonetes, Linoproductus and bryozoans, marine.

- .1 c. Coal, continental.
- ab. Shale, sandy to clayey, top few inches in some cases constitutes underclay of the coal, may contain plant fossils, continental
- .0 Sandstone, shaly to massive, may contain fragments of plants, continental.

Figure 3 is a composite of the maximum development of the cyclothem of the Bern and adjacent formations in the area of this report. The development of the individual units within these cyclothem will be discussed under Detailed Stratigraphy.

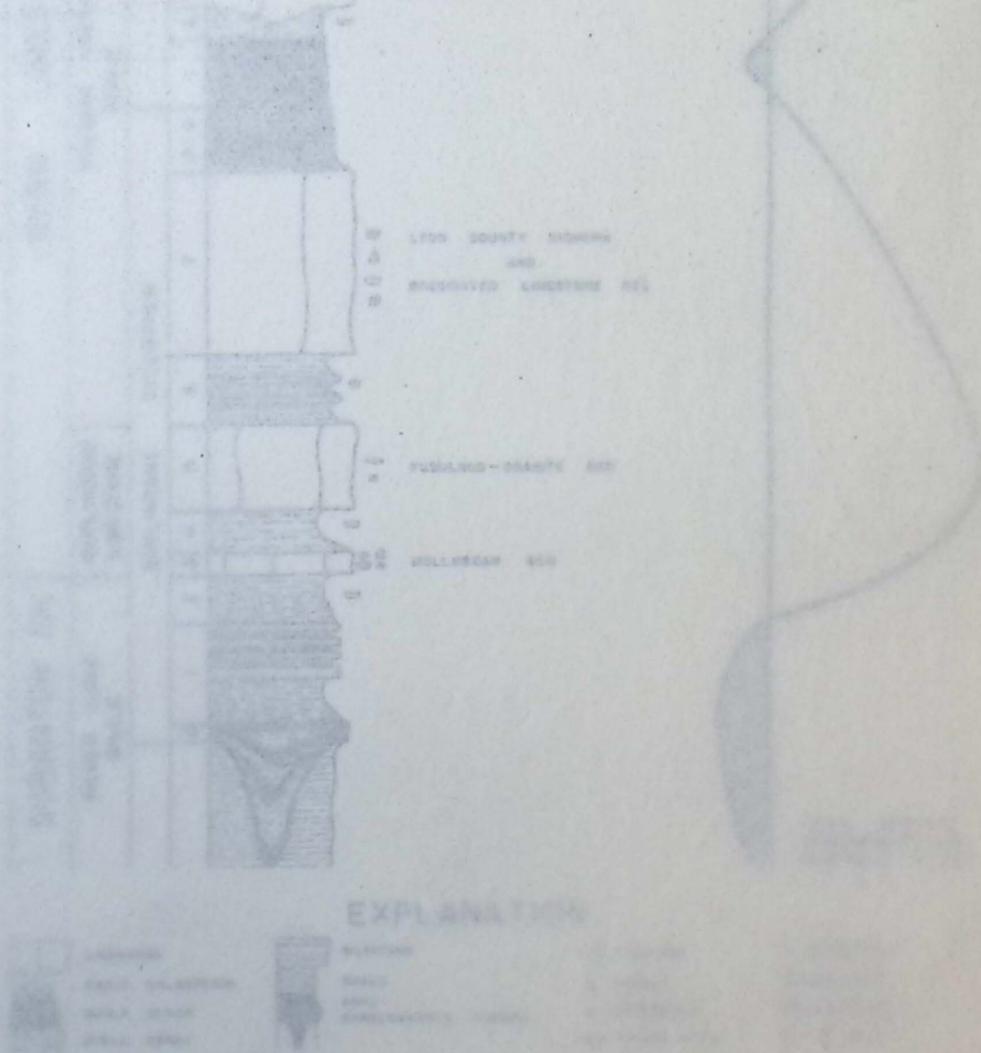


FIGURE 3—GENERALIZED STRATIGRAPHY

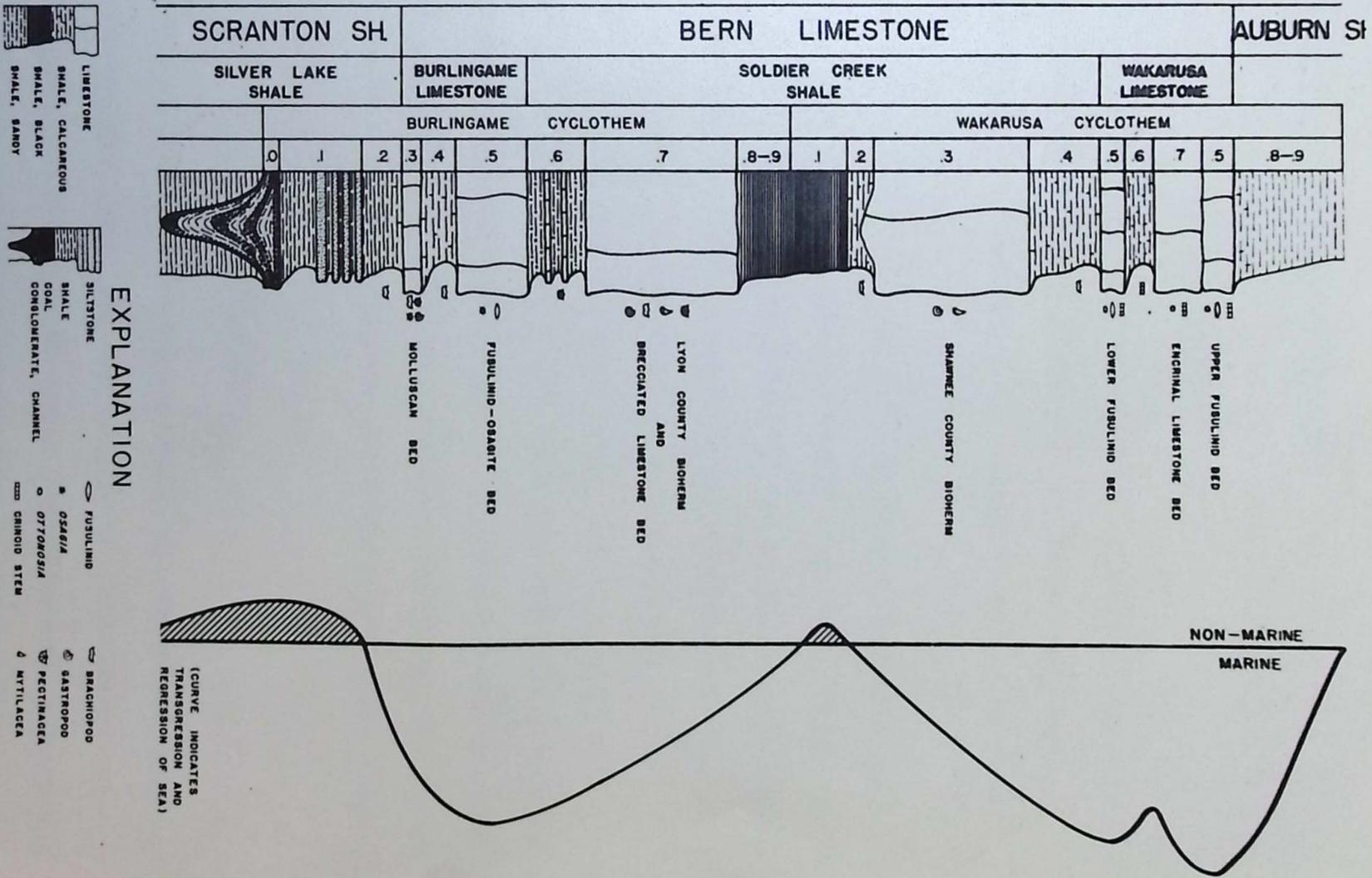


FIGURE 3—GENERALIZED CYCLOTHEM DIAGRAM

DETAILED STRATIGRAPHY

Introduction

The lithology, thickness, distribution, insoluble residues, paleontology, position within cyclothem, and sedimentary environment of each bed are discussed here. Emphasis is placed on the limestones.

For a particular locality or the distribution and thickness of certain beds, the reader is referred to the correlation chart of the measured stratigraphic sections (Plate 1) and to the location map (Fig. 1). For more detailed information on lithology, thickness, or fauna reference is made to the detailed measured stratigraphic sections (Appendix A). Information on insoluble residues is in Appendix B and C. The results of the insoluble residue analysis is arranged in these appendixes according to individual beds. For the position of a specific bed within a particular cyclothem, the reader is referred to the composite diagram of all the cyclic units (Fig. 3).

Rule Limestone

Although not the subject of this report, the Rule Limestone member of the Scranton Shale was measured at two localities. At Locality G the Rule is a single limestone bed eight inches thick that is bluish gray, dense, argillaceous, and has an abrupt upper and transitional lower contact. It contains a few crinoid stems and small gastropods.

At Locality R the Rulo thickens to one and a half feet and is yellow, dense, and argillaceous with sharp and flat contacts. This limestone is more fossiliferous at this locality. It contains crinoid stems, brachiopods, pelecypods, fenestrate and ramose bryozoans, small gastropods, and a few rare fusulinids (Fig. 4).

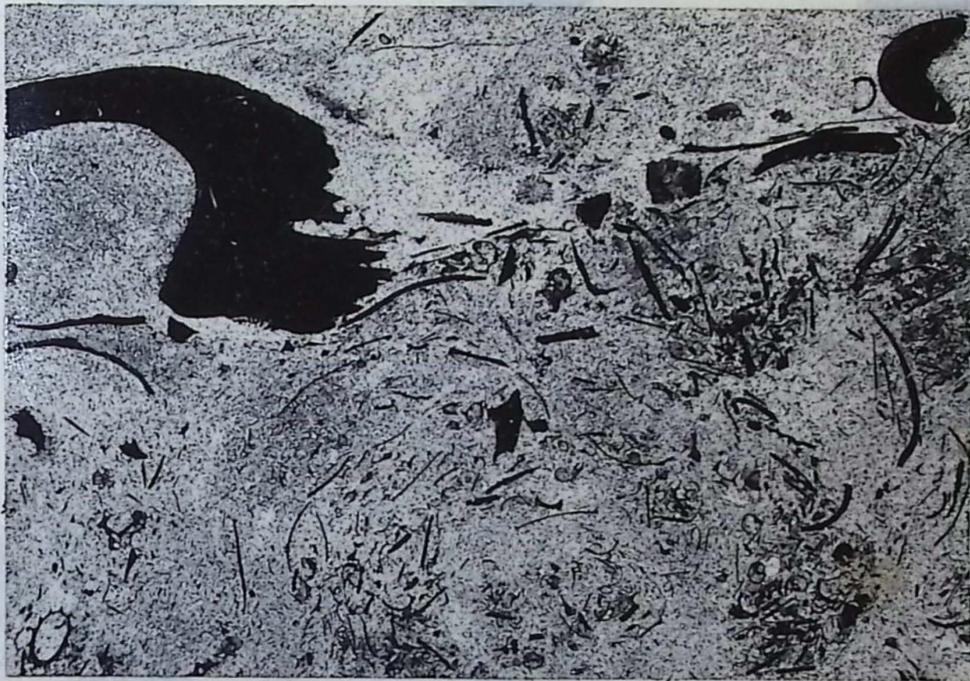


FIG. 4. Vertical peel print of Rulo Limestone. Note fine grained texture. (Loc. R). (X4).

Silver Lake Shale

The Silver Lake Shale includes the group of beds, mostly shale, between the Rulo and Burlingame Limestones. Three complete and several partial stratigraphic sections of this unit were measured in order to determine the general stratigraphic relationships of this member in the area of this report. Figure 5 graphically depicts these sections.

At the type locality of the Silver Lake a thin bed of olive gray, calcareous, marine shale overlies the Rulo Limestone. This shale is

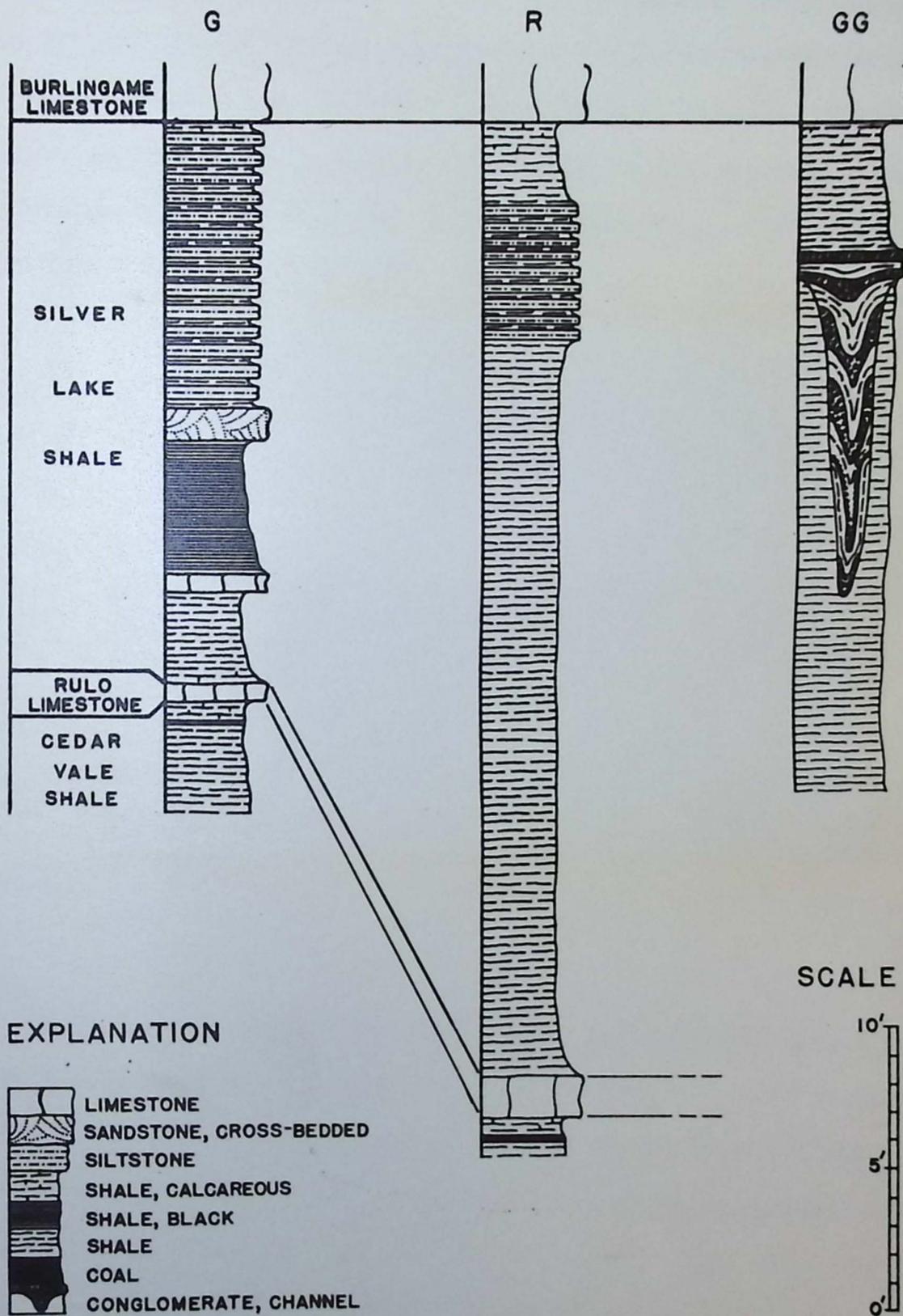


FIGURE 5 - SCRANTON SHALE MEASURED SECTIONS

overlain by a thin bluish gray, dense, argillaceous limestone bed that is sparsely fossiliferous, containing a few crinoid stems, brachiopods and small gastropods (Fig. 6). Above this limestone is a black, fissile shale containing kidney-shaped concretions of clay and a few rounded sandstone cobbles. The above units are presumably marine and represent the terminal stages of the Rulo Cyclothem.



FIG. 6. Vertical peel print of argillaceous limestone in lower part Silver Lake Shale. Loc. G. (X_h).

Resting on the black shale with apparent unconformity is a one foot bed of cross-bedded, micaceous, medium-grained quartz sandstone (Fig. 7). It represents the basal unit of the Burlingame Cyclothem (.0). Overlying the sandstone are ten feet of calcareous, argillaceous, unfossiliferous siltstone that is interbedded with shale (Fig. 8). This siltstone and shale is probably the most persistent unit within the Silver Lake, being present throughout Shawnee and almost all of Osage County. It is somewhat resistant to erosion, often forming low hills

or an escarpment immediately east of the Burlingame escarpment. This siltstone and shale unit is probably non-marine and represents phase .1 of the Burlingame Cyclothem. The coal bed that should be present in phase .1 was not observed in the area studied. However, O'Connor and others (1955, p. 12) report a thin coal bed in the Silver Lake in Osage County. In some places, such as the type locality, the Burlingame Limestone rests directly on this siltstone unit (Fig. 9). In other places a shale separates the two, as at Locality H. This shale consists of alternating, very thin layers of black and gray (Fig. 10) or olive green shale, containing clams. It represents the transgressive marine shale unit (.2) of the Burlingame Cyclothem.



FIG. 7. Cross-bedded sandstone of Silver Lake Shale. Loc. G.

FIG. 9. Siltstone unit of Silver Lake Shale overlain directly by Burlingame Limestone. Loc. H.



FIG. 8. Vertical peel print of siltstone at top Silver Lake Shale. Note fine-grained texture and cross laminations. Loc. G. (X1)



FIG. 9. Siltstone unit of Silver Lake Shale overlain directly by Burlingame Limestone. Loc. H.



FIG. 10. Uppermost shale unit of Silver Lake member. Note very thin laminations. Loc. H.

South of Kansas River in Shawnee County and in Osage County, the Silver Lake contains proportionally more shale. The limestone, black shale, and cross-bedded sandstone of the middle part of the member are usually absent in this area. At Locality R (Fig. 3) for example, 26 feet of shale separate the Rulo Limestone from the persistent siltstone beds. The siltstone zone is thinner here than at the type locality and is overlain by the uppermost shale unit of the Silver Lake.

Farther south, in Lyon County, the persistent siltstone zone is not present. Here the Silver Lake consists entirely of gray and black shale. Channel-fill deposits occur locally in the upper part of the shale in this area.

At Locality GG for example (Fig. 3), a small channel conglomerate

occurs in the upper part of the Silver Lake (Fig. 11). Its maximum thickness is 12 feet. The conglomerate itself is composed of sub-rounded shale and limestone pebbles of varying sizes (Fig. 12). This deposit almost certainly represents filling in of a former stream channel cut into the Silver Lake Shale during emergence. Pebbles of shale or mudstone existing in this conglomerate imply a very short distance of transportation. The fact that the pebbles closely resemble the shale in which the channel is cut, indicates that they were derived from the immediate vicinity of the channel. The existence of a conglomerate of this type in what closely resembles a cross section of a stream channel almost certainly proves that emergence and sub-aerial erosion occurred during the time that part of the Silver Lake was deposited. Unit .0 of the Burlingame Cyclothem is therefore represented by this channel.



FIG. 11. Stream channel deposit in upper part of Silver Lake Shale. Uppermost exposed strata is basal Burlingame. Loc. GG.



FIG. 12. Vertical peel print of channel conglomerate in Silver Lake Shale. Loc. GG. (X₄).

Another conglomerate is present south of the previously mentioned occurrence, near the town of Neosho Rapids in and near the channel of the Neosho River. It is a cross-bedded limestone conglomerate that is as much as 20 feet thick where it was measured in the NE $\frac{1}{4}$, Sec. 30, T. 19 S., R. 13 E., in a railroad cut (Fig. 13). Beds as low as the White Cloud Shale, the lowest member of the Scranton Shale are cut down into by this conglomerate. It was first recognized by Smith (1903, p. 99) who named it the Neosho Limestone from exposures along the Neosho River near Neosho Rapids. If this conglomerate, like the one previously discussed, also is a stream channel deposit, then it must have been a much larger stream. Besides having a greater thickness, the Neosho conglomerate is much more extensive than the small channel conglomerate.

There are numerous exposures along the Neosho River and for several miles northeast and southwest of Neosho Rapids. O'Connor and others (1953) discuss this deposit. They state that this conglomerate is the deposit of a former stream channel but are uncertain whether it is of Silver Lake or Cedar Vale age. A conglomerate is observed in this region in the lower part of the Silver Lake. However, it cannot definitely be traced into the Neosho Limestone. The author feels that since there are channel-filling conglomerates in this region in the Silver Lake, that it would be reasonable to correlate the Neosho Limestone channel with them. The Neosho Limestone would then represent the basal unit, .Q, of the Burlingame Cyclothem.

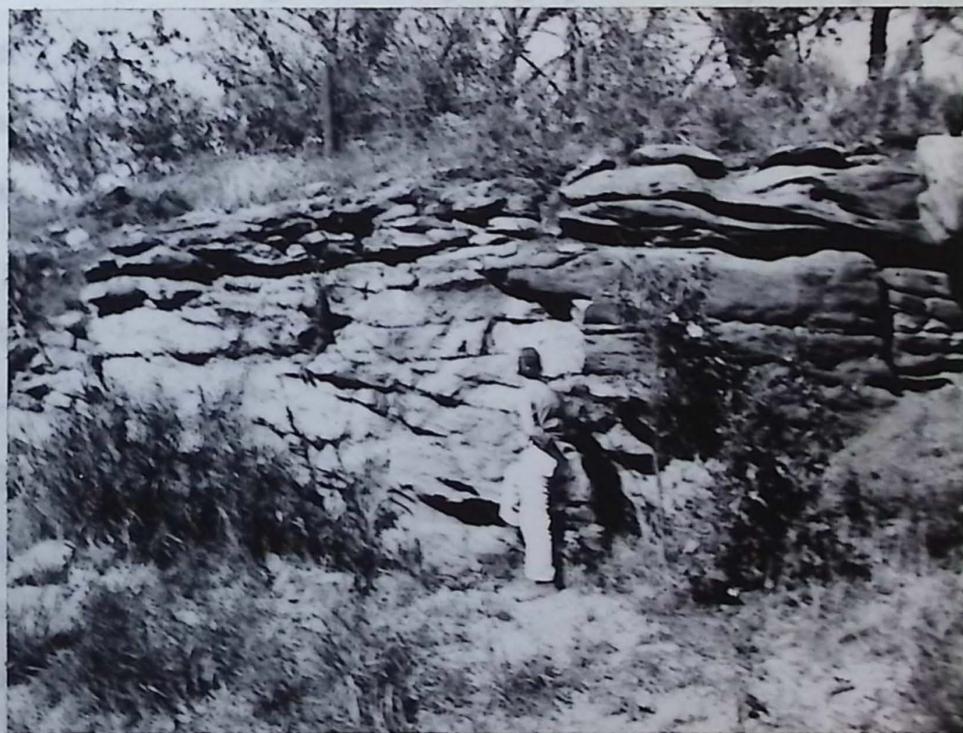


FIG. 13. Channel conglomerate of probable Silver Lake age near Neosho Rapids. Note cross-bedding to left of person.

The Silver Lake Shale, as a whole, thickens southward. It is just over 19 feet thick at the type locality in northern Shawnee County.

It thickens to slightly more than 33 feet near the Shawnee-Osage County Line at Locality R. O'Connor and others (1955, p. 112) report an average thickness of 35 feet in Osage County. The Silver Lake is as much as 40 feet thick in Lyon County (O'Connor and others, 1953, p. 20).

Burlingame Limestone

Molluscan Bed: A slightly argillaceous limestone characterized by the presence of mollusks occurs at the base of the Burlingame member. It is present at only a few localities and is quite variable in fauna and general lithologic features.

This limestone is argillaceous, highly detrital, and generally has an uneven contact that is transitional with the shale below and an abrupt upper contact.

The fauna is variable, but mollusks dominate. Pelecypods, especially Aviculopecten, are very abundant. Gastropods are very small, abundant, and varied. Brachiopods are almost as abundant as pelecypods. The productids are by far the most common group. Among the brachiopods, Derbyia, Chonetes, Marginifera, and Dictyoclostus were identified. The algae Osagia is present in abundance in all exposures of this bed along with arenaceous foraminifera. Remaining fossils, none of which are very numerous, include crinoid stems, and fenestrate and ramose bryozoans. Much broken fossil debris is present. The larger shell fragments are aligned parallel to the bedding but minute fossil debris is randomly oriented.

The insoluble residues of the molluscan limestone are quite variable in type. The total residue is normally about 10 percent by

weight. The coarse fraction is rather high, averaging about 20 percent, but it is quite variable in amount. Different percentages of subangular to rounded quartz sand are present in all samples.

Arenaceous foraminifera, present throughout, constitute from 20 to 50 percent of the coarse residue. Other constituents are different from place to place.

Considerable local variation, more so than in most other units of the Bern formation, occurs within the molluscan bed. For this reason, the molluscan limestone will be discussed in three different areas.

North of Kansas River the molluscan bed unit is present at Localities A, D, and G. It may also be present at Localities B and C where the base of the Burlingame is not exposed. The fauna at these exposures is dominated by various gastropods and the algae Osagia (Fig. 14). Pelecypods are less abundant here than to the south. At Locality A and D the bed is about six inches thick. It reaches its maximum thickness at Locality G. Here the unit consists of two limestone beds, each about a foot in thickness, separated by shale. The lower limestone bed at this outcrop grades laterally into shale, indicating its purely local nature.

Just south of Kansas River at Locality J and K, the molluscan bed is considerably different. Here the limestone is conglomeratic, especially at Locality J (Fig. 15). This conglomerate is composed of unsorted, subrounded limestone fragments in an algal matrix. The thickness is about a foot at both exposures. The clam Aviculopecten and the algae Osagia are especially abundant in this particular bed (Fig. 16).



FIG. 14. Vertical peel print of molluscan bed north of Kansas River. Note gastropods and algae (Osagia). Loc. D. (X4).



FIG. 15. Vertical peel print of limestone conglomerate from molluscan bed south of Kansas River. Note limestone fragments and algal matrix. Loc. J. (X4).



FIG. 16. Vertical peel print of molluscan bed south of Kansas River. Note numerous shells of Aviculopecten and encrustations of algae Osgia around small fragments. Loc. H. (X4).

The only other exposure of the molluscan bed observed is at Locality GG in Lyon County. Here it is a thin bed of limestone only three inches thick with the lower surface almost completely covered by clams and brachiopods. (Fig. 17). The following forms were identified: Aviculopecten; Chonetes; Marginifera; Derbyia crassa var. richmonda. Arenaceous foraminifera and algae are also very abundant (Fig. 18).

The molluscan limestone at the base of the Burlingame represents unit .3 of the Burlingame Cyclothen. It was the first limestone deposited by the very shallow transgressing sea. The discontinuous nature of this layer adds support to the postulated shallow-water environment. One would expect shallow-water deposits laid down near shore to be discontinuous and variable since this environment is more subject to

change than an open sea environment. The relative abundance of silt, sand, and conglomerate is another point in favor of such an environment. Coarse sediments such as these attest to the presence of currents of a locally strong nature. The abundance of fine-grained material and the abundance of arenaceous foraminifera also seem to be correlative. The abundance of pelecypods, gastropods, and algae provide the best evidence for a near-shore, shallow-water environment. Algae especially live in clear, shallow water because they need sunlight for growth. The absence of fusulinids, a far-from-shore form, adds weight to the suggested origin. It is interesting to note that corals, crinoids, and other attached organisms are either absent or very rare in this bed. The shelly bottom should have provided a good place of attachment for these forms. Because they were absent, the water must have been too shallow or too brackish or the currents too strong for them.



FIG. 17. Lower surface of molluscan bed in Lyon County. Loc. GG. (Fig. 17)



FIG. 18. Vertical peel print of molluscan bed in Lyon County. Note clam shells, algae, and extremely abundant arenaceous foraminifera in upper part. Loc. GG (X6).

Where present, the molluscan bed occurs at the base of the Burlingame Limestone and almost invariably rests on the first marine shale deposit of the transgressing sea (.2). It is overlain by varied units within the Burlingame cycle.

Fusulinid-Osagite Bed: The most persistent unit within the Burlingame member is a limestone bed characterized by the presence of very abundant fusulinids and the algae Osagia. It is present in almost every exposure south of Kansas River, and comprizes the entire thickness of the Burlingame at a large number of places.

This limestone is highly detrital and varies from argillaceous in the south to relatively pure in the north. Orientation of debris is almost completely random. In some places it is a single thin bed (Fig. 19)

and in others it is thin-bedded or even nodular (Fig. 20). Thickness varies from a minimum of only four inches at Locality K (Fig. 21) to a maximum of four feet nine inches at Locality HH (Fig. 22). At a few locations thin shale partings occur. In Shawnee County the color of this limestone is dark gray while in Osage and Lyon Counties, it is yellowish.



FIG. 19. Fusulinid-osagite bed overlain by black Soldier Creek Shale
Loc. L.



FIG. 20. Bern Limestone in southern area. Hammer head rests on top of thin molluscan bed. Nodular and massive limestone above is fusulinid-osagite bed. Thick limestone at top is Lyon County bioherm--part of Soldier Creek Shale. Loc. GG.



FIG. 21. Burlingame Limestone in northern area. M-molluscan bed; FO-fusulinid-osagite bed; B-brecciated limestone bed. Loc. K



FIG. 22. Bern Limestone in southern area. FO-massive fusulinid-osagite bed; SC-Soldier Creek Shale; W-Wakarusa Limestone. Loc. 111.

A rich and varied fauna is present in the fusulinid-osagite bed, but two forms stand out--fusulinids and Osagia. The fusulinids are quite distinctive in that they are all small and have an inflated fusiform shape. They can be easily distinguished in the field from the large elongate fusulinids of the upper part of the Wakarusa Limestone. These small fusulinids are probably Triticites cullomensis (Moore and others, 1944, p. 672-673). Moore describes Triticites cullomensis as being medium-sized and inflated fusiform in shape. At some localities fusulinids are numerous throughout this unit. More commonly, however, their abundance varies with a gradual increase toward the top of the unit. This is the relationship, for example, at the type locality of the Burlingame (Fig. 23 & 24). The alga Osagia, like the fusulinids, is also characteristic of this unit. In almost all cases Osagia is

most numerous at the base of the unit and rare or even absent at the top. Where present it encrusts many types of small debris. Encrustations of this organism are commonly found around elongate brachiopod and pelecypod fragments, small crinoid stems, small gastropods, arenaceous foraminifera, bryozoans, and fusulinids (Fig. 25). A complete gradation exists between what might be called the osagite bed (lower part of the unit) and the fusulinid bed (upper part of the unit). This transition zone occupies a greater volume of the unit than does the fusulinid zone at the top and the osagite zone at the bottom combined. For this reason the bed is referred to as the fusulinid-osagite bed. The intimate association of these organisms in the middle part of the unit is shown in Fig. 25. Both ramose and fenestrate bryozoans ^{are} plentiful in this bed, but ramose are by far the most numerous (Fig. 26). Crinoid stems of a generally small size are abundant. Small gastropods are present in nearly all exposures (Fig. 27). Arenaceous foraminifera are more profuse in this unit, on the whole, than any other. Brachiopods are numerous and varied. Neospirifer is especially plentiful. Composita and Dictyoclostus are very common. Rare genera of brachiopods in this unit include Derbyia and Chonetes. Pelecypods are not commonly present. Aviculopecten was observed at one exposure. Other fossils present in small numbers at a few localities include trilobites and horn corals.

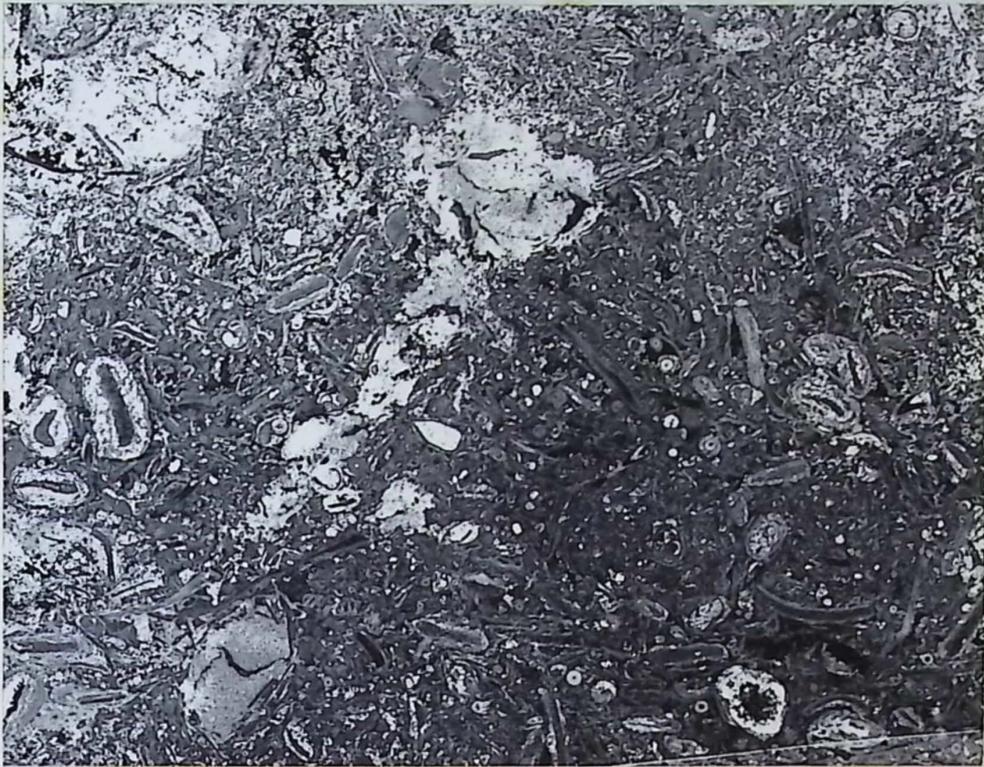


FIG. 23. Vertical peel print of lower part of fusulinid-osagite bed. Note abundant Osagia encrustations. Loc. X. (X₄).



FIG. 24. Vertical peel print of upper part of fusulinid-osagite bed. Note abundant small fusulinids. Loc. X. (X₄).

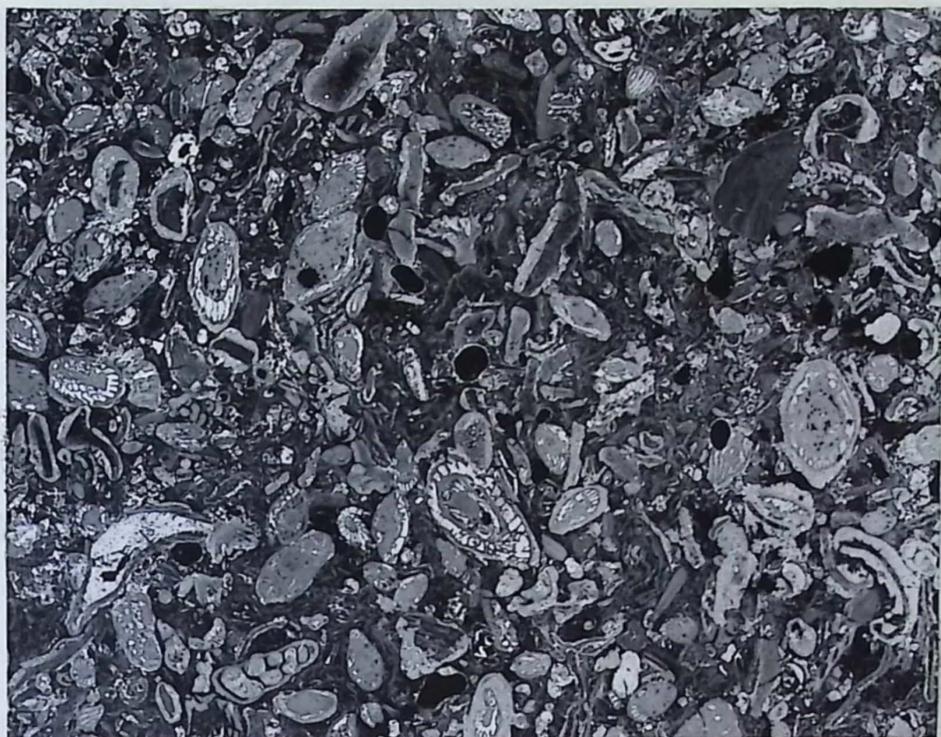


FIG. 25. Vertical peel print of transition zone in fusulinid-osagite bed. Note extremely numerous Osagia encrustations. Loc. HH. (X₁).

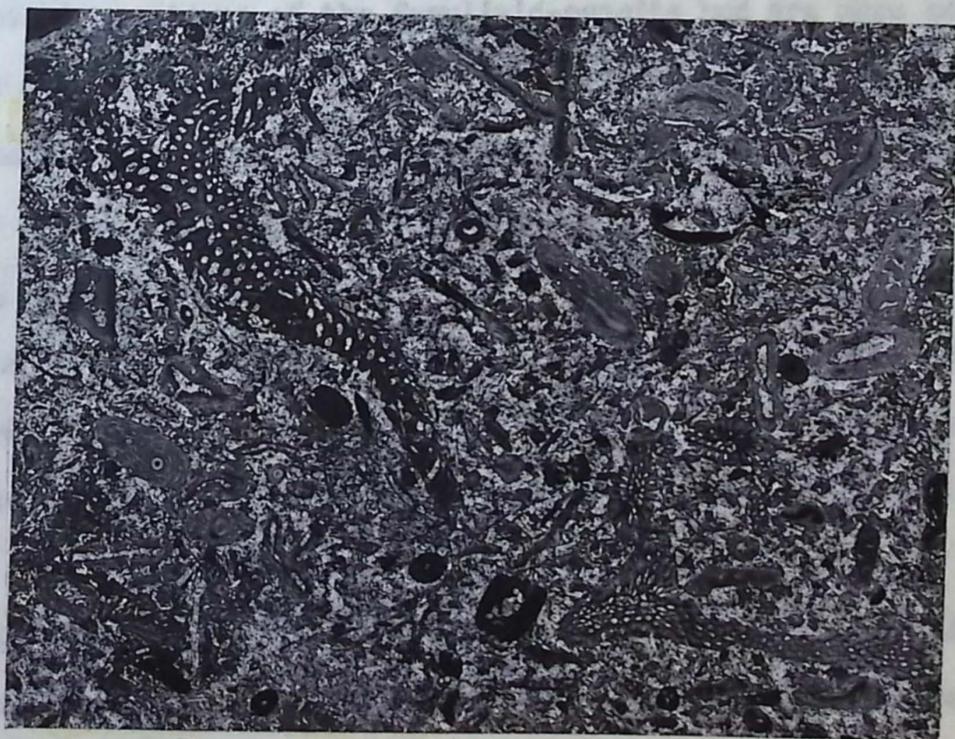


FIG. 26. Vertical peel print of fusulinid-osagite bed containing numerous bryozoans. Loc. JJ. (X₁).



FIG. 27. Vertical peel print of fusulinid-osagite bed containing numerous gastropods and Osagia encrustations. Loc. II. (Xh).

Insoluble residues of the fusulinid-osagite bed are more consistently uniform than those of the molluscan bed. Samples were analyzed from both the lower and upper part of the bed. Residues from the lower part average 12 percent of the sample, the coarse fraction averaging 8 percent. Arenaceous foraminifera are exceeding abundant, being generally between 70 and 90 percent. Silt and clay increases in percentage to the south where the unit becomes more argillaceous. Small percentages of carbonaceous material are generally present. Residues from the upper part are more consistent than the lower part. The total residue averages 11 percent, whereas the coarse fraction is quite consistently between 2 and 5 percent. Silt and clay aggregate is the most abundant residue, generally being near 60 percent. Arenaceous foraminifera are less abundant than in the lower part.

However, they were present in all samples at an average abundance of 40 percent.

The lateral distribution of the fusulinid-osagite bed is very extensive. It first appears as a very thin unit less than a foot thick at Localities J and K immediately south of Kansas River (Fig. 21). From this area south it is present in every exposure except at Locality BB. Normally, the thickness is about three feet. There is very little lateral variation. In the vicinity of the Shawnee County bioherm in the Soldier Creek Shale, this unit becomes dark gray. Southward in Osage and Lyon Counties it becomes progressively more argillaceous.

The fusulinid-osagite bed represents unit .5 of the Burlingame Cyclothem. It marks the maximum transgression of the sea at the peak of the cycle. Fusulinids are the characteristic fossil of this phase, and are commonly thought of as a fairly deep-water organism. Elias (1937, p. 432) concluded that fusulinids lived in 160 to 180 feet of water. However, Moore (1929, p. 467) points out that fusulinids indicate only a very quiet environment in which the bottom on which they lived was not agitated by strong wave action. It is true that deep water would produce such quiet, unagitated conditions. However, broad stretches of shallow water may have less agitation of the bottom than fairly deep water with large waves, provided the waves in the shallow water are small, as is generally the case. It would therefore, be better to say that fusulinids represent a quiet bottom environment which may occur in either shallow or deep water. The fusulinid-bearing limestones do, in general, represent a farther-from-shore environment than algal-molluscan limestones. Algae are not generally present in the .5 portion of the typical Wabaunsee cyclothem. The

Burlingame cycle does not seem to fit the general pattern in this respect, at least not in the area studied, because algae are abundant in the .5 unit. The fusulinid-osagite bed must represent the maximum transgression because of the profuse fusulinids present over such a wide area. Presence of copious algae indicate that this particular limestone was not deposited in as great a depth of water as other fusulinid beds without algae, since algae need water clear and shallow enough for sunlight penetration. The zone of near-shore algal life and the zone of far-from-shore fusulinid life must have overlapped somewhat. It probably was within this zone of overlap that the fusulinid-osagite limestone was deposited. The fact that the abundance of algae decreases consistently upward in this unit combined with the progressive increase in numbers of fusulinids upward indicates rather certainly that the water must have become progressively deeper during the deposition of this bed. The very fact that the bed is exposed in every outcrop but one from Locality J south attests to uniform conditions during deposition, such as should be expected in an open sea away from shore. Absence of coarse detritus and a smaller proportion of sand-sized material than in the molluscan bed indicates that deposition occurred farther away from shore and associated currents. There could not have been a great amount of agitation of the water near the bottom, or the bryozoans, crinoids, and other attached forms of life could not have survived in such large numbers. The fossil debris on the bottom must have provided a good base of attachment for these organisms.

Throughout the largest part of the area studied, the fusulinid-osagite bed makes up the total thickness of the Burlingame member. At

a few localities it overlies the transgressive molluscan bed (.3). Generally it overlies the uppermost marine shale of the Silver Lake (.2). It is overlain by the regressive limestone on the cyclothem where both are present.

Brecciated Limestone Bed: A thick, mottled, brecciated limestone that is almost unfossiliferous occurs widely in the northern part of Shawnee County in the upper part of the Burlingame member.

This limestone is composed of irregular-shaped, elongate fragments of lithographic limestone in a very fine, argillaceous matrix. Small-scale conchoidal fracture occurs when the fragments are broken. The fresh surface of this limestone has a mottled appearance (Fig. 28). A very rough surface develops upon weathering because of the greater resistance of the fragments (Fig. 29). The edges of the limestone fragments, especially the lower, are covered by a thin layer of darker colored, calcareous material of uncertain origin (Fig. 30). In nearly all cases the more convex side of the fragments is the lower one, an anomalous situation (Fig. 31). In some cases thin lenses or layers of very dense limestone without brecciated structure are interbedded with the brecciated limestone. More commonly however, there is an alternation of layers of fragments and layers of argillaceous matrix (Fig. 30). The limestone is typically thick and unevenly bedded (Fig. 32). The lowermost foot or more of this unit does not have the brecciated structure nearly as well developed as the upper part. Long linear fragments such like the darker layers that encrust the fragments in the upper part do occur in this lower part, but a lithographic texture is more common (Fig. 33).



FIG. 28. Fresh surface of brecciated limestone bed. Note mottled appearance.



FIG. 29. Brecciated limestone bed outcrop. Note characteristic rough weathering caused by more resistant fragments. Near Loc. I.

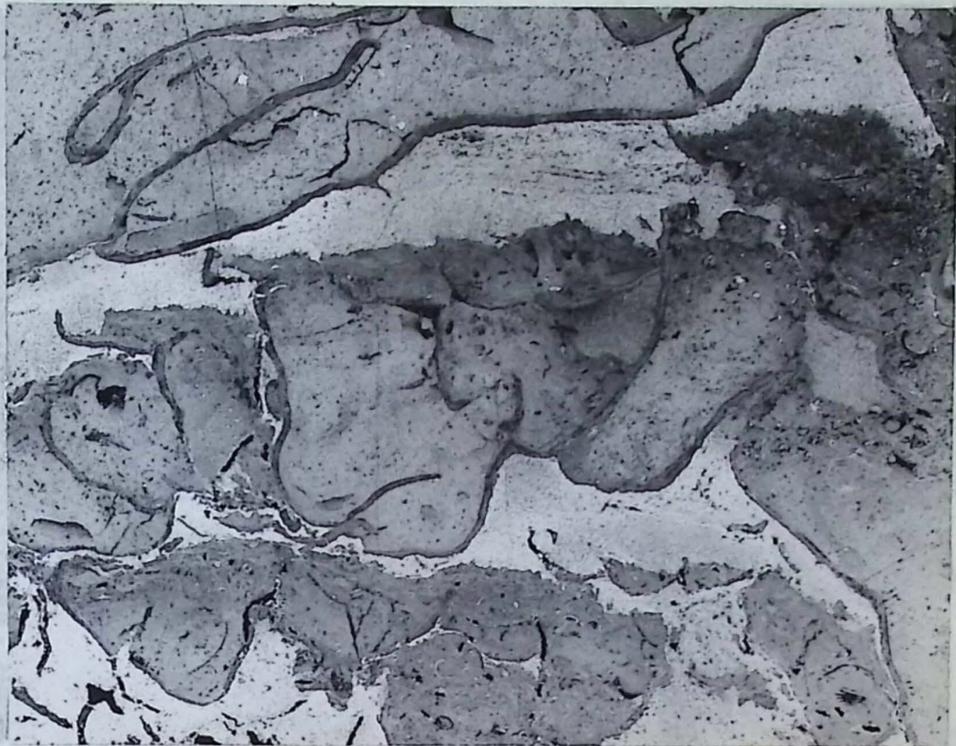


FIG. 30. Vertical peel print of brecciated limestone bed showing encrustations around fragments and argillaceous matrix between layers. Loc. B. (X2).



FIG. 31. Vertical peel print of brecciated limestone bed showing convex lower surface of fragments. Loc. H. (X4).

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FIG. 32. Brecciated limestone bed showing thick and uneven bedding. Loc. A.



FIG. 33. Vertical peel print of lower lithographic part of brecciated limestone bed. Loc. C. (X₁).

The brecciated limestone is almost unfossiliferous. Nearly all the fossils occur in the lowermost one or two feet. The following fossils were observed, all rarely: brachiopods; pelecypods; small gastropods; crinoid stems; ramose bryozoans; horn corals; fusulinids; arenaceous foraminifera. Brachiopods and gastropods (Fig. 34) are the most numerous of the fossils. Neospirifer, Entelates, and Composita, all brachiopods, were identified. At Locality A the uppermost 10 inches of this unit is quite fossiliferous and not as brecciated as usual. Crinoid stems are especially abundant in this zone (Fig. 35).



FIG. 34. Vertical peel prints of brecciated limestone bed fossils.
 A.- Low-spired gastropod from Loc. A. (X10).
 B.- Composita and fusulinid from Loc. C. (X10).
 C.- High-spired gastropod from Loc. D. (X10).

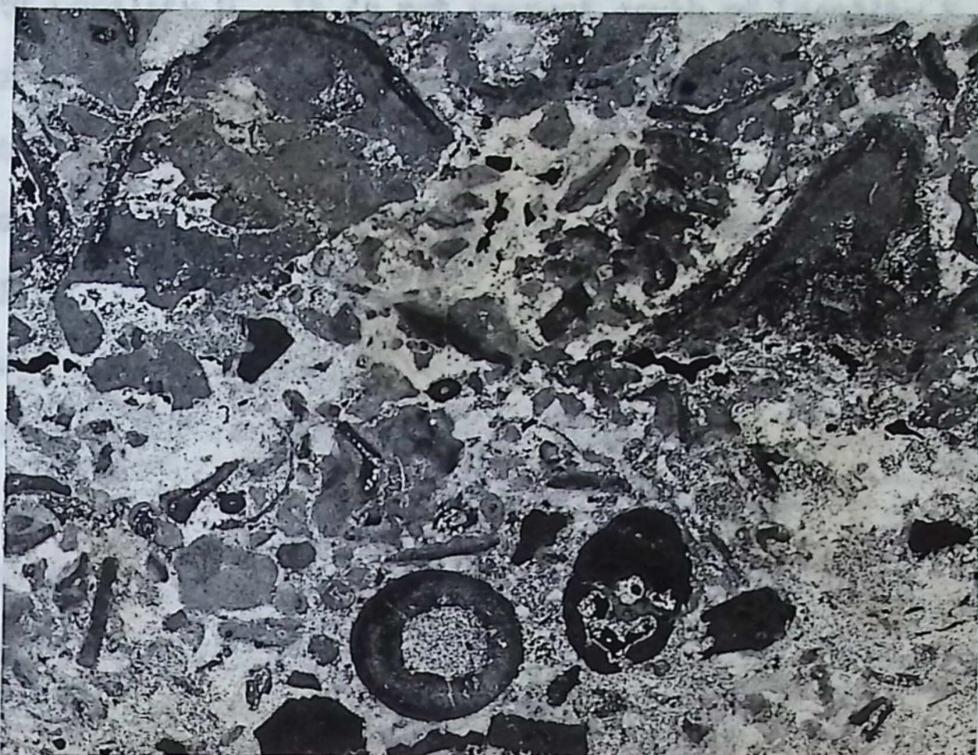


FIG. 35. Vertical peel print of fossiliferous limestone just above brecciated limestone bed. Note crinoid stems and fragments of limestone similar to brecciated limestone bed. Loc. A. (X₁).

The brecciated limestone has a very small and consistent insoluble residue. The total residue averages only a little over 2 percent and the coarse fraction averages only 3 percent. Clay and silt aggregate makes up from 70 to 90 percent of the coarse residue. Arenaceous foraminifera and carbonaceous material normally make up the remainder. The small, very fine grained residue serves to emphasize the purity of the lithographic limestone fragments and the argillaceous nature of the matrix.

Considerable variation in thickness of the brecciated limestone occurs. It ranges from a minimum of seven inches at Locality J to a maximum of about ten feet at Locality A (Fig. 32). This unit is present only in northern Shawnee County at Localities A to K with the

exception of Locality G. It is not present south of Locality K. This bed does extend northward well into Jackson County. Walters (1953, p. 42) describes the Burlingame of Jackson County as having an unusual mottled and brecciated appearance, being composed of light brown limestone fragments in a rusty brown matrix. The extent to the east of this bed is not known since erosion has removed it. The westernmost exposure of the Burlingame north of Kansas River, Locality G, does not contain this unit. Therefore, it may pinch out in this direction also.

This thick brecciated limestone represents unit .7, the regressive algal-molluscan phase of the Burlingame Cyclothen, according to Moore (1935, p. 217). The origin of this peculiar type of sediment is very uncertain. There seems to be four possibilities.

(1) It may be a true detrital breccia in which the limestone fragments were eroded, carried into the sea, and deposited along with the argillaceous material that forms the matrix. The absence of coarse clastic material in the residue is seemingly against this hypothesis. The fact that this is a single localized deposit is in favor of the theory since such deposition could have occurred in a local basin and not elsewhere.

(2) The mottled or brecciated structure may be secondary. A homogenous lime mud may have been first deposited. After burial the material may have begun to crystallize, gradually isolating some portions as large pseudobreccia fragments. Cayeux (1935, p. 271) discusses an origin such as this for mottled limestones. He declares that mottled limestone of secondary origin is always poor in insoluble residue, rarely contains organic remains, and usually forms in rock with

cryptocrystalline texture. The limestone under discussion has these characteristics. The secondary crystallization could have destroyed most of the fossil material, accounting for their rareness.

(3) The brecciated appearance could be due to waves and/or currents breaking up the lime mud deposits on the bottom and depositing the silt and clay matrix around the fragments. This process would have had to be repeated several times in order to produce several feet of roughly laminated, brecciated limestone. The imperfect layering of fragments and matrix as in Fig. 30 would be explained by this origin.

(4) The brecciated nature of this limestone could be due to some kind of algal structure. This would explain the dark-colored encrustations around the outside of the limestone fragments as algal material. These encrustations sometimes occur by themselves with the accumulation of silt upon their upper surface (Fig. 36). They could therefore be the remains of algal growth. Since this unit is the .7 phase of the cycle which, according to Moore (1950, p. 9), contains abundant remains of various sorts of algae, an algal origin may be the best explanation.

The brecciated limestone, where present, always forms the top of the Burlingame Limestone. It rests in some places on the fusulinid-osagite bed (.5) and in other places on marine shale (.2 or .4). Another development of the .7 bed of the Burlingame Cyclothem besides the brecciated bed occurs locally in Osage County. At Localities AA and BB a thick algal-molluscan limestone is present (Fig. 37). This was the only other development of the .7 bed that was observed. At Locality AA it overlies the fusulinid-osagite bed, and at Locality BB it forms the entire thickness of the Burlingame member.

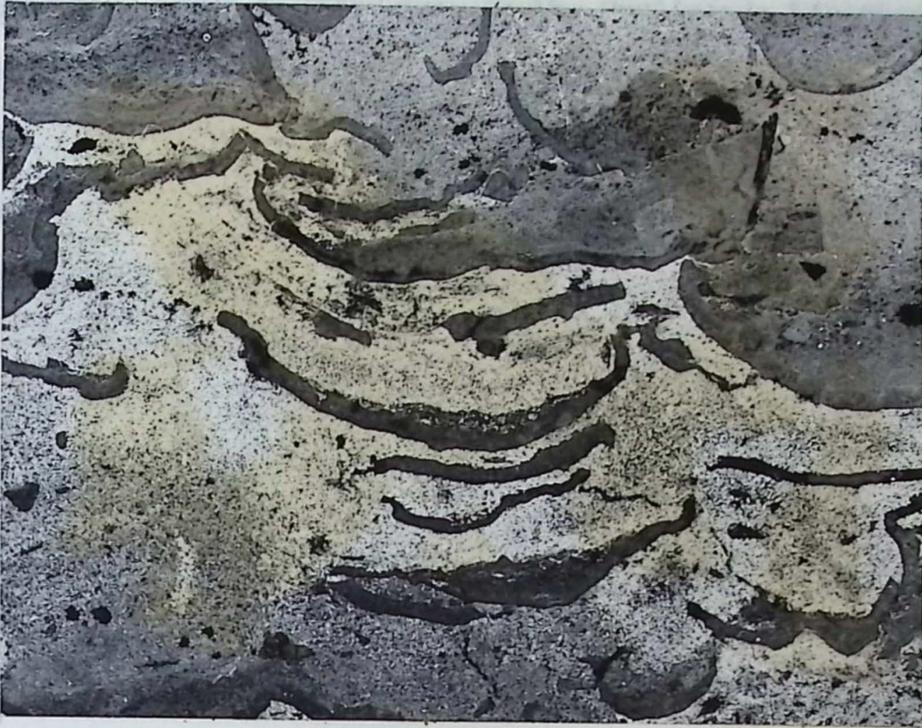


FIG. 36. Vertical peel print of brecciated limestone bed showing algal (?) encrustations with silt accumulation on top. Loc. D. (X4).



FIG. 37. Vertical peel print of algal-molluscan limestone bed. Note abundant pelecypods and gastropods. Loc. AA. (X4).

Shale Beds: Shale is very rare in the Burlingame Limestone. Two general types of shale beds are present, however: (1) Shale beds that separate different limestone units in the Burlingame Cyclothem from each other; (2) Shale partings within these limestone units. The latter type is more common than the former.

Unit .4 of the Burlingame Cyclothem is present at only three localities--A, D, and K. It is a gray, calcareous, marine shale that separates the transgressive molluscan bed below (.3) from later beds in the cycle. At Locality K it is overlain by the fusulinid-osagite bed (.5) while at Locality A and D it is overlain by the brecciated limestone (.7). Small brachiopods are found within this shale unit.

Unit .6 of the Burlingame Cyclothem, the marine shale that should separate units .5 and .7 does not seem to be present in the Burlingame Limestone of the area studied.

Calcareous, marine shale partings are present locally within all limestone units of the cyclothem. None of these exceed eight inches in thickness in the area studied. Since these shale partings are so discontinuous, they probably represent local deposition of argillaceous material for only a short interval of time.

Soldier Creek Shale

The Soldier Creek Shale is, as the name implies, composed mostly of shale. However, it is a complex stratigraphic unit containing some limestone, coal, and several different kinds of argillaceous rocks. In the area covered by this report it also contains two small but very important reefs. The word reef and associated terms have been defined

in many different ways by numerous authors. To avoid confusion, these terms are defined below as they are used in this report.

Reef: a rock structure, either moundlike or layered, built by sedentary organisms and usually enclosed in a rock of differing lithology.

Biostrone: a layered reef in which the layers are no greater in vertical dimension than the contemporaneously-deposited, surrounding sediments.

Bioherm: a moundlike reef in which the vertical dimension is greater than that of the contemporaneously-deposited, surrounding sediments.

As can be seen by reference to Plate 1 and Plate 2, both of the reef deposits discussed are moundlike bodies completely enclosed in shale. Therefore, they are bioherms. The southernmost of these reefs will be called the Lyon County bioherm and the northernmost, the Shawnee County bioherm. During the following discussion the reader should refer to Plate 2 for the measured stratigraphic sections of the Shawnee County bioherm and to Plate 1 for measured stratigraphic sections for the remainder of the area, including the Lyon County bioherm.

The Soldier Creek Shale will be discussed by dividing it into three geographic areas from south to north.

Southern Area: The Southern Area includes the Soldier Creek Shale exposed at Localities EE through LL. It includes almost all of the exposures in Lyon County. All of these sections are shown on Plate 1. The Soldier Creek of this area contains non-marine shale, marine shale, coal, and the Lyon County bioherm.

The Lyon County bioherm is located in east central Lyon County northeast and southwest of the town of Reading. It is exposed at Localities EE, FF, and GG.

In all cases this molluscan bioherm is a coquinoid limestone that is massive when fresh but weathers into relatively thin, flat beds. Since there are only three exposures of this bioherm, its size is difficult to determine. It extends for at least two miles in a northeast-southwest direction between Locality EE and GG. At Locality DD, one mile to the north of EE, it is apparently not present. At Locality HH, four miles southwest of GG, it is not present either. Therefore, the maximum extent in a northeast-southwest direction would be about seven and a half miles. Extent to the southeast could not be determined because the bioherm has been removed by erosion. The northwest extent could not be ascertained because of cover by younger formations.

Four different areas are recognized in the vicinity of reefs. The back reef is the zone between the reef and the shoreline. It includes the area of lagoonal and continental deposits connecting the land with the reef. The reef refers to the bioherm itself. The fore reef is a zone of clastics derived from the reef on its seaward side. The reef complex is the aggregate of the former three facies. The basin refers to the normal marine deposits seaward of the reef and the fore reef. The basin deposits are often referred to as deep-water deposits. The author does not feel that this is a necessary requirement of basin deposits however.

The Lyon County bioherm apparently is a local development of the regressive molluscan phase of the Burlingame Cyclothem. If this is the correct interpretation it would be a regressive bioherm. The main distinction between regressive bioherms (formed during regression or

shallowing of the sea) and transgressive bioherms (formed during transgression or deepening of the sea) is that regressive bioherms possess a typical back reef facies and transgressive bioherms do not. The Lyon County bioherm definitely contains a back reef facies along with a fore reef, reef, and basin facies. The molluscan coquina present at all three exposures makes up the reef facies. It comprizes the entire thickness at Locality EE, the lowermost and uppermost parts at Locality FF, and the upper part at Locality GG. The fore reef facies consists of the sandy zones composed mainly of reef detritus in the middle part at Locality FF and the lower part at Locality GG. For the most part these zones are composed of fine shell fragments, but complete shells of brachiopods and pelecypods are present (Fig. 39). At Locality FF the contact between the reef facies and the fore reef facies is abrupt (Fig. 40 & 41). At Locality GG this contact is gradational. A complete transition from very fine fossil debris and a large amount of sand at the base (Fig. 42-A) to medium sized fossil debris and less sand in the middle (Fig. 42-B) to true reef facies with no sand at the top (Fig. 42-C) exists. This reflects progressive lateral growth of the bioherm toward this locality. The basin facies consists of the non-marine shales and coal beds south and west of the bioherm. This back reef facies in the upper part of the Soldier Creek continues south to the extent of the area studied. These back reef continental deposits overlap the reef facies. At Locality EE for instance, the reef facies is overlain by two feet nine inches of black shale that becomes increasingly carbonaceous upward, terminating in a thin coal bed (Fig. 43).

According to the characteristics of regressive bioherms given by

Link (1950, p. 284), the Lyon County bioherm definitely is of the regressive type. The back reef, reef, fore reef and basin facies described by Link are very similar to the ones developed in this bioherm. Continental or possibly lagoonal shale and coal constitute the back reef facies which is the chief distinction between regressive and transgressive bioherms. Link also points out that the back reef and reef facies overlap the fore reef and basin facies during normal retreat of the sea. In Lyon County bioherm the back reef does overlap the reef and the reef does overlap the fore reef. The fact that this bioherm everywhere overlies marine deposits and is overlain by continental deposits is further proof that it is a regressive bioherm. Underlying marine deposits consist of sandy marine shale with thin limestone beds containing bryozoans and pelecypods. This marine shale extends both north and south from the bioherm in the lower part of the Soldier Creek. The continental shale above the bioherm extends both north and south, but the coal bed is not present north of the bioherm.

The fauna of the Lyon County bioherm is dominated by pelecypods but brachiopods and gastropods are abundant and bryozoans are common. A few very rare crinoid stems and fusulinids are present. Several hundred specimens of pelecypods and brachiopods were collected on large slabs of the reef material from the quarry at Locality EE (Fig. 44). The fossils are firmly imbedded in the limestone and do not weather out making identification difficult. It was almost impossible to examine internal features.



FIG. 38. Vertical peel print of reef facies of Lyon County bioherm. Loc. FF. (X₁).



FIG. 39. Vertical peel print of fore reef facies of Lyon County bioherm. Note whole shell of Derbyia crassa var. richmonda. Loc. FF. (X₁).



FIG. 40. Lyon County bichern. Hammer head is resting on abrupt contact between fore reef facies below and reef facies above. Loc. FF.



FIG. 41. Vertical peel print of abrupt reef-fore reef contact in Lyon County bichern. Reef facies below and fore reef facies above. Loc. FF. (X4).

C.



B.



A.

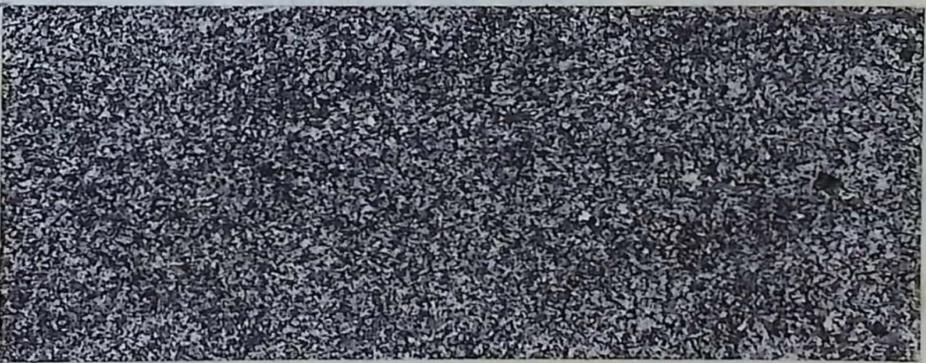


FIG. 42. Vertical peel print of transitional reef-fore reef contact in Lyon County bioherm. Note transition from very fine (A) to coarse (C). Loc. GG.
 C.- Reef facies (X₄).
 B.- Upper fore reef facies (X₄).
 A.- Lower fore reef facies (X₄).



FIG. 43. Contact of non-marine shale and coal with marine shale and limestone. SC-Soldier Creek Shale; C-Coal bed; W-Waharusa Limestone. Loc. EE.

Three suborders of pelecypods are present in this bioherm: Mytilacea, Pectinacea, and Cypricardiacea. The Mytilacea are the most abundant, the Pectinacea are next in abundance, and the Cypricardiacea are not nearly as abundant as the first two groups. The following genera and species of the Mytilacea were identified:

Promytilus priscus Newell
Septinyalina scitula Newell
Myalina (Orthomyalina) cf. sloconi Sayre.

The following genera of Pectinacea were identified:

Aviculopecten sp.
Fasciculiconcha sp.

Only one species of Cypricardiacea was identified:

Pleurophorus subcostatus Meek and Worthen.

Identification of the pelecypods was made using the excellent work of Newell on Late Paleozoic Mytilacea (1942) and Pectinacea (1937) and by comparison with holotypes and topoparatypes from the University of Kansas Museum of Paleontology. Dunbar and Condra (1932) was used for identification of brachiopods.



FIG. 44. Upper surface of reef limestone from Lyon County bicerna. Note abundance of clans. Loc. EE.

Only one species of brachiopod, Derbyia crassa var. richmonda, is present, but it is rather common (Fig. 39). Because of poor preservation of the gastropods, it was not possible to identify any of them. However, a large number of bellerophontid and spiral forms are present.

Fenestrate, ramose and encrusting types of bryozoans are present. They were not nearly as abundant as the mollusks and brachiopods, however.

The insoluble residues of the reef facies compose a small part of the limestone--about 2 percent. In the fore reef facies, on the other hand, the percent of residue is very high. It averages 30 percent. The coarse fraction is rather large, averaging about 45 percent in the reef facies and 66 percent in the fore reef facies. Rounded to angular quartz sand was present in all samples of this unit, averaging 73 percent. Muscovite, averaging 8 percent, and chert, averaging 4 percent, were also present in all samples.

In order to discuss the environment of deposition of this bioherm, something must be known of the environment under which the reef-forming organisms lived. Because almost all of the organisms found in this deposit are sessile forms, almost all of them must have had a part in the formation of the bioherm.

The mytiloid clams are all sedentary (Moore and others, 1952, p. 429). They lived in a shallow-water, near-shore environment and could tolerate relatively large variations of salinity (Newell, 1942, p. 14). Because these organisms are the most abundant in the bioherm, they probably played a major part in its formation.

The pectinoid clams lived in a near-shore, shallow-water environment also. They are commonly attached, at least in early life, and may remain sedentary or become free-moving in later life (Moore and others, 1952, p. 423). Newell (1937, p. 12 & 20) says that the Late Paleozoic pectinoid clams were active organisms that may or may not have been free-swimming. One of his evidences is that these clams are seldom covered

by encrusting organisms, even when they occur with other clams that are encrusted. In the Lyon County bioherm the pectinoid clams were commonly found encrusted by bryozoans. So, possibly these forms in this bioherm remained attached throughout their life.

The brachiopods and bryozoans are all attached organisms that prefer shallow water. According to Moore (1929, p. 469) the brachiopod Derbyia, found in such abundance in this reef, preferred a muddy environment. Its occurrence in this reef is therefore a seemingly anomalous situation. But, it was found that Derbyia definitely occurs in zones within the bioherm, being abundant in some layers and absent in others. Possibly the occurrence of this form coincided with times of muddy water in the area of the reef, and would, therefore, be found only in certain zones. Derbyia was also found commonly in the fore reef facies, a more muddy environment than the reef itself.

The gastropods, although probably not sessile forms, were, like all gastropods, sluggish, slow-moving creatures that commonly occur on hard, shelly bottoms (Moore, 1929, p. 470). Their occurrence in this bioherm, therefore, is not surprising.

In general, the organisms found in this bioherm are shallow-water, near-shore, forms that thrive in warm water and brisk currents--an ideal reef fauna.

A detailed history of reef growth and deposition of the associated sediments is impossible to reconstruct from as few a number of outcrops as were studied. However, the general conditions in relation to cyclic sedimentation can be reconstructed. After deposition of the fusulinid-osagite bed (.5) of the Burlingame Cyclothes in the area of the Lyon

County bioherm the sea became progressively shallower. Sandy marine shale and thin limestone beds were deposited under these shallowing conditions. These deposits represent unit .6 of the cyclothem. Clams, which later formed the bioherm, lived in this shaly environment. When conditions of depth, salinity, temperature, currents, food supply, etc. became ideal for the growth of these clams along with other mollusks and molluscoids, they began to inhabit the area in profuse numbers and great quantities accumulated on the bottom. Other mollusks and molluscoids attached themselves to the hard bottom formed by the accumulated shells. Continued growth of these organisms began to build up a vertical mass from the sea floor forming the bioherm, .7 of the Burlingame Cyclothem. The exposure at Locality EE that contains no fore reef deposits was probably near the point of origin of this bioherm. Vertical growth of the bioherm combined with the continued shallowing of the sea brought the reef mass into the zone of heavy wave turbulence. This resulted in marine erosion of the reef mass and deposition of the eroded material as fore reef on the seaward flanks to the south and east (Locality GG) and locally on top of the reef itself (Locality FF). As the sea regressed further, the shoreward, highest part of the reef mass was left in too shallow a water for further growth. Lateral growth in a seaward direction to the south and east then resulted, causing overlap of forereef deposits by the reef facies at Localities FF and GG. The rate of regression eventually exceeded the rate of reef growth, causing the back reef facies that had been accumulating shoreward from the bioherm to overlap the reef complex, thereby bringing growth to a close. The lagoonal and continental shale which thus accumulated above the bioherm represents the terminal phase

of the Burlingame Cyclothem (.8-.9). This shale grades imperceptibly upward into more continental shale and coal (.1 of the Wakarusa Cyclothem). The basal sandstone, .0 of the Wakarusa Cyclothem, which should separate these shales is absent in this area of Lyon County as it is throughout the area of this report. Figure 45 illustrates the distribution of the different facies around this bioherm.

Northern Area: The northern area includes the exposures of the Soldier Creek Shale at Localities A through W. It includes all of Shawnee County and the northernmost part of Osage County. A large variety of deposits are contained in the Soldier Creek of this area. Included are non-marine shale, coal, marine shale, mudstone, limestone, and the Shawnee County bioherm. The reader should refer to Plate 2 for correlation of the stratigraphic sections in the vicinity of the Shawnee County bioherm and to Plate 1 for the area north of the bioherm.

The small molluscan bioherm in the southern part of this area is quite similar lithologically to the Lyon County bioherm. The reef facies is a massive, coquinoid limestone that weathers into thin beds (Fig. 46). Many of the fossils are aligned parallel to the bedding (Fig. 47), but most have a completely random orientation. The fossils are interbedded in and filled with clear crystalline calcite, probably of secondary origin, in which rhombohedral cleavage is well-developed (Fig. 48). The reef facies makes up the entire thickness at Localities R, Q, S, and U and the upper part at Localities O and V and the lower part at Locality P. The fore reef facies is also well-developed. In most cases it consists of finely divided, broken fragments of the fossils that make up the reef facies (Fig. 49). Such a development of the fore

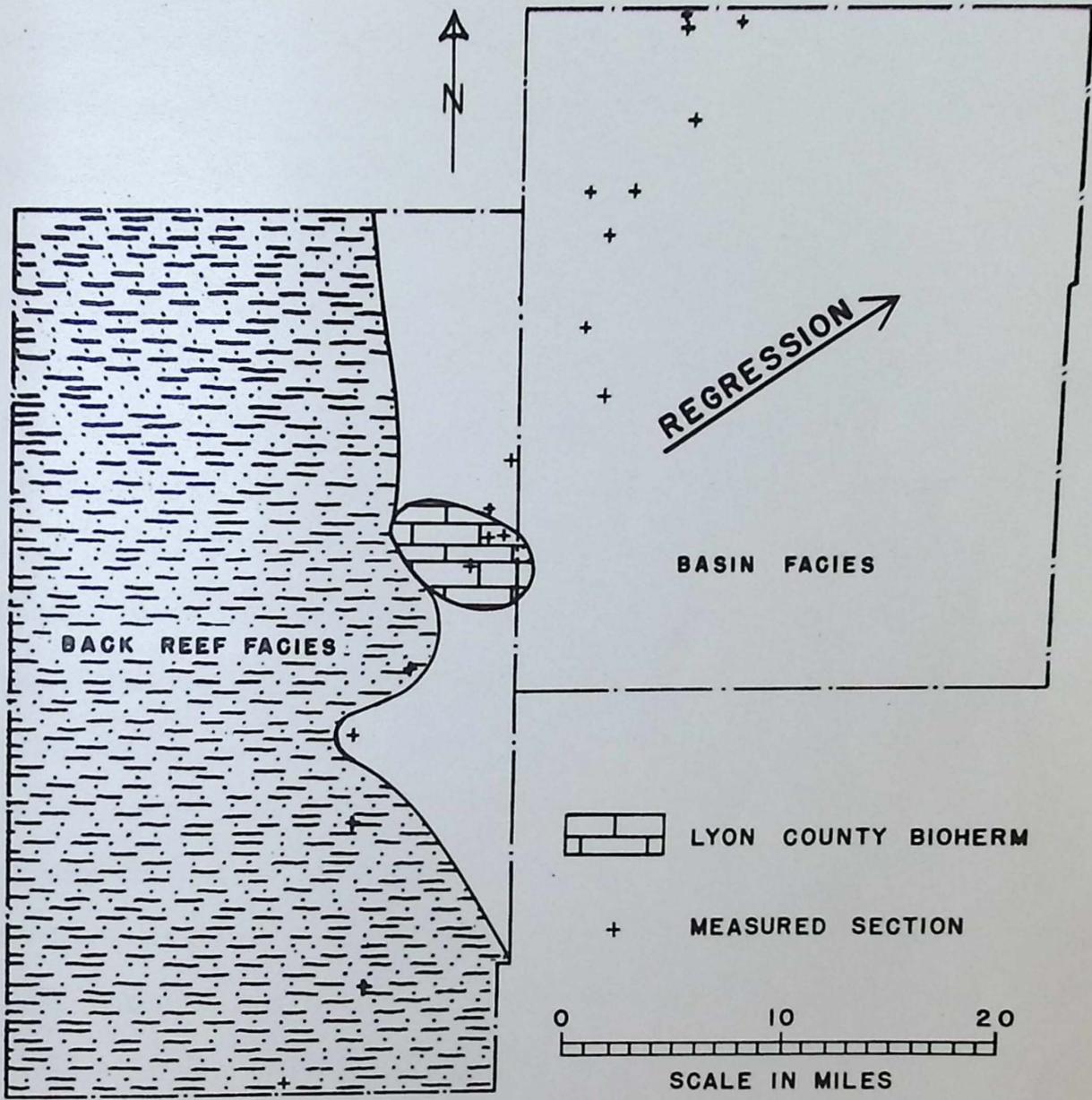


FIGURE 45
PALEOGEOGRAPHIC MAP OF BIOHERM AREA IN LYON
& OSAGE COUNTIES

reef is found in the lower part of the exposure at Localities O and V and the upper part at Locality P. At Locality U a conglomerate containing reef fragments and rounded fragments of dense limestone in a calcareous matrix occurs above the reef facies (Fig. 50). This also is interpreted as part of the fore reef facies. It probably represents destruction of the upper part of the reef by wave action. Reef facies, therefore, is flanked by fore reef deposits on all but the east side. The east flank has been removed by recent erosion, but it seems reasonable to assume that fore reef deposits existed on this side also. The basin facies is apparently represented by a calcareous zone in the Soldier Creek Shale that is present north of the bioherm (Fig. 51 & 52). This zone is present at all localities north of the bioherm, but has a slightly different development at each locality. It consists of calcareous shale, "punk beds", slightly calcareous mudstone, argillaceous limestone, and algal-molluscan limestone. The term "punk bed" refers to a very earthy, yellowish orange limestone that weathers into a limestone boxwork (Fig. 53). There seems to be a gradation from west to east of "punk beds" to mudstone and/or argillaceous limestone (Fig. 54) to algal-molluscan limestone (Fig. 55). These beds also grade from unfossiliferous on the west to fossiliferous on the east. This series of deposits, therefore, probably represent fresh-water or lagoonal deposition in the western part where the argillaceous content is high and fossils are absent and normal marine deposition in the eastern part where pure limestone with marine fossils occurs. This calcareous zone overlies non-marine shale and local coal beds. No back reef facies was observed anywhere in connection with this bioherm.

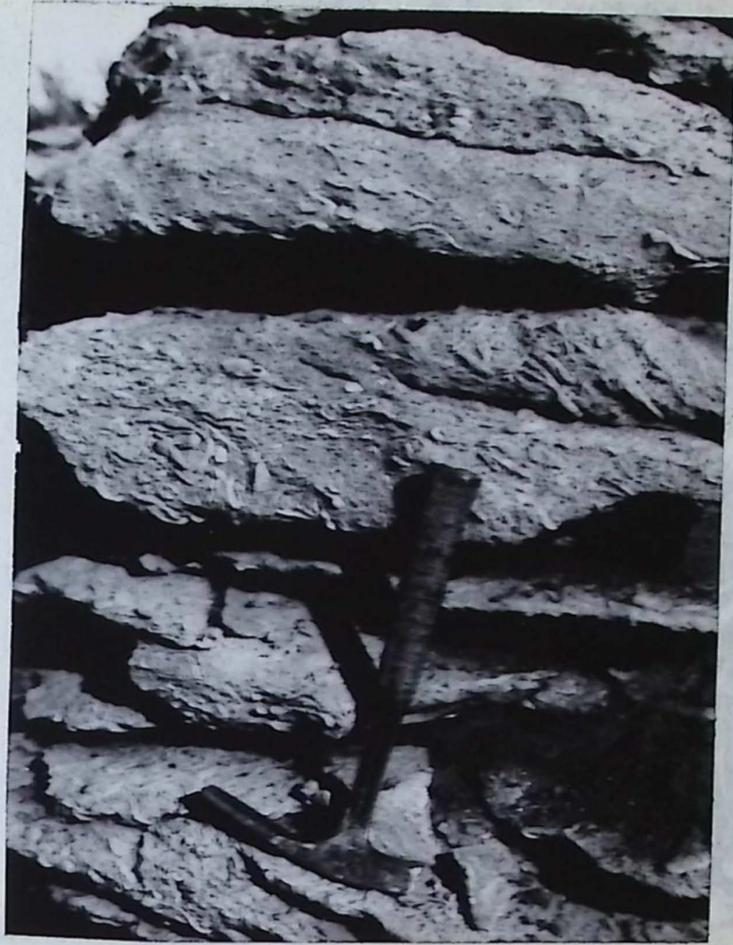


FIG. 46. Reef facies of Shawnee County bioherm. Note numerous fossils.
Loc. S.



*This print
repeats
down*

FIG. 47. Vertical peel print of reef facies of Shawnee County bioherm
showing parallel shell fragments. Loc. S. (X4).



FIG. 48. Horizontal peel print of Shawnee County bioherm reef facies showing rhombohedral cleavage of transparent calcite cement. Loc. R. (X7)



FIG. 49. Vertical peel print of fore reef facies of Shawnee County bioherm. Note finely divided fossil debris. Loc. V. (X4).



FIG. 50. Vertical peel print of fore reef conglomerate. Note reef fragments and rounded limestone fragments. Loc. U. (X₄).



FIG. 51. Mudstone zone in Soldier Creek Shale below Wakarusa Limestone. Loc. I.



FIG. 52. Bern Limestone just south of Kansas River. Note numerous thin mudstone layers in Soldier Creek Shale. B-Burlingame Limestone; SC-Soldier Creek Shale; W-Wakarusa Limestone. Loc. H.



FIG. 53. Vertical peel print of weathered "punk bed". Note development of calcareous boxwork pattern. Loc. E. (X₁).



FIG. 54. Vertical peel print of mudstone. Note fine-grained texture and laminations parallel to bedding. Loc. J. (X4).



FIG. 55. Vertical peel print of algal-molluscan limestone of Soldier Creek Shale. Note fine fossil debris. Loc. B. (X4).

The insoluble residues of the reef complex fit in quite well with the division into reef and fore reef facies. The percentage of residue of the reef facies is very low, averaging only $1\frac{1}{2}$ percent. Angular to subangular quartz sand, averaging 40 percent; clay and silt aggregate, averaging 45 percent; and muscovite, averaging 5 percent; are present in all samples analyzed from the reef facies. The fore reef contains much more clastic material, as should be expected. It is composed almost entirely of angular to subangular quartz sand.

The relationship of the Shawnee County bioherm to underlying and overlying strata is quite distinctive and important. The lower contact of the bioherm is a pronounced unconformity that cuts across the lower part of the Soldier Creek Shale, the entire Burlingame Limestone, and slightly down into the Silver Lake Shale. This unconformable relationship can be seen by examining the sections at Localities P, Q, R, S, and V (Plate 2). At Locality P the bioherm rests unconformably on the non-marine shale of the Soldier Creek. At Locality R and V it rests unconformably on the Burlingame Limestone. The upper surface of the Burlingame is deeply weathered (Fig. 56). Because of the very small thickness of the Burlingame at Locality R, it is thought that several feet were removed by erosion before formation of the overlying bioherm. The unconformity is well exposed at Locality S along the southeast side of the Kansas Turnpike. Here the unconformity cuts across the entire Burlingame Limestone along the outcrop, causing the bioherm to rest directly on the Silver Lake Shale at one point (Fig. 57). At all localities where the upper contact of the bioherm was observed, it graded upward into calcareous marine shale that locally contains limestone nodules.

The basin facies is also overlain by calcareous marine shale. This marine shale, is, in turn, overlain by fusulinid-bearing Wakarusa Limestone.

The above-mentioned characteristics and relationships of the Shawnee County bioherm serve to substantiate one thing--this bioherm, unlike the Lyon County bioherm, is of the transgressive type. According to Link (1950, p. 284), the absence of back reef facies above and shoreward of the reef is a necessary prerequisite for a transgressive bioherm, and the presence of back reef facies always indicates a regressive bioherm. No back reef deposits were found to be in any way associated with the Shawnee County bioherm. Link also points out that the adjacent and overlying sediments of a transgressive bioherm are essentially the same. Such is the case in the Shawnee County bioherm, where adjacent and overlying deposits consist of calcareous marine deposits. Added to the above general characteristics brought out by Link is the fact that the bioherm rests on an unconformity, that it is underlain by non-marine deposits--even coal, and that it is overlain by marine deposits. This gives us substantial evidence that the bioherm was developed during transgression of the sea. The unconformity attests to previous sub-aerial erosion or possibly marine erosion by the transgressing sea. It has been suggested that this deposit could be a detrital deposit laid down in a depression in the sea floor. In the author's opinion, the sessile nature of the reef-forming organisms, the absence of detrital material in the reef itself, the almost complete absence of insoluble residue in the central and thickest part of the feature, and other factors almost completely rule out this possibility.



FIG. 56. Vertical peck print of weathered Burlingame Limestone below unconformity. Pseudocrossbedding is due to limonite concentrations. Loc. V. (X₄).



FIG. 57. Unconformity at base of Shawnee County bioherm. At left edge of photograph bioherm rests directly on Silver Lake Shale. SL-Silver Lake Shale; B-Burlingame Limestone; R-Reef facies on Shawnee County bioherm. Loc. S.

The fauna of the Shawnee County bioherm is dominated by mollusks. Pelecypods are the most abundant, but gastropods are very numerous. Other fossils present, but not in abundance, include ramose bryozoans, fusulinids, crinoid stems, nautiloid cephalopods, and shark teeth.

Pelecypods present are almost entirely mytiloid types. Among this group Nyalina and Fromytilus were identified. Aviculopecten was also found (Fig. 58). The pelecypods are firmly imbedded in the limestone and do not weather out. For this reason identification is difficult.



FIG. 58. Vertical peel print of reef facies of Shawnee County bioherm showing numerous pelecypods. Loc. P. (X4).

Gastropods are quite varied. High-spired, low-spired, and bellerophonid types were present in abundance (Fig. 48, 59, & 60). They do not weather out of the limestone and were too badly weathered for identification.

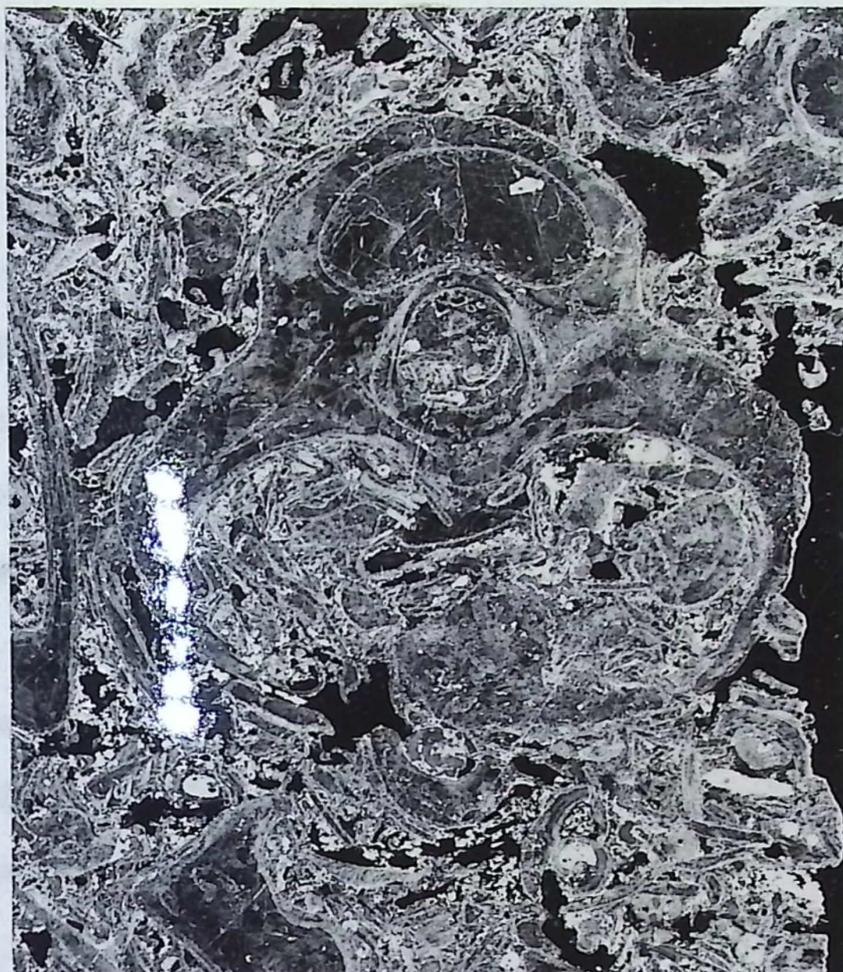


FIG. 59. Horizontal peel print of reef facies of Shawnee County bioherm showing bellerophontid gastropod. Loc. S. (X6)

Bryozoans present are all of the ramose type and are present only in the lower and middle part of the reef facies.

The very sparse fusulinids present are of the small, inflated, fusiform type present in the underlying Burlingame Limestone (Triticites cullemensis ?).

The occurrence of shark teeth is noteworthy. Three teeth were found, all at Locality S in the reef facies. They were identified as belonging to Xenacanthus compressus (Newberry) (Fig. 61). Xenacanthus is a member of the only known group of fresh-water sharks. One Pennsylvanian species (compressus) and two Permian species (texensis and platypternus) are known.



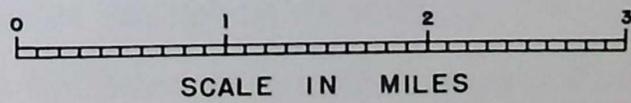
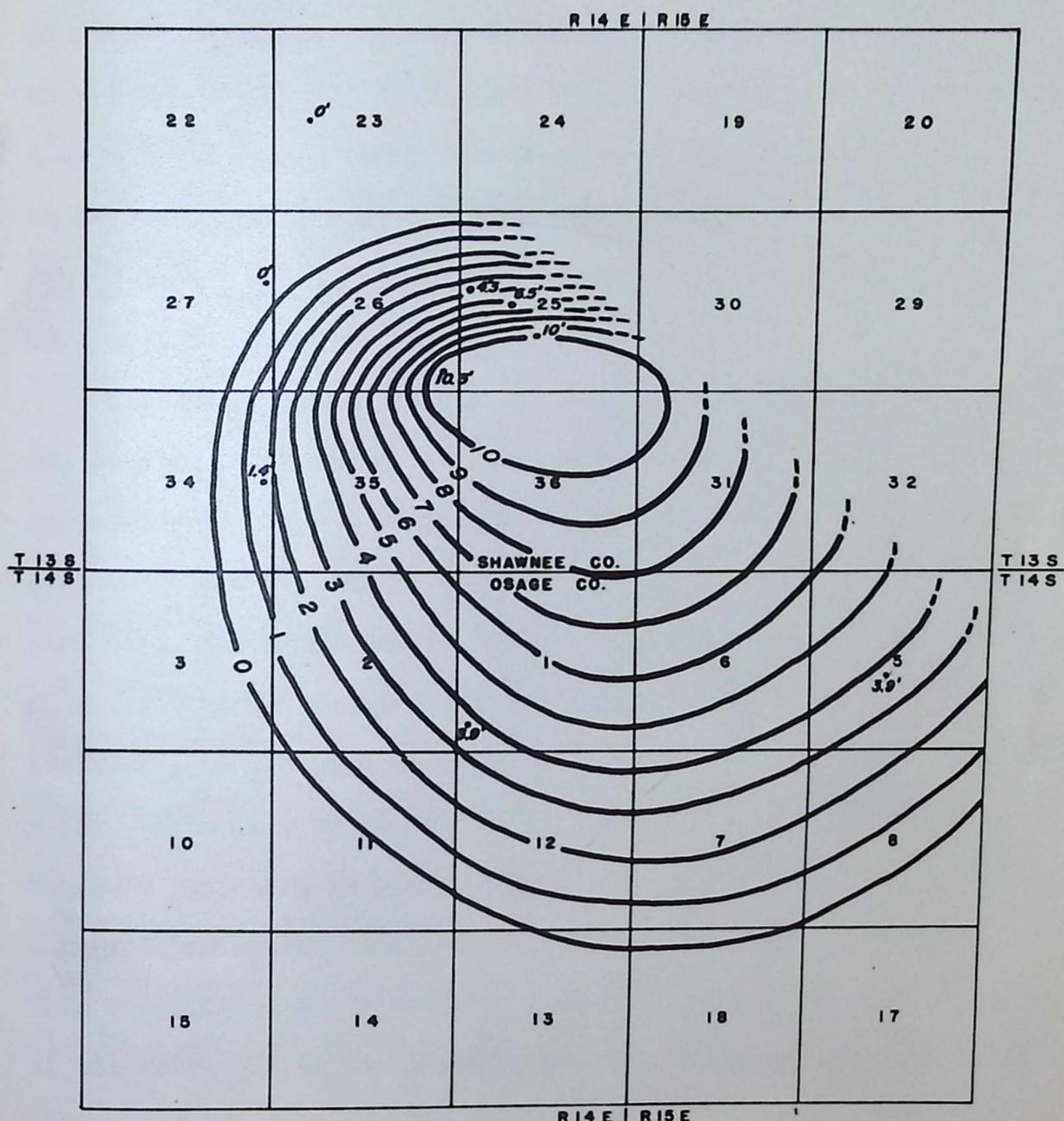
FIG. 60. Horizontal peel print of reef facies of Shawnee County bioherm showing coiled gastropod. Loc. V. (X₁).



FIG. 61. Teeth of *Xenacanthus compressus* (Newberry). Loc. S. (X₂).

A little more is known about the extent of this bioherm than the Lyon County bioherm. Eight stratigraphic sections were measured that contained a portion of the bioherm, and several more were measured close to the bioherm. The maximum thickness measured was at Locality Q where $10\frac{1}{2}$ feet are exposed. The minimum thickness, one and a half feet, is at Locality O. Figure 62 shows the thickness of the reef complex throughout the area. No sections were measured on the northeast flank because recent erosion has removed the bioherm in this area. As can be seen by reference to Figure 62, the bioherm is roughly circular in shape with the steepest slope on the northwest flank. If it was possible to obtain more control points the bioherm would probably be found to be much more irregular than is shown. The diameter is interpreted to be about four miles. It is possible that this bioherm extended much further in a northeast direction, but this can not be determined because there are no more exposures in this direction.

In comparing this bioherm with the Lyon County bioherm, only small differences in fauna are found. In the Shawnee County bioherm, gastropods are more abundant and Pectinacea are less abundant. Otherwise, the faunas are very similar. The occurrence of shark teeth in the Shawnee County bioherm is actually not too significant, since only three teeth were found. Hotton (1952, p. 498) discussed the environment of Kenacanthus. He states that this shark lived in ponds and streams since its remains are found in channel and lacustrine deposits. The type specimen of Kenacanthus compressus was described by Newberry (1856, p. 99) from apparently non-marine Carboniferous deposits in Ohio.



CONTOUR INTERVAL: 1 FOOT

FIGURE 62
ISOPACH MAP OF SHAWNEE COUNTY BIOHERM

The author has not seen reference to this organism having been found in marine deposits. Since this bioherm is definitely a marine deposit, this shark probably did not live in this environment. It could have been carried from a river into the sea by currents which left it to become buried in the bioherm. There is also the possibility that Xenacanthus compressus could have invaded the lagoonal or marine environment or that actually this was a marine animal.

The cyclic relationships of the Soldier Creek Shale in this area are complex. Overlying the Burlingame Limestone is an unfossiliferous, apparently non-marine shale that represents unit .8-.9 of the Burlingame Cyclothem. Above this shale should be the basal sandstone (.0) that marks the beginning of the Wakarusa Cyclothem. It was not observed within the three counties studied for this report. However, the unconformity at the base of the bioherm does show that erosion did take place. Since the basal sandstone is absent, the first deposit of the Wakarusa Cyclothem is the continental shale and local coal (.1). It merges imperceptibly with the non-marine shale below it (.8-.9). This continental shale and coal (.1) is present in the northern part of the area, and it was probably present throughout the area. But, because of the unconformity in the area of the Shawnee County bioherm, its former presence can not be determined. The marine shale unit (.2) of the Wakarusa Cyclothem is present above the non-marine shale and coal, but was probably removed by erosion near the area of the present bioherm. The Shawnee County bioherm and associated calcareous zone (basin facies) represents unit .3, the transgressive molluscan limestone phase of the Wakarusa Cyclothem. This phase is well-developed at all

localities within this area. The marine shale overlying the bioherm and calcareous zone represent unit .4 of the cyclothem. It is likewise present in all localities in the northern area.

The Shawnee County bioherm appears to have been formed in an environment that was essentially the same as that of the Lyon County bioherm. It is quite reasonable to assume that the same environmental conditions could occur at two different times--once during the regression of the sea and again during the transgression of this sea. The organisms that form these bioherms did not die out between regression and the following transgression. They simply followed the retreat and advance of the sea. If the Soldier Creek Shale was studied in detail over a larger area it is quite likely that similar bioherms would be found. The only difference between these two bioherms, then, is that the Lyon County bioherm was formed during the regression of the sea and was covered by non-marine deposits while the Shawnee County bioherm was formed during transgression of the sea and was covered by marine deposits. Wave erosion took place over the reef facies of the Shawnee County bioherm much as it did over the other bioherm, resulting in the deposition of fore reef debris. The Shawnee County bioherm grew laterally over this fore reef, and some fore reef material was deposited on top of the reef facies, just as occurred to the south in the other bioherm. When, due to continued transgression of the sea, the water became too deep for further reef growth, the Shawnee County bioherm was covered by marine shale that ended growth. The distribution of the different facies around the Shawnee County bioherm is shown in Figure 63.

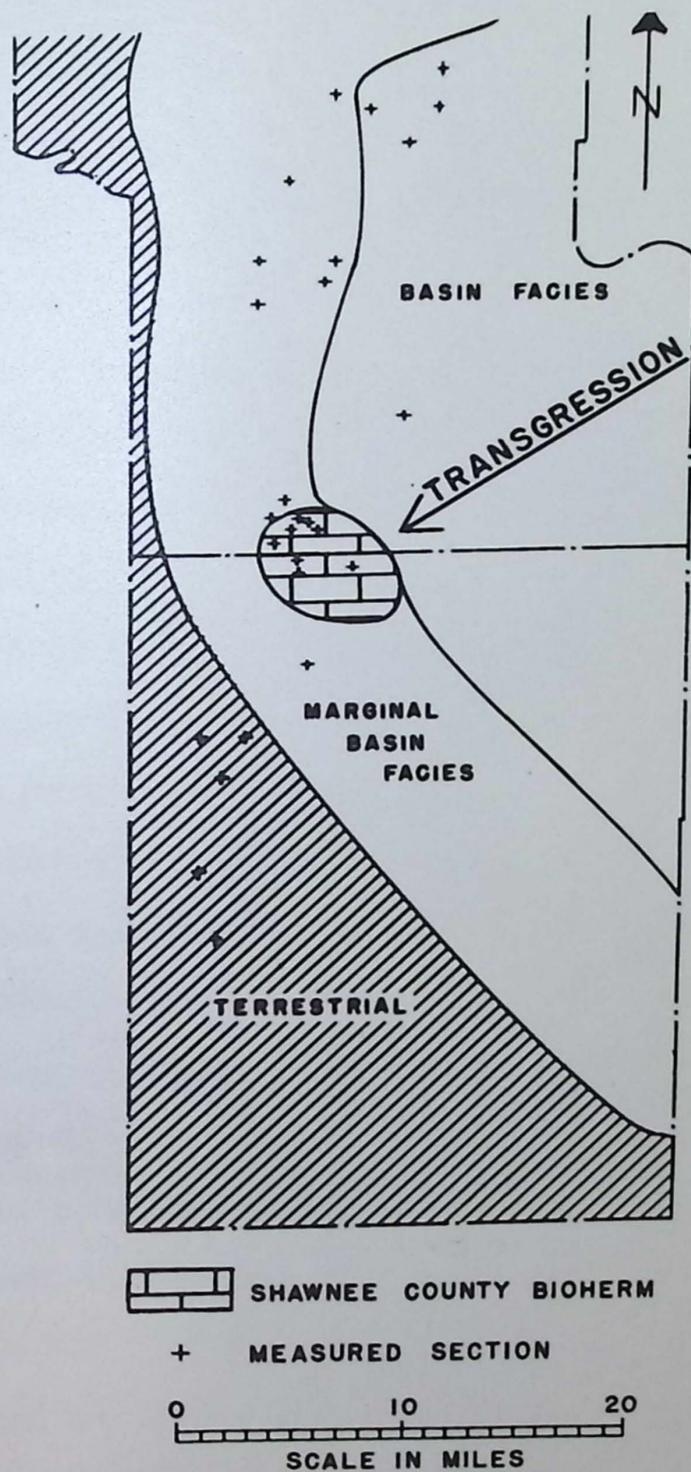


FIGURE 63—PALEOGEOGRAPHIC MAP OF BIOHERM AREA
IN SHAWNEE & OSAGE COUNTIES

Central Area: The Central area includes the Soldier Creek Shale exposures from Locality W to DD. This is the area between the two bioherms. It includes almost all of Osage County and a small part of Lyon County. The stratigraphic sections measured in this area will be found in Plate 1.

The Soldier Creek Shale between the two bioherms consists entirely of shale which is apparently non-marine except for a few inches near the upper and lower contacts. It represents a transition between unit .8-.9 of the Burlingame Cyclothem and unit .1 of the Wakarusa Cyclothem --both non-marine shales. The basal sandstone (.0) of the Wakarusa Cyclothem, which separates these two shale units in the typical cyclothem, is absent in this area as it is throughout the area studied. When traced laterally this non-marine shale (.8-.9 and .1) in the central area correlates with the non-marine shale that overlies the Lyon County bioherm and underlies the Shawnee County bioherm.

The lower few inches of the Soldier Creek just above the Burlingame in this area is generally calcareous and often contains brachiopods, indication of a marine origin. It represents unit .6 of the Burlingame Cyclothem and correlates laterally with the marine shale just below the Lyon County bioherm, but does not seem to be present in the northern area.

The upper few inches of the Soldier Creek just below the Wakarusa Limestone is a calcareous shale containing marine fossils. It represents unit .4 of the Wakarusa Cyclothem and correlates laterally with the marine shale above the Shawnee County bioherm to the north and with the marine shale above the coal bed below the Wakarusa Limestone to the south.

Regional Relationships of Bioherms: The area of this report is on the southwestern edge of the Forest City Basin. The axis of the Nemaha Anticline is just west of the area and the axis of the Bourbon Arch crosses the southern part of Lyon County (Fig. 64).

The Lyon County bioherm and the Shawnee County bioherm were formed on the edge of the Forest City Basin. In this respect these bioherms are similar to others that were formed on the flanks of basins. The Forest City Basin underwent dominantly subsiding movements throughout Late Pennsylvanian and Early Permian time according to Lee (1943, p. 10). The Bourbon Arch to the south and the Nemaha Anticline to the west were positive elements around the edge of the Forest City Basin during this same time. The deepest part of the Forest City Basin is to the north of the area studied (Fig. 64).

The arrangement of facies around the two bioherms definitely indicates regression of the sea to the northeast followed by transgression of the sea to the southwest during the time that the bioherms were being formed (Fig. 45 & 63). This is seemingly in conflict with the general regional regression to the southwest and transgression to the northeast. However, the Soldier Creek bioherms are small, local features. Therefore, irregularities in the shoreline could produce such apparent differences in direction of transgression and regression. It is reasonable, however, to assume that the Nemaha Anticline and Bourbon Arch emerged during regression at an earlier time than the Forest City Basin emerged. After these two positive areas emerged, the sea would necessarily regress to the northeast into the deeper portion of the Forest City Basin. If these positive areas emerged, then the Lyon County bioherm probably formed after

emergence of the Nemaha Anticline and Bourbon Arch to the west and south. It therefore, was formed during regression of the sea to the northeast into the Forest City Basin during the latter part of the Burlington cycle (Fig. 45). The Shawnee County bioherm was formed during the succeeding transgression of the sea to the southwest toward the emerged Nemaha Anticline and Bourbon Arch during the early part of the Waukesha cycle (Fig. 63). The Nemaha Anticline and Bourbon Arch were probably covered by the sea except during the early and late parts of the cycles.

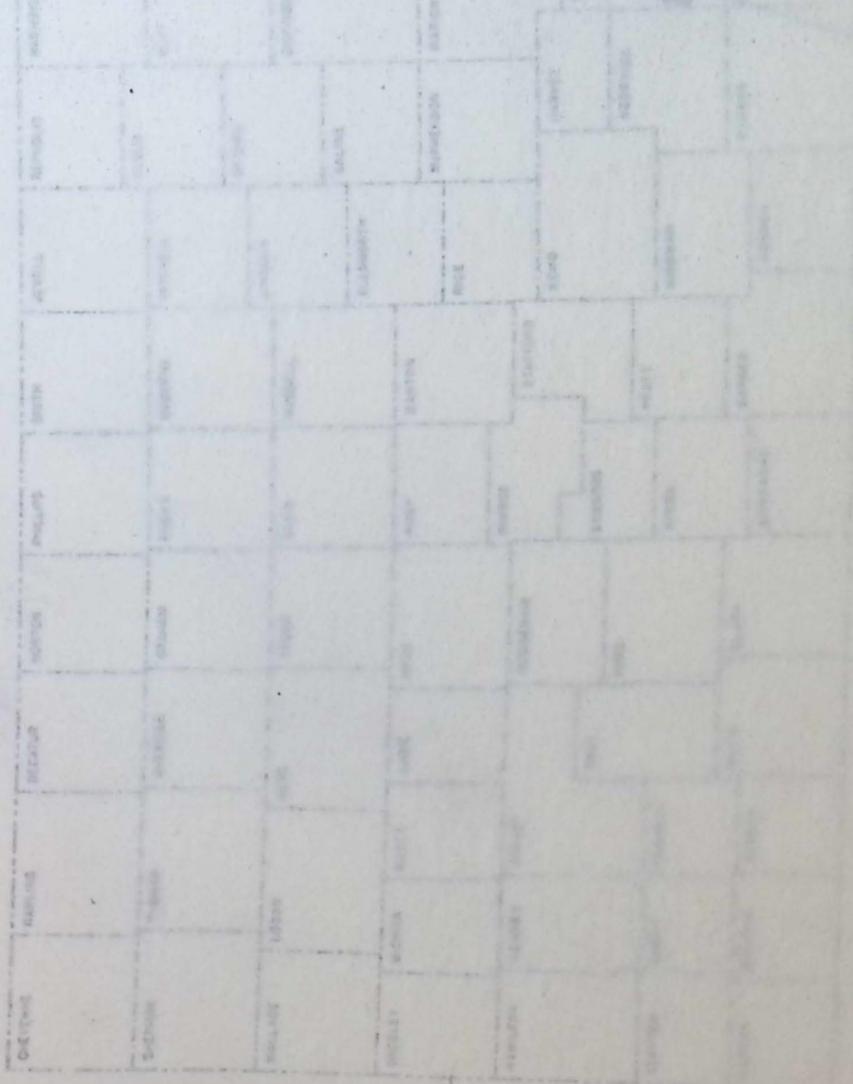
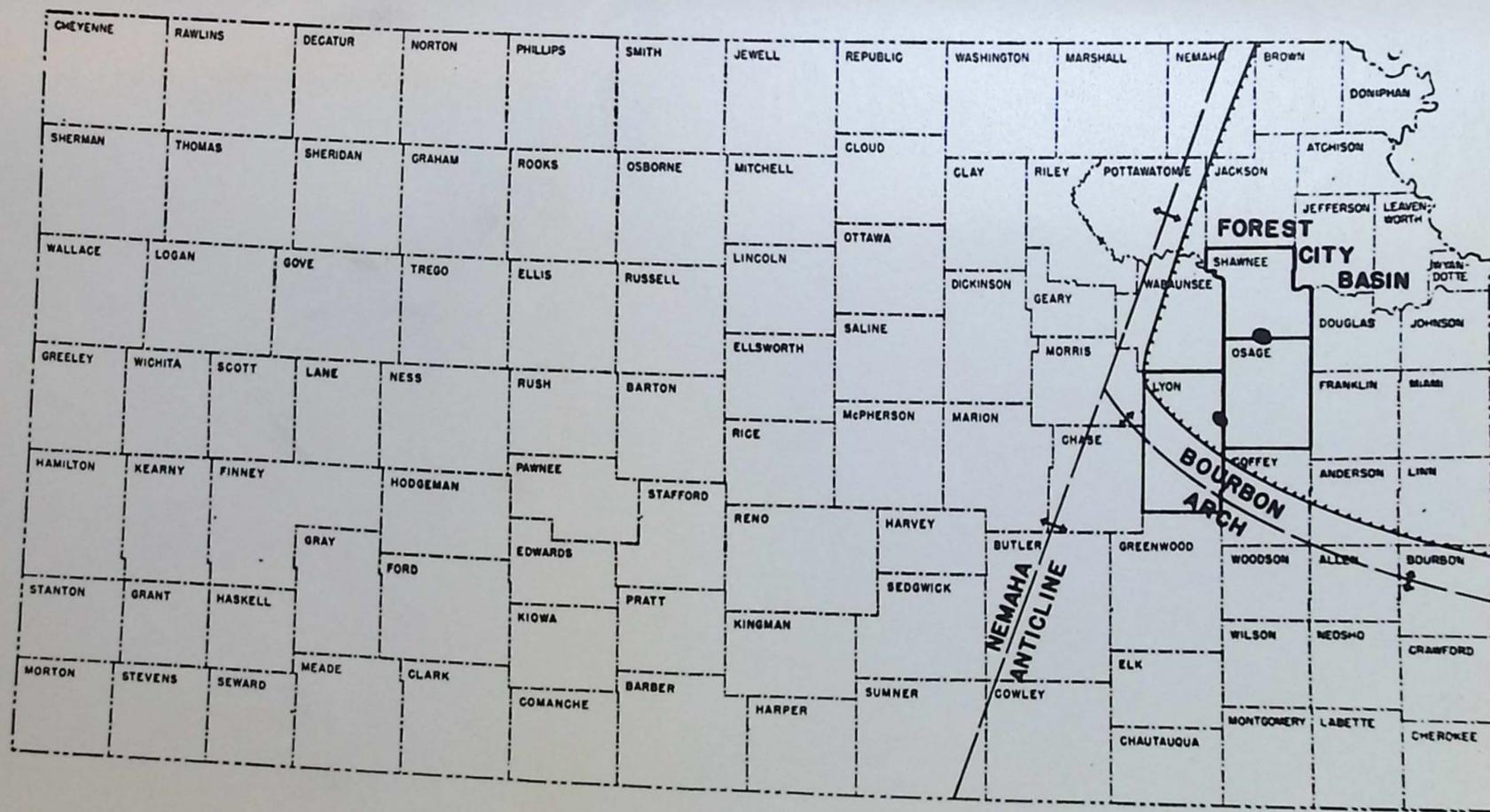


FIGURE 64—EASTERN



(FROM JEWETT, 1951)

FIGURE 64—EASTERN KANSAS STRUCTURES

Wakarusa Limestone

Lower Fusulinid Bed: A dense limestone characterized by the presence of small fusulinids occurs at the base of the Wakarusa Limestone. It is fairly persistent, being present throughout Shawnee County and the southern portion of Lyon County but absent in Osage County and the northern part of Lyon County.

This limestone is dense, homogenous, fairly pure, and almost everywhere consists of one thin bed about seven inches thick. Throughout Shawnee County it is separated from the remainder of the limestone beds above by a thin shale (Fig. 65). In Lyon County, where the lower fusulinid limestone is again present, this shale is not present. The homogenous nature of the lower fusulinid bed can not be overemphasized. It is essentially the same in the northern part of the area studied (Fig. 66) as it is in the southern part (Fig. 67).



FIG. 65. Wakarusa Limestone typical of northern part of area. Note lower fusulinid bed at base separated by a shale bed from encrinural limestone bed and upper fusulinid bed above. Loc. E.



FIG. 66. Vertical peel print of lower fusulinid bed typical of northern part of area. Loc. H (X4).



FIG. 67. Vertical peel print of lower fusulinid bed typical of southern part of area. Note similarity to Fig. 66. Loc. KK. (X4).

The fauna of the lower fusulinid bed is dominated by fusulinids and crinoid remains. The fusulinids are very small and have an inflated fusiform shape like those of the Burlingame Limestone (Fig. 67). If these fusulinids and the ones in the Burlingame are Triticites cullomensis, as is thought, then the upper boundary of the subzone of this species should be moved up from its present position of the Burlingame. Crinoid remains are common, but not as abundant as fusulinids. Columnals make up almost all of these remains, however a few parts of the calyx were found. Most of the columnals are of a small size. Algae are numerous. Both Ottonosia and Osagia are present. Osagia is present in most exposures but not in large numbers. It is small and encrusts fragments. Ottonosia is the most abundant type of algae in this unit. It forms large encrusting masses. This organism was observed to encrust horn corals especially (Fig. 68). Encrustations of the brachiopod Dictyoclostus were also observed commonly. Apparently Ottonosia favors large fossils. Also brachiopods are numerous in this lower unit. Dictyoclostus and Composita especially are abundant. Bryozoans, especially the ramose type, are abundant. The mollusks are represented by fairly common small gastropods and a very few sparse pelecypods. Horn corals, especially Lophophyllidium, are common. Rare arenaceous foraminifera are present.

The insoluble residues of the lower fusulinid bed have little coarse material. The amount of residue generally increases from south to north. The percent of coarse fraction is relatively consistent at about 5 percent on the average. Clay and silt aggregate is the most abundant, averaging approximately 50 percent. Arenaceous foraminifera constitute an average of about 30 percent. Other constituents are minor and varied.



FIG. 68. Vertical peel print of lower fusulinid bed showing algal encrustation of horn coral. Algae is Ottonosia. Loc. N (X₄).

The lower fusulinid bed of the Wakarusa Limestone represents unit .5 of the Wakarusa Cyclothem and probably represents a depositional environment quite similar to the fusulinid-osagite bed in the Burlingame Limestone, previously discussed. Algae are present in both of these units, but they are not nearly as abundant in the unit under discussion as in the Burlingame fusulinid-osagite bed. As previously mentioned, a fusulinid bed such as this could be deposited in shallow water if the waves and the resulting bottom agitation were small. Algae flourish in shallow, clear water. The algae present in this unit attest to such conditions, but, since they are not very abundant, conditions were probably something less than ideal. The water may have been a little deep for these algae. Crinoids, since they are delicate animals, require sufficient depth to avoid destruction by waves (Moore, 1929, p. 474).

Crinoid remains are abundant in this unit, but they are small and broken up, indicating at least some turbulence on the bottom. In light of the evidence furnished by the fusulinids, algae and crinoids, it is concluded that the fusulinid bed was deposited in clear water far from shore. The depth was less than that of a limestone composed almost entirely of fusulinids but more than that of algal-molluscan limestones.

As previously mentioned, there are two areas of outcrop of the lower fusulinid bed. It is present from the vicinity of the Shawnee County bioherm to the northern extent of the area studied. In this area it always overlies the marine shale that represents unit .4 of the Wakarusa Cyclothem. To the south it is present in southern Lyon County from Locality II to the southern extent of the area studied. Here it apparently rests on unit .2, a marine shale above a coal bed (.1c). Instead of unit .2, this marine shale may be unit .4, also a marine shale, or it could be units .2 and .4 combined. Since the transgressive molluscan limestone (.3) is absent in this southern part, there is no way of determining whether this is unit .2 or unit .4. The lower fusulinid bed is overlain by a marine shale (.6) in Shawnee County (Fig. 65). This shale is not present in Lyon County. Instead the lower fusulinid bed is overlain by the encrinal limestone bed, the next unit to be discussed.

Encrinal Limestone Bed: A detrital limestone characterized by the presence of very abundant crinoid fragments, especially stems, occurs in the middle part of the Wakarusa Limestone. This bed is the most persistent unit within the entire Bern formation. It is present in all exposures of the Wakarusa studied within Shawnee, Osage, and Lyon Counties.

The encrinal limestone is predominantly detrital, massive to thick-bedded, and usually has uneven transitional contacts with the beds above and below. Fossil fragments have a random orientation (Fig. 69). The thickness of the encrinal limestone is generally a foot or more in the northern part of the area (Fig. 70). It thickens southward to as much as five feet (Fig. 71). At a very few localities thin shale partings or nodular zones occur within the limestone. Overall the encrinal limestone is very homogenous throughout. However, it does tend to be slightly more detrital and coarse grained to the north (Fig. 72).



FIG. 69. Vertical peel print of encrinal limestone bed showing random orientation of fragments. Loc. C. (X₁).



FIG. 70. Upper part of Wakarusa Limestone. Encrinal limestone bed is on level with hammer. Upper fusulinid bed is above hammer. Note Ottenosia encrustations weathering in relief. Loc. A.

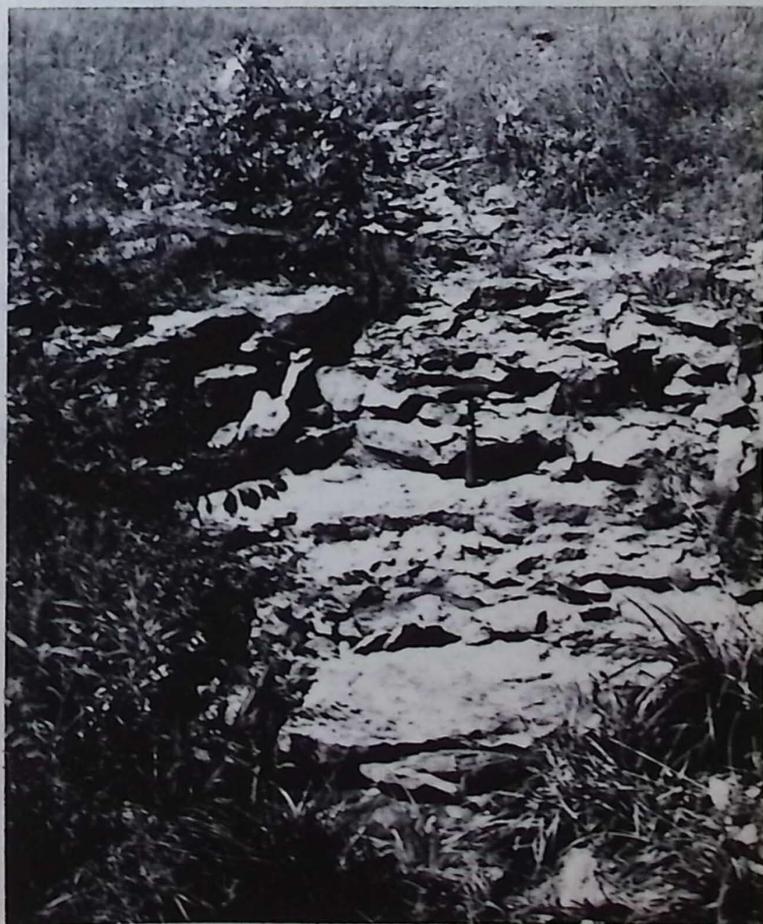


FIG. 71. Maximum thickness of encrinal limestone bed. Loc. CC.



FIG. 72. Horizontal peel print of encrinal limestone bed showing coarse grained texture. Loc. H. (X₄).

The fauna is overwhelmingly dominated by crinoid debris. Individual and connected columnals almost entirely compose this debris (Fig. 73). Stems as long as a foot were observed. These columnals are generally larger than those of the lower fusulinid bed. Algae are fairly numerous. Ottonosia is the most abundant of the algae (Fig. 74). It forms large growths that weather in relief on an outcrop (Fig. 70). Ottonosia also encrusts horn corals in this unit (Fig. 75). The algae Osagia is also present, but it is not as numerous as Ottonosia (Fig. 76). Several specimens of the trilobite Ditnopyge were collected from this unit. They generally occur in the transition zone with the shale below and were numerous at Locality H and I. Horn corals also are fairly numerous

within this bed. They are commonly encrusted with algae (Fig. 75). Both Caninia and Lophophyllidium were identified, but the latter is by far the most abundant (Fig. 75). Other fossils present, but fairly rare, include arenaceous foraminifera, brachiopods, pelecypods, small gastropods, and bryozoans--both ramose and fenestrate types. Fusulinids are absent.



FIG. 73. Horizontal peel print of encrinal limestone bed showing individual and connected crinoid columnals. Loc. II. (X₄).

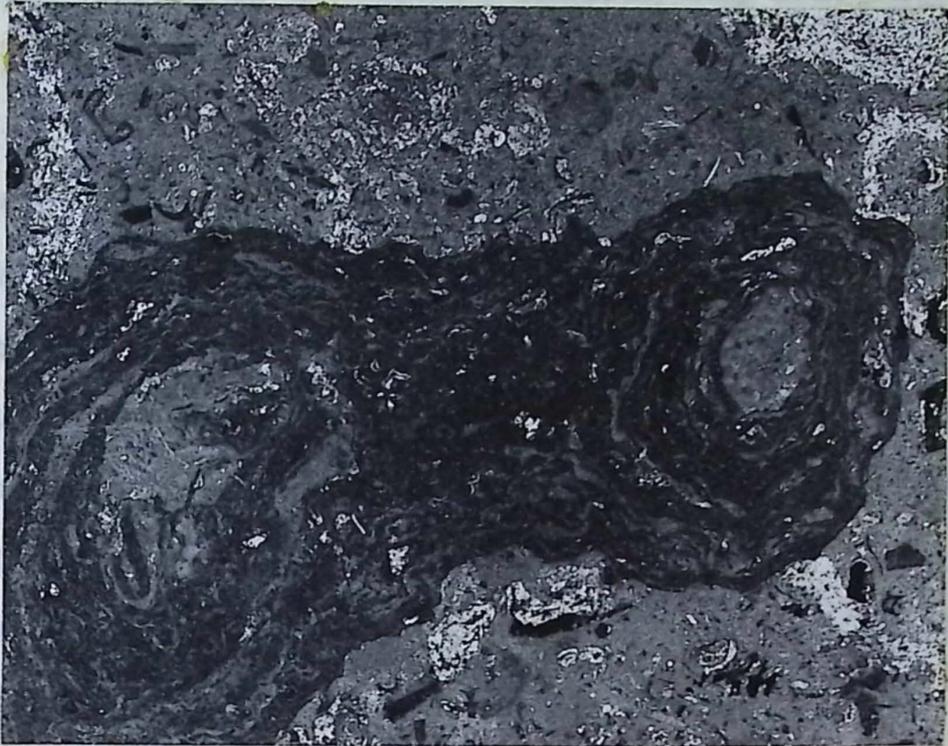


FIG. 74. Vertical peel print of encrinal limestone bed showing Ottonosia.
Loc. Y. (X4).



FIG. 75. Vertical peel print of encrinal limestone bed showing algal
encrustations of coral. Algae is Ottonosia. Coral is
Lophophyllidium. Loc. CC. (X6).

Insoluble residues of the encrinal limestone vary from place to place. It is relatively detrital as is brought out by the rather high percent of total residus--15 percent on the average, and the rather large coarse fraction. Arenaceous foraminifera and clay and silt aggregate make up essentially all of the residus.

The encrinal limestone represents a regression of the sea after the deposition of the lower fusulinid bed. It therefore represents unit .7, the regressive limestone of the Wakarusa Cyclothen. Algae generally characterize this particular phase of the cycle, but it is quite variable in fauna. The encrinal limestone does contain a large number of algae, but crinoid remains are more abundant. Algae of course require shallow, clear water for growth. Crinoids, because they are delicate, require sufficient depth to avoid destruction by waves. But, as Moore (1929, p. 470) points out, crinoids may flourish in broad, shallow bodies of water where the waves are small and do not greatly disturb the bottom. The horn corals present in this bed, if their habitat was the same as modern corals, lived in warm, shallow waters. Lophophyllidium, according to Moore (1929, p. 468) has the particular feature of flourishing in muddy environments. Since fusulinids are absent the water may have been too shallow or too near shore for them. Also, mollusks are more abundant in this bed than they generally are in fusulinid limestone. A fairly high amount of residus and correspondingly high coarse fraction indicates a fairly close proximity to shore. Taking into account the evidence furnished by the fauna and the insoluble residus, it is concluded that this bed was deposited in a fairly quiet, shallow water near shore. The environ-

ment was not in as shallow a water or as near shore as the molluscan bed of the Burlingame Limestone, however. The encrinal limestone represents regression after deposition of the underlying fusulinid bed. The regression was not long, however. A fusulinid limestone is the next bed to follow. The encrinal limestone is the result, then, of a small fluctuation of the sea (Fig. 3).

In Shawnee County the encrinal limestone is underlain by a marine shale, .6 of the cycle. In Osage and northern Lyon Counties where the lower fusulinid bed is absent, it rests on marine shale that may be either unit .2 or .4 of the cycle. In southern Lyon County it rests directly on the lower fusulinid bed, .5 of the Wakarusa Cyclothem. In all cases where the top of the Wakarusa member is exposed, the encrinal limestone is overlain by the upper fusulinid bed of the Wakarusa Limestone, the next bed to be discussed.

Upper Fusulinid Bed: A detrital limestone bed characterized by the presence of abundant large fusulinids occurs at the top of the Wakarusa Limestone. It is very persistent, being present in every outcrop within the area studied where the top of the Wakarusa member was exposed.

This limestone is detrital, massive to thick-bedded, and ordinarily has an undulating, transitional lower contact and a flat, abrupt upper contact. Fusulinids and crinoid stems customarily have their long axis oriented parallel to the bedding. Other detritus is randomly oriented. The bed is about a foot or less in thickness. It becomes progressively thinner in the southern part of the area. It is lithologically and faunally very homogenous throughout the area (Fig. 77 & 78). In the field this unit is easily recognized by the profuse fusulinids that weather in relief.



FIG. 76. Horizontal peel print of encrinal limestone bed showing small algal encrustation. Algae is Osagia in lower left. Loc. L. (X₁)



*This print
is upside
down*

FIG. 77. Vertical peel print of upper fusulinid bed typical of northern part of area. Note abundant large fusulinids and fairly coarse detrital material. Loc. H. (X₁)

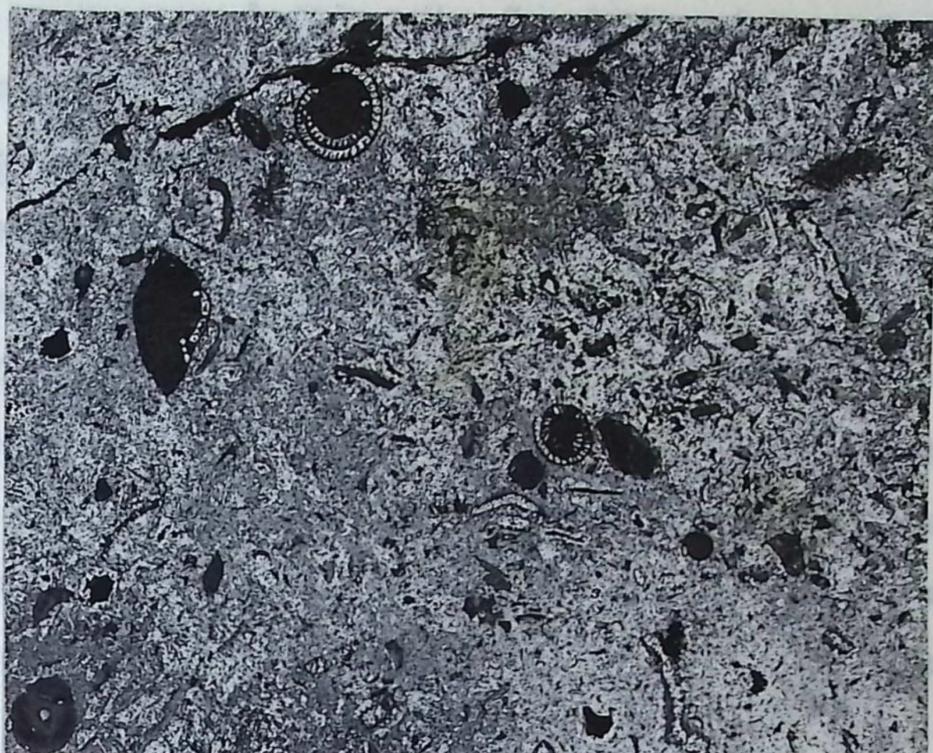


FIG. 78. Vertical peel print of upper fusulinid bed typical of southern part of area. Note large fusulinids and slightly finer detrital material than in Fig. 77. Loc. LL. (X₄).

The fauna of the fusulinid bed is rich and varied, but is dominated by fusulinids. They are large and thickly fusiform. According to Moore and others (1944, p. 672-673) the subzone of Triticites ventricosus extends from the Wakarusa Limestone to the base of the Permian. Triticites ventricosus is large and thickly fusiform like the fusulinids found in the upper fusulinid bed of the Wakarusa (Fig. 79). So, possibly the upper fusulinid bed of the Wakarusa marks the first appearance of Triticites ventricosus. Crinoid remains, especially stems, are almost as abundant as fusulinids (Fig. 80). However, they are less abundant in the encrinal limestone bed. Most of the stems found are of medium size. Brachiopods are numerous and varied in the upper fusulinid bed. Dictyoclostus and Enteletes are the most abundant. Also identified were Hustedia, Derbyia, Composita, and Neospirifer.

Bryozoans are numerous in this unit. Fenestrate and ramose types are present in about equal abundance. The algae are represented by plentiful Ottonosia and sparse Osagia. Other fossils present include rare gastropods, pelecypods, arenaceous foraminifera and horn corals.

Amount of insoluble residue is small in this unit. The average percent of residue is quite consistent at about 8 percent while the coarse fraction is generally very small. Clay and silt aggregate make up nearly all of the coarse residue, averaging 75 percent. Other constituents vary. Arenaceous foraminifera increase in abundance to the south and muscovite is present up to about 10 percent in the north.



FIG. 79. Peel print of large fusulinid of upper fusulinid bed.
Loc. L. (X10).

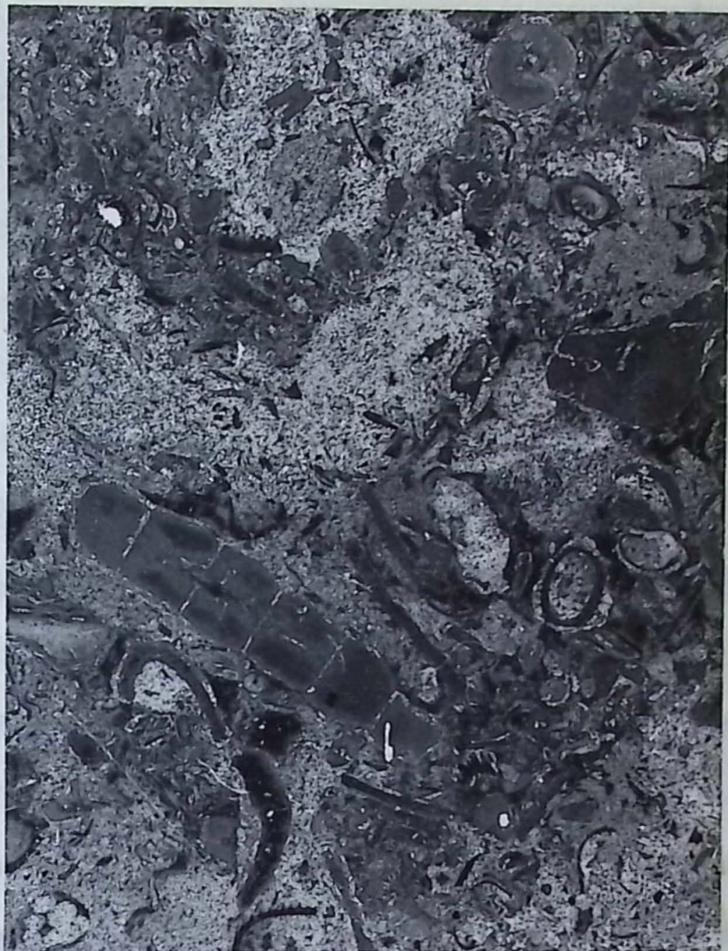


FIG. 80. Horizontal peel print of upper fusulinid bed showing numerous crinoid stems. Loc. II. (X₄).

The upper fusulinid bed represents a recurrence of unit .5, the maximum transgressive phase of the Wakarusa Cyclothem. Fusulinids are the characteristic fossil of this phase. Normally, only one fusulinid-bearing unit (.5) occurs in a Wabaunsee type cyclothem. However, in the Wakarusa Cyclothem there are apparently two well-defined fusulinid beds. These beds, the lower and upper fusulinid limestones, represent two maximum peaks of transgression that are separated by a regressive phase, the encrinal limestone (.7). The upper fusulinid bed probably represents almost the same depositional environment as the lower fusulinid bed, already discussed. Faunas of both are similar. However,

fusulinids are slightly more abundant and algae less abundant in the upper fusulinid bed. Also, the insoluble residue of the upper bed is smaller and finer grained than that of the lower bed. Taking into account the environment of fusulinids and algae and the insoluble residue data, it is concluded that the upper fusulinid bed was deposited in slightly deeper water farther from shore than the lower fusulinid bed. The upper limestone therefore represents a slightly greater transgression than the lower limestone.

The upper fusulinid limestone is underlain by the encrinal limestone bed at all localities save one. At Locality II a thin marine shale parting containing brachiopods, crinoid stems, and horn corals separates them. The upper fusulinid bed is always overlain by the Auburn Shale. However, this contact is not commonly seen because the Wakarusa is the uppermost resistant unit in the Bern Limestone that forms an escarpment. As a result, the upper part of the Wakarusa Limestone and the Auburn formation are generally removed by erosion at a given outcrop.

Shale Beds: There is only one persistent shale unit within the Wakarusa member. It is the shale that separates the lower fusulinid limestone from the encrinal limestone in Shawnee County. This is a calcareous marine shale that contains abundant crinoid stems and brachiopods. It locally contains thin beds and lenses of encrinal limestone as at Locality A (Fig. 81). This shale generally has a gradational contact with the limestones above and below. Trilobites sometimes occur in this transition zone. This unit is present only north of the Shawnee County bicorn, but is quite persistent there. In the area studied it ranges from 6 to 16 inches in thickness, averaging about 9 inches.



FIG. 81. Vertical peel print of crinoidal limestone bed in shale of Wakarusa Limestone. Loc. A. (X6).

This persistent shale unit of the Wakarusa separates unit .5 from unit .7 of the Wakarusa Cyclothem. It therefore, represents the regressive marine shale unit, 16, of this cycle. Because of the abundant crinoid remains and the calcareous nature of the shale, it probably was deposited in a very similar environment to unit .7, the encrinal limestone. The only difference in conditions would be that much more argillaceous material was deposited in the area of the shale bed.

Auburn Shale

The Auburn Shale directly overlies the Bern Limestone. Although not part of this study, a few partial exposures of this formation were measured where it was exposed above the Wakarusa Limestone.

The few inches of this shale next above the Wakarusa is calcareous and contains a few marine fossils. Above this is thin-bedded, unfossiliferous shale that probably is non-marine. These two shales apparently represent the terminal shale units of the Wakarusa Cyclothem (.8-.9). Above these units is the incompletely developed Auburn Cyclothem.

SUMMARY AND CONCLUSION

1. The most efficient method for the study of carbonate lithologies is by the use of acetate peels.
2. Insoluble residues of the individual microlithologic zones within the Bern Limestone are distinctive enough and sufficiently constant to permit correlation and differentiation of these zones. Quartz sand, arenaceous foraminifera, and silt and clay aggregate are the only abundant insoluble residues.
3. The Bern Limestone contains two Wabauunsee-type cyclothems. The Burlingame Cyclothem differs from the typical cyclothem in that it contains an algal-fusulinid unit rather than a fusulinid unit. The Wabauunsee Cyclothem differs from the typical cyclothem in that it does not contain a basal sandstone and that it contains two fusulinid units rather than one.
4. Several channel conglomerate deposits in the Silver Lake Shale indicate sub-aerial erosion at the beginning of the Burlingame Cyclothem.
5. The molluscan bed of the Burlingame Limestone is a very thin, discontinuous limestone characterized by the presence of mollusks. It was deposited very near shore by a transgressing sea.
6. The fusulinid-osagite bed of the Burlingame Limestone is a medium thick, persistent limestone bed characterized by the presence of fusulinids and algae. It becomes progressively more argillaceous southward. It was deposited just before and during the maximum transgression of the sea at the peak of the Burlingame Cyclothem.

7. The brecciated limestone bed of the Burlingame Limestone is a thick, mottled, brecciated, nearly unfossiliferous limestone of uncertain origin present only in the northern part of the area. It was deposited in shallow water during regression of the sea.
8. The Soldier Creek Shale in Shawnee County contains a small transgressive molluscan bioherm and associated reef, fore reef, and basin facies.
9. The Soldier Creek Shale in Lyon County contains a small, regressive molluscan bioherm and associated reef, fore reef, back reef, and basin facies.
10. The Soldier Creek Shale in Osage County is composed entirely of shale, most of which is non-marine.
11. The Soldier Creek bioherms were formed on the southwest flank of the Forest City Basin during regression of the sea to the northeast and again during transgression of the sea to the southwest.
12. The lower fusulinid bed is a very thin, dense limestone characterized by the presence of small fusulinids at the base of the Wakarusa Limestone in Shawnee and southern Lyon County. It was deposited far from shore during the first maximum transgression of the sea in the Wakarusa Cyclothem.
13. The encrinal limestone bed of the Wakarusa Limestone is a coarse, medium-thick, extremely persistent limestone characterized by the presence of abundant crinoid columnals. It was deposited during a small regression of the sea.

14. The upper fusulinid bed is a dense, thin limestone at the top of the Wakarusa Limestone characterized by the presence of abundant large fusulinids. It was deposited very far from shore during the last maximum transgression of the sea in the Wakarusa Cyclothem.

Cox, S. L., 1927, The stratigraphy of the Pennsylvanian System in Nebraska. Nebraska Geol. Survey, Ser. 2, Bull. 1.

1930, Correlation of the Pennsylvanian beds in the Platte and James Fork sections of Nebraska. Nebraska Geol. Survey, Ser. 2, Bull. 3.

1935, Geologic cross section, Forest City, Missouri, to Kansas. Nebraska Geol. Survey Paper 4.

1949, The nomenclature, type localities, and correlation of the Pennsylvanian subdivisions in eastern Nebraska and adjacent states. Nebraska Geol. Survey, Ser. 2, Bull. 16.

and Buckner, H. A., 1915, The Pennsylvanian formations of southeastern Nebraska. Nebraska Geol. Surv., v. 9, no. 2.

and Reed, E. C., 1913, Geological section of Nebraska. Nebraska Geol. Survey, Ser. 2, Bull. 14.

Dalrymple, C. G., and Cox, S. L., 1917, Handbook of the Pennsylvanian System in Nebraska. Nebraska Geol. Survey, Ser. 2, Bull. 5.

Ellis, H. C., 1917, Depth of deposition of the Big Bend (Late Paleozoic) section in Kansas. Geol. Soc. America Bull., v. 28, p. 413-432.

Fenneman, H. H., 1930, Physiography of eastern United States. New York, McGraw-Hill Book Co., Inc., p. 588-620.

Fisher, W. L., 1953, Geology of the Beard Formation (Mississippian) in southern Illinois. Swets Univ., unpublished master's thesis.

Gould, C. H., 1925, Index to the stratigraphy of Oklahoma. Oklahoma Geol. Survey Bull. 15.

Hall, John, 1856, A geologic section from State Line, opposite Missouri, to Alton, principally along the Gage River. Kansas Geol. Survey, v. 1, p. 105.

Howarth, S., and Stewart, J., 1902, General stratigraphy. Kansas Univ. Geol. Survey, v. 9, p. 11-22.

REFERENCES

- Beede, J. W., 1898, The stratigraphy of Shawnee County: Kansas Acad. Sci. Trans., v. 15, p. 27-34.
- Cayeux, Lucien, 1935, Les roches sedimentaires de France; roches carbonatees: Paris, Masson et Cie.
- Condra, G. E., 1927, The stratigraphy of the Pennsylvanian System in Nebraska: Nebraska Geol. Survey, Ser. 2, Bull. 1.
- _____ 1930, Correlation of the Pennsylvanian beds in the Platte and Jones Point sections of Nebraska: Nebraska Geol. Survey, Ser. 2, Bull. 3.
- _____ 1935, Geologic cross section, Forest City, Missouri, to DuBois, Nebraska: Nebraska Geol. Survey Paper 8.
- _____ 1949, The nomenclature, type localities, and correlation of the Pennsylvanian subdivisions in eastern Nebraska and adjacent states: Nebraska Geol. Survey, Ser. 2, Bull. 16.
- _____ and Bengtson, N. A., 1915, The Pennsylvanian formations of southeastern Nebraska: Nebraska Acad. Sci. Pub., v. 9, no. 2.
- _____ and Reed, E. C., 1943, Geological section of Nebraska: Nebraska Geol. Survey, Ser. 2, Bull. 14.
- Dunbar, C. O., and Condra, G. E., 1932, Brachiopoda of the Pennsylvanian System in Nebraska: Nebraska Geol. Survey, Ser. 2, Bull. 5.
- Elias, M. K., 1937, Depth of deposition of the Big Blue (Late Paleozoic) sediments in Kansas: Geol. Soc. America Bull., v. 48, p. 403-432.
- Fenneman, N. M., 1938, Physiography of eastern United States: New York, McGraw-Hill Book Co., Inc., p. 588-630.
- Fisher, W. L., 1958, Geology of the Menard Formation (Mississippian) in southern Illinois: Kansas Univ., unpublished master's thesis.
- Gould, C. N., 1925, Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey Bull. 35.
- Hall, John, 1896, A geologic section from state line, opposite Biocourt, to Alma, principally along the Osage River: Kansas Univ. Geol. Survey, v. 1, p. 105.
- Haworth, E., and Bennett, J., 1908, General stratigraphy: Kansas Univ. Geol. Survey, v. 9, p. 57-121.

- Hotton, Nicholas III, 1952, Jaws and teeth of American xenacanth sharks: Jour. Paleont., v. 26, p. 489-500.
- Ireland, H. A., 1947, Terminology for insoluble residues: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 1479-1490.
- _____, 1951, in LeRoy, L. W., and others, Subsurface geologic methods: Golden, Colo., Colorado School Mines, Dept. Pubs., p. 140-156.
- _____, 1956, Upper Pennsylvanian arenaceous foraminifera from Kansas: Jour. Paleont., v. 30, p. 831-864.
- Ives, William, Jr., 1954, Evaluation of acid etching of limestone: Kansas Univ., unpublished master's thesis.
- Jewett, J. M., 1951, Geologic structures in Kansas: Kansas Geol. Survey Bull. 90, pt. 6, p. 105-162.
- Lee, Wallace, 1943, The stratigraphy and structural development of the Forest City Basin in Kansas: Kansas Geol. Survey Bull. 51.
- Link, T. A., 1950, Theory of transgressive and regressive reef (bioherm) development and origin of oil: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 263-294.
- Lowman, P. D., 1959, An analysis of the cyclothem problem: Compass, v. 36, no. 2, p. 104-113.
- Noore, R. C., 1929, Environment of Pennsylvanian life in North America: Am. Assoc. Petroleum Geologists Bull., v. 13, p. 459-489.
- _____, 1935, Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey Bull. 22. (1936).
- _____, 1949, Divisions of the Pennsylvanian System in Kansas: Kansas Geol. Survey Bull. 83.
- _____, 1950, Late Paleozoic cyclic sedimentation in central United States: Internat. Geol. Cong. Rept., 18th. Session., Great Britain. (1948).
- _____ and Mudge, M. R., 1956, Reclassification of some Lower Permian and Upper Pennsylvanian strata in northern Mid-Continent: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2271-2278.
- _____ and others, 1944, Correlation of the Pennsylvanian formations of North America: Geol. Soc. America Bull., v. 55, p. 657-706.
- _____, 1951, The Kansas rock column: Kansas Geol. Survey Bull. 89.
- _____, 1952, Invertebrate fossils: New York, McGraw-Hill Book Co., Inc.

- National Research Council, 1948, Rock color chart: Washington, D. C.
- Newberry, J. S., 1856, Description of several new genera and species of fossil fishes, from the Carboniferous strata of Ohio: Philadelphia Acad. Sci. Proc., v. 8, p. 96-100.
- Newell, N. D., 1937, Late Paleozoic pelecypods: Pectinacea: Kansas Geol. Survey, v. 10, pt. 1.
- _____ 1942, Late Paleozoic pelecypods: Mytilacea: Kansas Geol. Survey, v. 10, pt. 2.
- O'Connor, H. G., and others, 1953, Geology, mineral resources, and ground-water resources of Lyon County, Kansas: Kansas Geol. Survey, v. 12.
- _____ 1955, Geology, mineral resources and ground-water resources of Osage County, Kansas: Kansas Geol. Survey, v. 13.
- Runnels, R. T., and Schleicher, J. A., 1956, Chemical composition of eastern Kansas limestones: Kansas Geol. Survey Bull. 19, pt. 3, p. 81-103.
- Smith, A. J., 1903, Geology of Lyon County, Kansas: Kansas Acad. Sci. Trans., v. 18, p. 99-103.
- Tilton, J. L., 1920, The Missouri Series of the Pennsylvanian System in southwestern Iowa: Iowa Geol. Survey, v. 29.
- Verville, G. J., and others, 1958, Geology, mineral resources, and ground-water resources of Elk County, Kansas: Kansas Geol. Survey, v. 14.
- Wahrhaftig, Leon, 1952, Insoluble residues of the Wabaunsee Group limestones of the Upper Pennsylvanian in northeastern Kansas: Kansas Univ., unpublished master's thesis.
- Walters, K. L., 1953, Geology and ground-water resources of Jackson County, Kansas: Kansas Geol. Survey Bull. 101.
- Weller, J. M., 1932, in Wanless, H. R., and Weller, J. M., Correlation and extent of Pennsylvanian cyclothems: Geol. Soc. America Bull., v. 42, p. 1003-1016.
- _____ 1956, Argument for diastrophic control of Late Paleozoic cyclothems: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 17-50.

APPENDIX A

MEASURED SECTIONS IN EASTERN KANSAS

The colors and color symbols used in the descriptions are taken from the Rock-Color Chart of the National Research Council (1948).

The measured sections are located on the Location Map (Fig. 1).

Locality A

SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 31, T. 9 S., R. 16 E., Jackson County and NE $\frac{1}{4}$, NE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 6, T. 10 S., R. 16 E., Shawnee County; measured in roadcut on north side of U. S. Highway 75 west of the creek and in roadcut across county line on northeast side of the curve in U. S. Highway 75.

Good exposure.

Thickness
Feet Inches

Auburn Shale (1'+ exposed)

13. Shale, yellowish brown, weathers brown, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts, calcareous..... 1' 0"

Bern Limestone (16')

Wakarusa Limestone member (2' 8")

12. Limestone, light olive gray (5Y6/1), weathers brownish yellow, hard, resistant, well consolidated, dense, one massive bed, sharp and even upper contact, transitional and undulating lower contact, small gastropods, horn corals, small clams, fenestrate and ramose bryozoans, brachiopods, linear algae, crinoid stems, few fusulinids in upper part, Ottonosia, Hustedia, Derbyia, Dictyoelostus..... 1' 6"
11. Shale, light gray, weathers yellowish brown, soft, fair consolidation, non-resistant, thin-bedded, transitional and uneven contacts, calcareous, crinoid stems..... 0' 4 $\frac{1}{2}$ "
10. Limestone, light olive gray (5Y6/1), weathers light brown, hard, well consolidated, resis-

tant, one thin bed, transitional and undulating contacts, very fossiliferous, abundant crinoid stems, brachiopod shell fragments, ramose bryozoans..... 0' 1½"

9. Shale, light gray, weathers yellowish brown, soft, fair consolidation, non-resistant, thin-bedded, transitional and undulating upper contact, sharp and even lower contact, calcareous, crinoid stems..... 0' 3"

8. Limestone, yellowish gray (5Y7/2), weathers yellowish brown, hard, well consolidated, resistant, one bed, sharp and smooth contacts, crinoid stems, very small gastropods, small clams, Osagia..... 0' 5"

Soldier Creek Shale member (1' 7")

7. Shale, yellowish green, weathers grayish green, soft, good consolidation, non-resistant, blocky, sharp and smooth upper contact, gradational and uneven lower contact, carbonaceous material..... 1' 7"

Burlingame Limestone member (11' 9")

6. Limestone, pale yellowish orange (10YR8/6) fresh and weathered, medium hard, good consolidation, resistant, one massive bed, transitional and undulating contacts, "punk bed", unfossiliferous.. 0' 8" 0.7

5. Limestone, dark yellowish orange (10YR6/6), weathers pale yellowish orange, hard, well consolidated, resistant, one bed, transitional and undulating contacts, brachiopods, crinoid stems, ramose and fenestrate bryozoans, gastropods, few small fusulinids..... 0' 10" 0.8

4. Limestone, yellowish gray (5Y7/2), weathers pale yellowish orange, hard, well consolidated, resistant, thick-bedded, brecciated, transitional and undulating contacts, relatively unfossiliferous, zones of Osagia, few brachiopods, Entelates..... 9' 0" 9.0

3. Shale, gray, weathers yellowish gray, soft, fair consolidation, non-resistant, thin-bedded, transitional and undulating contacts, small brachiopods..... 0' 9" 0.8

2. Limestone, light olive gray (5Y6/1), weathers brownish yellow, hard, well consolidated, resis-

tant, one thin bed, transitional and undulating contacts, small gastropods, brachiopods, clams, ramose and fenestrate bryozoans, crinoid stems, Osagia..... 0' 6" 0.5

Scranton Shale

Silver Lake Shale member (1' exposed)

- 1. Shale, gray, weathers yellowish gray, soft, fair consolidation, non-resistant, contains limestone nodules, thin-bedded, transitional and undulating contacts, calcareous..... 1' 0"

Locality B

Sec. 14

NW $\frac{1}{4}$, SE $\frac{1}{4}$, T. 10 S., R. 15 E., Shawnee County; measured along east wall of abandoned quarry. Good exposure.

Thickness
Feet Inches

Auburn Shale (2' exposed)

- 13. Shale, yellowish gray, weathers yellowish brown, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts, calcareous..... 2' 0"

Bern Limestone (22' 9 $\frac{1}{2}$ " exposed)

Waurusa Limestone member (3' 9")

- 12. Limestone, light olive gray (5Y5/2), weathers brownish yellow, hard, well consolidated, resistant, dense, one massive bed, sharp and smooth contacts. crinoid stems, horn corals, brachiopods, small clams, fenestrate bryozoans, few large fusulinids in upper part, abundant Ottonesia, Lophophyllidium, Dictyoclostus..... 1' 11"
- 11. Shale, greenish brown, weathers yellowish brown, soft, good consolidation, non-resistant, thin-bedded, sharp and flat upper contact, transitional and undulating lower contact, calcareous... 0' 7"
- 10. Shale, yellowish orange, fresh and weathered, soft, good consolidation, non-resistant, contains thin lenses of argillaceous limestone, thin-bedded, transitional and undulating contacts, calcareous.. 0' 9"
- 9. Limestone, yellowish gray (5Y7/2), weathers yellow-

ish brown, hard, well consolidated, resistant, dense, one bed, transitional and undulating upper contact, sharp and flat lower contact, crinoid stems, brachiopods, fenestrate and ramose bryozoans, rare fusulinids, Ottensia..... 0' 6"

Soldier Creek Shale member (11' $\frac{1}{2}$ ")

8. Shale, grayish green, weathers yellowish green, medium hard, good consolidation, weakly resistant, blocky, sharp and smooth upper contact, transitional and undulating lower contact, slightly calcareous..... 2' 0"
7. Shale, greenish yellow, weathers yellow, medium hard, good consolidation, weakly resistant, blocky, transitional and uneven contacts, calcareous..... 3' 0"
6. Limestone, grayish red (5R4/2), weathers reddish yellow, hard, well consolidated, resistant, one bed, sharp and undulating contacts, abundant shell fragments, Osagia, small gastropods..... 0' 5"
5. Shale, reddish brown, fresh and weathered, soft, good consolidation, weakly resistant, contains thin lenses of argillaceous limestone, sharp and undulating contacts, calcareous..... 0' 2"
4. Coal, black fresh and weathered, medium hard, non-resistant, impure, mixed with clay, transitional and uneven contacts..... 0' $\frac{1}{4}$ "
3. Shale, gray, weathers yellowish gray, soft, fair consolidation, non-resistant, thin-bedded, sharp and flat contacts..... 3' 8"
2. Shale, dark gray, weathers light gray, soft, good consolidation, non-resistant, fissile, sharp and flat contacts, clams..... 1' 9"

Burlingame Limestone member (8' exposed)

1. Limestone, pale yellowish brown (10YR6/2), weathers yellowish gray, hard, well consolidated, resistant, brecciated, thick-bedded, sharp and undulating contacts, relatively unfossiliferous, rare brach-

lopods, very small gastropods..... 8' 0"

Locality C

E $\frac{1}{2}$, NE $\frac{1}{4}$, Sec. 26, T. 10 S., R. 15 E., Shawnee County; measured on round hill in west part of active quarry. Good exposure.

Thickness
Feet Inches

Auburn Shale (1'± exposed)

13. Shale, brownish gray, weathers yellowish gray, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts, calcareous..... 1' 0"

Bern Limestone (24' 1" exposed)

Wakarusa Limestone member (3' 8")

12. Limestone, pale yellowish brown (10YR6/2), weathers yellowish gray, hard, well consolidated, resistant, one massive bed, sharp and even contacts, abundant crinoid stems, brachiopods, clams, fenestrate and ramose bryozoans, Dictyoclostus, Neospirifer..... 1' 8"
11. Shale, yellowish brown, weathers yellow, soft, poor consolidation, non-resistant, poorly-bedded, sharp and flat contacts, silty, very calcareous... 1' 0"
10. Limestone, pale yellowish orange (10YR8/6), weathers pinkish orange, hard, well consolidated, resistant, one bed, sharp and even contacts, shell fragments, abundant crinoid stems..... 0' 4"
9. Shale, yellowish brown, weathers yellow, soft, poor consolidation, non-resistant, poorly-bedded, sharp and smooth contacts, silty, very calcareous. 0' 1"
8. Limestone, yellowish gray (5Y7/2), weathers grayish orange, hard, well consolidated, resistant, one bed, abrupt and smooth upper contact, gradational and undulating lower contact, crinoid stems, shell fragments, Osagia..... 0' 7"

Soldier Creek Shale member (15' 3")

7. Shale, yellowish brown, weathers light brown, soft, poor consolidation, non-resistant, poorly-bedded,

- gradational and uneven contacts, silty, very calcareous..... 0' 4"
6. Mudstone, yellowish green, weathers light olive, medium hard, good consolidation, weakly resistant, thick-bedded, transitional and uneven contacts, silty, slightly calcareous..... 1' 9"
 5. Shale, dark greenish gray, weathers light yellowish orange, soft, good consolidation, non-resistant, blocky, transitional and uneven contacts, silty, calcareous..... 2' 10"
 4. Limestone, pale yellowish orange, (10YR8/6) fresh and weathered, medium hard, well consolidated, weakly resistant, one massive bed, gradational and undulating contacts, "punk bed", unfossiliferous..... 1' 11"
 3. Limestone, pale yellowish brown (10YR6/2), weathers yellowish orange, hard, well consolidated, resistant, suboolitic, one bed, gradational and uneven upper contact, sharp and smooth lower contact, crinoid stems, shell fragments, gastropods, Csagia..... 0' 6"
 2. Shale, variegated shades of black, gray, green and brown, medium hard, well consolidated, weakly resistant, varies greatly in thickness throughout quarry, thin-bedded, gradational and uneven contacts, carbonaceous material, abundant small clam fragments..... 7' 11"

Burlingame Limestone member (5' 2" exposed)

1. Limestone, pale yellowish brown (10YR6/2), weathers grayish orange, hard, well consolidated, resistant, upper part brecciated, lower part lithographic, thick-bedded, gradational and undulating contacts, relatively unfossiliferous, crinoid stems, brachiopods, clams, rare fusulinids in lower part..... 5' 2"

Locality D

GR-12

S $\frac{1}{2}$, NE $\frac{1}{4}$, Sec. 29, T. 10 S., R. 15 E., Shawnee County; measured along west wall of abandoned quarry. Good exposure.

Thickness
Feet Inches

Bern Limestones (7' 6" exposed)

Soldier Creek Shale member (1' 11" exposed)

5. Limestone, pale yellowish brown (10YR6/2), weathers light brown, hard, well consolidated, resistant, one bed, abrupt and smooth contacts, shell fragments, crinoid stems, rare small fusulinids, Osagia..... 0' 3"
4. Shale, pale olive, weathers greenish yellow, soft, good consolidation, weakly resistant, thin-bedded, abrupt and smooth upper contact, gradational and uneven lower contact, silty, micaceous, carbonaceous material, lower part calcareous..... 1' 8"

Burlingame Limestone member (5' 7" exposed)

3. Limestone, pale brown (5Y5/2), weathers brownish yellow, hard, well consolidated, resistant, brecciated, thick-bedded, gradational and uneven contacts, crinoid stems, very small gastropods..... 4' 10"
2. Shale, light gray, weathers light olive, soft, fair consolidation, non-resistant, medium-bedded, transitional and uneven contacts, silty, calcareous..... 0' 4"
1. Limestone, medium gray (5M), weathers yellowish gray, hard, well consolidated, resistant, one bed, transitional and uneven contacts, slightly argillaceous, crinoid stems, abundant small gastropods, ramose bryozoans, shell fragments, Osagia..... 0' 5"

Locality E *W. Law*

GR-8

(Type Locality of Soldier Creek Shale)

W $\frac{1}{2}$, SW $\frac{1}{4}$. Sec. 19, T. 10 S., R. 15 E., Shawnee County; measured in ditch on east side on north-south road. Fair exposure.

	Thickness Feet Inches
Auburn Shale (1'± exposed)	
10. Shale, covered.....	1' 0"
Bern Limestone (15' 2")	
Wakarusa Limestone member (3' 2")	
9. Limestone, light olive gray (5Y6/2), weathers yellowish gray, hard, well consolidated, one massive bed, abrupt and smooth contacts, abundant crinoid stems, ramose bryozoans, small gastropods, brachiopods, large fusulinids, <u>Ottonosis</u>	1' 11"
8. Shale, dark greenish gray, weathers light gray, soft, poorly consolidated, non-resistant, poorly-bedded, sharp and smooth contacts, calcareous.....	0' 8"
7. Limestone, light olive gray (5Y6/1), weathers yellowish gray, hard, well consolidated, resistant, dense, one bed, abrupt and smooth contacts, crinoid stems, fusulinids, <u>Osagia</u>	0' 7"
Soldier Creek Shale member (9' 3")	
6. Shale, covered.....	2' 7"
5. Limestone, pale yellowish orange (10YR8/6), fresh and weathered, medium hard, good consolidation, weakly resistant, one bed, gradational and undulating contacts, "punk bed", unfossiliferous....	1' 0"
4. Shale, covered.....	5' 8"
Burlingame Limestone member (2' 9")	
3. Limestone, light olive gray (5Y6/1), weathers yellowish gray, hard, well consolidated, resistant, brecciated, thick-bedded, abrupt and undulating contacts, relatively unfossiliferous, rare brachiopods, crinoid stems.....	2' 0"
2. Limestone, yellowish gray (5Y7/2), weathers grayish orange, hard, well consolidated, resistant, one bed, abrupt and undulating contacts, small gastropods, crinoid stems, brachiopods, small fusulinids, <u>Osagia</u>	0' 9"

Scranton Shale

Silver Lake Shale member (1' exposed)

1. Shale, light olive gray, weathers light olive, soft, poor consolidation, non-resistant, poorly bedded, silty..... 1' 0"

Locality F

$S\frac{1}{2}$, $SW\frac{1}{4}$, Sec. 34, T. 10 S., R. 15 E., Shawnee County; measured in roadcut on north side of east-west road. Good exposure.

Thickness
Feet Inches

Bern Limestone (4' exposed)

Burlingame Limestone member (4' exposed)

5. Limestone, pale yellowish brown (10YR6/2), weathers light orange, hard, well consolidated, resistant, brecciated, medium-bedded, sharp and uneven contacts, unusually fossiliferous, crinoid stems, brachiopods, fusulinids..... 3' 2"
4. Shale, grayish orange, weathers light orange, soft, fair consolidation, non-resistant, poorly-bedded, transitional and undulating contacts, calcareous.. 0' 2"
3. Limestone, pale yellowish brown (10YR6/2), weathers light orange, hard, well consolidated, resistant, one bed, sharp and even contacts, upper part fossiliferous, crinoid stems, brachiopods, fusulinids..... 0' 8"

Scranton Shale

Silver Lake Shale member (9' 5" exposed)

2. Shale, yellowish gray, weathers grayish yellow, medium hard, good consolidation, weakly resistant, thin-bedded, sharp and smooth contacts, very calcareous..... 5' 11"
1. Siltstone, yellowish brown, weathers grayish yellow, hard, good consolidation, resistant, thin-bedded, separated by thin silty shale parting, transitional and wavy contacts, calcareous..... 3' 6"

Locality G

56-6

(Type Locality of Silver Lake Shale)

SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 11 T. 11 S., R. 14 E., Shawnee County; measured
in roadcut on north side of east-west road. Good exposure.

	Thickness Feet Inches
Bern Limestone (11' 5" exposed)	
Wakarusa Limestone member (9" exposed)	
18. Limestone, yellowish gray (5Y7/2), weathers grayish brown, hard, well consolidated, resistant, one bed, sharp and even contacts, partially slumped, crinoid stems, brachiopods, abundant <u>Ottenosia</u>	0' 9"
Soldier Creek Shale member (7' 10")	
17. Shale, brownish yellow, weathers yellowish orange, soft, good consolidation, non-resistant, unbedded, sharp and flat upper contact, gradational and undulating lower contact, very calcareous.....	1' 11"
16. Limestone, pale yellowish orange (10YR8/6), fresh and weathered, medium hard, good consolidation, weakly resistant, massive, gradational and uneven contacts, "punk bed", <u>Dictyoclostus</u>	1' 5"
15. Shale, light gray, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven upper contact, abrupt and even lower contact, calcareous.....	4' 2"
14. Coal, black fresh and weathered, impure, lignitic, mixed with clay.....	0' 1"
13. Shale, grayish yellow, weathers yellowish brown, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts.....	0' 3"
Burlingame Limestone member (2' 10")	
12. Limestone, dark yellowish orange (10YR6/6), weathers light yellowish orange, hard, well consolidated, resistant, one bed, sharp and flat contacts, brachiopods, clams, large and small gastropods, ramose bryozoans, <u>Chonetes</u> , <u>Osagia</u>	1' 2"
11. Shale, light brown, weathers grayish orange, soft,	

poorly consolidated, non-resistant, poorly-bedded, sharp and even contacts, calcareous, silty... 0' 8"

10. Limestone, dark yellowish orange (10YR6/6), weathers brownish yellow, hard, well consolidated, resistant, one bed, abrupt and even contacts, becomes thinner and argillaceous to the west, crinoid stems, brachiopods, small gastropods, Derbyia, Dictyocleotus, Osagia..... 1' 0"

Scranton Shale (23' 10" exposed)

Silver Lake Shale member (19' 4")

9. Siltstone, yellowish gray, weathers yellow, medium hard, well consolidated, resistant, thin-bedded, transitional and even contacts, calcareous, separated by shale partings that are brown, weathers yellowish brown, soft, good consolidation, non-resistant, thin-bedded, argillaceous, calcareous..... 9' 11"

8. Sandstone, dark yellowish orange, weathers yellowish gray, hard, good consolidation, resistant, medium grained, cross bedded, sharp and undulating contacts, micaceous..... 1' 1"

7. Shale, black fresh and weathered, soft, good consolidation, non-resistant, fissile, contains kidney-shaped shale masses and rounded cobbles of sandstone, sharp and smooth contacts..... 4' 7"

6. Limestone, medium bluish gray (5B5/1), weathers light orange, hard, well consolidated, resistant, very dense, one bed, sharp and even contacts, argillaceous, crinoid stems, brachiopods, small gastropods..... 0' 7"

5. Shale, olive gray, weathers light gray, soft, fair consolidation, non-resistant, blocky, sharp and smooth contacts, lower part calcareous..... 3' 2"

Rulo Limestone member (8")

4. Limestone, medium bluish gray (5B5/1), weathers yellowish gray, hard, well consolidated, resistant, one bed, sharp and even upper contact, transitional and undulating lower contact, argillaceous, crinoid stems, shell fragments, small gastropods..... 0' 8"

Cedar Vale Shale member (1' 10" exposed)

3. Shale, yellowish orange, weathers yellowish gray, medium hard, good consolidation, weakly resistant, thin-bedded, transitional and uneven contacts, calcareous, crinoid stems, clams, brachiopods..... 0' 8"
2. Elmo Coal, black fresh and weathered, soft, impure, mixed with clay..... 0' 2"
1. Shale, yellowish gray, weathers yellow, soft, fair consolidation, non-resistant, transitional and uneven contacts, plant fossils..... 3' 0"

Locality H

56-4

N $\frac{1}{2}$, Sec. 31, T. 11 S., R. 15 E., Shawnee County; measured in roadcut on north side of U. S. Highway 40. Good exposure.

Thickness
Feet Inches

Auburn Shale (9" exposed)

15. Shale, yellowish gray, weathers orange, soft, good consolidation, non-resistant, thin-bedded, sharp and even contacts, silty..... 0' 9"

Bern Limestone (20' 1")

Wakarusa Limestone member (3' 3")

14. Limestone, yellowish gray (5Y7/2), weathers grayish yellow, hard, well consolidated, resistant, massive, gradational and uneven contacts, crinoid stems, brachiopods, fenestrate and ramose bryozoans, gastropods, Neospirifer, Ottonosia..... 2' 4"
13. Shale, yellowish gray, weathers yellowish orange, soft, good consolidation, non-resistant, very thin-bedded, transitional and wavy contacts, silty, calcareous, small brachiopods, crinoid stems, ramose bryozoans, trilobites in transitional zone with limestone, Ditomopyge..... 0' 6"
12. Limestone, light olive gray (5Y6/1), weathers grayish yellow, hard, well consolidated, resistant, one bed, transitional and uneven contacts, brachiopods, crinoid stems, ramose bryozoans, abundant fusulinids, Osagia..... 0' 6"

Soldier Creek Shale member (10' 7")

11. Shale, light olive gray, weathers yellow, soft, good consolidation, non-resistant, blocky, transitional and undulating contacts, calcareous at top..... 2' 1"
10. Shale, gray, weathers yellowish orange, soft, fair consolidation, non-resistant, unbedded, transitional and uneven contacts, calcareous..... 3' 2"
9. Shale, light orange fresh and weathered, soft, fair consolidation, non-resistant, blocky, transitional and undulating contacts, calcareous..... 0' 6"
8. Mudstone, light yellow, weathers light brown, medium hard, fair consolidation, non-resistant, contains clay pebbles, massive, transitional and undulating contacts, slightly calcareous..... 0' 8"
7. Shale, yellowish green, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, transitional and undulating contacts, calcareous..... 1' 3"
6. Mudstone, light yellow, weathers light brown, medium hard, fair consolidation, non-resistant, contains clay pebbles, massive, transitional and undulating contacts, slightly calcareous..... 0' 4"
5. Shale, greenish gray, weathers yellow, soft, fair consolidation, non-resistant, thick-bedded, transitional and wavy contacts, silty, calcareous at top..... 2' 8"

Burlingame Limestone member (6' 3")

4. Limestone, yellowish gray, (5Y7/2), weathers yellowish orange, hard, well consolidated, resistant, brecciated, thick-bedded, gradational and wavy contacts, relatively unfossiliferous, rare brachiopods..... 2' 0"
3. Shale, light olive, weathers grayish yellow, soft, good consolidation, non-resistant, very thin-bedded, transitional and uneven contacts, calcareous. 0' 2"
2. Limestone, pale yellowish brown (10YR6/2), weathers grayish orange, hard, well consolidated, resistant, brecciated, massive to thick-bedded, transitional and uneven contacts, relatively unfossiliferous except in lowest part, rare gastropods and brachiopods, Enteletes..... 4' 1"

Scranton Shale

Silver Lake Shale member (2'± exposed)

1. Shale, dark gray fresh and weathered, soft, good consolidation, non-resistant, very thin-bedded, gradational and uneven upper contact, sharp and smooth lower contact..... 2' 0"

Locality I

SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 31, T. 11 S., R. 15 E., Shawnee County; measured along extreme south wall of abandoned quarry. Good exposure.

Thickness
Feet Inches

Auburn Shale (1'± exposed)

14. Shale, grayish brown, weathers yellowish brown, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts, silty..... 1' 0"

Bern Limestone (16' 4" exposed)

Wakarusa Limestone member (3' 3")

13. Limestone, dark gray (N5), weathers brownish gray, hard, well consolidated, resistant, one massive bed, sharp and smooth contacts, abundant crinoid stems, brachiopods, gastropods, abundant fusulinids in upper part, trilobites in lower part, Ottonosia, Ditomepyge..... 2' 0"

12. Shale, dark gray, weathers brownish gray, soft, good consolidation, non-resistant, medium-bedded, sharp and smooth upper contact, gradational and uneven lower contact, carbonaceous, calcareous, silty..... 0' 6"

11. Limestone, dark gray (N6), weathers light gray, hard, well consolidated, resistant, one bed, transitional and uneven contacts, crinoid stems, brachiopod fragments, very small gastropods, abundant fusulinids, Osagia..... 0' 9"

Soldier Creek Shale member (7' 5")

10. Shale, dark gray, weathers reddish brown, soft, good consolidation, non-resistant, transitional and uneven contacts..... 0' 10"

9. Mudstone, dark gray, weathers yellowish gray, medium hard, good consolidation, weakly resistant, contains clay pebbles, transitional and undulating contacts, slightly calcareous..... 0' 4"
8. Shale, gray, weathers reddish brown, soft, good consolidation, non-resistant, transitional and uneven contacts..... 0' 10"
7. Mudstone, light gray, weathers grayish white, medium hard, good consolidation, weakly resistant, contains clay pebbles, one massive bed, transitional and undulating contacts, slightly silty..... 1' 8"
6. Shale, greenish gray, weathers brownish gray, soft, well consolidated, non-resistant, blocky, transitional and uneven contacts..... 2' 2"
5. Mudstone, light greenish brown, weathers light brown, medium hard, well consolidated, resistant, medium-bedded, gradational and uneven upper contact, sharp and smooth lower contact, very calcareous, abundant fossils on bedding planes, abundant clams, rare productid brachiopods and crinoid stems, Derlyia..... 0' 11"
4. Shale, yellowish gray, weathers orange, soft, good consolidation, non-resistant, medium-bedded, gradational and undulating contacts, calcareous... 0' 8"

Burlington Limestone member (5' 8" exposed)

3. Limestone, yellowish gray (5Y7/2), weathers grayish orange, hard, well consolidated, resistant, brecciated, one massive bed, transitional and undulating contacts, abundant chalcopryrite and pyrite, relatively unfossiliferous, brachiopod fragments, rare crinoid stems, rare small gastropods..... 1' 8"
2. Shale, light olive gray, weathers yellowish brown, soft, good consolidation, non-resistant, thick-bedded, transitional and uneven contacts, silty, calcareous..... 0' 4"
1. Limestone, medium light gray (N6), weathers grayish orange, hard, well consolidated, resistant, brecciated, massive to thick-bedded, transitional and wavy contacts, pyrite abundant, relatively unfossiliferous, lower part, contains small gastropods, ramose bryozoans, and brachiopods..... 3' 8"

Locality J

SL-7

NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 34, T. 11 S., R. 14 E., Shumee County; measured
in roadcut on south side of service road at beginning of curve on
Hickory Knob. Good exposure.

Thickness
Feet Inches

Auburn Shale (22' 6" exposed)

19. Shale, covered..... 1' 0"
18. Limestone, pale yellowish orange (10YR8/6), weathers
grayish orange, hard, good consolidation, resis-
tant, one massive bed, transitional and uneven
contacts, sandy, abundant broken shell fragments
and large and small gastropods..... 1' 6"
17. Shale, covered..... 0' 2"
16. Limestone, pale yellowish orange (10YR8/6), weathers
grayish orange, medium hard, good consolidation,
resistant, one bed, transitional and undulating
contacts, sandy, abundant shell fragments and
large and small gastropods..... 0' 5"
15. Shale, covered..... 1' 5"
14. Limestone, pale yellowish orange, (10YR8/6), weathers
grayish orange, hard, medium consolidation, resis-
tant, one bed, gradational and uneven contacts,
sandy, abundant shell fragments and large and
small gastropods..... 1' 0"
13. Shale, partially covered..... 17' 0"

Bern Limestone (17' 8")

Wakarusa Limestone member (3' 9")

12. Limestone, light olive gray, (5Y5/2), weathers
yellowish gray, hard, well consolidated, resis-
tant, one massive bed, transitional and slightly
uneven contacts, crinoid stems, shell fragments,
ramose bryozoans, Osagia, Ottenosia..... 2' 6"
11. Shale, medium gray, weathers yellowish gray, soft,
good consolidation, non-resistant, contains thin
limestone lenses at top and bottom, thin-bedded,
transitional and uneven contacts, very calcareous,

- slightly micaceous, clams..... 0' 8"
10. Limestone, pale yellowish brown (10YR6/2), weathers yellowish gray, hard, well consolidated, resistant, one bed, gradational and slightly uneven contacts, crinoid stems, shell fragments, ramose bryozoans, small gastropods, abundant fusulinids, Osagia..... 0' 7"

Soldier Creek Shale member (11' 6")

9. Shale, greenish gray, weathers yellowish gray, soft, fair consolidation, non-resistant, thin-bedded, transitional and uneven contacts, silty, slightly micaceous..... 2' 3"
8. Mudstone, light gray, weathers yellowish gray, medium hard, good consolidation, weakly resistant, contains clay pebbles, one bed, transitional and undulating contacts, slightly calcareous..... 1' 6"
7. Shale, light bluish gray, weathers yellowish gray, medium hard, good consolidation, weakly resistant, contains thin mudstone layers that make up almost half of the thickness, transitional and uneven contacts, slightly micaceous, slightly calcareous, silty..... 3' 5"
6. Mudstone, gray, weathers yellowish gray, medium hard, well consolidated, weakly resistant, one bed, contains fine color laminations, gradational and flat contacts, very calcareous, abundant pyrite, clam fragments..... 0' 5"
5. Shale, medium gray, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, sharp and flat contacts, silty, micaceous..... 3' 11"

Burlingame Limestone member (2' 5")

4. Limestone, pale yellowish brown (10YR6/2), weathers greenish brown, hard, well consolidated, resistant, one bed, slightly brecciated, sharp and even upper contact, gradational and uneven lower contact, relatively unfossiliferous, shell fragments..... 0' 7"
3. Limestone, yellowish gray (5Y7/2), weathers brownish yellow, hard, well consolidated, resistant, one bed, transitional and uneven contacts, crinoid stems, shell fragments, small gastropods, ramose bryozoans, abundant small fat fusulinids, abundant Osagia..... 0' 10"

- 2. Limestone conglomerate, light bluish gray (5B7/1), subrounded limestone pebbles in a dark bluish gray (5B4/1) osagite matrix, weathers mottled shades of yellow and brown, hard, well consolidated, resistant, unsorted, breaks through the pebbles, one bed, transitional and undulating upper contact, abrupt and even lower contact, very abundant Osagia..... 1' 0"

Scranton Shale

Silver Lake Shale member (5'+ exposed)

- 1. Shale, light bluish gray, weathers gray, soft, good consolidation, non-resistant, thin-bedded, abrupt and flat contacts, silty, micaceous..... 5' 0"

Locality K

56-8

SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 3, T. 12 S., R. 14 E., Shames County; measured along south wall of active quarry near road and on both sides of east-west road between Sec. 3 and Sec. 10. Good exposure.

Thickness
Feet Inches

Auburn Shale (1'+ exposed)

- 16. Shale, yellowish gray, weathers orange, soft, good consolidation, non-resistant, thin-bedded, sharp and smooth contacts..... 1' 0"

Bern Limestone (17' 1 $\frac{1}{2}$ ")

Wakarusa Limestone member (3' 6")

- 15. Limestone, medium gray (N5), weathers yellowish gray, hard, well consolidated, resistant, one massive bed, very dense, sharp and flat contacts, small crinoid stems, brachiopod fragments, fusulinids in upper part..... 2' 6"
- 14. Shale, gray, weathers yellowish gray, soft, good consolidation, non-resistant, medium-bedded, sharp and smooth contacts, silty, calcareous..... 0' 7"
- 13. Limestone, light olive gray (5Y6/1), weathers yellowish gray, hard, well consolidated, resistant, one bed, sharp and even contacts, crinoid stems, brachiopods, abundant fusulinids,

Composita, Osagia..... 0' 5"

Soldier Creek Shale member (8' 1/2")

12. Shale, gray, weathers orange, soft, good consolidation, non-resistant, blocky, sharp and even upper contact, gradational and uneven lower contact..... 3' 3"
11. Shale, light gray, weathers yellowish gray, soft, good consolidation, non-resistant, contains thin beds and nodules of argillaceous limestone and mudstone, medium-bedded, transitional and undulating contacts, silty..... 1' 1"
10. Mudstone, light gray, weathers brownish gray, medium hard, good consolidation, weakly resistant, nodular in part, thick-bedded, transitional and uneven contacts, slightly calcareous, silty..... 2' 8"
9. Limestone, very light gray (N8), weathers yellowish gray, hard, good consolidation, resistant, dense, one bed, transitional and even contacts, argillaceous, very abundant pyrite, rare shell fragments..... 0' 5"
8. Shale, light gray, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, transitional and even upper contact, abrupt and flat lower contact, micaceous, silty..... 0' 6"
7. Gypsum, transparent fresh and weathered, soft, good consolidation, non-resistant, interbedded with calcareous shale, thickly laminated, sharp and smooth contacts, selenite..... 0' 1 1/2"

Burlingame Limestone member (5' 7")

6. Limestone, grayish orange pink (5YR7/2), weathers yellowish gray, hard, well consolidated, resistant, brecciated, grades from highly brecciated at top to slightly brecciated and somewhat similar to Unit 5 at base, thick-bedded to massive, very transitional and undulating contacts, relatively unfossiliferous, rare crinoid stems and Neospirifer in lower part, small gastropods... 4' 1"
5. Limestone, yellowish gray (5Y7/2), weathers yellowish gray, hard, well consolidated, resistant, one bed, sharp and uneven contacts, brachiopods, small gastropods, crinoid stems, abundant small fat fusulinids, abundant Osagia..... 0' 4"

- 4. Shale, yellowish gray, weathers orange, soft, poor consolidation, non-resistant, poorly bedded, sharp and undulating contacts, silty, calcareous.. 0' 3"
- 3. Limestone, pale yellowish brown (10YR6/2), weathers brownish yellow, hard, well consolidated, resistant, grades from limestone conglomerate at base to conglomeric limestone at top, one bed, sharp and uneven contacts, most fossiliferous at top, very abundant clams and gastropods and Osagia..... 1' 11"

Scranton Shale

Silver Lake Shale member (11' 4" exposed)

- 2. Shale, greenish gray, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, smooth and sharp contacts, calcareous.....1' 4"
- 1. Limestone, grayish orange (10YR7/4), weathers yellowish brown, medium hard, good consolidation, weakly resistant, separated by thin layers of silty shale, thin-bedded, gradational and even contacts, very silty, sandy, argillaceous, micaceous..... 10' 0"

Locality 1.

SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 34, T. 12 S., R. 15 E., Shawnee County; measured in roadcut on northwest side of Kansas Turnpike. Good exposure.

Thickness
Feet Inches

Auburn Shale (1'± exposed)

- 14. Shale, covered..... 1' 0"

Bern Limestone (15' 6")

Wakarusa Limestone member (3' 8")

- 13. Limestone, pale yellowish brown (10YR6/2), weathers grayish orange, hard, well consolidated, resistant, one massive bed, sharp and flat upper contact, transitional and uneven lower contact, crinoid stems, gastropods, brachiopods, large fusulinids very abundant in middle and rare in upper and lower, Osagia, Ottonosia..... 1' 11"

12. Limestone, moderate yellowish brown (10YR5/4), weathers dark yellowish orange, hard, well consolidated, resistant, nodular, transitional and very uneven contacts, crinoid stems abundant.....0' 5"
11. Shale, pale olive, weathers yellowish brown, soft, fair consolidation, non-resistant, thin-bedded, transitional and uneven contacts, calcareous, crinoid stems..... 0' 6"
10. Limestone, yellowish gray (5Y7/2), weathers grayish yellow, hard, well consolidated, resistant, one bed, gradational and even upper contact, sharp and smooth lower contact, crinoid stems, brachiopods, rare small fusulinids, abundant Osagia..... 0' 10"

Soldier Creek Shale member (10')

9. Shale, pale olive and yellow variegated, weathers grayish yellow, soft, fair consolidation, non-resistant, medium-bedded, sharp and smooth contacts, some calcareous zones, silty, horn corals. 7' 5"
8. Limestone, pale olive (10Y6/2), weathers grayish yellow, medium hard, well consolidated, resistant, dense, thin-bedded, abrupt and very smooth contacts, very argillaceous, clams..... 0' 7"
7. Shale, black, weathers grayish black, soft, fair consolidation, non-resistant, fissile, upper contact abrupt and flat, lower contact gradational and uneven, carbonaceous, clams, Lingula..... 1' 9"
6. Shale, light olive gray, weathers yellowish gray, soft, poor consolidation, non-resistant, medium-bedded, transitional and uneven contacts, calcareous, clams, fenestrate bryozoans..... 0' 3"

Burlingame Limestone member (1' 10")

5. Limestone, medium light gray (N6), weathers yellowish gray, medium hard, well consolidated, resistant, medium to thin-bedded, gradational and uneven contacts, silty, argillaceous, brachiopods, crinoid stems, rare small gastropods, ramose bryozoans, small fat fusulinids most abundant in upper part, Osagia most abundant in lower part..... 0' 9"
4. Shale, yellowish brown, weathers yellowish gray,

soft, poor consolidation, non-resistant, thin-bedded, gradational and undulating contacts, calcareous..... 0' 2"

3. Limestone, medium gray (N5), weathers greenish gray, hard, well consolidated, resistant, one bed, sharp and flat upper contact, gradational and uneven lower contact, argillaceous, brachiopods, ramose bryozoans, crinoid stems, Neospirifer, Osagia.....0' 11"

Scranton Shale

Silver Lake Shale member (6' 8" exposed)

2. Shale, light brown, weathers yellowish brown, soft, fair consolidation, non-resistant, thin-bedded gradational and uneven contacts, calcareous..... 2' 0"
1. Shale, black, weathers gray, soft, good consolidation, non-resistant, thin-bedded, gradational and flat contacts, carbonaceous..... 4' 8"

Locality M

(Type Locality of Wakarusa Limestone)

Sec. 23, T. 13 S., R. 14 E., Shawnee County; measured in roadcuts and roadside ditches on both sides of half section road west of Auburn on both sides of the North Branch of Wakarusa River.

Fair exposure.

Thickness
Feet Inches

Bern Limestone (14' 7" exposed)

Wakarusa Limestone member (3' 7" exposed)

13. Limestone, light olive gray (5Y6/1), weathers yellowish brown, hard, well consolidated, resistant, one massive bed, transitional and flat contacts, crinoid stems, very abundant large fusulinids, Osagia, Ottonosia..... 1' 4"
12. Limestone, light olive gray (5Y6/1), weathers yellowish brown, hard, well consolidated, resistant, one thick bed, transitional and uneven upper contact, sharp and smooth lower contact, crinoid stems,

horn corals, brachiopods, small gastropods,
Caninia, Lophophyllidium..... 0' 9"

11. Shale, yellowish brown, weathers yellow, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts, calcareous..... 0' 9"
10. Limestone, light olive gray (5Y6/1), weathers yellowish gray, hard, well consolidated, resistant, one thick bed, sharp and flat contacts, grinoid stems, ramose bryozoans, brachiopods, abundant Ottonosia encrusting horn corals and Dictyoclostus, Osagia.. 1' 10"

Soldier Creek Shale member (8' 6")

9. Shale, dark yellowish orange, weathers orange, soft, poor consolidation, non-resistant, poorly-bedded, transitional and uneven contacts, calcareous..... 1' 1"
8. Limestone, grayish orange (10YR7/4), weathers yellowish orange, medium hard, good consolidation, resistant, medium to thin-bedded, gradational and uneven contacts, contains thin calcareous shale partings..... 0' 9"
7. Shale, dark yellowish orange, weathers orange, soft, poor consolidation, non-resistant, poorly-bedded, transitional and uneven contacts, calcareous..... 0' 9"
6. Limestone, dark yellowish orange (10YR6/6), weathers light yellowish orange, hard, well consolidated, resistant, thin-bedded, transitional and uneven upper contact, abrupt and flat lower contact..... 1' 0"
5. Shale, grades from dark gray at base to olive gray at top, weathers greenish gray, soft, good consolidation, non-resistant, thin-bedded, sharp and flat contacts, micaceous, upper part slightly sandy..... 4' 11"

Burlingame Limestone member (2' 6")

4. Limestone, medium gray (N5), weathers grayish orange, hard, well consolidated, resistant, one bed, transitional and even contacts, silty, argillaceous, brachiopods, abundant fusulinids, Osagia..... 0' 9"
3. Limestone, medium gray (N5), weathers grayish orange, hard, well consolidated, resistant, one bed, transitional and even contacts, abundant pyrite, argillaceous, brachiopods, gastropods,

crinoid stems, fenestrate bryozoans,
Neospirifer, Dictyodictya, abundant Osagia..... 0' 9"

2. Limestone, light olive gray (5Y6/1), weathers yellowish gray, medium hard, good consolidation, resistant, medium to poorly-bedded, transitional and undulating contacts, very argillaceous and silty, small gastropods, abundant Osagia..... 1' 0"

Scranton Shale

Silver Lake Shale member (3'+ exposed)

1. Shale, grayish olive, weathers olive brown, soft, fair consolidation, non-resistant, blocky, transitional and uneven contacts, silty..... 3' 0"

Locality II

SE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 27, T. 13 S., R. 14 E., Shames County, measured in ditch on west side of north-south road and in small stream about 200 feet west of road. Poor exposure.

Thickness
 Feet Inches

Auburn Shale (1'+ exposed)

11. Shale, covered..... 1' 0"

Bern Limestone (16' 4")

Wakarusa Limestone member (3' 2")

10. Limestone, light olive gray (5Y6/1), weathers yellowish gray, hard, well consolidated, resistant, massive, sharp and even contacts, crinoid stems, brachiopods, small gastropods, abundant large fusulinids, Osagia, Eteletes..... 1' 9"
9. Shale, yellowish gray, weathers yellow, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts, calcareous, abundant crinoid stems..... 0' 9"
8. Limestone, greenish gray (5GY6/1), weathers yellowish gray, hard, well consolidated, resistant, one bed, sharp and even contacts, crinoid stems, small gastropods, small fusulinids, brachiopods, ranose bryozoans, Ottonosia, encrusting horn corals. 0' 8"

Soldier Creek Shale member (10' 6")

7. Shale, greenish gray, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, sharp and even contacts, slightly calcareous..... 2' 3"
6. Limestone, pale yellowish orange (10YR8/6) fresh and weathered, medium hard, good consolidation, weakly resistant, contains thin layers and lenses of sand especially in lower part, thin-bedded, sharp and smooth contacts, "punk bed"..... 2' 11"
5. Shale, greenish gray, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, sharp and fiat contacts..... 5' 4"

Burlingame Limestone member (2' 8")

4. Limestone, pale yellowish brown (10YR6/2), weathers greenish brown, hard, well consolidated, resistant, thin-bedded, abrupt and even upper contact, gradational and uneven lower contact, crinoid stems, ramose bryozoans, brachiopods, small fat fusulinids, Osagia..... 0' 10"
3. Limestone, dark gray (N3), weathers yellowish gray hard, good consolidation, resistant, suboolitic, thin-bedded, transitional and uneven contacts, small gastropods, ramose bryozoans, crinoid stems, abundant Osagia..... 0' 10"
2. Limestone, light olive gray (5Y6/1), weathers yellowish gray, medium hard, good consolidation, weakly resistant, interbedded with shale increasing downward, thin-bedded, nodular in part, very gradational and undulating contacts, silty, argillaceous, crinoid stems, small gastropods, brachiopod fragments, clams, Osagia..... 1' 0"

Scranton Shale

Silver Lake Shale member (3'+ exposed)

1. Shale, greenish gray, weathers light gray, soft, good consolidation, non-resistant, blocky, very transitional contacts, calcareous..... 3' 0"

Locality O

SE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 34, T. 13 S., R. 14 E., Shawnee County; measured in ditch on north side of east-west road just west of curve. Poor exposure.

	Thickness Feet Inches
Bern Limestone (13' 7" exposed)	
Wakarusa Limestone member (10" exposed)	
7. Limestone, moderate yellowish brown (10YR5/4), weathers orange, hard, well consolidated, resistant, one bed, transitional and uneven contacts, abundant crinoid stems, brachiopod fragments, clams...	0' 10"
Soldier Creek Shale member (10' 11")	
6. Shale, covered.....	4' 6"
5. Limestone, light olive gray (5Y6/1), weathers yellowish brown, hard, well consolidated, resistant, reefoid, coquinaid, thick-bedded, sharp and uneven contacts, silty, sandy, lower part micaceous, shell material highly broken, very abundant clams and varied gastropods cemented together by algae..	1' 5"
4. Shale, covered.....	5' 0"
Burlingame Limestone member (1' 10")	
3. Limestone, light olive gray (5Y6/1), weathers yellowish brown, hard, well consolidated, resistant, thick-bedded, transitional and uneven contacts, crinoid stems, brachiopods, clams, small gastropods, ramose bryozoans, small fat fusulinids, <u>Osagia</u>	1' 10"
Scranton Shale	
Silver Lake Shale member (6' 11" exposed)	
2. Shale, greenish gray, weathers grayish brown, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven upper contact, sharp and flat contact.....	3' 2"
1. Siltstone, reddish brown, weathers brownish yellow, medium hard, good consolidation, weakly resistant, thin-bedded, sharp and flat contacts, argillaceous, calcareous.....	2' 9"

Locality P

W $\frac{1}{2}$, Sec. 25, T. 13 S., R. 14 E., Shawnee County; measured in roadcut on both sides of north-south road on south bank of Wakarusa River near center of section. Good exposure.

Thickness
Feet Inches

Bern Limestone (8' 6" exposed)

Soldier Creek Shale member (6' 3" exposed)

5. Limestone, pale yellowish brown (10YR6/2), weathers yellowish brown, hard, well consolidated, resistant, reefoid, coquinoid, thick-bedded, abrupt and uneven contacts, very abundant mytiloid clams, abundant small and large gastropods..... 4' 4"
4. Shale, greenish gray, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, sharp and uneven contacts, decreases in thickness to the south..... 1' 11"

Burlingame Limestone member (2' 3")

3. Limestone, medium gray (N5), weathers yellowish brown, hard, well consolidated, resistant, thick-bedded, sharp and flat upper contact, gradational and uneven lower contact, argillaceous, lower part grades into shale to the southwest, crinoid stems, brachiopods, abundant Osagia, Derbyia..... 2' 3"

Scranton Shale

Silver Lake Shale member (5' 11" exposed)

2. Shale, greenish gray, weathers grayish brown, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven upper contact, sharp and flat lower contact, calcareous at top..... 3' 7"
1. Siltstone, light gray, weathers light brown, hard, well consolidated, weakly resistant, thin-bedded, sharp and smooth contacts, sandy, very calcareous, argillaceous..... 1' 4"

Locality Q

NE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 25, T. 13 S., R. 14 E., Shawnee County; measured

in roadcut on northwest side of the Kansas Turnpike by H. W. Miller of the State Geological Survey of Kansas. The upper part of this section was later removed for completion of the turnpike. Good exposure.

A-10

	Thickness Feet Inches
Bern Limestone (21' 4" exposed)	
Wakarusa Limestone member (3" exposed)	
6. Limestone, light olive gray (5Y6/1), weathers in grayish orange flattened plates, hard, cryptocrystalline, highly fossiliferous, brachiopod fragments, gastropods, ramose bryozoans, crinoid stems, fusulinids, <u>Osagia</u>	0' 3"
Soldier Creek Shale member (14' 7")	
5. Shale, dusky yellow, weathers grayish yellow, slightly sandy, calcareous, non-fossiliferous.....	1' 6"
4. Limestone, yellowish gray (5Y7/2), weathers dark yellowish orange, coarsely crystalline, well-bedded, more massive in lower part, almost coquina, exposure contains a clay parting of 0"-18" in thickness 30" above the base of the limestone, not present in part of exposure, clay is olive gray, weathers grayish yellow, contains streaks of pyrite, contains brachiopods, pelecypods and <u>Aviculopecten</u> , limestone contains nautiloid cephalopods, gastropods, pelecypods, brachiopods, crinoid stems, fusulinids, <u>Nyalina</u> , <u>Aviculopecten</u>	10' 6"
3. Siltstone, grayish olive, weathers yellowish gray, blocky, slightly sandy, upper 5" in places is more argillaceous and contains highly calcareous streaks, unfossiliferous.....	2' 7"
Burlingame Limestone member (6' 6")	
2. Limestone, light gray (N7), weathers dark yellowish orange, thin-bedded, micaceous, thin interbeds of shale between limestone beds.....	6' 6"

Scranton Shale

Silver Lake Shale member (8' 10" exposed)

1. Siltstone, very light gray, weathers light gray, blocky, with thin interbeds of fissile shale and limestone bed 10" thick in upper part, brachiopods, clams..... 8' 10"

Locality R

SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 26, T. 13 S., R. 14 E., Shawnee County; measured in roadcut on small road that passes under the Kansas Turnpike on the southeast side of the South Branch of Wauharusa River. Good exposure.

Thickness
Feet Inches

Bern Limestone (11' 11" exposed)

Soldier Creek Shale member (10' 4")

13. Limestone, pale yellowish brown (10YR6/2), weathers dark yellowish orange, hard, well consolidated, resistant, reefoid, coquinoid, thick-bedded, sharp and uneven contacts, contains a tongue of breccia with reef fragments and foreign material in a light-colored matrix near the center, very abundant mytiloid clams and assorted gastropods throughout, ramose bryozoans in central part, rare fusulinids in lower part..... 10' 4"

Burlingame Limestone member (1' 7")

12. Limestone, moderate yellowish brown (10YR5/4), weathers brownish yellow, hard, well consolidated, resistant, one bed, abrupt and undulating contacts, crinoid stems, brachiopods, ramose bryozoans, small gastropods, small fat fusulinids..... 0' 9"
11. Shale, moderate brown, weathers orange, soft, poor consolidation, non-resistant, thin-bedded, transitional and uneven contacts, silty, calcareous.... 0' 2"
10. Limestone, pale yellowish brown (10YR6/2), weathers yellowish orange, hard, well consolidated, resistant, one thin bed, gradational and uneven contacts, crinoid stems, ramose bryozoans, small gastropods, brachiopods, Osagia..... 0' 3"

9. Shale, moderate brown, weathers orange, soft, poor consolidation, non-resistant, thin-bedded, gradational and uneven contacts, silty, calcareous..... 0' 2"

8. Limestone, pale yellowish brown (10YR6/2), weathers yellowish orange, hard, well consolidated, resistant, one thin bed, transitional and uneven contacts, crinoid stems, abundant small gastropods, brachiopods, Osagin..... 0' 3"

Scranton Shale (36' 5" exposed)

Silver Lake Shale member (33' 3")

7. Shale, grayish green, weathers grayish brown, soft, good consolidation, non-resistant, blocky, gradational and uneven upper contact, sharp and smooth lower contact, calcareous at top..... 2' 9"
6. Siltstone, reddish brown, weathers brown, medium hard, good consolidation, weakly resistant, interbedded with calcareous shale, thin-bedded, sharp and even contacts, sandy, argillaceous, calcareous..... 4' 8"
5. Shale, brownish gray, weathers brown, soft, good consolidation, non-resistant, medium-bedded to blocky, sharp and even contacts, carbonaceous material..... 25' 10"

Rule Limestone member (1' 6")

4. Limestone, dusky yellow (5Y6/4), weathers grayish brown, hard, well consolidated, resistant, one massive bed, sharp and even contacts, argillaceous, crinoid stems, brachiopods, clams, fenestrate bryozoans, rare fusulinids..... 1' 6"

Cedar Vale Shale member (1' 8" exposed)

3. Shale, yellowish gray, weathers orange, soft, fair consolidation, non-resistant, thin-bedded, sharp and smooth contacts, calcareous..... 0' 6"
2. Elmo coal, black fresh and weathered, soft, impure.. 0' 2"
1. Shale, gray, weathers yellowish gray, soft, good consolidation, non-resistant, blocky, gradational and uneven upper contact..... 1' 0"

Locality S

N $\frac{1}{2}$, SW $\frac{1}{4}$, Sec. 25, T. 13 S., R. 14 E., Shawnee County; measured
in roadcut on southeast side of Kansas Turnpike. Good exposure.

Thickness
Feet Inches

Bern Limestone (10' exposed)

Soldier Creek Shale member (9-10' exposed)

4. Limestone, light brown (5TR6/4), weathers brown, hard, well consolidated, resistant, reefoid, coquinaid, thick-bedded, lower contact unconformable, reef limestone rests in part on lower Burlingame Limestone and in part on upper Silver Lake Shale, weathered zone along unconformity, contains some rounded limestone fragments, abundant mytiloid clams and assorted gastropods throughout, rare ramose bryozoans and fusulinids in lower part, Kenacanthus (shark) teeth..... 10' maximum

Burlingame Limestone member (0-1' exposed)

3. Limestone, medium gray (N5), weathers yellowish gray, hard, well consolidated, resistant, one bed, unconformable upper contact, gradational and uneven lower contact, crinoid stems, brachiopods, abundant Osagia..... 1' maximum

Seranton Shale

Silver Lake Shale member (14' 2" exposed)

2. Shale, grayish green, weathers light brown, soft, fair consolidation, non-resistant, thin-bedded, gradational and uneven upper contact, sharp and flat lower contact, upper part calcareous..... 2' 2"
1. Siltstone, light gray, weathers brownish gray, medium hard, well consolidated, resistant, thin-bedded, sharp and even contacts, sandy, argillaceous, calcareous, micaceous..... 12' 0"

Locality T

NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 1, T. 14 S., R. 14 E., Osage County; measured
in roadcut on east side of north-south road just south of small
stream. Fair exposure.

Thickness
Feet Inches

Bern Limestone (7' exposed)

Soldier Creek Shale member (4' 8" exposed)

5. Limestone, moderate yellowish brown (10YR5/4), weathers dark brown, hard, good consolidation, resistant, thin-bedded, sharp and uneven contacts, very sandy, micaceous, mytiloid clams..... 1' 0"
4. Shale, olive green, weathers brown, soft, good consolidation, non-resistant, medium-bedded, sharp and uneven upper contact, sharp and even lower contact..... 3' 8"

Burlingame Limestone member (2' 4")

3. Limestone, yellowish gray (5Y7/2), weathers yellowish gray, hard, well consolidated, resistant, one massive bed, abrupt and smooth upper contact, uneven and transitional lower contact, crinoid stems, small gastropods, rare bryozoans, small fat fusulinids, Osagia..... 1' 7"
2. Limestone, light olive gray (5Y6/1), weathers yellowish brown, hard, good consolidation, resistant, grades from medium-bedded at top to nodular at base, uneven and very transitional contacts, lower part silty and argillaceous, crinoid stems, shell fragments, small gastropods, abundant Osagia 0' 9"

Scranton Shale

Silver Lake Shale member (10"+exposed)

1. Shale, brown, weathers light brown, soft, fair consolidation, non-resistant, poorly-bedded, very transitional contacts, calcareous, upper part contains limestone nodules..... 0' 10"

Locality U

SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 1, T. 14 S., R. 14 E., Osage County; measured in roadcut and ditch on east side of north-south road just south of small stream. Fair exposure.

	Thickness Feet Inches
Auburn Shale (30'+ exposed)	
6. Covered, shale (?).....	30' 0"
Bern Limestone (7' 9" exposed)	
Soldier Creek Shale member (5' 10")	
5. Limestone conglomerate, yellowish gray (5Y7/2), weathers yellowish brown, hard, well consolidated, resistant, medium-grained, rounded to subrounded particles of limestone and reef material in a calcareous algal matrix, sharp and uneven contacts, micaceous, shell fragments...	1' 1"
4. Covered, shale (?).....	0' 10"
3. Limestone, yellowish gray (5Y7/2), weathers yellowish brown, hard, well consolidated, resistant, reefoid, coquinoid, thick-bedded, sharp and uneven contacts, some sandy zones in lower part, upper part entirely sandy, very abundant mytiloid clams and assorted gastropods.....	3' 11"
2. Shale, grayish green, weathers grayish brown, soft, good consolidation, non-resistant, thick-bedded, sharp and even contacts, slightly micaceous.....	0' 11"
Burlingame Limestone member (1' exposed)	
1. Limestone, grayish orange (10YR7/4), weathers brown, hard, well consolidated, resistant, one bed, sharp and even contacts, crinoid stems, small gastropods, abundant small fat fusulinids, abundant <u>Osagia</u>	1' 0"

Locality V

NE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 5, T. 14 S., R. 15 E., Osage County; measured in roadcut and ditch on northwest side of road. Fair exposure.

	Thickness Feet Inches
Bern Limestone (10' exposed)	

Soldier Creek Shale member (3' 11" exposed)

14. Covered

13. Limestone, pale yellowish brown, (10YR6/2), weathers yellowish gray, hard, well consolidated, resistant, reefoid, coquinoid, thick-bedded, sharp and uneven contacts, contains a few limestone fragments, abundant mytiloid clams and assorted gastropods throughout, lower contact unconformable..... 3' 11"

Burlingame Limestone member (6' 1")

12. Limestone, dark yellowish orange (10YR6/6) fresh and weathered, medium hard, good consolidation, weakly resistant, very badly weathered, upper contact unconformable, thin-bedded, sharp and uneven contacts, iron stain producing "pseudo cross-bedding", shell fragments..... 1' 6"
11. Shale, greenish gray, weathers brown, soft, fair consolidation, non-resistant, medium-bedded, sharp and uneven contacts, calcareous, silty..... 0' 2"
10. Limestone, grayish orange (10YR7/4), weathers light yellowish gray, hard, well consolidated, resistant, medium-bedded, sharp and uneven contacts, crinoid stems, small gastropods, shell fragments, ramose bryozoans, abundant small fat fusulinids, Osagia..... 3' 1"
9. Limestone, pale yellowish brown (10YR6/2), weathers brownish yellow, hard, well consolidated, resistant, thick-bedded, sharp and uneven contacts, crinoid stems, fenestrate bryozoans, small gastropods, abundant Osagia..... 0' 4"
8. Shale, brown fresh and weathered, soft, fair consolidation, non-resistant, blocky, sharp and uneven contacts, calcareous, silty..... 0' 2"
7. Limestone, pale yellowish brown (10YR6/2), weathers brownish yellow, hard, well consolidated, resistant, one bed, sharp and uneven contacts, crinoid stems, fenestrate bryozoans, small gastropods, abundant Osagia..... 0' 2"
6. Shale, brown fresh and weathered, soft, fair consolidation, non-resistant, blocky, sharp and uneven contacts, silty, calcareous..... 0' 2"
5. Limestone, pale yellowish brown (10YR6/2), weathers yellowish brown, hard, well consolidated, resistant, one thin bed, sharp and uneven contacts, crinoid stems, ramose bryozoans, brachiopods, small gastropods, abundant Osagia..... 0' 1"

4. Shale, brown fresh and weathered, soft, fair consolidation, non-resistant, blocky, sharp and uneven contacts, silty, calcareous..... 0' 3½"
3. Limestone, yellowish gray (5Y7/2), weathers yellowish brown, hard, well consolidated, resistant, one thin bed, sharp and uneven contacts, crinoid stems, brachiopods, clams, abundant small gastropods, abundant Osagia, Dictyoclostus, Chonetes, Neospirifer, Aviculopecten..... 0' 1½"

Scranton Shale

Silver Lake Shale member (22' exposed)

2. Shale, olive green, weathers greenish gray, soft, good consolidation, non-resistant, blocky, sharp and uneven contacts, slightly silty..... 4' 0"
1. Siltstone, grayish green, weathers yellowish green, hard, well consolidated, weakly resistant, thin-bedded, sharp and uneven contacts, calcareous, argillaceous, sandy, clams..... 18' 0"

Locality W

SW¼, SE¼, Sec. 25, T. 14 S., R. 14 E., Osage County; measured in small stream just north of east-west road. Poor exposure.

Thickness
Feet Inches

Bern Limestone (15' 10" exposed)

Wakarusa Limestone member (4' 9" exposed)

4. Limestone, pale yellowish brown (10YR6/2), weathers yellowish gray, hard, well consolidated, resistant, one massive bed, transitional and uneven contacts, crinoid stems, gastropods, abundant large fusulinids, Ottonosia..... 1' 11"
3. Limestone, pale yellowish brown (10YR6/2), weathers yellowish brown, hard, well consolidated, resistant, one massive bed, transitional and undulating contacts, brachiopods, ramose bryozoans, abundant crinoid stems..... 2' 10"

Soldier Creek Shale member (6' 7")

2. Shale, yellow, weathers yellowish orange, soft,

poor consolidation, non-resistant, thin-bedded, transitional and uneven contacts, silty, upper part calcareous and contains shell fragments..... 6' 7"

Burlingame Limestone member (1' 6" exposed)

1. Limestone, pale yellowish brown (10YR6/2), weathers yellowish brown, hard, well consolidated, resistant, one massive bed, transitional and undulating contacts, crinoid stems, brachiopods, ramose bryozoans, large algal bodies, small fat fusulinids.. 4' 6"

Locality X

(Type Locality of Burlingame Limestone)

SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 9, T. 15 S., R. 14 E., Osage County; measured in ditch on north side of Kansas Highway 31. Poor exposure.

Thickness
Feet Inches

Bern Limestone (12' 10" exposed)

Wakarusa Limestone member (1' exposed)

6. Limestone, moderate yellowish brown (10YR5/4), weathers yellowish brown, hard, well consolidated, resistant, thick-bedded, sharp and even contacts, crinoid stems, brachiopods, abundant large fusulinids and Ottonosia..... 0' 6"

5. Limestone, pale yellowish brown (10YR6/2), weathers yellowish brown, hard, well consolidated, resistant, thick-bedded, sharp and smooth contacts, limonite concretions, crinoid stems, ramose bryozoans, brachiopods, Ottonosia..... 0' 6"

Soldier Creek Shale member (9' 9")

4. Shale, grades from dark gray at bottom to grayish green at top, weathers grayish brown, soft, good consolidation, non-resistant, blocky, sharp and even contacts..... 9' 9"

Burlingame Limestone member (2' 1")

3. Limestone, grayish orange (10YR7/4), weathers brownish orange, hard, well consolidated, resistant, thick-bedded, sharp and smooth upper contact, gradational and uneven lower contact, crinoid

stems, small gastropods, ramose bryozoans, brachiopods, abundant small fat fusulinids, few Osagia..... 1' 9"

2. Limestone, pale yellowish brown (10YR6/2), weathers yellowish brown, hard, well consolidated, resistant, one thin bed, gradational and uneven contacts, brachiopods, small gastropods, clams, abundant Osagia..... 0' 4"

Scranton Shale

Silver Lake Shale member (3'+ exposed)

1. Shale, grayish green, weathers grayish brown, soft, good consolidation, non-resistant, medium-bedded, gradational and uneven contacts..... 3' 0"

Locality Y

NE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 18, T. 15 S., R. 14 E., Osage County; measured in ditch at intersection of north-south road and Kansas Highway 31. Poor exposure.

Thickness
Feet Inches

Bern Limestone (11' 9" exposed)

Wakarusa Limestone member (1' 9" exposed)

4. Limestone, moderate yellowish brown (10YR5/4), weathers brown, hard, well consolidated, resistant, one bed, transitional and uneven contacts, crinoid stems, brachiopods, large fusulinids, Ottonosia... 0' 11"
3. Limestone, moderate yellowish brown (10YR5/4), weathers yellowish brown, hard, well consolidated, resistant, one bed, transitional and uneven contacts, crinoid stems, brachiopods, small gastropods, clams, Aviculopecten, Ottonosia..... 0' 10"

Soldier Creek Shale member (8')

2. Shale, olive green, weathers yellowish brown, soft, good consolidation, non-resistant, blocky, transitional and uneven upper contact, sharp and uneven lower contact, upper part calcareous, lower part carbonaceous..... 8' 0"

Burlingame Limestone member (2' exposed)

1. Limestone, dark yellowish orange (10YR6/6), weathers orange, hard, well consolidated, resistant, one bed, sharp and irregular contacts, crinoid stems, brachiopods, small gastropods, bryozoans, abundant small fat fusulinids, Osagia..... 2' 0"

Locality 2

SE $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 20, T. 15 S., R. 14 E., Osage County;

measured in roadcut on north side of east-west road. Poor exposure.

Thickness
Feet Inches

Bern Limestone (10' 7" exposed)

Wakarusa Limestone member (1' 6" exposed)

5. Limestone, yellowish gray (5Y7/2), weathers brown, hard, well consolidated, resistant, dense, oolites, one bed, gradational and uneven contacts, slightly sandy, shell fragments..... 1' 6"

Soldier Creek Shale member (6')

4. Shale, covered..... 6' 0"

Burlingame Limestone member (3' 1")

3. Limestone, dark yellowish orange (10YR6/6), weathers yellowish gray, hard, well consolidated, resistant, massive, sharp and flat upper contact, gradational and uneven lower contact, crinoid stems, ramose bryozoans, small gastropods, brachiopod fragments, abundant small fat fusulinids, Osagia..... 1' 8"
2. Limestone, grayish orange, (10YR7/4), weathers yellowish brown, medium hard, good consolidation, weakly resistant to resistant, grades from thick-bedded at top to thin-bedded at base, very transitional and uneven contacts, silty and argillaceous especially in lower four inches, crinoid stems, shell fragments, very abundant Osagia especially in lower part..... 1' 5"

Scranton Shale

Silver Lake Shale member (3'+ exposed)

1. Shale, olive gray, weathers greenish gray, soft, good consolidation, non-resistant, thin-bedded, very transitional and uneven contacts, upper part calcareous, silty..... 3' 0"

Locality AA

NE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 18 and SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 7, T. 16 S., R. 14 E., Osage County; measured along small stream about 300 feet west of north-south road. Fair exposure.

Thickness
Feet Inches

Bern Limestone (13' 7" exposed)

Wakarusa Limestone member (2' 3" exposed)

5. Limestone, pale yellowish brown (10YR6/2), weathers brownish gray, hard, well consolidated, resistant, one massive bed, sharp and smooth contacts, crinoid stems, brachiopods, abundant horn corals, abundant large fusulinids only in upper part, Dictyoelostus, Chonetes, Ottensia..... 2' 3"

Soldier Creek Shale member (6")

4. Shale, brownish yellow, weathers yellowish orange, soft, fair consolidation, non-resistant, thin-bedded, sharp and even contacts, calcareous..... 0' 6"

Burlingame Limestone member (5' 4")

3. Limestone, olive gray, (5Y4/1), weathers brownish orange, hard, well consolidated, resistant, one massive bed, dense, sharp and even contacts, carbonaceous in lower part, brachiopods, clams, horn corals, abundant crinoid stems, Dictyoelostus..... 3' 7"
2. Limestone, white (10Y), weathers yellowish white, hard, well consolidated, resistant, dense, one massive bed, sharp and even contacts, crinoid stems, shell fragments, abundant small fat fusulinids in upper part only, few Osagia in lower part..... 1' 9"

Scranton Shale

Silver Lake Shale member (5'± exposed)

1. Shale, yellowish brown, weathers grayish yellow, soft, good consolidation, non-resistant, thin-bedded, sharp and even contacts, calcareous in upper part..... 5' 0"

Locality BB

NW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 32 and SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 29, T. 16 S., R. 14 E.,
Osage County; measured on east bank of small stream in Sec. 29 and
in ditch south of east-west road in Sec. 32. Poor exposure.

Thickness
Feet Inches

Bern Limestone (11' 7" exposed)

Wakarusa Limestone member (3' exposed)

7. Limestone, grayish yellow (5Y8/4), weathers light gray, hard, well consolidated, resistant, thick-bedded, sharp and even contacts, ramose bryozoans, shell fragments, crinoid stems, abundant fusulinids..... 1' 5"
6. Limestone, grayish yellow (5Y8/4), weathers yellow, hard, well consolidated, resistant, thick-bedded, sharp and uneven contacts, crinoid stems, brachiopods, fenestrate and ramose bryozoans, Derbyia, Osagia..... 0' 9"
5. Shale, grayish yellow, weathers yellow, soft, good consolidation, weakly resistant, contains abundant osagite limestone nodules similar to limestone immediately below, thin-bedded, gradational and uneven contacts, very calcareous, shell fragments, ramose bryozoans..... 0' 6"
4. Limestone, moderate yellowish brown (10YR5/4), weathers yellow, hard, well consolidated, resistant, medium-bedded, gradational and uneven upper contact, sharp and uneven lower contact, shell fragments, abundant small gastropods and Osagia..... 0' 4"

Soldier Creek Shale member (3')

3. Shale, grayish green, weathers yellowish gray, soft, good consolidation, non-resistant, blocky, sharp and uneven contacts..... 3' 0"

Burlingame Limestone member (5' 7")

2. Limestone, grayish yellow green (5GY7/2), weathers brown, hard, well consolidated, resistant, badly weathered, thick-bedded, sharp and uneven upper contact, lower contact very transitional, nodular limestone at base, abundant small grains of glauconite, sandy in part, abundant clams and gastropods in matrix of clear calcite..... 5' 7"

Scranton Shale

Silver Lake Shale member (5' exposed)

1. Shale, grayish green weathers yellowish gray, soft, well consolidated, non-resistant, medium-bedded, gradational and uneven contacts..... 5' 0"

Locality CC

SE $\frac{1}{4}$, Sec. 10, T. 17 S., R. 13 E., Lyon County; measured in a small stream north of east-west road. Fair exposure.

Thickness
Feet Inches

Bern Limestone (9' 2" exposed)

Wakarusa Limestone member (5' 2" exposed)

4. Limestone, light olive gray (5Y6/1), weathers grayish brown, well consolidated, resistant, dense, medium-bedded, sharp and uneven contacts, crinoid stems, ramose and fenestrate bryozoans, brachiopods, horn corals, clams, trilobites, gastropods, rare fusulinids in upper part, Ottonosia, Osagia, Lophophyllidium..... 5' 2"

Soldier Creek Shale member (1' 6")

3. Shale, partially covered..... 1' 6"

Burlingame Limestone member (2' 6")

2. Limestone, grayish orange (10YR7/4), weathers yellow-

ish orange, hard, well consolidated, resistant, one massive bed, sharp and uneven contacts, gradational and uneven lower contact, crinoid stems, clams, brachiopods, horn corals, small fat fusulinids increase in abundance upward, Osagia decrease in abundance upward, Orbitolina..... 2' 6"

Scranton Shale

Silver Lake Shale member (1' exposed)

1. Shale, mottled brown and black, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, gradational and uneven contacts, contains some limestone nodules, very calcareous, trilobites, horn corals, brachiopods, Hustedia.... 8L 0"

Locality DD

SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 21, T. 17 S., R. 13 E., Lyon County; measured in ditch and roadcut on north side of east-west road east of a small stream. Poor exposure.

Thickness
Feet Inches

Bern Limestone (8' 6" exposed)

Wakarusa Limestone member (1' 6" exposed)

3. Limestone, grayish orange (10YR7/4), weathers yellowish brown, hard, well consolidated, resistant, thick-bedded, transitional and uneven contacts, shell fragments, ramose bryozoans, abundant crinoid stems, Dictyoelostus..... 1' 6"

Soldier Creek Shale member (5')

2. Shale, partially covered..... 5' 0"

Burlingame Limestone member (2' exposed)

1. Limestone, pale yellowish brown (10YR6/2), weathers yellowish orange, hard, well consolidated, resistant, one massive bed, obscured contacts, crinoid stems, fenestrate bryozoans, small fat fusulinids in upper part, Osagia especially in lower part.... 2' 0"

Locality EE

NE $\frac{1}{4}$, Sec. 33, T. 17 S., R. 13 E., Lyon County; measured in south part of active quarry. Good exposure.

	Thickness Feet Inches
Auburn Shale (1'± exposed)	
10. Shale, yellowish brown, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, sharp and even contacts.....	1' 0"
Bern Limestone (12' 11" exposed)	
Wakarusa Limestone member (5' 2")	
9. Limestone, yellowish gray (5Y7/2), weathers brownish yellow, hard, well consolidated, resistant, dense, one massive bed, sharp and smooth upper contact, gradational and uneven lower contact, local concentrations of fossil material in lower part, large fusulinids in upper part, crinoid stems, brachiopods, horn corals, <u>Enteleles</u> , <u>Ottonesia</u>	4' 2"
8. Shale, brownish gray, weathers yellowish brown, soft, good consolidation, non-resistant, contains limestone nodules, thin-bedded, transitional and undulating contacts, crinoid stems.....	0' 3"
7. Limestone, light gray (N7), weathers yellowish gray, hard, well consolidated, resistant, one thin bed, gradational and undulating contacts, abundant crinoid stems.....	0' 3"
6. Shale, light gray, weathers gray, soft, good consolidation, non-resistant, thin-bedded, gradational and uneven contacts, abundant crinoid stems.....	0' 2"
5. Limestone, olive gray (5Y4/1), weathers dark yellowish gray, hard, well consolidated, resistant, grades from thin-bedded at base to medium-bedded at top, transitional and uneven contacts, abundant crinoid stems.....	0' 4"
Soldier Creek Shale member (7' 9" exposed)	
4. Shale, gray, weathers yellowish gray, soft, fair consolidation, non-resistant, fissile, transitional and uneven contacts.....	0' 3"

3. Coal, black fresh and weathered, impure, vitreous, transitional and uneven contacts..... 0' 1"
2. Shale, black, weathers gray, soft, good consolidation, non-resistant, fissile, transitional and uneven upper contact, sharp and even lower contact, carbonaceous, less carbonaceous in lower part..... 2' 9"
1. Limestone, light olive gray (5Y6/1), weathers yellowish gray, hard, well consolidated, resistant, reefoid, coquinoid, thick-bedded, sharp and uneven contacts, fenestrate and ramose bryozoans, very abundant mytiloid and pectinoid clams, Promytilus, Pleurophorus, Septinyalina, Nyalina, Aviculopecten, Fasciculiconcha, abundant Derbyia, bryozoans encrusting shells..... 5' 0"

Locality FF

SE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 33 and NW $\frac{1}{4}$ Sec. 34, T. 17 S., R. 13 E., Lyon County; measured in ditch on north side of east-west road in Sec. 33 and in abandoned quarry in Sec. 34. Good exposure.

Thickness
Feet Inches

Bern Limestone (16' 2" exposed)

Wakarusa Limestone member (1' 5" exposed)

10. Limestone, grayish orange (10YR7/4), weathers brownish orange, hard, well consolidated, resistant, medium-bedded, transitional and uneven contacts, crinoid stems, fenestrate and ramose bryozoans, brachiopods, horn corals, trilobites, rare fusulinids in upper part, Ottonosia..... 1' 5"

Soldier Creek Shale member (13' 9" exposed)

9. Shale, greenish gray, weathers yellowish gray, soft, poor consolidation, non-resistant, blocky, transitional and uneven upper contact, sharp and flat lower contact, slightly silty..... 2' 3"
8. Limestone, yellowish gray (5Y7/2), weathers orange-yellow, hard, well consolidated, resistant, reefoid, coquinoid, medium-bedded, sharp and even contacts, ramose and fenestrate bryozoans, crinoid stems, abundant mytiloid and pectinoid clams, Promytilus, Pleurophorus, Septinyalina, Nyalina, Aviculopecten, Fasciculiconcha, Derbyia..... 0' 11"

7. Limestone, yellowish gray (5Y7/1), weathers brownish yellow, hard, good consolidation, resistant, thick-bedded, gradational and uneven contacts, very sandy, abundant clams..... 2' 11"
6. Limestone, yellowish gray (5Y8/1), weathers yellowish white, hard, well consolidated, resistant, reefoid, coquinoid, massive to thick-bedded, sharp and even contacts, rumose and fenestrate bryozoans, gastropods, rare fusulinids in lower part, abundant mytiloid and pectinoid clams..... 4' 0"
5. Shale, greenish gray, weathers yellowish gray, soft, fair consolidation, non-resistant, contains thin ($\frac{1}{4}$ "- $\frac{1}{2}$ ") beds of sandy micaceous limestone, sharp and flat contacts, crinoid stems..... 3' 1"
4. Limestone, moderate brown (5YR3/4), weathers yellowish orange, hard, well consolidated, resistant, one thin bed, sharp and even contacts, bryozoans, Aviculopecten..... 0' 2"
3. Shale, yellowish green, weathers gray, soft, fair consolidation, non-resistant, thin-bedded, sharp and even contacts, calcareous..... 0' 5"

Burlingame Limestone member (1')

2. Limestone, grayish orange (10YR7/4), weathers grayish yellow, hard, well consolidated, resistant, one bed, sharp and even contacts, silty, slightly argillaceous, shell fragments, abundant crinoid stems and small gastropods, small fat fusulinids in upper part, abundant Osagia especially in lower part..... 1' 0"

Scranton Shale

Silver Lake Shale member (8"+ exposed)

1. Shale, yellowish green, weathers yellowish gray, soft, fair consolidation, non-resistant, thin-bedded, sharp and even contacts, calcareous..... 0' 8"

Locality GG

$S\frac{1}{2}$, $SE\frac{1}{4}$, Sec. 5, T. 18 S., R. 13 E., Lyon County; measured in southeast bank of stream that parallels railroad. Good exposure.

Thickness
Feet Inches

Bern Limestone (12' 5" exposed)

Wakarusa Limestone member (1' exposed)

12. Limestone, light olive gray (5Y5/2), weathers yellowish gray, hard, well consolidated, resistant, medium-bedded, gradational and uneven contacts, crinoid stems, brachiopods, horn corals, few fusulinids in upper part, Dictyocestus, Ottonosia..... 1' 0"

Soldier Creek Shale member (8' 4")

11. Shale, brown, weathers dark brown, soft, fair consolidation, non-resistant, thin-bedded, transitional and uneven contacts, calcareous..... 1' 6"
10. Limestone, yellowish gray (5Y7/2), weathers yellowish orange, hard, well consolidated, resistant, suboolitic in upper part, grades from thin-bedded at base to massive at top, abrupt and smooth contacts, grades from very sandy at base to non-sandy at top, crinoid stems, ramose and fenestrate bryozoans, rare small fusulinids in upper part, small gastropods, very abundant mytiloid and pectinoid clams..... 3' 9"
9. Shale, gray, weathers yellowish gray, soft, fair consolidation, non-resistant, contains thin ($\frac{1}{4}$ "- $\frac{1}{2}$ ") sandy limestone layers, sharp and even contacts, sandy, silty, calcareous, micaceous..... 1' 6"
8. Limestone, grayish yellow (5Y6/4), weathers yellowish brown, hard, well consolidated, weakly resistant, one thin bed, sharp and flat contacts, very sandy..... 0' 1"
7. Shale, gray, weathers yellowish gray, soft, fair consolidation, non-resistant, contains thin ($\frac{1}{4}$ "- $\frac{1}{2}$ ") sandy limestone layers, silty, sandy..... 1' 6"

Burlingame Limestone member (3' 1")

6. Limestone, pale yellowish orange (10YR6/6) fresh and weathered, hard, well consolidated, resistant, one bed, sharp and even contacts, crinoid stems, small gastropods, fenestrate and ramose bryozoans, abundant small fat fusulinids, Osagia..... 1' 1"

5. Limestone, pale yellowish orange (10YR8/6) fresh and weathered, hard, well consolidated, resistant, nodular, abrupt and uneven contacts, crinoid stems, shell fragments, ramose bryozoans, abundant small fat fusulinids, abundant Osagia.... 1' 9"

4. Limestone, pale yellowish brown (10YR6/2), weathers yellow, hard, well consolidated, resistant, one bed, sharp and even contacts, brachiopods, abundant clams, abundant arenaceous foraminifera, Derbyia, Marginifera, Chonetes, Aviculopecten..... 0' 3"

Scranton Shale

Silver Lake Shale member (28' exposed)

3. Shale, greenish gray, weathers gray, soft, good consolidation, non-resistant, blocky, sharp and even contacts..... 4' 6"

2. Conglomerate, varicolored fragments in gray matrix, weathers grayish brown, hard, good consolidation, resistant, coarse, angular to subrounded fragments of mudstone and limestone, channel filling, medium beds separated by gray shale partings, gradational and uneven contacts at top and between beds, lower contact unconformable, slightly calcareous..... 12' 0" maximum

1. Shale, black and gray, weathers light gray, soft, good consolidation, non-resistant, thin-bedded, sharp and even contacts, carbonaceous, eroded by channel..... 23' 6" maximum
11' 6" minimum

Locality NN

SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 25, T. 16 S., R. 12 E., Lyon County; measured in roadcut on north side of east-west road. Good exposure.

Thickness
Feet Inches

Bern Limestone (11' 7" exposed)

Wakarusa Limestone (3' 10" exposed)

9. Limestone, moderate yellowish brown (10YR5/4), weathers dark brown, hard, well consolidated, resistant, massive, sharp and even contacts, crinoid stems, ramose bryozoans, small gastropods,

horn corals, large fusulinids in upper part..... 3' 10"

Soldier Creek Shale member (3')

8. Shale, grayish green, weathers brown, soft, good consolidation, non-resistant, medium-bedded, sharp and even contacts, slightly calcareous..... 0' 7"
7. Coal, black fresh and weathered, impure, vitreous... 0' 1"
6. Shale, grayish yellow, weathers yellowish brown, soft, good consolidation, non-resistant, blocky, sharp and even contacts..... 2' 4"

Burlingame Limestone member (4' 9")

5. Limestone, pale yellowish orange (10YR8/6), weathers yellow, medium hard, good consolidation, non-resistant, massive, gradational and uneven contacts, impure, "punkly", crinoid stems, abundant small fat fusulinids, Osagia..... 1' 6"
4. Limestone, grayish orange (10YR7/4), weathers light brown, hard, well consolidated, resistant, oolitic, one bed, gradational and uneven upper contact, sharp and even lower contact, brachiopods, clams, ramose bryozoans, small gastropods, abundant fat fusulinids, very abundant Osagia, Chonetes..... 0' 9"
3. Limestone, moderate yellowish brown (10YR5/4), weathers yellowish brown, hard, well consolidated, resistant, massive, sharp and even upper contact, gradational and uneven lower contact, crinoid stems, horn corals, brachiopods, fenestrate and ramose bryozoans, small fat fusulinids, abundant Osagia, Composita, Dictyoelostus..... 2' 2"
2. Limestone, grayish orange (10YR7/4), weathers yellow, medium hard, good consolidation, weakly resistant, nodular, transitional and uneven contacts, brachiopods, ramose bryozoans, abundant Osagia..... 0' 4"

Scranton Shale

Silver Lake Shale member (6" exposed)

1. Shale, yellow, weathers yellowish brown, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven contacts, very calcareous..... 0' 6"

Locality II

SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 9, T. 19 S., R. 12 E., Lyon County; measured along north facing wall in east part of abandoned quarry. Good exposure.

Thickness
Feet Inches

Auburn Shale (1' exposed)

10. Shale, gray, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, sharp and uneven contacts..... 1' 0"

Bern Limestone (8' 7")

Wakarusa Limestone member (2' 7 $\frac{1}{2}$ ")

9. Limestone, grayish orange (10YR7/4), weathers brownish orange, hard, well consolidated, resistant, one bed, sharp and uneven contacts, brachiopods, ramose bryozoans, small gastropods, abundant crinoid stems, Osagia, Ottonesia, Dictyoclostus, Composita, Entelletes..... 0' 6"
8. Shale, gray, weathers yellowish brown, soft, good consolidation, non-resistant, thin-bedded, sharp and uneven contacts, calcareous, horn corals, brachiopods, crinoid stems, Neospirifer, Derbyia, Composita..... 0' 4"
7. Limestone, light olive gray (5Y6/1), weathers orange-brown, hard, well consolidated, resistant, dense, one bed, sharp and uneven contacts, ramose bryozoans, abundant crinoid stems..... 0' 4"
6. Shale, yellowish gray, weathers yellowish brown, soft, good consolidation, non-resistant, medium-bedded, sharp and uneven contacts, calcareous..... 0' 1 $\frac{1}{2}$ "
5. Limestone, light olive gray (5Y6/1), weathers yellowish brown, hard, well consolidated, resistant, dense, one massive bed, sharp and uneven contacts, crinoid stems, brachiopods, horn corals, rare fusulinids in lower part, Dictyoclostus, Composita, Osagia, Ottonesia..... 1' 4"

Soldier Creek Shale member (2' 5 $\frac{1}{2}$ ")

4. Shale, grades from light gray at base to dark gray at top, weathers yellowish gray, soft, good con-

solidation, non-resistant, thin-bedded, sharp and uneven upper contact, gradational and uneven lower contact, upper part slightly calcareous, clams in upper part..... 2' 5½"

Burlingame Limestone member (3' 6")

3. Limestone, white (N9), weathers yellow, hard, well consolidated, resistant, massive, dense, transitional and uneven contacts, glauconite, crinoid stems, brachiopods, ramose bryozoans, small gastropods, abundant small fat fusulinids in upper part, Osagia, Enteletes..... 1' 3"
2. Limestone, white (N9), weathers yellow, hard, well consolidated, resistant, massive dense, transitional and uneven upper contact, sharp and even lower contact, lower part silty, crinoid stems, brachiopods, fenestrate and ramose bryozoans, trilobites, small gastropods, rare small fat fusulinids in middle, abundant Osagia..... 2' 3"

Scranton Shale

Silver Lake Shale member (2' exposed)

1. Shale, grayish green, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, sharp and even contacts, silty, brachiopods..... 2' 0"

Locality JJ

SE¼, SE¼, Sec. 33, T. 19 S., R. 12 E., Lyon County; measured in roadcut and ditch on north side of east-west road. Fair exposure.

Thickness
Feet Inches

Bern Limestone (7' 7½" exposed)

Wakarusa Limestone member (1' ¼" exposed)

7. Limestone, dark yellowish orange (1-YR6/6), weathers orange, hard, well consolidated, resistant, thick-bedded, sharp and uneven contacts, crinoid stems, fenestrate and ramose bryozoans, brachiopods, Ottonosia..... 1' ¼"

Soldier Creek Shale member (4' ½")

6. Shale, dark brownish gray, weathers yellowish brown,

- soft, good consolidation, non-resistant, medium-bedded, sharp and uneven contacts, calcareous..... 0' 6"
5. Coal, black fresh and weathered, impure, lignitic, transitional and uneven contacts..... 0' ½"
4. Shale, grades from light gray at base to dark gray at top, weathers yellowish brown, soft, good consolidation, non-resistant, medium-bedded, transitional and uneven contacts..... 3' 6"

Burlingame Limestone member (2' 3")

3. Limestone, yellowish gray (5Y8/1), weathers yellowish gray, hard, well consolidated, resistant, one bed, transitional and uneven contacts, crinoid stems, brachiopods, fenestrate and ramose bryozoans, abundant small fat fusulinids, Osagia..... 1' 0"
2. Limestone, grayish orange (10YR7/4), weathers brownish orange, hard, well consolidated, resistant, thick-bedded, transitional and uneven contacts, crinoid stems, ramose and fenestrate bryozoans, brachiopods, abundant Osagia..... 1' 3"

Scranton Shale

Silver Lake Shale member (2'+ exposed)

1. Shale, yellow, weathers yellowish brown, soft, good consolidation, non-resistant, medium-bedded, transitional and uneven contacts, very calcareous, brachiopods..... 2' 0"

Locality KK

S½, Sec. 10, T. 21 S., R. 12 E., Lyon County; measured in ditch on south side of east-west road east of small stream. Good exposure.

Thickness
Feet Inches

Bern Limestone (12' 7" exposed)

Wakarusa Limestone member (2' 8" exposed)

10. Limestone, yellowish gray (5Y7/2), weathers brownish yellow, hard, well consolidated, resistant, thick-bedded, transitional and uneven contacts, abundant crinoid stems, brachiopods, abundant Ottonosia..... 1' 0"

9. Limestone, dark yellowish orange (10YR6/6), weathers brownish yellow, hard, well consolidated, resistant, thick-bedded, gradational and undulating contacts, crinoid stems, brachiopods, bryozoans, small gastropods, small fusulinids..... 1' 8"

Soldier Creek Shale member (5' 8")

8. Shale, greenish gray, weathers gray, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven contacts, calcareous..... 2' 3"
7. Coal, black fresh and weathered, impure, mixed with clay, transitional and uneven contacts..... 0' ½"
6. Shale, yellowish brown and bluish gray alternating, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven contacts, upper part carbonaceous, lower part calcareous..... 2' 8½"

Burlingame Limestone member (4' 3")

5. Limestone, pale yellowish orange (10YR8/6), weathers yellow, hard, well consolidated, resistant, one bed, transitional and uneven contacts, crinoid stems, fenestrate and ramose bryozoans, brachiopods, clams, abundant small fat fusulinids, Osagia..... 0' 11"
4. Shale, gray, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven contacts, calcareous, brachiopods..... 0' 2"
3. Limestone, pale yellowish orange (10YR8/6), weathers yellow, hard, well consolidated, resistant, one bed, gradational and undulating contacts, crinoid stems, small gastropods, fenestrate and ramose bryozoans, brachiopods, clams, abundant small fat fusulinids, Osagia..... 1' 3"
2. Limestone, pale yellowish orange (10YR8/6), weathers yellow, medium hard, good consolidation, weakly resistant, thin-bedded, transitional and uneven contacts, slightly argillaceous, crinoid stems, brachiopods, clams, ramose bryozoans, rare small fat fusulinids especially in upper part, abundant Osagia..... 1' 11"

Scranton Shale

Silver Lake Shale member (3³/₄ exposed)

1. Shale, brownish yellow, weathers yellow, soft, good consolidation, non-resistant, thin-bedded, transitional and uneven contacts, calcareous, brachiopods..... 0' 3"

Scranton Shale Locality LL

NW¹/₄, Sec. 31, T. 21 S., R. 12 E., Lyon County; measured in roadcut on both sides of north-south road. Fair exposure.

Thickness
Feet Inches

Auburn Shale (1¹/₂ exposed)

6. Shale, gray, weathers yellowish gray, soft, good consolidation, non-resistant, thin-bedded, sharp and even contacts..... 1' 0"

Bern Limestone (10' 9¹/₂"

Wakarusa Limestone member (5' 6")

7. Limestone, light olive gray (5Y6/1), weathers brownish yellow, hard, well consolidated, resistant, thick-bedded, sharp and even upper contact, transitional and uneven lower contact, crinoid stems, brachiopods, fenestrate bryozoans, horn corals encrusted with *Ottonosia*, fusulinids abundant in upper part and rare in lower part and absent in middle part, clams and *Osgoia* in middle part, small gastropods in lower part, Composita..... 5' 5"

Soldier Creek Shale member (3' 3¹/₂"

6. Shale, grayish brown, weathers yellowish brown, soft, fair consolidation, non-resistant, gradational and uneven contacts, calcareous..... 0' 8"
5. Coal, black fresh and weathered, lignitic, transitional and uneven contacts..... 0' 1¹/₂"
4. Shale, brownish gray, weathers yellowish brown, soft, fair consolidation, non-resistant, blocky, transitional and uneven upper contact, sharp and smooth lower contact, calcareous..... 2' 6"

Burlingame Limestone member (2')

- 3. Limestone, moderate yellowish brown (10YR5/1), weathers yellowish gray, hard, well consolidated, resistant, thick-bedded, sharp and even upper contact, transitional and uneven lower contact, crinoid stems, brachiopods, ramose bryozoans, abundant small fat fusulinids especially in upper part, abundant *Osagia* especially in lower part, Neospirifer, Dictyoelostus..... 2' 0"

Scranton Shale

Silver Lake Shale member (8' 10" exposed)

- 2. Shale, yellowish brown, weathers yellow, soft, fair consolidation, non-resistant, poorly-bedded, transitional and uneven contacts, calcareous..... 3' 3"
- 1. Shale, grayish green, weathers gray, soft, good consolidation, non-resistant, blocky, transitional and uneven contacts, calcareous..... 5' 7"

Burlingame Limestone - Crinoid Bed

	Total		Crinoid		Fossiliferous	
	Feet	Percent	Feet	Percent	Feet	Percent
1-20	2.50	12.50	0.10	2.50	2.50	27.50
2-3	1.25	5.75	0.10	11.25	1.25	28.25
3-20	3.10	17.35	0.10	3.10	3.10	25.35
2-2	1.25	7.15	0.10	2.35	1.25	26.75
0-20	2.00	9.00	0.20	11.00	1.00	28.00

Burlingame Limestone - Fossiliferous

	Total		Crinoid		Fossiliferous	
	Feet	Percent	Feet	Percent	Feet	Percent
1-20	2.00	10.00	0.20	2.00	2.00	26.00
1-10	2.10	10.50	0.20	2.10	2.10	27.50
0-2	2.00	10.00	0.20	2.00	2.00	27.00
1-20	1.50	7.50	0.20	1.50	1.50	26.50
1-20	2.00	10.00	0.20	2.00	2.00	26.00

APPENDIX B

PERCENT CHART OF THE INSOLUBLE RESIDUES OF THE BERN LIMESTONE

Burlingame Limestone - Molluscan Bed:

<u>Sample Number</u> *6	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
A-2	2.58	12.8%	0.47	18.4%	2.11	81.6%
J-2	1.33	6.6%	0.18	13.5%	1.15	86.5%
K-3a	1.34	6.7%	0.46	34.2%	0.88	65.8%
K-3b	1.94	9.7%	0.13	6.8%	1.81	93.2%
GG-4	3.14	15.7%	1.00	31.8%	2.14	68.2%

Burlingame Limestone - Osagite Bed:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
L-3a	3.99	19.9%	0.10	2.5%	3.89	97.5%
N-3	1.14	5.7%	0.13	11.4%	1.01	88.6%
P-3a	3.46	17.3%	0.13	3.7%	3.33	96.3%
X-2	1.43	7.1%	0.19	13.3%	1.24	86.7%
CC-2c	1.79	9.0%	0.20	11.2%	1.59	88.8%

Burlingame Limestone - Fusulinid Bed:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
N-4b	2.40	12.0%	0.08	3.3%	2.32	96.7%
V-10a	2.16	10.8%	0.06	2.8%	2.10	97.2%
GG-6	2.06	10.3%	0.05	2.4%	2.01	97.6%
II-3b	1.40	7.0%	0.05	3.6%	1.35	96.4%
LL-3b	2.99	14.9%	0.13	4.3%	2.86	95.7%

Burlingame Limestone - Brecciated Limestone Bed:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
A-4f	0.73	3.7%	0.01	1.4%	0.72	98.6%
H-2b	0.17	0.9%	0.01	5.9%	0.16	94.1%
K-6a	0.53	2.7%	0.01	1.9%	0.52	98.1%

Soldier Creek Shale - Shawnee County Bioherm:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
O-5b	3.51	17.6%	3.05	85.8%	0.46	14.2%
R-13d	0.30	1.5%	0.02	6.7%	0.28	93.3%
S-4f	0.25	1.3%	0.01	4.0%	0.24	96.0%
U-3a	1.37	6.8%	0.91	66.5%	0.46	33.5%
V-13e	0.39	1.9%	0.02	5.1%	0.37	94.9%

Soldier Creek Shale - Lyon County Bioherm:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
EE-1	0.29	1.5%	0.16	55.2%	0.13	44.8%
FF-6b	0.32	1.6%	0.07	30.0%	0.25	70.0%
FF-7a	8.31	41.6%	7.43	89.4%	0.88	10.6%
GG-10b	6.92	34.6%	6.03	87.2%	0.89	12.8%
GG-10c	0.69	3.4%	0.34	49.3%	0.35	50.7%

Wakarusa Limestone - Lower Fusulinid Bed:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
A-8	2.60	13.0%	0.07	2.7%	2.53	97.3%
L-10	1.86	9.3%	0.09	4.8%	1.77	95.2%
LL-7a	0.63	3.2%	0.04	6.4%	0.59	93.6%

Wakarusa Limestone - Encrinal Limestone Bed:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
EE-4	1.99	9.9%	0.38	19.1%	1.61	80.9%
EE-7	4.16	20.8%	0.13	3.1%	4.03	96.9%

Wakarusa Limestone - Upper Fusulinid Bed:

<u>Sample Number</u>	<u>Total Residue</u>		<u>Coarse Fraction</u>		<u>Fine Fraction</u>	
	Grams	Percent	Grams	Percent	Grams	Percent
A-12d	1.67	8.4%	0.02	1.2%	1.65	98.8%
L-13b	1.63	8.2%	0.04	2.5%	1.59	97.5%
BB-7	1.83	9.1%	0.05	2.7%	1.78	97.3%
EE-9b	1.22	6.1%	0.06	4.9%	1.16	95.1%
LL-7c	1.78	8.9%	0.75	42.2%	1.03	57.8%

* - Note: All samples weighed 20 grams before digestion in acid.
 The numbering system for the samples is as follows:
 The capital letter (A) refers to the locality; the number (1)
 refers to the unit; the small letter (a) when used, refers to
 the sample within the unit. The letter "a" would be from the
 base of the unit, "b" from above "a", etc.

APPENDIX C

CONSTITUENTS OF THE COARSE FRACTION OF THE INSOLUBLE RESIDUES
OF THE BERN LIMESTONE

Burlingame Limestone - Molluscan Bed:

A-2	70%	clay and silt aggregate
	25%	arenaceous foraminifera and fragments
	5%	subrounded to subangular quartz sand
J-2	50%	arenaceous foraminifera and fragments
	30%	subrounded to rounded quartz sand
	15%	pyrite aggregate
	5%	muscovite
K-3a	50%	clay and silt aggregate
	25%	subrounded to subangular quartz
	20%	arenaceous foraminifera and fragments
	3%	muscovite
	1%	carbonaceous material
	1%	gypsum
K-3b	30%	clay and silt aggregate
	30%	arenaceous foraminifera and fragments
	30%	rounded to subangular quartz sand
	10%	muscovite
GG-4	50%	arenaceous foraminifera and fragments
	30%	clay and silt aggregate
	15%	subangular to rounded quartz sand
	5%	muscovite

Burlingame Limestone - Osagite Bed:

L-3a	80%	arenaceous foraminifera and fragments
	15%	pyrite aggregate
	5%	carbonaceous material
N-3	70%	arenaceous foraminifera and fragments
	30%	clay and silt aggregate
P-3a	70%	arenaceous foraminifera and fragments
	10%	clay and silt aggregate
	10%	pyrite aggregate and foraminifera replacements
	5%	muscovite
	5%	carbonaceous material

X-2	90%	arenaceous foraminifera and fragments
	10%	pyrite, large amorphous masses
CC-2c	60%	clay and silt aggregate
	30%	subrounded to rounded quartz sand
	5%	muscovite
	3%	carbonaceous material
	2%	chert, irregular fragments

Burlingame Limestone - Fusulinid Bed:

M-4b	60%	clay and silt aggregate
	35%	arenaceous foraminifera and fragments
	5%	pyrite, very small cubes
V-10a	60%	clay and silt aggregate
	25%	arenaceous foraminifera and fragments
	10%	carbonaceous material
	5%	gypsum, massive
GG-6	70%	clay and silt aggregate
	25%	arenaceous foraminifera and fragments
	5%	subangular quartz sand
II-3b	70%	arenaceous foraminifera and fragments
	30%	pyrite aggregate
LL-3b	55%	clay and silt aggregate
	40%	arenaceous foraminifera and fragments
	5%	carbonaceous material

Burlingame Limestone - Brecciated Limestone Bed:

A-4f	90%	clay and silt aggregate
	5%	gypsum, massive
	5%	carbonaceous material
H-2b	85%	clay and silt aggregate
	10%	arenaceous foraminifera and fragments
	5%	carbonaceous material
K-6a	70%	clay and silt aggregate
	20%	arenaceous foraminifera and fragments
	10%	carbonaceous material

Soldier Creek Shale - Shawnee County Bioherm:

O-5b	80%	subangular to angular quartz sand
	10%	muscovite
	5%	chert, irregular fragments
	3%	arenaceous foraminifera and fragments
	2%	pyrite, irregular masses
R-13d	45%	subangular to angular quartz sand
	30%	clay and silt aggregate
	10%	muscovite
	5%	tourmaline, euhedral crystals, slightly rounded
	3%	carbonaceous material
	2%	gypsum, massive
S-4f	70%	clay and silt aggregate
	25%	subangular to angular quartz sand
	2%	muscovite
	2%	gypsum
	1%	carbonaceous material
U-3a	85%	subangular to angular quartz sand
	5%	muscovite
	4%	tourmaline, euhedral crystals, slightly rounded
	3%	arenaceous foraminifera and fragments
	3%	carbonaceous material
V-13e	50%	subangular to angular quartz sand
	40%	clay and silt aggregate
	5%	arenaceous foraminifera fragments
	3%	muscovite
	2%	carbonaceous material

Soldier Creek Shale - Lyon County Bioherm:

EE-1	55%	subangular to subrounded quartz sand
	20%	arenaceous foraminifera and fragments
	20%	muscovite
	5%	chert, irregular fragments
FF-6b	75%	subangular to rounded quartz sand
	10%	pyrite aggregate
	5%	arenaceous foraminifera and fragments
	5%	muscovite
	3%	chert, irregular fragments
	2%	gypsum, massive

FF-7a	85%	subangular to angular quartz sand
	5%	arenaceous foraminifera and fragments
	5%	muscovite
	5%	chert, irregular fragments
GG-10b	90%	subangular to angular quartz sand
	5%	muscovite
	5%	chert, irregular fragments
GG-10c	60%	subangular to rounded quartz sand
	20%	arenaceous foraminifera and fragments
	10%	clay and silt aggregate
	5%	muscovite
	3%	chert, irregular fragments
	2%	tourmaline, slightly rounded euhedral crystals

Wakarusa Limestone - Lower Fusulinid Bed:

A-8	50%	clay and silt aggregate
	40%	arenaceous foraminifera and fragments
	5%	angular quartz sand
	5%	carbonaceous material
L-10	40%	clay and silt aggregate
	40%	arenaceous foraminifera and fragments
	20%	silica-replaced fusulinids and shell fragments
LL-7a	70%	clay and silt aggregate
	15%	arenaceous foraminifera and fragments
	10%	muscovite
	5%	subangular quartz sand

Wakarusa Limestone - Encrinal Limestone Bed:

BB-4	70%	arenaceous foraminifera and fragments
	30%	clay and silt aggregate
EE-7	55%	clay and silt aggregate
	40%	arenaceous foraminifera and fragments
	5%	carbonaceous material

Wakarusa Limestone - Upper Fusulinid Bed:

A-12d	80%	clay and silt aggregate
	10%	muscovite
	4%	carbonaceous material
	3%	arenaceous foraminifera and fragments
	3%	gypsum, massive
L-13b	80%	clay and silt aggregate
	10%	muscovite
	5%	arenaceous foraminifera and fragments
	5%	gypsum, selinite
BB-7	80%	clay and silt aggregate
	15%	arenaceous foraminifera and fragments
	3%	subrounded quartz sand
	2%	carbonaceous material
EE-9b	60%	clay and silt aggregate
	30%	arenaceous foraminifera and fragments
	10%	carbonaceous material
LL-7e	70%	clay and silt aggregate
	15%	arenaceous foraminifera and fragments
	10%	carbonaceous material
	5%	subangular quartz sand

GILBERT

SUPERASE BOND

25% COTTON FIBRE