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STRATIGRAPHY OF THE UPPER PENNSYLVANIAN MERRIAM LIMESTONE IN EASTERN KANSAS

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Instructor in charge

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ABSTRACT

The analysis of field and laboratory data obtained from the Merriam limestone member of the Plattsburg formation in eastern Kansas formed the basis for the determination of the environment of deposition and nature of the cyclothem units. The analysis showed the member to be divisable into three distinct and persistent units. The lower limestone unit is conglomeratic at the base, aphanitic above the base, and oolitic in the upper part. Zones of Composita and Osagia-Myalina occur in the lower part in the northern portion of the area. ~~This unit is extremely variable in thickness.~~ The upper limestone unit is constant in thickness, aphanitic, and contains worm-borings, fusulinids, and algae at various localities. In southern Kansas the unit is yellow and slabby with abundant sponges and there it represents the entire member. A thin shale bed occurs in most places between the limestones. The numerous lithofacies and biofacies reflect different environments of deposition in the shallow water of the eulittoral zone and are the result of variations of substrata, positions of currents, depths of water, and amounts of clastic influx. After the greatest advance of the sea, which resulted in the deposition of the upper limestone, the sea became more shallow. The southern shoreline of the Merriam sea was in Oklahoma and the northeastern shoreline probably was in Iowa. Although the member represents a fairly complete cyclothem in east-central Kansas, less cyclothemic units are present to the south and northeast where the relation of cyclothemic units to rock units is transgressive.

INTRODUCTION

Purpose of investigation

The purpose of this report is a study of the Merriam limestone member of the Plattsburg formation with regard to the local and regional stratigraphy and the environment of deposition. Such a study involves the megascopic and microscopic investigation of the lithology and biota, and the ~~evaluation~~ of the results ~~of the investigation through~~ the processes and conditions of sedimentation and ecology.

Previous work

The Lansing formation of Hinds (1912, p. 7), as originally defined, included the beds between the middle of the present Wyandotte limestone and the top of the Stanton limestone, with the Plattsburg limestone considered as one of its members. After later work delimited persistent members within the Plattsburg and Stanton limestones, the Lansing formation was changed to the Lansing group and revised by Moore (1932) to include only those beds between the base of the Plattsburg limestone and the top of the Stanton limestone. Thus the Merriam limestone member became the base of the Lansing group. (Fig. 1).

The Plattsburg formation was first studied in detail by Newell (1931, pp. 47-48) who recognized lesser units within the formation. In this study Newell referred to the Merriam as the lower Plattsburg limestone, and it was not until the following year that the name Merriam was formally proposed (Newell, in Moore, 1932, p. 93) from outcrops near the town of Merriam in Johnson County, Kansas. However, this description did not include a designation of a type section.

The next works which included a study of the Merriam were by Newell (1935, pp. 70-72) and Jewett and Newell (1935, p. 181) on the geology of Miami, Johnson, and Wyandotte counties, Kansas. The former work was a revision of Newell's thesis (1931). The Merriam limestone thus far had been described as consisting of two distinct units. The lower unit is blocky, even-bedded, gray, and fossiliferous with abundant Composita, Myalina, and Osagia. The unit is locally oolitic and cross-bedded and has an average thickness of about 18 inches. The upper unit is a one-foot layer that is massive, dense, gray, and slightly fossiliferous with common "worm borings".

The following year Moore (1936, pp. 128-129) also described the member as above; in addition he referred to the type locality as "village of Merriam, in quarry at NW cor. sec. 7, T. 12 S., R. 25 E., in northern Johnson County, Kansas." This locality, which was subsequently referred to by Zinser (1950, p. 15) as the type locality, was not published by Newell in his previous works, nor is it listed by Wilmarth (1938, p. 1325) as the type locality. Investigation by the author shows this locality to be stratigraphically below the Merriam. Because the author considers an arbitrary standard section necessary for the description and comparison of the Merriam limestone throughout the area, he proposes that the section referred to in this paper as Locality 5 (Fig. ?) be considered the type section. This section is located within the city limits of Merriam on U. S. Highways 50 and 169, just south of the highway interchange.

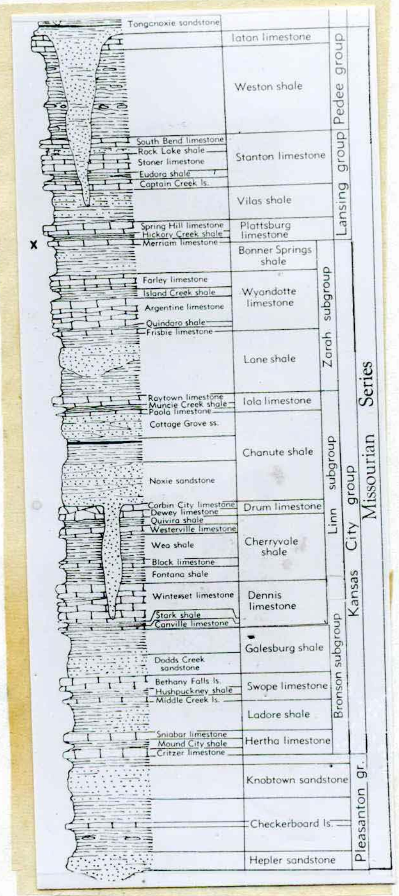


FIG. 1. Columnar section of Missourian series in Kansas (modified from Moore, Frye, Jewett, Lee, and O'Conner, 1952).

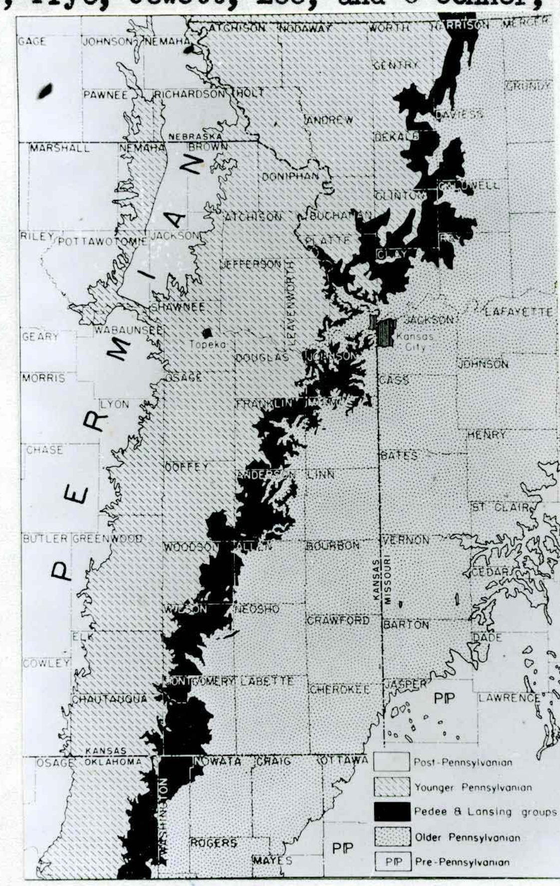


FIG. 2. Geologic map of Pedee and Lansing groups in eastern Kansas. The boundary between the black and stippled areas is outcrop belt of Merriam limestone (after Moore 1949).

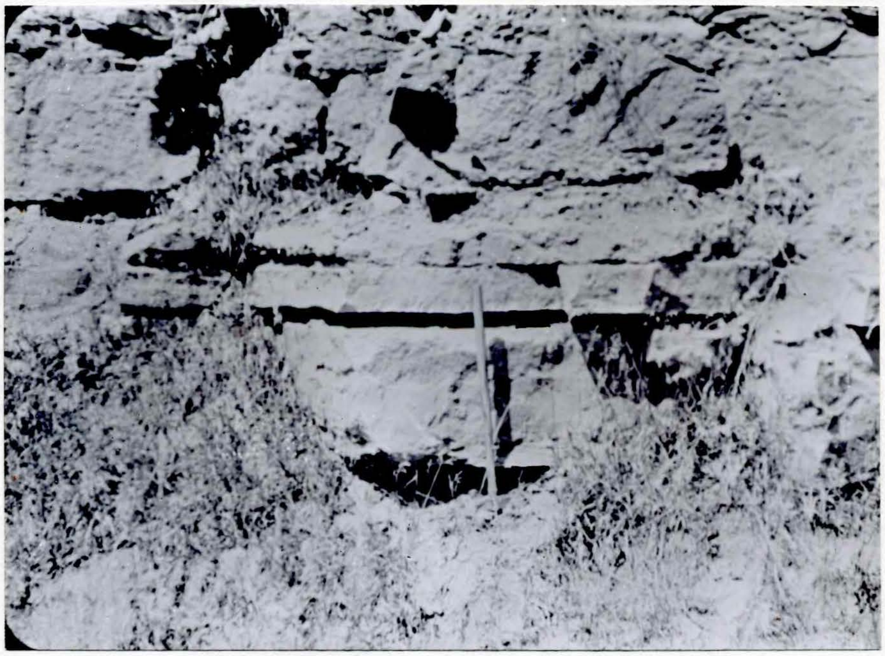
The next dexcription of the Merriam is by Moore, Frye, and Jewett (1955, p. 187). Only a few additions were made to the previous descriptions of the member. Nautiloid cephalopods were described as being locally common where the Merriam is very oolitic, and the member was described as being thicker locally because of the accumulation of algal and granular limestone in its uppermost part.

The next general description of the unit, ~~is~~ by Moore (1949, pp. 115-116), ~~who recognised~~ three divisions within the member: "1) a lower, blocky, drab to light-gray, highly fossiliferous layer, which weathers gray or white; 2) a middle unit consisting of fine-grained, dense, vertically-jointed bluish limestone; and 3) an upper unit consisting of algal and granular limestone." The lower and middle units are essentially the lower and upper units of Newell. The upper unit of Moore is described as ranging from a featheredge to eight feet in thickness, less persistent than the lower two parts, and containing rather abundant nautiloid cephalopods.

The most recent description of the member is by Moore, Frye, Jewett, Lee, and O'Conner (1951, p. 81) and is the same as that by Moore, Frye, and Jewett (1955). The differences between these descriptions and the result of the present study is discussed below.

"Meadow" limestone

The Merriam limestone is equivalent to the "Meadow" limestone named by Condra and Bengtson in 1915 with a type locality near Meadow Station, north of Louisville, Nebraska. Contra (1949, p. 34) later



Pl. 1A
FIG. 3. Type section of the Merriam limestone (Locality 5). Note the three distinct units of the member and the extremely flat upper contact.

states that although the member was properly defined with relation to its position and sequence in the section, its age correlation ~~has~~ proved to be in error, and although the name ~~has~~ been used locally for more than thirty years, it ~~is now~~ dropped, because of the original error in age correlation, and the name Merriam ~~is~~ accepted by the Nebraska Survey. The history of the term "Meadow" limestone is given in detail by Wilmarth (1938, p. 1330).

Location of area

The Merriam limestone crops out in the states of Iowa, Missouri and Kansas; it is also exposed locally in southeastern Nebraska on the Nemaha Uplift. ~~In Kansas the outcrop belt extends from Leavenworth County in the North to Montgomery County in the south (Fig. 2)~~. The Merriam was studied in the area from Wyandotte County to ~~Wilson~~ County (~~Pl. 1~~),

~~Outcrops~~

Characteristically, the Merriam limestone is ledge-forming throughout the outcrop area in eastern Kansas (Fig. 4). However, in places where the overlying Hickory Creek shale is thin, the upper limestone member of the Plattsburg formation, the Spring Hill limestone, is the main ledge-former. In general, the Spring Hill limestone is the main ledge-former in the southern part of the ~~area studied~~, and this relation effects the abundance of outcrops of the Merriam which is much thinner in the south. The scarp-forming nature of the Plattsburg in the central and southern parts of the area is shown in figure 5.

With the exception of the bluffs along the Missouri and Kansas rivers most of the outcrop area in Leavenworth and Wyandotte counties is covered with loess. The Merriam is also poorly exposed in eastern Johnson County, but there are several good exposures in the northern part of the county along the northward-draining creeks. Many outcrops of the Merriam occur in northwestern Miami County, eastern Franklin County, and northern and central Anderson County. Outcrops, except eroded rubble, are rare ~~from southern~~ Anderson County, ~~to central~~ Wilson County, but even there the abundance of outcrops is not comparable with that of northeastern Kansas.

The most accessible outcrops in the area are the many road cuts, but the Merriam is also exposed in several quarries and along stream banks. In many quarries, however, the Merriam is exposed high in the quarry wall.

Acknowledgements

The writer wishes to thank Dr. M. L. Thompson of the Department of Geology, University of Kansas, for supervision and aid in the preparation of this report. Thanks are also due the State Geological Survey of Kansas for field expenses and access to the stratigraphic sections, Mrs. Shirley McElroy who typed the manuscript, and Mrs. Barbara Daly for preparation of the plates.

Pl. 2B ~~FIG. 4.~~ Common topographic expression of the Merriam as ledge-former. Note the remainder of the Plattsburg is represented by rubble.

FIG. 5. Common topographic expression of the Plattsburg formation in the central and southern parts of the area.

TECHNIQUES

Field Techniques

Outcrops were located for the most part by following section line roads with reference to the outcrop belt shown on the Geologic Map of Kansas. This method showed a surprising accuracy of the geologic map. Most exposures were found in road cuts and a few were found along stream banks and in quarries. Stratigraphic sections from the State Geological Survey of Kansas aided in this procedure.

At each exposure the member was measured and field notes were written describing the member and the adjacent beds. Also, samples were taken at most of the outcrops. These samples represent the complete exposure at some localities and were randomly selected at other localities. The use of complete and random samples instead of entirely complete samples was the result, not of complete or partial exposure of the section, but of the interest in determining the relative merit of the two methods of sampling for the purpose of stratigraphic correlation. The samples were taken in the form of large hand specimens and the fragments for insoluble residue study were later chipped off the specimens in the laboratory. Samples of the shale bed were also taken where possible.

Appendix A contains the detailed field descriptions of the member.

Laboratory Techniques

The procedure followed in the laboratory may be divided into that part dealing with the study of the limestones and that part dealing with the study of the shale bed. One of the techniques used in the study of the limestones was the analysis of insoluble residues from treatment with hydrochloric acid. For the most part, the procedure which was used is that of Perkins (1952, pp. 12-33) and the reader is referred to that paper for a detailed discussion of the procedure. In general, the steps involved are as outlined below. The crushed sample of 20 grams is dissolved in thirty percent hydrochloric acid, after which it is filtered, washed, and dried. After weighing the residue to determine the weight and percentage of soluble and insoluble parts, the residue is boiled in hydrochloric acid to remove any limonite. The residue is again filtered, washed, dried, and weighed. The difference between this weight and the first weight is the weight of the limonite which was present. The residue is placed in a 0.01N sodium oxylate solution and agitated on an electric shaker for several hours to deflocculate the fine particles. The coarse fraction of the residue is separated off by washing the sodium oxylate solution and residue through a 230 mesh screen (one-sixteenth millimeter). The coarse fraction is then weighed and stored for study. The rest of the residue is placed in a beaker for sufficient time to permit the fine fraction to settle out and is then poured into a graduate five inches in height and let settle for five minutes (Lamar, 1926). The liquid which is siphoned off contains the fine fraction, and the medium fraction is left in the graduate. After these two fractions have been dried, the residue preparation is complete. Although the method used to separate the medium and fine fractions is that of Lamar, a similar method is described by Krumbein and Pettijohn (1938); but as Perkins (1952, pp. 27-30) points out, the Lamar method is quicker and there is not much difference in the results.

Another technique used in the study of the limestones was acid etching. The procedure is primarily that of Lamar (1950) and Ives (1955). The sample is sawed in a plane normal to the bedding and then smoothed on a lap with grinding powder. Afterwards, the sample is submerged in a pan containing eight percent hydrochloric acid and left for three to eight minutes, depending upon the density of the limestone. The sample is placed in the acid pan with the smooth side of the sample up and as nearly level as possible to prevent furrowing by streams of carbon dioxide bubbles. Acetic acid was also used for acid etching but did not prove so effective as hydrochloric acid for differentiating the soluble and insoluble materials. Also, as in insoluble residue studies (St. Clair, 1935), the greater length of time necessary in acetic acid studies did not produce significantly better results.

Dry peels, as described by Sternberg and Belding (1942), were also made by dipping the etched specimen of limestone in acetone and then pressing it on a sheet of acetate. However, in this study dry peels did not show color contrasts and did not permit easy identification of the carbonate and noncarbonate material. A complete study would involve both dry peels and acid etching inasmuch as the etched rocks do not show the structure of organisms and are difficult to photograph.

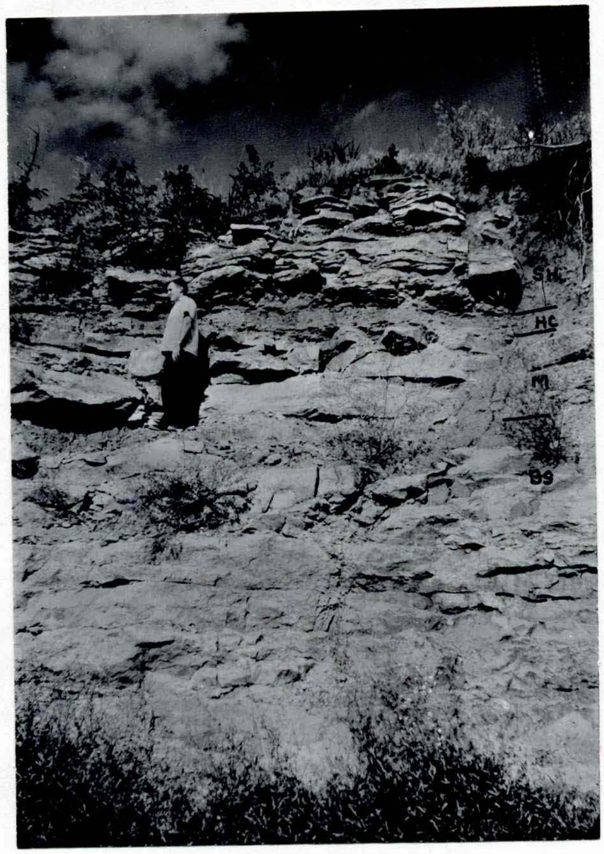
Thin-sections of the limestone were made from several sections, and their possible use for correlation is described later.

Two methods were used in the study of the shale bed. The first method consisted of preparing the shale for study of the microfauna. A unit weight of shale is boiled until the clay is driven off and the fossils and coarse material are left as a residue. More indurated shale samples are first soaked in kerosene and then boiled. A few chips of fresh shale from each section are placed in a watch glass (Krumbein, 1947). After covering the shale chips with water, a few drops of acid are added. Then after washing and decanting to remove the clay, the residue is examined for mineralogical composition. The degree of effervescence is also noted and the relation of this to the results of the boiling study will be noted later.

STRATIGRAPHY

Bonner Springs shale

One of the main reasons for the ledge-forming character of the Merriam, besides the denseness and relative purity of the limestone, is the thick sequence of shale which underlies it. This shale is named the Bonner Springs shale in the northern part of the area, (Fig. 1) but because of the disappearance of the underlying Wyandotte limestone to the south, the shale is termed the Lane-Bonner Springs shale in southern Kansas. The Bonner Springs shale is a somewhat variable unit in both lithology and thickness. The most striking variation occurs in the



A. 2A

~~FIG. 6.~~ Section at De Soto, Kansas, (Locality 10) showing local limestone developed in the Bonner Springs shale.

vicinity of the town of De Soto in northwestern Johnson County, Kansas (Fig. 6). In this area the typical thick section of shale is replaced by a sequence of up to five feet of granular cross-bedded limestone with only one foot or less of shale at the top. This variation involves not only lithology, but also thickness as only a short distance away from this area the Bonner Springs attains a thickness of 20 to 25 feet. This area (Localities 3, 10, and 12) is the only part of the region studied in which this development of the cross-bedded limestone is observed.

To the north of this area the Bonner Springs is composed of four units: 1) an upper unit about seven feet thick composed of limy shale and thin limestone beds; 2) an upper sandy unit of olive-green silty shale and thin to thick beds of fine-grained sandstone; 3) a unit of blue clay-shale; and 4) a lower sandy unit of olive-green silty shale and thin sandstone beds. The total formation is about 30 feet thick. A more typical section of the Bonner Springs is developed south of the limestone area in Johnson County. The sequence in this area from bottom to top is arenaceous shale, maroon shale, marlite, arenaceous and argillaceous shale, and local calcareous shale. The most distinctive units in this sequence are the maroon shale and the marlite which can be traced as far south as sec. 32, T. 18 S., R. 22 E. in Miami County and sec. 9, T. 18 S., R. 21 E. in Franklin County. North of this line of southern limit the maroon shale and overlying marlite are only locally absent. Each of the two units is commonly less than one foot in thickness. The maroon shale is composed mainly of clay and the marlite is an argillaceous, yellow, nodular limestone. The remainder of the section is predominantly olive-green with the upper one foot or less a yellow or yellow-brown limy shale. Small limestone nodules are not uncommon in this upper part of the Bonner Springs. The contact between the Bonner Springs and the Merriam is sharp in this part of the area.

In southeastern Franklin County and to the south a two-fold change occurs in the Bonner Springs, a change in color and lithology. The upper five to 20 feet of the formation remains an olive-green to pale olive somewhat arenaceous shale, but below this unit in most of the area is a dark gray to blue more argillaceous shale. In several localities the olive-green shale contains thin beds of sandstone. The sequence just described is found at Locality 36 (Pl. 1) and in eastern Anderson County in the area including Localities 44, 48, and 53. At Iola and farther south the blue shale comprises almost all the upper part of the Lane-Bonner Springs shale.

At those localities west of a line through Locality 34, 45, and 49 and at Localities 54 and 55 in southeastern Anderson County a thin-bedded to massive, thick to thin, cross-bedded sandstone occurs at the base of the olive-green shale. This sandstone contains ripple marks at some localities. The thickness of the sandstone ranges from three feet to about 30 feet, although in the latter section several very thin beds of shale are interbedded with the sandstone. The top of the sandstone occurs from five to 20 feet below the top of the formation.

Although the contact between the Bonner Springs and the Merriam is usually sharp in this part of the region, it appears gradational at some localities where the lower two-tenths foot of the Merriam is somewhat earthy and conglomeratic with shale pebbles.

Plattsburg formation

Merriam limestone member

Introduction. Throughout the region studied certain units within the Merriam limestone are recognized and, for the most part, traced without difficulty. For the purpose of description these units are termed the lower limestone unit, the shale bed, and the upper limestone unit. This tripartite division is recognized throughout the area; however in those parts of the area where the shale bed is missing, it is difficult to separate the two limestone units.

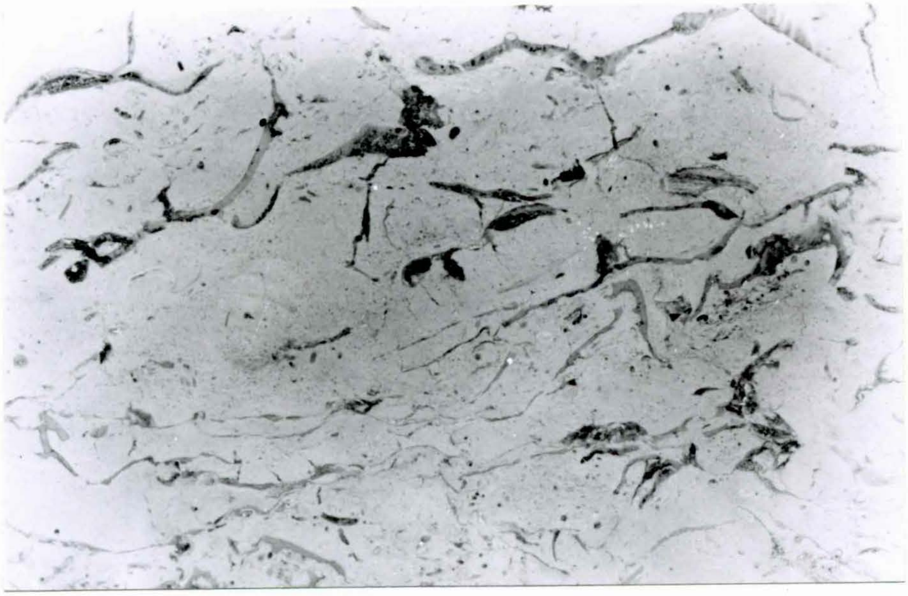
Lower limestone unit. The lower limestone unit is the most variable unit in lithology and thickness. The thickness ranges from a featheredge to over eight feet, with an average thickness of about two feet. In the few localities where this unit is absent, the upper limestone unit rests on the Bonner Springs shale. The unit is absent at one locality in western Johnson County and at another in northern Miami County (Pl. 2). In general, the lower limestone unit is thin to the east and west and thicker in the middle part of the area, especially in the north where the lower part of the unit is massive and the upper part is oolitic and cross-bedded, with indistinct low angle cross-beds. These are the only localities in which any part of the Merriam is cross-bedded.

The lower unit is composed of two beds in most of the area, however at places there is only one bed and in southeastern Franklin County the unit is represented by three beds. At several localities the lower 0.2 foot of the unit is greatly weathered and contains small pebbles of shale similar to that of the upper part of the Bonner Springs shale. The remainder of the unit is characteristically massive and in places oolitic. However for the most part, the limestone is light gray and fine to medium grained although in the lower part the grain size is reduced to an aphanitic texture. The appearance of shale pebbles in the basal few inches of the unit is more common toward the south, but throughout the area the base is commonly earthy, shaly, and greatly weathered. At certain localities this basal part of the unit resembles the punky limestone bed which overlies the Merriam in the northern part of the area. Also, this part of the unit is yellow-brown for an inch or so beneath the outcrop surface at some localities, as Locality 16, and at others it grades into the Bonner Springs shale. Although the lower few inches of the unit is conglomeratic in many parts of the area, especially toward the south, this part of the unit is very earthy in appearance but still dense at some localities. The texture is somewhat granular with unequal sized grains, giving the rock the appearance of a fine-grained conglomerate; however no shale pebbles are present.

At a few places a thin shale bed of one- or two-tenths of a foot in thickness is present within the unit, and commonly this shale contains plate-like limestone nodules of the surrounding rock. Shale partings and slabby weathering along irregular planes are common in certain parts of the area.

Three especially interesting features occur in the limestone of this unit. The first is numerous small cavities which are filled with orange limonite; however, as would be expected, this feature is found only in the zone of oxidation. Another feature present is worm-borings which are filled with ferruginous clay; however, inasmuch as this feature is more characteristic of the upper limestone unit, a discussion of the feature will be postponed until that unit is described. The most characteristic features of the lower unit are the dolomite veinlets, one type of which is composed of dark crystalline dolomite whereas the other type is composed of light gray dense dolomite. Although both types of veinlets are present together in the same rock, they more commonly occur separately. At a few localities the veinlets weather out in relief. The veinlets are about one millimeter in width and have a maximum length of about three inches along an irregular plane (Fig. 7). These dolomite veinlets resemble the laminated masses of calcareous algae which are present locally. In some specimens the limestone is observably oolitic only near the veinlets. Eventhough this unit shows prominent vertical jointing in some localities, this type of jointing is more common in the upper limestone unit.

A minor fauna of fauna ramose and fenestrate bryozoans, productids and other brachiopods, gastropods, and crinoid columnals is present throughout the area with the crinoid columnals being the most abundant representative of this fauna. Besides the above fauna there are certain rare remains which are present in a few localities. Horn corals do not



Pl. 2B ~~FIG. 7.~~ Dolomite veinlets in the lower limestone unit. X1.8

~~FIG. 8. *Composita* zone near base of Merriam limestone.~~

occur in the northern part of the area; however southward from southeastern Franklin County rare specimens are present at a few localities. Another rare element of the fauna is sponges, which are present at a few localities in the western half of Johnson County, in Allen County, and sparsely in between. The third rare element of the fauna is even more restricted areally because cephalopods occur only in east-central Franklin County.

Four forms represent the major part of the biota; these are *Osagia*, *Myalina* (*Orthomyalina*), *Composita*, and fusulinids. The first three forms are present in two somewhat definita zones in that part of the area north of northeastern Anderson County. In this northern part of the area the brachiopod *Composita* very commonly occurs in a zone of about 0.4 foot in thickness either just above the basal conglomeratic part or, if the conglomeratic layer is absent, at the very base of the member. *Composita* is not restricted to this zone as it is present throughout the unit; however in no other part of the unit are the specimens so abundant as in the lower few inches (Fig. 8).

At a few localities an ideal relationship is present in that overlying the *Composita* zone is a zone of *Osagia* and *Myalina*; however throughout most of this northern part of the area *Composita* also ranges up into the overlying zone. In general, *Osagia* (Fig. 9) and *Myalina* (Fig. 10) occur together only in the lower half of the unit as *Myalina* is commonly absent in the upper part. Definitely *Myalina* is more restricted than *Osagia* inasmuch as the latter is present throughout the unit vertically and throughout the area. South of northeastern Anderson County *Myalina* and *Composita* are very rare and finally disappear.

FIG. 9. Photomicrograph of *Osagia* and ooliths from upper part of lower limestone unit.

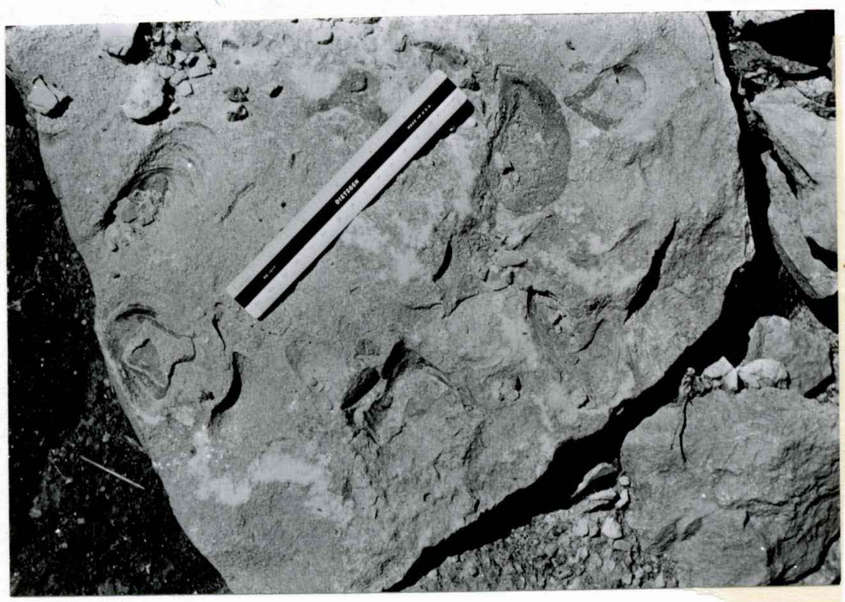


FIG. 10. *Myalina* (*Orthomyalina*) *ampla* zone in lower part of lower limestone unit.

Fusulinids are absent north of central Johnson County, Locality 16, and are very rare south of this locality to east-central Franklin County. At the latter locality fusulinids are rare in the upper part of the unit, but to the south fusulinids are more common and are present lower in the unit until in southern Anderson County fusulinids are common throughout the unit. Two types of fusulinids are present and both are probably species of *Triticites*. One type is large and elongate whereas the other is more robust.

In parts of Allen County this lower unit contains common irregular yellow clay laminae whereas in other places the lower part of the unit is marly. Throughout the area the unit weathers dusky yellow to light olive gray and where the overlying shale bed is absent, the unit weathers even with the upper limestone unit. Although the Merriam is present in Wilson County, it is of a different sedimentary facies and the writer considers it unlikely that the lower limestone unit is represented in the southern sequence.

Shale bed. Overlying the lower limestone unit is a very thin but persistent unit, the shale bed. The unit is as much as 0.5 foot in thickness but averages 0.2 foot. ~~As is shown in Fig. 11, the shale bed~~ is absent in eastern Johnson County, along a belt from western Johnson County to northern Anderson County, and to the southwest. Throughout the area the shale is papery and laminated; however in the northern part of the area it is somewhat more irregular in thickness along the outcrop. Also in this part of the area it is pale olive to yellow-orange and appears to grade downward through an earthy limestone at the base and into the underlying lower limestone unit. The shale is limy

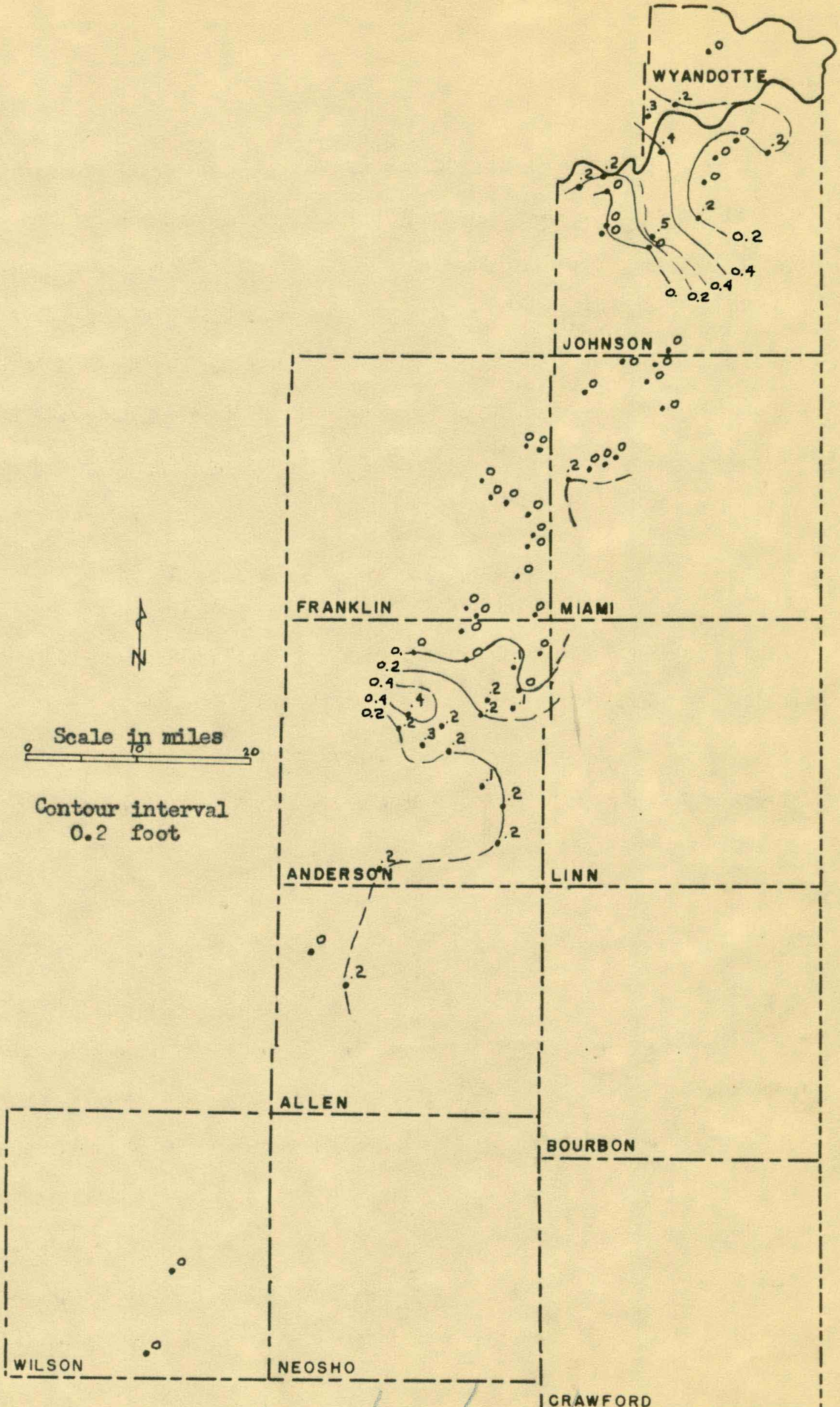


FIG. 11. Thickness map of the Shale bed.

throughout most of the area and in general is more limy and yellow where it is thinnest; however to the south the shale is more clayey and is in other ways somewhat different from the northern appearance.

In almost every section in the southern part of the area north of Iola the shale is light greenish-gray, olive gray, and moderate olive-brown, but these colors are not interlaminated. Also characteristic of this southern part of the area are common, small symmetrical, open folds with vertical axes. At some localities limestone nodules are present in the shale.

In general, the shale bed contains very few megafossils, in fact the only fossils observable in the shale are brachiopods and crinoid columnals. Crinoid columnals were found at only two localities, but brachiopods are somewhat more abundant. Along the Kansas River the shale contains extremely abundant, well preserved spiriferoid brachiopods; and although brachiopods are found in the shale along the eastern edge of the outcrop belt, they are nowhere so abundant as in the Kansas River area. The laboratory study of the shale showed other fossils to be present in the shale.

It is possible that the shale bed is present in those areas where the lower limestone unit is absent; however if the shale is present, it can not be distinguished from the underlying Bonner Springs shale. The southern limit of the shale is unknown but it is possible that the shale is contained in the shale sequence of southern Kansas and northern Oklahoma.

Upper limestone unit. The uppermost unit of the Merriam limestone is the upper limestone unit. This unit is the most distinctive of the

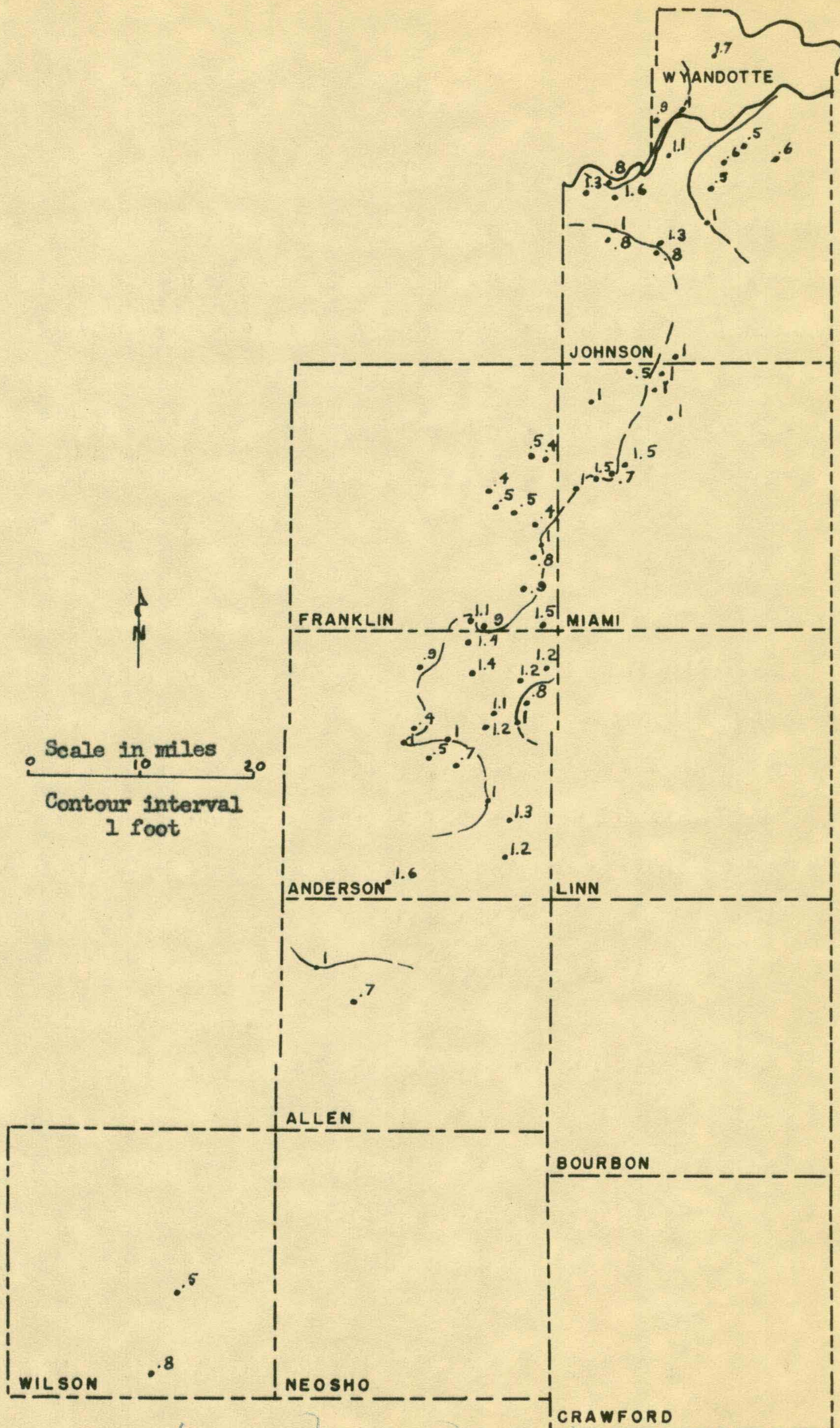


FIG. 12. Thickness map of the Upper limestone unit.

triad and with few exceptions can be readily identified throughout the area. Also, it is the most constant unit in terms of thickness as the thickness ranges from 0.4 foot to 1.5 feet with an average of about one foot. As is shown in Fig. 12, this unit is somewhat thinner to the northwest and thicker to the southeast, except in northern Johnson County.

In most parts of the area the upper limestone unit is composed of only one bed of fine-grained to aphanitic limestone which is massive and is crossed by prominent vertical joints. The unit commonly weathers dusky yellow although in places it is a very light gray. On a fresh fracture the limestone is light to dark gray with commonly a bluish tinge. Where erosion has progressed to a more complete stage, this unit is represented by rubble composed of angular blocks; this appearance is more common in the southern part of the area. In less eroded localities the unit is characterized by pitted weathering. The contacts of the unit are fairly even, especially the upper contact which is almost flat in most places. Although the dolomite veinlets characteristic of the lower limestone unit are present in this unit, their abundance is far less. At only two localities was this unit observed to be oolitic.

The writer considers this unit to be the only representative of the Merriam limestone in southern Kansas and in that part of the area this unit is classified by others as equal to the entire member. The reason for the hypothesis that the entire member is not present in the south will be discussed later under the topic of environment of deposition. The unit in southern Kansas is characteristically a yellow irregular slabby limestone and contains an abundant fauna of sponges and crinoid columnals. One of the better exposures of the unit is shown in Fig. 13.

FIG. 13. Section of Merriam limestone in southern Kansas (Locality 59).

Pl.2C

FIG. 14. Worm boring in upper limestone unit. Note near vertical orientation and fragments of rod filling tube.

This unit is less fossiliferous than the lower unit and contains a fauna of crinoids in the form of common columnals; rare small brachiopods with some *Composita*; rare echinoid spines; rare horn corals; common calcareous algae in Allen County; common *Osagia*, usually in the lower part; and fusulinids. The fusulinids are of two types as in the lower unit and are much more common toward the south; however in the upper unit they extend as far north as the Kansas River as compared to central Johnson County in the lower unit. The above faunal list, however, does not include the most characteristic feature of the unit. This feature is the worm borings filled with yellow ferruginous clay. Worm borings are, for the most part, very common in the upper unit and are found in the upper part of the lower unit at only four localities. The worm borings are three to five millimeters in width and have a maximum length of eight centimeters. Some specimens are oriented vertically in the rock but in general the tubes are inclined. Many of the borings are single tubes whereas others bifurcate at the base and some intersect. It is extremely possible, and indeed very likely, that not all the tubes present in the rock are worm borings; however the discussion of most of the tubes under the title of worm borings seems justified.

The soft, yellow, ferruginous, micaceous clay which by inspection appears to fill the tube, does not in fact completely fill it, for, as is shown in ~~Fig. 14~~, part of the tube is filled by a thin rod of hard, red, ferruginous matter. That this rod is not the result of secondary replacement or precipitation is shown by the fact that the entire tube is not filled by it, and yet it retains its circular cross section instead of being planed off or irregularly constructed as would be expected from solution action. Undoubtedly, the ferruginous clay represents the alteration product of the rod as well as primary deposition.

Solutions have applied a thin film of ferruginous matter along the small vertical joints, which might more descriptively be called cracks; however it is rare if more than one of these cracks cross one of the tubes. It seems very improbable that the amount of ferruginous material necessary to fill the tube could have been introduced through these cracks and not have resulted in a bleached zone along the cracks. The rock for a distance of two to four millimeters around the tubes is bleached; but if the bleaching is due to the ferruginous material filling the tube, then why is there no bleached zone along the cracks? According to Dapples (1942, p. 123) the sediment surrounding worm tubes is commonly bleached, "apparently by the reducing action of the body juices. After the death of the organism, the burrows become filled with fine sediment and are preserved as small cylinders." The clay fillings of the tubes are not limonite and the origin of the fillings can not be put down to the near surface occurance of limonite or the weathering of pyrite; however much of the clay has, in turn, been altered to limonite.

It seems very likely, therefore, that these tubes with their indistinct annular convolutions and rod-like fillings are actually worm borings. These worm borings are very similar to the description of worm borings given by Shimer and Shrock (1949, p. 234) in which they mention the various attitudes of the hole, the fillings of castings of detrital material differing slightly from the surrounding rock, and the occurance of the granular filling weathering out as a curved or straight rod. They also point out that where worm borings are present in number, other fossils are almost always scarce or absent. At certain localities the worm borings of the upper limestone unit are certainly present "in number"; however it is very rare that other fossils are absent, although when compared with the lower limestone unit, they are definitely less abundant.

At several localities abundant limonite replacement has occured randomly in the unit with the result that on casual inspection the limonite replacement resembles the worm borings; however the limonite replacement lacks the tubular development of the clay-filled worm borings. These features are not related to the worm borings and definitely are not collapsed worm borings, inasmuch as the collapsed borings retain all the characteristics of the normal tubes.

Hickory Creek shale member

The middle member of the Plattsburg formation is also a unit of variable thickness and lithology. Although the average thickness of the shale is about one foot, it is absent at some localities and is as much as five feet thick at other localities; however Newell (1935, p. 69) reports the member to be 20 feet thick at one locality in Johnson County. The increase in thickness seems to be more a result of local thickening than of regional factors.

Throughout the area the member essentially consists of two units, one of shale and another of earthy, punky limestone. The limestone is commonly from 0.2 foot to 0.4 foot in thickness and is overlain by the main part of the shale. Underlying the punky bed is usually less than one inch of shale. The limestone is grayish-orange on a fresh fracture and weathers a yellowish-gray. Although the unit is punky and earthy on the weathered surface, it is massive and hard on a fresh fracture. The appearance is that of a greatly weathered rock and it is impossible to determine textural detail from megascopic investigation. The unit commonly contains crinoid columnals, and at some localities brachiopods, including Composita, or fusulinids are present.

At some localities that part of the shale underlying the punk bed is black, carbonaceous, and platy; however the black shale is not developed nearly so well as in the Shawnee group. The main part of the shale is limy or clayey; where it is limy the shale is commonly yellowish, whereas the clay shale is mainly olive gray and slightly green. Throughout the area the shale is laminated; however in the localities of more limy composition the shale is nodular in splitting. In the region of southeastern Franklin County the Hickory Creek could be represented by the thin, platy limestone at the base of the Spring Hill limestone member.

In the southern part of the area this shale resembles the shale bed in the Merriam limestone member in that it is composed of several colors which are not interlaminated; however it is thicker than the shale in the Merriam and also contains the punk bed. The small symmetrical open folds characteristic of the shale in the Merriam were not observed in the Hickory Creek shale. In southern Kansas the member thickens to as much as 30 feet although more commonly the thickness is between eight and 16 feet. The shale is dark gray and weathers light gray with a bluish tinge. The shale is more fossiliferous than elsewhere and contains common sponges, crinoid remains, and brachiopods, especially in association with the thin beds of argillaceous limestone which are present. At some localities the shale and interbedded limestone are difficult to differentiate from the limestone and interbedded shale of the lower part of the Spring Hill limestone member.

Spring Hill limestone member

The upper member of the Plattsburg formation is less variable than the underlying members. Throughout the area it consists of a lower part of dense, massive limestone which commonly weathers into thin beds, and an upper part of thin, irregularly-bedded limestone with the characteristic wavy bedding surfaces.

Because of the stratigraphic position which places a thick shale sequence above it, the Spring Hill is usually well eroded and only rarely is a complete section of the member found. South of central Anderson County the member is commonly represented by only the lower foot or so of the section and in places this is present only in the form of erosion rubble.

In most places the member is light olive gray on a fresh fracture and weathers a dusky yellow similar to the Merriam. The limestone is fine-grained and although the lower part of the member is massive, weathering produces thin plates which give the impression that the entire unit is composed of thin wavy beds. The wavy beds of the upper part of the unit are separated by thin shale partings.

The Spring Hill is very fossiliferous and contains abundant fragments as well as specimens of brachiopods, as Enteletes and Composita; bryozoans; echinoid spines; and crinoid columnals up to one-half inch in diameter. The lower part of the member is characterized by brachiopods and bryozoans whereas the upper part contains a large molluscan element.

In southern Kansas the member thickens locally to as much as 80 feet and contains yellow and more irregular beds than in the north. Although the member is also fossiliferous in the south, the most abundant element of the fauna is sponges. The member is somewhat shaly near the base and top at some localities. The formation as a whole thins and thickens greatly in short lateral distances in this part of the region.

SEDIMENTARY ANALYSIS

Insoluble Residues

An insoluble residue, as defined by Ireland (1936, p. 1087), "includes all material remaining after a sample has been digested by cold dilute hydrochloric acid." This definition is applicable to the material studied from the Merriam limestone. However, if this definition is taken in a strict sense, then the insoluble material remaining after the digestion by acetic acid would not be insoluble residues. The writer sees no reason for not including this latter material as insoluble residues.

Insoluble residues have been studied by many geologists, especially since McQueen's (1931) work on the residues from the Cambrian and

Ordovician rocks of Missouri. In Kansas, Hiestand (1938) described the residues from Mississippian rocks and Perkins (1952) and Wahrhaftig (1952) described the residues from Virgilian rocks. However, the works of other authors are more closely related to the sequence involved in this report. Preliminary reports on the insoluble residues of certain Pennsylvanian rocks by Schowe, Keroher, and Keroher (1937) and by Keroher (1939) describe the residues from the Plattsburg formation and the Merriam limestone. Also, Wenberg (1942) described the residues from the Plattsburg formation in Iowa. A comparison will be made later of the findings of these reports and of the present report.

Table 1 is a classification of the insoluble residues of the Merriam limestone member. Each type will be described in the order of its appearance in the table, and since the particles forming the coarse fraction of the residue are the most characteristic, they will be described more fully.

Appendix B is composed of tables showing the types and percentages of material present in the residues of each sampled section. The terminology is that if Ireland and others (1947).

TABLE 1. Classification of insoluble residues of the Merriam limestone member.

I. Allogenic - Constituents derived from previous sediments.

   1. Sand, quartz and minor amounts of mica
   2. Silt, quartz, minor amounts of mica, and aggregates
   3. Clay

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

   A. Syngenetic - Constituents formed contemporaneously with the deposition of the sediments.
      1. Glauconite
      2. Fossils

   B. Epigenetic - Constituents formed subsequent to deposition and lithification of the sediments.
      1. Interstitial silica
      2. Silicified fossils
      3. Secondary quartz
      4. Beekite

   C. Syngenetic or Epigenetic
      1. Chert
      2. Pyrite
      3. Limonite

Allogenic

Sand. Sand grains composed of detrital quartz occur in various amounts throughout the sequence of the Merriam limestone and throughout the area. The grains are loose, subrounded to angular, etched, and predominately a milky color, although in places the grains are orange or red with limonite stain. The size of the grains ranges from 0.05 millimeter to 0.5 millimeter with the average being somewhere between 0.1 and 0.2 millimeter. There is no relation between the size of the grain and the color; however, probably because of the greater ease in viewing, the larger grains appear to be more angular and etched. Most of the grains are subrounded to subangular.

Although the average percent of the coarse residue formed by sand grains is 13.5, the percent in the individual residues ranges from less than one to 90 percent. For the member as a whole no regional change in the percent of sand grains is evident, however a change is present when the units within the member are considered. If the two beds in the lower limestone unit are considered separately, there is a difference in the amount of local concentration of sand grains, however the regional plan is about the same. Therefore, an Isopercentile Map of the sand grains in the lower limestone unit is plotted (Fig. 15), but because of the great variation which is present, the significance of the map is not in the course of the isopercentile lines, but rather in the illustration of the great amount of local variation which is present. A comparison of this map with an Isopercentile Map of the sand grains in the upper limestone unit (Fig. 16) points out the great difference in the regional distribution of the sand grains during the two times of deposition. In southern Kansas sand grains form as much as ten percent of the residue.

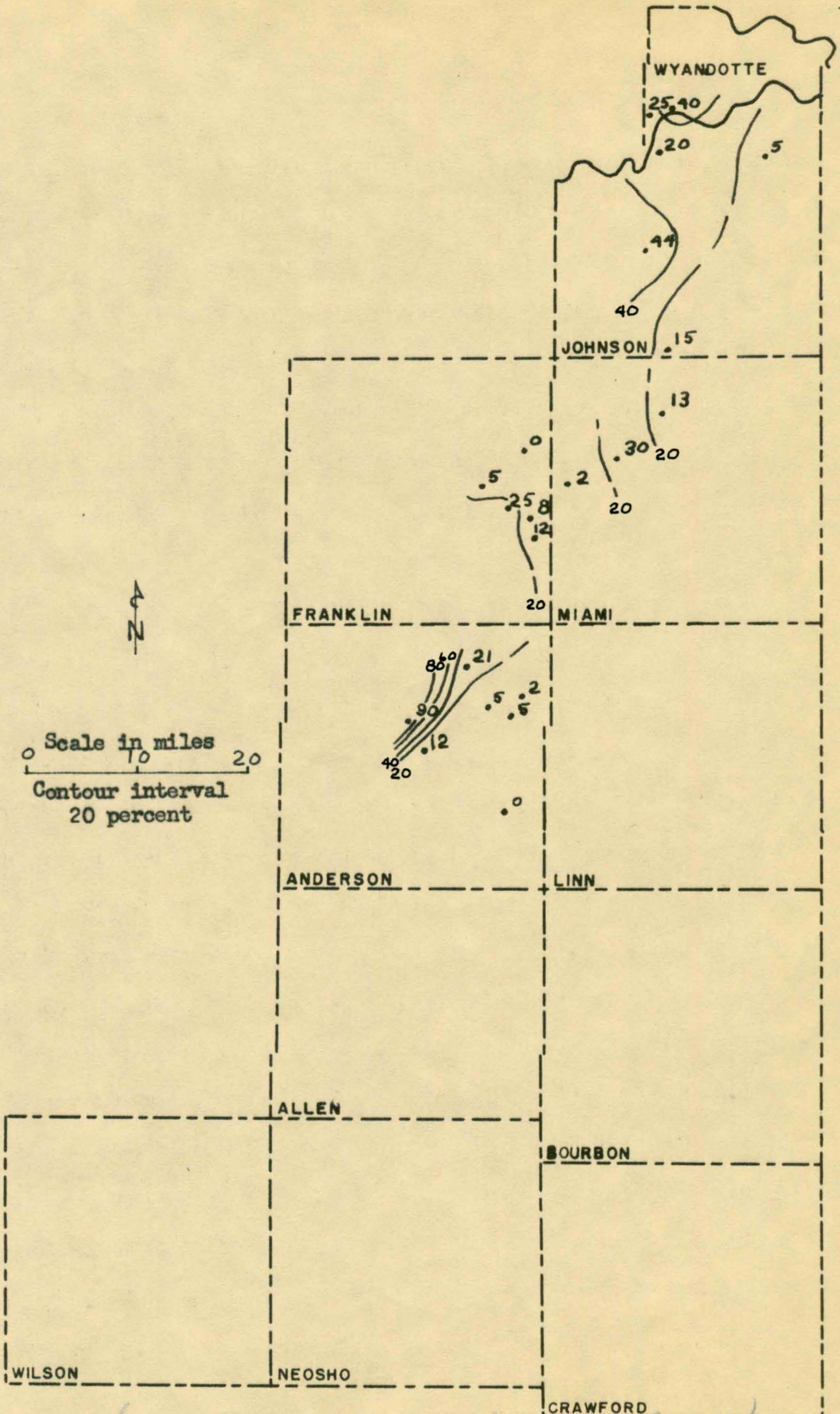


FIG. 15. Isopercentile map of sand grains in residue of Lower limestone unit.

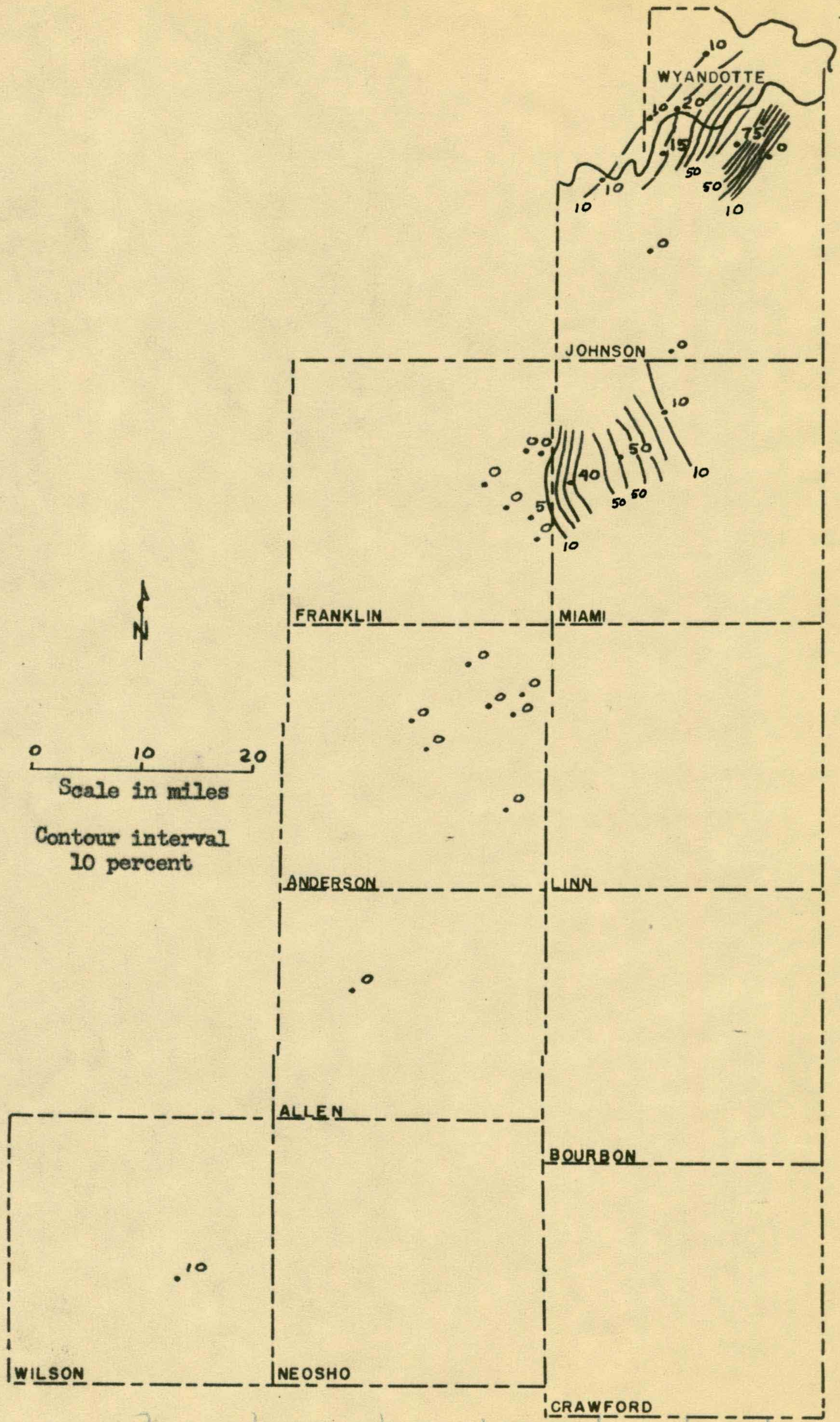


FIG. 16. Isopercentile map of sand grains in residue of Upper limestone unit.

Small clear mica flakes are rare in the coarse residues although in three sections in the southern part of the area the mica comprises up to ten percent of the coarse fraction of the residue. In two of these sections the mica is in the lower limestone unit and is associated with a relatively high percent of sand grains; in the one section in which the mica is common in the upper limestone unit, sand grains are rare.

Silt. The medium fraction, or silt fraction, of the residue averages about 30 percent of the residue less the iron weight (Table 2). The coarse fraction averages about 20 percent and the fine fraction averages about 50 percent. The medium fraction is composed predominantly of white to tan silt-sized quartz grains and locally common pyrite grains, white mica flakes, and silt aggregates. Small chert fragments are also present. The quartz silt grains are about the same size as those comprising the tests of arenaceous foraminifers and many of the grains may represent the disaggregated tests of foraminifers. Only a few of the quartz grains are larger than those comprising this dominant size group. No difference was noted in the composition of the silt of the various units or parts of the area.

The coarse fraction of the residue is characterized in many samples by aggregates of silt-sized silica and clay; these aggregates were referred to by Perkins (1952, p. 37) as "algaloids". The aggregates are small wad-like features which are generally light to dark brown and rarely white. As Perkins states, these features have no organic structure, although on the top and bottom of the discoid aggregates are distinct concentric grooves. These aggregates however are not organic, but are the result of the chemical action of the digestion of the sample in hydrochloric acid. Residues of the same sample derived from digestion in hydrochloric and acetic acids show no aggregates in the acetic residue; this is probably due in part to the lack of formation of a gelatinous material in the acetic residue (St. Clair 1935, p. 148) which causes flocuation of the finer particles. As a secondary test of the possibility that these aggregates are organic and are primary in the rock, the same sample from which the aggregate-containing residue was obtained was etched in hydrochloric acid. The result was that none of these insoluble aggregates were observed on the etched face of the limestone although the residue contained up to 60 percent of these aggregates. For some reason the sodium oxylate solution does not deflocculate these aggregates and it can not be shown that it actually does not add to the aggregation.

Because of this aggregation the silt-sized particles were caught on the sieve and were counted as part of the coarse fraction of the residue; thus the total weights of these two fractions of the residue are misleading. The aggregates comprise from zero to almost 100 percent of the residue. The cause of this variation is not known, however certain percentage relations are strikingly uniform, especially the relation between the percentage of aggregates and foraminifers. Wherever the percentage of aggregates is high, the percentage of foraminifers is low; this relation is present not only in the residues of the Merriam, but an examination of Perkins (1952) work shows the relation to be also present in the residues of the Shawnee group. In those residues in which the percentage of sand grains is high, aggregates are almost always absent. There seems to be no relation between the percentage of aggregates and the degree of dolomitization of the limestone.

Clay. Clay forms about 50 percent of the residue although some clay is retained in the silt aggregates caught in the coarse fraction. This fraction was not studied except to determine the weight and subsequently the percentage of the residue.

Syngenetic

Glauconite. Glauconite occurs only rarely in the limestones of the Merriam and in no individual residue is the mineral common. The color varies from light to dark green; however the light, or pistaccio, green is more common. Although glauconite is present in both limestone units, it is more commonly observed in the residues of the upper unit; however because of the rarity of the mineral throughout the residues, this seemingly greater abundance in the upper unit may be the result of sampling.

Fossils. Arenaceous foraminifers are the most abundant fossils present in the residues. They are composed of silt-sized grains of white quartz which are very similar to the grains comprising the silt fraction of the residue. The percent of arenaceous foraminifers in the coarse fraction ranges from less than one to almost 100 with an average of about 45 percent. In general, these foraminifers are less common in the southern part of the area and somewhat more common toward the east. This statement applies to both limestone units; however the upper limestone unit seems to show a more local concentration of the organisms. Not only does the abundance of the organisms change to the south, the types of foraminifers also change. In the northern part of the area species of Ammovertella and related genera are predominant; however these species are less common in the south where more tubular forms are abundant. In the south the foraminifers are mostly represented by fragments of tests rather than by complete tests.

Other types of fossils are only locally common; these types include brachiopod spines, sponge spicules, bryozoan fragments, and some probable organic remains including massive, brown chitinous-like material.

Epigenetic

Interstitial silica. Insterstitial silica comprises from zero to 20 percent of the residue with an average of about five percent. It is characteristically white fine-grained, and dolomoldic, and has scattered to abundant dolomolds, which are the voids left after the digestion of carbonate grains by the acid. The interstitial silica seems to be more abundant in the northern part of the area; however where the silica is represented by fragments, it is difficult to differentiate this silica from the silica grains of disaggregated foraminifer tests. Because of this similarity in appearance the two types of silica are not differentiated in some residues. Digestion by acetic acid produces both the interstitial silica and the dolomite rhombs filling the dolomolds.

TABLE 2. ~~Percentage Chart of~~ Residue Analysis of the Merriam limestone member.

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
1B*	0.49g	2.5	0.36g	0.13g	26.5	2.9	33.3	63.9
2A	1.06	5.3	0.86	0.20	18.8	33.7	31.4	34.8
2B	1.21	6.1	0.85	0.36	29.7	35.2	27.0	37.6
2Ca	0.48	2.4	0.41	0.07	14.6	14.6	36.6	48.8
2Cb	0.47	2.4	0.38	0.09	19.0	7.9	52.6	39.4
3A	1.57	7.9	1.34	0.23	14.7	7.5	52.2	40.3
3B	1.00	5.0	0.84	0.16	16.0	10.7	36.9	52.3
3C	0.78	3.9	0.69	0.07	8.9	2.9	37.6	59.4
4A	0.53	2.7	0.46	0.07	13.2	2.2	41.3	56.5
4B	0.47	2.4	0.42	0.05	10.6	2.4	26.2	71.4
4C	0.36	1.8	0.30	0.06	16.6	1.7	36.6	60.0
5AB	0.34	1.7	0.30	0.04	11.8	33.3	30.0	36.7

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
5C	0.41g	2.1	0.34g	0.07g	17.1	38.2	20.6	41.2
5D**	3.22	16.1	2.06	1.16	36.0	35.4	21.8	42.7
6B	1.63	8.2	1.37	0.26	15.9	8.8	49.6	41.6
6C	0.27	1.4	0.24	0.03	11.1	2.1	29.1	66.6
7AB	0.32	1.6	0.27	0.05	15.6	7.4	37.0	55.5
9A	0.29	1.5	0.25	0.04	13.8	12.0	44.0	44.0
11C	0.37	1.9	0.26	0.11	29.7	4.3	42.3	53.8
11D**	3.90	19.5	3.31	0.59	15.1	3.3	22.9	73.7
16A	0.45	2.3	0.27	0.18	40.0	22.2	25.9	51.8
16Ba	0.25	1.3	0.19	0.06	25.0	36.8	21.0	42.1
16Bb	0.25	1.3	0.20	0.05	20.0	35.0	25.0	40.0
16Bc	0.66	3.3	0.57	0.09	13.6	8.8	24.5	66.6
16C	0.21	1.1	0.18	0.03	14.3	22.2	22.2	55.5

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member.

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
17A	0.34g	1.7	0.29g	0.05g	14.7	13.8	41.3	44.8
17B	0.62	3.1	0.59	0.03	4.8	5.1	30.3	64.4
17C	0.36	1.8	0.22	0.14	38.8	4.5	59.0	36.3
20A	1.09	5.5	0.98	0.11	10.1	14.2	42.8	42.8
20B	0.38	1.9	0.32	0.06	15.8	12.5	53.1	34.4
20C	0.34	1.7	0.31	0.03	8.8	12.9	22.6	64.5
23A	0.72	3.6	0.62	0.10	13.9	17.7	35.5	46.7
23B	0.78	3.9	0.67	0.11	14.1	14.9	28.3	56.7
23C	0.64	3.2	0.54	0.10	15.6	9.3	31.4	59.2
26Aa	1.67	8.4	1.55	0.12	7.2	8.4	36.7	54.8
26Ab	0.91	4.5	0.78	0.13	14.2	7.7	42.3	50.0
26B	0.83	4.2	0.70	0.13	15.6	8.6	14.3	77.1
26C	0.30	1.5	0.20	0.10	33.3	15.0	25.0	60.0

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member.

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
27B	0.32g	1.6	0.28g	0.04g	12.5	35.7	14.3	50.0
27C	0.28	1.4	0.24	0.04	14.2	20.7	12.5	66.6
28AB	0.47	2.4	0.38	0.09	19.1	23.7	21.0	55.2
28Ca	0.60	3.0	0.48	0.12	20.0	14.6	33.3	52.0
28Cb	0.38	1.9	0.32	0.06	15.8	21.9	21.9	56.2
28S***	0.55	2.8	0.40	0.15	27.2	10.0	15.0	75.0
29A	0.74	3.7	0.67	0.07	9.5	41.8	17.9	40.2
29B	0.62	3.1	0.48	0.14	22.5	29.1	27.0	43.7
29C	0.39	2.0	0.27	0.12	30.8	25.9	22.2	51.8
31A	1.06	5.3	0.92	0.14	13.2	19.5	43.4	36.9
31B	0.57	2.9	0.48	0.09	15.8	27.0	25.0	47.9
31C	0.26	1.3	0.19	0.07	26.9	26.3	42.1	31.5
32A	0.36	1.8	0.23	0.13	36.1	26.0	26.0	47.8

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member.

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
27B	0.32g	1.6	0.28g	0.04g	12.5	35.7	14.3	50.0
27C	0.28	1.4	0.24	0.04	14.2	20.7	12.5	66.6
28AB	0.47	2.4	0.38	0.09	19.1	23.7	21.0	55.2
28Ca	0.60	3.0	0.48	0.12	20.0	14.6	33.3	52.0
28Cb	0.38	1.9	0.32	0.06	15.8	21.9	21.9	56.2
28S***	0.55	2.8	0.40	0.15	27.2	10.0	15.0	75.0
29A	0.74	3.7	0.67	0.07	9.5	41.8	17.9	40.2
29B	0.62	3.1	0.48	0.14	22.5	29.1	27.0	43.7
29C	0.39	2.0	0.27	0.12	30.8	25.9	22.2	51.8
31A	1.06	5.3	0.92	0.14	13.2	19.5	43.4	36.9
31B	0.57	2.9	0.48	0.09	15.8	27.0	25.0	47.9
31C	0.26	1.3	0.19	0.07	26.9	26.3	42.1	31.5
32A	0.36	1.8	0.23	0.13	36.1	26.0	26.0	47.8

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member.

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
32B	0.37g	1.9	0.30g	0.07g	18.9	23.3	33.3	43.3
32C	0.38	1.9	0.22	0.16	42.1	27.2	31.8	40.9
33Aa	1.33	6.7	1.20	0.13	9.8	10.8	52.5	36.6
33Ab	0.91	4.6	0.75	0.16	17.5	20.0	46.6	33.3
33B	0.47	2.4	0.39	0.08	17.0	38.4	28.2	33.3
33C	0.29	1.5	0.22	0.07	24.1	59.0	22.7	18.1
43A	2.65	13.3	2.48	0.17	6.4	18.1	40.7	41.1
43B	0.62	3.1	0.49	0.13	20.9	20.4	38.8	40.8
43C	0.33	1.7	0.22	0.11	33.3	27.3	27.3	45.4
44AB	3.63	18.2	3.38	0.25	6.9	23.9	35.5	40.5
44C	0.33	1.7	0.25	0.08	24.1	52.0	16.0	32.0
44S***	0.73	3.7	0.64	0.09	12.3	25.0	34.3	40.6
45A	1.61	8.1	1.40	0.21	13.0	22.1	38.5	39.2

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member.

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
45B	1.14g	5.7	0.93g	0.21g	18.4	11.8	43.0	45.1
45C	0.24	1.2	0.15	0.09	37.5	40.0	26.6	33.3
46A	1.26	6.3	1.10	0.16	12.7	10.9	45.5	43.6
46B	0.86	4.3	0.77	0.09	10.4	24.7	20.8	54.5
46C	0.87	4.4	0.72	0.15	17.2	20.8	43.1	36.1
48AB1****	2.40	12.0	2.06	0.34	14.2	36.9	29.1	34.0
48C1	0.71	3.6	0.53	0.18	24.4	24.5	22.6	52.8
48AB2	4.26	21.3	3.65	0.61	14.3	38.9	26.8	34.2
48C2	1.13	5.7	0.83	0.30	26.5	20.5	39.8	39.8
49A	0.45	2.3	0.31	0.14	31.1	9.7	32.3	58.1
50A	0.56	2.8	0.48	0.08	14.3	37.5	27.1	35.4
50Bb	0.93	2.7	0.74	0.19	20.4	18.9	33.8	47.3
50C	0.72	3.6	0.55	0.17	23.6	12.7	29.1	58.2

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member

Sample Number	Total Residue Weight	Residue Percent	Residue Minus Iron Weight	Iron Weight	Iron Percent	Coarse Fraction Percent	Medium Fraction Percent	Fine Fraction Percent
54AB	0.94g	4.7	0.73g	0.21g	22.3	20.5	30.1	49.3
54C	0.51	2.6	0.36	0.15	29.4	16.7	33.3	50.0
58C	1.33	6.7	1.21	0.12	9.0	11.6	38.0	50.4
59C	7.06	35.3	6.38	0.68	9.6	11.4	44.5	44.0
Averages for Merriam limestone member								
	0.77g	3.9	0.66g	0.13g	18.7	19.9	32.7	47.3
Averages for upper limestone unit								
	0.49g	2.5	0.39g	0.10g	22.4	19.9	31.4	48.6
Averages for lower limestone unit								
	0.97g	4.8	0.83g	0.14g	16.5	19.8	33.5	46.6

TABLE 2 (CONTINUED). Percentage Chart of Residue Analysis of the Merriam limestone member

* In the sample numbers the arabic numeral refers to the measured section at which the sample was taken; the capital letters A and B refer to the lower and upper part of the lower limestone unit and the capital letter C refers to the upper limestone unit; the small letters are subdivisions.

** Residues from the yellow punky limestone bed in the Hickory Creek shale member.

*** Residues from the Spring Hill limestone member.

**** Residues 48AB1 and 48C1 are from the thick section of the Merriam at Locality 48, whereas residues 48AB2 and 48C2 are from the thin section of the Merriam at the same locality. See text for details.

Silicified fossils. Silica replaced organisms represent various percentages of the residue but the percentage is always small. The silica is generally white with a granular to smooth texture.

Secondary Quartz. Secondary quartz is rare in the residues of the Merriam but is represented by clear, subhedral to anhedral, loose grains. Although the grains attain the length of 0.5 millimeter, the average length is about 0.1 millimeter or less.

Beekite. Beekite is present in many residues as a minor constituent and only rarely exceeds five percent of the residue. The beekite in these residues is white and occurs as nodules and fossil replacements. The nodules are commonly round whereas the replacement is of a discoid form and rarely of other fossils as shell fragments and crinoid columnals. Beekite is defined by Rice (1954, p. 38) as "a cryptocrystalline variety of quartz, resembling chalcedony, formed by the replacement of limestone, as coral or shells, with silica." Beekite is referred to by Ireland (1947, p. 1490) as "botryoidal, subspherical, or discoid accretions of opaque silica replacing organic matter, generally white." According to Hatch, Rastall, and Black (1938, p. 209) in many calcareous rocks which have been partly silicified in a diffuse manner, only the fossils are found to be replaced and this silica is commonly beekite which characteristically shows a pattern of interfering systems of concentric circles.

Sygenetic or Epigenetic

Chert. Chert is a minor but diagnostic part of the coarse fraction of the insoluble residues. The chert is smooth, chalcedonic and ordinary, unmodified and dolomoldic, with colors of clear, reddish, gray, smoky, green, brown, and, most important, blue to blue-black. The most common chert is clear, ordinary, and unmodified. In only one residue was the amount as much as five percent of the residue. Much of the chert is etched, especially the more brilliantly colored varieties. The green and brown chert is present in only a few residues of the upper limestone unit from the southern part of the area; these varieties of the chert are very rare, as is the blue to blue-black chert. Although this blue chert is so rare that only one or two grains may be present in a twenty gram residue, the chert is present in over half of the sections sampled and of these sections the blue chert is present in three times as many residues from the upper limestone unit as from the lower limestone unit.

Keroher (1939, p. 349) describes the characteristic feature of the Winterset limestone residue as a black or dark blue-black chert which, although present in practically all samples, shows some variations from sample to sample and even within the sample. Some of the chert specimens are black, opaque, and shiny; others are blue and waxy; whereas others are translucent. These variations are duplicated in the chert of the Merriam residues, with the more translucent grains being a lighter color of blue; however, none of the Merriam blue chert is mottled with smaller bits of white chert as is reported from the

Winterset residues. Keroher considers the blue-black chert of the Winterset to be the most distinctive marker in the Missourian limestones, however chert of the same color occurs in the Merriam. The Merriam chert lacks the dotted, mottled, or banded features of the Winterset chert.

Pyrite. Pyrite is exceedingly rare north of Anderson County although in one residue pyrite formed ten percent of the residue; however in Anderson County and to the south pyrite is more common. A great abundance is present in northeastern Anderson County where the pyrite forms as much as 40 percent of the residue, however this large percentage is restricted to the lower bed of the lower limestone unit. The pyrite in the upper beds is less abundant and persistant. Pyrite is present in the forms of octohedrons, pyritohedrons, striated cubes, botryoidal aggregates up to four millimeters in length, laminar aggregates, as fossil replacements, and as small fragments adhering to arenaceous foraminifer tests and sand grains. The fossils replaced by the pyrite are long, hollow, segmented tubes which are possibly crinoid columnals and small, thin wire-like tubes which are about the same dimensions as the sponge spicules. Schowe, Keroher, and Keroher (1937, p. 274) describe pyrite commonly replacing tubular organisms in the residue of the Rock Bluff member (another "middle" limestone of the megacyclothem) of the Deer Creek limestone.

Limonite. Limonite is present in all residues and comprises from six to 42 percent of the residue (Table 2); however the average percent of limonite is about 18. Although the weight of limonite in the lower limestone unit is somewhat greater, the limonite in the upper limestone unit forms a greater percentage of the residue. The limonite is present in the form of replacements of fossils and of amorphous lumps. Because the limonite is disseminated throughout the residues, it masks the remaining part of the residues and for this reason was removed from the residue previous to final study.

Summary

The residues of the Merriam limestone are characterized by three fractions; coarse, medium, and fine, which average, respectively, about 20, 30, and 50 percent of the residue. The difference in the percentage of medium and fine fractions of the two units averages about two percent, whereas a difference of only 0.1 percent exists between the coarse fractions of the two units.

The most abundant elements in the insoluble residues are arenaceous foraminifers, silt aggregates, and sand grains with other elements only locally common. According to Keroher (1939, p. 349) the residues of the Merriam are distinguished from those of the Spring Hill limestone member by the presence of gray, waxy chert, some fragments of which are translucent and others are opaque. The only chert found in the Merriam residues which approaches this description is the blue to black chert. Also described from the Merriam residues by Keroher are "gray to white porous chert, white rough chert, and organic remains" of common brachiopod spines, encrusting foraminifers, crinoid fragments, and rare ostracodes, fusulinid fragments, and mollusk shells. These remains differ greatly from those comprising the residues of the Plattsburg formation of southwestern Iowa as studied by Wenberg (1942). Wenberg found that the residues of the Plattsburg formed about 11 percent of the sample, however most of the residues from the Missourian and Virgilian limestones studied formed about the same percent. In the two sections of the Plattsburg which were studied, Wenberg found the fine fraction to be about twice the percentage of the coarse fraction and to be composed of red and green clay. The coarse fraction of the lower part of the Plattsburg was characterized by pyrite and iron oxides, with sand and silt in the upper part of the formation. From this study one would conclude that arenaceous foraminifers are either absent in the Merriam of Iowa or are completely disaggregated, and that sand grains form a somewhat smaller percentage of the overall composition of the residue.

Acid Etching

Introduction

The process of acid etching might be considered an incomplete process of obtaining insoluble residues; however the samples which are etched in acid show more than just the nature and distribution of the insoluble material. This process also illuminates the gross lithology of the rock including the nature and distribution of the fossils. The insoluble material which is present on the etched block is the same as the material forming the insoluble residues and needs no further description. The carbonate grain sizes used are after DeFord (1946).

Lower limestone unit

In the northern part of the area the lower bed of the lower limestone unit is characterized by abundant sand grains which in the lower part of the bed are so abundant as to obliterate any calcareous cement (Fig. 17). The texture of the unit is aphanitic to very fine meso-grained. Brachiopod and pelecypod shells of dark crystalline calcite and light gray dense calcite are common in the lower part of the unit. The longer shell fragments at the base of the unit have very thin to no crusts of Osagia-type algae; however most of the smaller shell fragments in the unit are bounded by a thin to thick coating of the algae and limonite. The shell fragments near the base of the unit are variously orientated, with the concave side, convex side, or an end upward. High- and low-spired gastropods are common with abundant low-spired gastropods near the middle of the unit, also at this horizon are rare crinoid columnals, fusulinids, and small ramose bryozoans. Below this horizon are common ostracodes, however these animals occur in rare quantities throughout the unit. Osagia is more abundant in the upper part of the unit. Some of the limonite which is present contains local red to black, iron or carbonaceous hard parts. Throughout the unit are rare nodules of buff to light gray silt with locally common blue chert fragments.

In the thicker sections of the Merriam in the northern portion of the area the lower part of the unit is oolitic with the ooliths averaging about 0.3 millimeter in diameter. The ooliths are commonly concentricly layered and spherical; however some are elliptical. Small

Pl. 2D

~~FIG. 17.~~ Basal bed of Merriam limestone showing abundant sand grains near base. Note thin to thick algal coatings (Osagia) of shell fragments. X2.6

nodules of greenish-gray silt and clay with locally abundant blue chert fragments are rare and are altered to limonite near the surface. The rare sand grains are not concentrated, but with rare grains of blue chert they are disseminated throughout the unit. Although Osagia is common above the middle of the unit, the rest of the fauna in the lower part is rare and is composed of small brachiopods, crinoid columnals, and gastropods. Fusulinids are rare near the middle of the unit. The upper part of the unit is very fine mesograined with extremely abundant Osagia. The remaining fauna consists of rare ramose bryozoans, crinoid columnals, and small gastropods.

The thinner sections of the unit in Miami County contain rocks of lithology and sequence similar to those in the north. The lower bed is characteristically composed of predominant shell fragments and sand grains. The larger shell fragments commonly are preserved with the convex side up and contain very thin or no Osagia-type encrustations. These encrustations are more common on the smaller fragments. The remainder of the fauna is the same as that in the north. Above the lower shell and sand grain part the unit is oolitic with ooliths of about 0.3 millimeter in diameter. In this upper part of the unit shell fragments are less common and some of the gastropod shells, brachiopod shells, and ostracodes are filled or partly filled with silt grains. The matrix filling the interstices of the ooliths is aphanitic.

In general, the same lithologic and paleontologic characteristics are present in western Miami County. The lower part of the unit is again composed primarily of shell fragments with laminae and nodules of silt. Although the basal part of the unit is fine mesograined, the lower part in general is aphanitic and dolomitized with veinlets, rhombs, and rhomboids of dark crystalline dolomite. In this part of the area very rare fusulinids are present in the basal part of the unit. Although the upper part of the unit is again oolitic, the ooliths are locally rare in a coarse paurograined matrix. Where the ooliths are rare, the limestone is composed of very abundant crinoid columnals and is actually a crinoidal limestone with abundant ramose bryozoans.

At those localities where the lower unit is expanded in thickness by the development of the cross-bedded oolitic limestone, as at Locality 27, acid etching shows the ooliths to be very abundant with the aphanitic matrix present only as a filling of the interstices. The ooliths are of the same average size as elsewhere. The rare fauna is a continuation of the previously described forms, however the Osagia is abundant in thin zones with associated very rare fusulinids. Also present in rare quantities are algae-encrusted shell fragments and rhombs of dark crystalline dolomite.

In sections near the thickened Merriam the matrix is only indistincly oolitic with an aphanitic, dolomitized matrix. The matrix, as in all this type rock, appears to be composed of silt-sized particles with abundant small fragments of fossils. Not only are rare fusulinids present, but rare bands of calcareous algae are also present and resemble the veinlets of dense dolomite.

As compared with the northern part of the area, the sections in southeastern Franklin County show the shell fragments to be less common at the base of the unit and Osagia and fusulinids to be more common throughout the unit. Little change is noticeable in the fauna of of gastropods, ramose and fenestrate bryozoans, ostracodes, and brachiopods. The unit is oolitic throughout, however the ooliths in the lower part are not jammed together so that the aphanitic crystalline matrix is present as more than just fillings of interstices. In the upper part the ooliths are very abundant.

In some localities, as in northeastern Anderson County, Locality 44, the base of the unit is composed not of shell fragments, but of abundant crinoid columnals producing a crinoidal argillaceous limestone. The interstices between the columnals are filled with a gray silty matrix. Most of the columnals are encrusted with dolomoldic interstitial silica and arenaceous foraminifers. Pyrite grains are abundant in this rock.

To the south the unit continues as a somewhat silty-appearing limestone with more common fusulinids and somewhat rarer shell fragments. The fauna of crinoid columnals, bryozoans, and gastropods continues; however *Osagia* is absent. The matrix again is aphanitic and locally composed primarily of fossil fragments.

Upper limestone unit

The upper limestone unit in that part of the area north of the Kansas River is aphanitic to medium mesograined, and locally contains abundant *Osagia*. The fauna, as in the lower unit, is composed of crinoid columnals, small high- and low-spired gastropods, ostracodes, shell fragments, and fusulinids, all of which are rare. The arenaceous foraminifers, chert, and sand grains are locally common together.

In Johnson County the unit is composed of an aphanitic dolomitized matrix with common veinlets, rhombs, and rhomboids of dark crystalline dolomite. The main amount of fossils forms a very fine hash in the areas of less dense matrix. The predominant element of the fauna is elongate and robust fusulinids. Rare small nodules of buff to gray silt and nodules of light-green glauconitic clay are present. The long axes of the fossils, as fusulinids and crinoid columnals, are very commonly parallel to the bedding. At some localities certain zones in the bed are more fossiliferous with intervening zones almost unfossiliferous and denser; some fossils are replaced by crystalline calcite. These features characterize the unit as far south as northern Allen County, however other features are locally present. These other features include small, horizontally-elongate, irregular cavities filled with yellow oxidized silt; small, thin, hollow tubes of iron oxide; and ooliths. Where the unit is oolitic, the fossil material is concentrated in a thin zone containing fewer ooliths. Osagia is only locally common, and is associated with algae-encrusted (Osagia-type) gastropod and brachiopod shells and fragments.

In Anderson County calcareous algae are increasingly more common and fusulinids begin to show a decrease in abundance; however the algae is rare in Allen County and absent to the south. Fusulinids are also missing in this southern part of the area. With the exception of Osagia and brachiopods the remainder of the biota is unchanged. Osagia is present locally and brachiopod shells and fragments increase in number to the south. Some of the shells are fairly long, however they are not encrusted with algae. Also fenestrate bryozoans make up a greater percentage of the rock and in places sponges are predominant. The matrix of the unit is more silty than in the north with the main components of the rock being fossil fragments and quartz silt grains. In the southernmost part of the area blue chert grains are very abundant.

Summary

The result of the acid etching study shows that the lower limestone unit of the Merriam consists of a basal limestone with abundant silt nodules and brachiopod and, in the north, pelecypod shell fragments. The remainder of the unit consists of oolitic limestone with *Osagia*; commonly the upper part of the unit is more oolitic. The biota changes only slightly throughout the area, the main changes being the appearance of fusulinids in the central and southern parts of the area and the lessening in the amounts of shell fragments and *Osagia*. Also in the southern part of the area the unit is more silty and not oolitic.

The upper limestone unit is very uniform in lithology and fauna throughout most of the area, being characterized by an aphanitic somewhat dolomitized matrix with veinlets and rhombs of dark crystalline dolomite. The biota is distinctive from that in the lower unit in that *Osagia* is rarer, fusulinids are more common, and calcareous algae are common in the central part of the area. Toward the south both the algae and fusulinids are absent, and shell fragments and sponges comprise a higher percentage of the remains. Also in the south, the unit is much more silty, completely lacking the dense, aphanitic texture present in the north.

Thin-sections

The study of oriented thin-sections from the beds in the limestone units adds only little to the previous descriptions of the units. The advantage of the thin-section study is a better definition of the texture of the rock and the structure of the microorganisms. As examples of the latter, Figures 9 and 18 are photomicrographs of Osagia from Locality 16 and calcareous algae from Locality 54, respectively. The most significant result of the study is the relative uniformity of the different beds throughout the area and the sharp differences between the beds. The lower bed of the lower limestone unit, above the conglomeratic zone, is characteristically very dense (Fig. 19), but with common organic remains. A thin-section from this bed is very similar to that from the upper limestone unit (Fig. 20), the main difference being the lack of common organic remains and the somewhat denser t texture of the upper bed. The figures adequately show the extreme denseness of the rock. The upper part of the lower limestone unit is very commonly oolitic (Fig. 9) with more abundant organic remains than the other beds. Thus each part of the member consists of a fairly distinctive micro-assemblage of lithologic and biotic characters which remains somewhat constant and comprises a "micro-facies" (Fairbridge, 1954). Even with a small number of thin-sections this feature is more or less apparent and by the use of several hundred thin-sections this method of sedimentary petrology could probably be used very

FIG. 18. Photomicrograph of calcareous algae in the upper limestone unit.

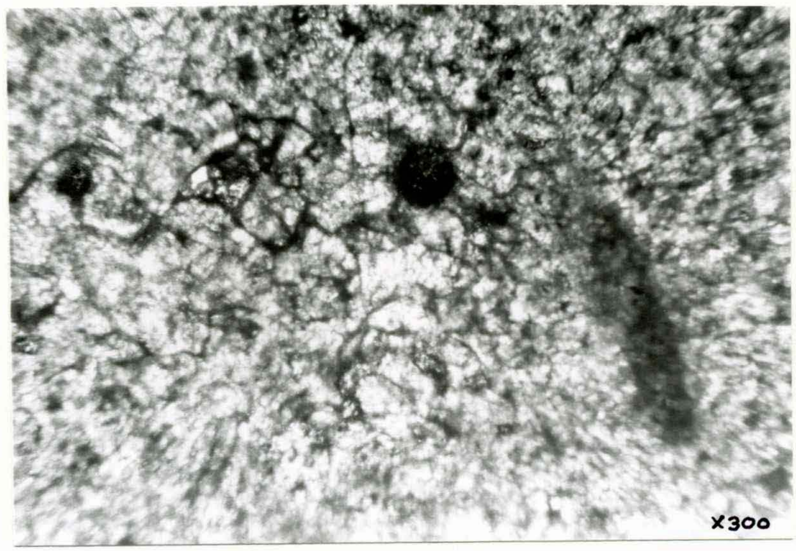


FIG. 19. Photomicrograph of lower part of lower limestone unit.

FIG. 20. Photomicrograph of upper limestone unit.

satisfactorly to correlate the Pennsylvanian limestones into the clastic area of southern Kansas and northern Oklahoma. However, a large number of stratigraphic units would have to be studied inasmuch as the individual units become less distinctive toward the south and because stratigraphic repetition of similar micro-facies could occur.

Shale ~~study~~

The examination of the Merriam shale bed is a modification of the method proposed by Krumbein (1947, p. 106). The result of the study shows the bed to be very fossiliferous in general. In that part of the area along the Kansas River the bed is characterized by abundant ramose bryozoans forming the predominant element of the fauna, with very abundant brachiopod shell fragments and spines, and fenestrate bryozoans. Fragments of crinoid stems are less common and conodonts, ostracodes, calcareous foraminifers, and small gastropods are present only rarely. Also present in common quantities are fish remains. In this part of the area the shale is moderately calcareous, being less calcareous toward the east, and is composed mainly of brownish-gray to grayish-yellow silt-sized quartz grains and clay with rare subspherical, subrounded, etched, medium-sized, clear quartz sand grains. Mica is present in rare amounts, as are flakes of black shale. To the east the black shale flakes equal the other shales in percentage; also, glauconite is present.

In that part of the area between the Kansas River and Anderson County, fossils commonly form only a small percentage of the shale. Of these fossils, fragments of crinoid stems are abundant whereas fenestrate bryozoans, brachiopod spines and shell fragments, and calcareous foraminifers are rare. The shale is highly calcareous with only a small percentage of black shale. Samples of the shale partings of the lower limestone unit in this part of the area were also studied and the results differ only slightly from that of the shale bed.

In northern Anderson County the shale is formed of from 50 to 75 percent fossils. These fossils include common crinoid stem fragments, ramose bryozoans, brachiopod spines, ostracodes, and rare conodonts, fusulinids, and fish remains. The mineral composition is the same as in the north with a small percentage of black shale and glauconite and locally very common sand grains. The shale is moderately to very highly calcareous.

In Central Anderson County fossils again form a very small percentage of the shale. They include abundant fish remains, common crinoid stem fragments, common calcareous foraminifers, rare bryozoans, and rare conodonts. The mineral composition is the same as in the northern part of the county, except that the black shale is absent. The only difference in the composition of the shale in the southern part of the county is that it is more calcareous.

Near the southern outcrop limit of the shale in Allen County fossils comprise about 50 percent of the shale, and include common bryozoans, common brachiopod spines and shell fragments, common crinoid stem fragments, and rare ostracodes. The mineral constituents include limonite-stained quartz silt grains, rare glauconite, and rare mica flakes. The shale is very calcareous.

Summary

Little change is noticed in the mineralogical composition of the shale throughout the area, the main difference being the disappearance of black shale fragments toward the south, also the shale is somewhat more calcareous in the south. The other mineralogical characters vary throughout the area, but are still present. Part of the fauna: ostracodes, conodonts, crinoid stem fragments, and echinoid spines, changes only slightly in the area; the principal differences being in the extreme abundance of brachiopods and ramose bryozoans near the Kansas River, the abundance of fish remains in the northern and central parts of the area, the increased abundance of calcareous foraminifers to the south, and the increase in percentage of brachiopod remains near the southern limit of the shale.

STRATIGRAPHIC RELATIONSHIPS AND SEDIMENTARY ANALYSIS

This section of the report represents an integration of the data obtained with field and laboratory methods. Only the general features and relationships are considered and the reader is referred to the previous descriptions for more detailed analysis.

Lower limestone unit

The lower part of the Merriam is not, in reality, a single unit; however the gradation which exists in the sequence makes subdivisions of the unit too arbitrary. Although the unit varies in lithology, thickness, fauna, and insoluble material, the magnitude of the variation is small when the entire Pennsylvanian System is considered.

The basal part of the unit is commonly granular and conglomeratic with small rounded nodules of silt and clay which in places contain abundant fragments of blue chert. This part of the unit also contains abundant fine quartz sand grains and brachiopod and pelecypod shells. Most of the smaller shell fragments are encrusted with algae, thus differing from the bare, large shell fragments, most of which are preserved with the convex side upward. The percentage of sand grains, shell remains, and algae increases to the north and south from the central part of the area. In this central part some sections show the basal portion of the unit to be a crinoidal argillaceous limestone with common arenaceous foraminifers and nodules of silt. The pelecypods disappear to the south.

The remainder of the unit is divided very generally into an aphanitic lower part and an oolitic upper part. At some localities the lower part shows veinlets and rhombs of dolomite. To the south the unit is a marly limestone. Part of the fauna: bryozoans, crinoids, and arenaceous foraminifers, is relatively unchanged throughout the area; however certain elements of the fauna show a geographic change. Osagia is abundant in the northern part of the area, as is Composita and Myalina; however all these forms are less common or absent farther south. The distribution of fusulinids is a complete reversal of this trend. Brachiopods decrease in number in the central part of the area. The distribution of the ostracodes and gastropods is somewhat local and the distribution of algae, worms, horn corals, sponges, and cephalopods is even more local. In the northern part of the area a zone of Composita and a zone of Osagia-Myalina are present. With the exception of these zones which are confined to the lower part of the unit and the cephalopods which are confined to the upper part, the description of the fauna applies to the entire unit.

Although the upper part of the unit is dense and fine-grained in parts of the area, it is very commonly oolitic and in general contains a smaller percentage of coarse insoluble material than the lower part. The ooliths are almost constant in diameter, 0.3 millimeter, and are commonly more abundant near the top of the unit. For the unit as a whole certain percentage relations of the insoluble material exist. To the east there is a decrease in the percentage of the coarse residue, percentage of silt aggregates, and percentage of quartz sand grains, with a corresponding increase in the percentage of arenaceous foraminifers.

Shale bed

For the purpose of description, the areal extent of the shale bed is divided into four units (Fig. 11), the northern "basin" in Wyandotte and Johnson Counties, the area east of the central "highland", in Miami County, the central "basin" in Anderson County, and the southern area in southeastern Anderson County and western Allen County. Each division is characterized by a certain relation of thickness, color, and mineralogical and paleontological constituents.

In the northern basin the shale is yellow-orange, moderately calcareous, and composed predominantly of clay-sized particles. The coarser fraction consists of silt and some sand grains. To the east the shale is only slightly calcareous, but the percentage of clay, glauconite, and black shale fragments increases. The predominant elements of the fauna are brachiopods and bryozoans, especially ramose bryozoans. These two elements comprise a greater percentage of the fauna than all the other forms combined. The remainder of the fauna is composed of remains of crinoids, fish, ostracodes, conodonts, gastropods, and calcareous foraminifers.

In that part of the area east of the central highland the shale is mainly yellow-green with only a minor amount of yellow-brown as in the northern basin. Although the shale is more calcareous than in the north, clay represents a somewhat smaller percentage of the shale. Black shale fragments are also less common than in the north. The brachiopod-bryozoan element of the fauna comprises a smaller percentage of the fauna than does the remaining group, however the entire fauna is poorly represented.

The central basin contains the most complex assemblage of the shale. In the northern part of the basin the shale is olive-green, but in the remainder of the basin, except the western "margin" where it is yellow-brown, the shale is multicolored. In this basin the shale contains numerous small open folds and limestone nodules. The shale is moderately to very strongly calcareous with a high to low percentage of clay material, respectively; however, as a whole, the clay forms a smaller percentage of the shale than in the northern basin. The only differences in mineralogical constituents in the basin are that black shale fragments are rare in the northern part of the basin and are absent farther south, and that, even more so than in the northern basin, quartz sand grains are locally common. Except for the presence of fusulinids the fauna is the same as in the northern part of the area, however the remains form a smaller percentage of the shale in the central part of the basin than around the margin. The brachiopod-bryozoan element of the fauna is not predominant.

In the southern area the shale changes from multicolored to yellowish-brown toward the south with a great increase in the calcareous content and a decrease in the clay content. Quartz silt grains form the major part of the shale which contains only rare glauconite and mica flakes. The ratio of the brachiopod-bryozoan element to the rest of the fauna changes from equality at the southeastern margin of the central basin to one of predominant brachiopod-bryozoans in the south. Also the fossil composition of the shale increases greatly from that in the central part of the central basin.

Upper limestone unit

The upper limestone unit is a very distinctive and uniform bed with an aphanitic, and commonly dolomitized, matrix. Ooliths and dolomite veinlets are rare. As in the lower unit the percentage of coarse insoluble material and silt aggregates decreases to the east; however the arenaceous foraminifers and sand grains show no such regional distribution. The foraminifers are concentrated in sub-regional parts of the area. The distribution of the sand grains is shown in Fig. 16. The somewhat sparsely fossiliferous unit has a uniform fauna of gastropods, bryozoans, and ostracodes, but the remaining part varies. Brachiopods, crinoids, and calcareous algae increase in predominance to the south at the expense of the Osagia. Fusulinids are most abundant in the central part of the area where the worm-borings are rare. The minute fossil fragments commonly form a hash in the less dense parts of the matrix. In southern Kansas the unit, which contains abundant sponges, is argillaceous, ferruginous, and very irregular.

Summary

The analysis of the field and laboratory data shows the Merriam limestone member to be composed of three distinct units (Pl. 2), which are similar to the units recognized in previous descriptions, excluding Moore (1949, pp. 115-116). With this one exception the previous descriptions recognized the present lower and upper limestone units; however the shale bed went unnoticed. An upper unit of algal and granular limestone described by Moore was not observed as the development of oolitic limestone and the presence of cephalopods are in the lower limestone unit.

~~AREAL~~ VARIATION

The variation of the Merriam within the area studied has been discussed, however the relation of this part of the area to the sedimentary basin has not been mentioned.

The Merriam in Nebraska, along the Platte River from Ashland to Plattsmouth, has been described by Condra and Scherer (1939). The Merriam overlies a thin Bonner Springs shale, seven to ten feet thick, which is consistently blue to bluish-gray, at least in the upper part, with a thin limy and fossiliferous layer near the top. The Merriam is three to five feet thick, with the apparent increase in thickness toward the east. The limestone is bluish-gray, massive, and has a conchoidal to shelly fracture. Concretionary forms occur in the upper part which the writer considers to be possibly algae, however he has not seen these outcrops. Blue chert is present locally and black shaly streaks along the middle of the unit at some localities. The unit is described as very fossiliferous. The Hickory Creek shale ranges in thickness from one to three feet and in composition from a bluish, argillaceous shale through a dark gray, massive shale to a black, carbonaceous shale. Some fossils, as brachiopods and bryozoans, are present. Locally, a thin dark limestone bed occurs in the middle of the member. Overlying the Hickory Creek is the massive Spring Hill limestone.

According to McQueen and Greene (1938, Pl. V) the Merriam is a gray, even-bedded limestone with many algae and a thickness of 0.5 to 1.5 feet throughout northwestern Missouri. This description differs from that of Hinds and Greene (1915, pp. 155-156) who describe the basal layer of the Plattsburg as a blue, argillaceous to arenaceous limestone with abundant pelecypods and as ranging in thickness from four feet in the south to several inches in the north where the entire formation is only about three feet thick. These different descriptions of the Merriam are not irreconcilable if the description of Hinds and

Greene is of the lower part of the Merriam and that of McQueen and Greene is of the upper part of the Merriam. However, the difference in thickness of the two sources is not so easily explained. The Bonner Springs shale is 25 to 40 feet of locally red or sandy shale which in many places has a thin coal bed and sandy conglomeratic limestone in the upper three or four feet. The Hickory Creek shale is 0.5 to 1.5 feet of gray, calcareous, fossiliferous shale overlain by the gray Spring Hill limestone containing chert beds and dark shale partings.

The variation of the Merriam in Kansas, as far south as Wilson County, has been described. Moore (1937, p. 13) recommends that the Oklahoma classification of the Missourian beds be used south of a line near the Wilson-Montgomery county line because of the lack of clear differentiation of the groups within the Missourian which are defined farther north. Near the Oklahoma state line the entire Plattsburg formation is absent and it is recognized only locally in Oklahoma, as west of Ramona in Washington County (Moore, Newell, Dott, and Borden, 1937, p. 43). The Wann formation of Oklahoma includes beds correlated with those between the Iola formation and the uppermost limestone member of the Stanton formation in Kansas (Oakes, 1940, pp. 72-80). Thus the correlative of the Merriam is placed somewhere near the middle of the sequence. The Wann formation is predominantly shale with some limestone and sandstone beds. The formation consists of four main lithologic units, which are, from bottom to top: 1) dark clay shale, 2) dark shale and thin platy limestone, 3) calcareous and fossiliferous shale and limestone, and 4) sandstone and shale which probably do not follow stratigraphic levels.

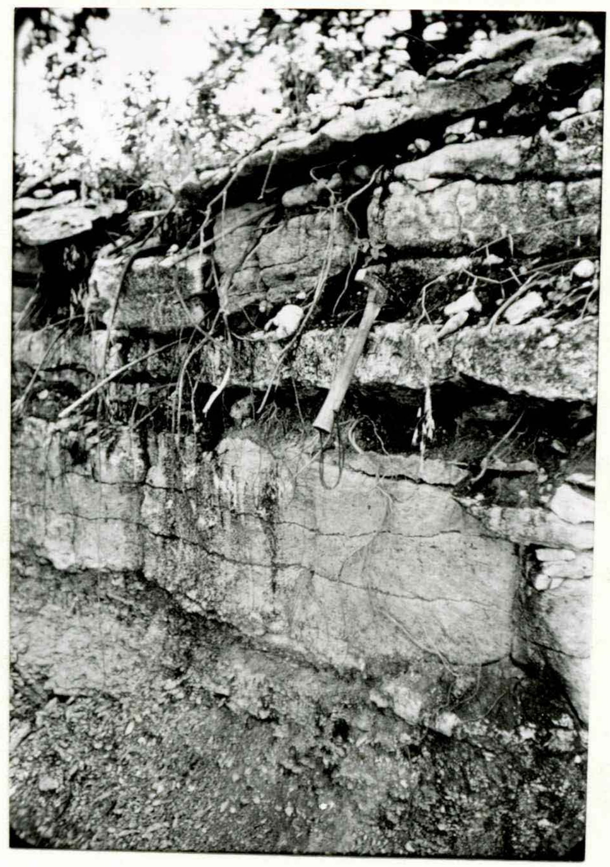
Even within a single facies, as eastern Kansas, the member is not uniform. At a locality in central Anderson County (Fig. 21) the lower limestone unit thins from a thickness of 1.5 feet to one of 0.2 foot in a lateral distance of nine yards. The unit changes from massive limestone to a rubbly shaly limestone and grades into the limy shale of the uppermost Bonner Springs shale. Thus the lower unit at this locality is represented in places by a limy shale and rubbly limestone sequence and with greater thinning of the lower unit, the upper units of the member would rest on the Bonner Springs shale. The insoluble residues from the thin and thick sections are almost the same. However, the lower unit contains abundant sand grains in the large insoluble residue (Appendix B).

In southern Kansas the Plattsburg formation locally thins or thickens. Because of the relation between the Plattsburg, Vilas, and Stanton formations, Chelikowsky and Burgat (1947) refer this variation to channel deposition of the Plattsburg in the Lane-Bonner Springs shale and a continuation of limestone deposition during deposition of the Vilas shale.

The Merriam limestone member has now been described in detail in part of the sedimentary basin and described in general on a regional scale. Thus the foundation has been laid for the discussion of the environment of deposition.

A.

B.



C.

Pl. 3

~~FIG. 21.~~ Section of Merriam (Locality 48) showing thinning of lower limestone unit in lateral distance of nine yards, A, from thick section on right, C, to thin section on left, B. Hammer is at upper contact of the member.

ENVIRONMENT OF DEPOSITION

Introduction

Any study of the environment of deposition requires the consideration of certain factors: lithology, sedimentation, paleontology, paleoecology, paleogeography, paleoclimatology, and stratigraphy, to name a few. Therefore, in this section of the report the data presented previously will be interpreted in the light of these various factors. Inasmuch as environment of deposition is intimately related to the cyclical repetition of beds in the Upper Pennsylvanian of this region, the relation of the Merriam limestone and the cyclothems will be described following the discussion of environments.

Bonner Springs shale

The Bonner Springs shale is represented in Oklahoma by part of the thick sequence of coarse clastics which were derived from the uplifted Arbuckle Mountains if, as Dott (1928, p. 63) states, this uplift occured somewhat after mid-Kansas City time. The coarser material was deposited in the region of northern Oklahoma and the finer material was carried to the north, into Kansas. The stratigraphic sequence of the Bonner Springs shows it to be composed of gray and blue shale in the south, with thin irregular limestone beds and limestone nodules at the top. In the central area olive-green arenaceous shale predominates with minor beds of sandstone and little blue shale. This sequence with limestone beds locally at the top continues to the north into the blue shale of

Nebraska with its limy upper part. In Missouri the blue shale is absent, but coal, as well as limestone, occurs near the top of the formation. The red shale of Missouri may be represented by the maroon clay in the central part of the area. Along the Kansas River the cross-bedded conglomeratic limestone is present. Although fossils are not common in the shale, some plants have been reported from the lower part of the formation and Lingula is locally present near the top. The local limestone beds at the top contain brachiopods, bryozoans, and Osagia.

The predominant color of the shale is green, except in the blue and gray sequences. Although a green color is commonly considered as indicative of a reducing environment, according to Grim (1951, p. 231) the relation need not necessarily hold inasmuch as the chlorite clay mineral is green and a reducing environment is not considered necessary for its formation. Also, as Thompson (1955, p. 75) points out, the clay of the submarine delta of the Atchafalaya River in Louisiana changes from nonchloritic to chloritic as the average depositional environment grows more marine from the river source to sea. The green shale area of the Bonner Springs occurs from the central part of the area to northern Kansas and in the middle of this region is the cross-bedded marine limestone, indicating that the sea, or an isolated remnant of it, was not too far to the west. Therefore the green shales represent the more seaward aspect of the area with the blue shales having formed locally farther "inland".

Blue muds are commonly the result of a reducing environment (Twenhofel, 1932, p. 255) in which a covering of the surface layer by subsequent deposits results in the reduction of iron oxide or hydroxide to ferrous sulphide and ultimately to pyrite or marcasite. However, the dark gray to blue shale of the Bonner Springs contains no plant or animal remains which would be expected in a reducing environment. Also, according to Elias (1936, p. 694) the land plants in this part of the Missourian series are indicative of a somewhat arid environment, a Cordaites forest, thus reducing the possibility of the development of extensive growths of plants to so reduce the aeriation as to form an environment with a fairly negative Eh.

According to Grim (1951, p. 231) the color of red argillaceous sediments, as occur in Missouri and form the maroon shale in the central area, is usually due to the presence of pigmentary iron oxide or hydroxide rather than the clay mineral component. Regardless of whether the ferric oxide or hydroxide is transported from a source area or forms from nonferric iron or iron-bearing silicates deposited, the environment is still one of oxidation. The formation of the marlite is possibly related to this environment inasmuch as it always overlies the maroon shale. During the time of the deposition of the marlite, the amount of clastic material in the area may have been lessened with the result that the clastic material did not completely mask the calcium carbonate deposited in this oxidizing environment. The northern limit of the yellow marlite is near the area of development of the cross-bedded limestone.

The cross-bedded limestone in the Bonner Springs is a limestone and shell conglomerate. The shells are mainly pelecypods. In this part of the area clastic material was absent and currents either eroded older limestones and deposited the material here or limestone was formed in the water with not too gentle currents.

The environment of such units as the Bonner Springs is considered to be deltaic by many geologists, such as Twenhofel (1932, p. 848). Moore (1929, p. 476) states that non-marine shales possibly built out into the sea in a deltaic manner and he points out that if the sea were so shallow that no foreset beds could develop, the sedimentary structure would be preserved as only topset beds. However, certain factors present in the submarine delta of the Atchafalaya River, which is developed in the Gulf of Mexico off the Louisiana coast, should be considered. Thompson (1955) discusses the sedimentation of this coastal area and points out (p. 61) that "in terms of the classical concept of a delta the Atchafalaya delta appears to consist almost entirely of foreset deposition." Even though the top of the delta is developed in water of less than three fathoms in depth, wave action planes off the topset beds and this wave action, even in times of hurricanes, effects only the upper few inches of the delta. Therefore the question arises as to how shallow the water would have to be for only topset beds to form and how these beds could be preserved when the destruction of only the upper few inches of the deposit could obliterate them. The result would be water too shallow to add appreciable marine factors to the environment, thus contradicting the interpretation of the origin of the different shales. However, inasmuch as the green and blue shales could not have been formed in a subaerial environment, a governing factor other than the depth of water must be present.

The water over the "delta" need not be less than three fathoms deep and it could have been somewhat deeper as the wave action would have been reduced by refraction and frictional dissipation over the bottom in traveling over the extremely broad shoal sea floor. The cause of the development of only topset beds might not have been extremely shallow water but the small vertical distance separating the plane of the sea floor from the plane of the equilibrium surface of the transporting currents. The subsidence of this low gradient region was not rapid enough to permit the formation of a substantial differential between the depositional interface and the surface of equilibrium that would be necessary for the formation of foreset bedding. Thus it is possible to consider the Bonner Springs as composed of topset delta beds, however such an interpretation would imply that all material deposited in water bodies by currents are deltas of a sort. An increase in the capacity and competency of the streams would produce a new surface of equilibrium and the sandstone which is present in the Bonner Springs might be deposited as a result.

In Missouri, swamps were formed which are preserved in the coals near the top of the Bonner Springs; however, these swamps were not extensive, unless possibly to the east. Many geologists consider the coal swamps of Missouri to have been so close to sea level that submergence immediately covered the plants, thus accounting for the thin coals.

The limy composition of the upper part of the formation throughout almost all the region and the local development of limestone beds and nodules indicate the beginning of the transgression of the sea.

In summary, the history of the deposition of the Bonner Springs shale might be as follows. As the sea became shallower at the beginning of Bonner Springs time, the strand line receded far to the north with the encroachment of arenaceous deposits to the north. The rivers draining the source area to the south and east carried the material into the sea, forming thin strata because of the high density of the silty sluggish currents which formed an equilibrium surface near the bottom of the shallow depositional area. Subaerial planes developed in the east with local coal swamps near the shore. As the sea gradually spread back over the region, limestones formed locally until the clastic inflow almost stopped in the northern part of the area where the Merriam limestone was deposited.

Merriam limestone member

As the sea re-covered the area, the water became deeper in the north with the result that marine factors developed dominance. With the deepening of the water, the previous shales of the Bonner Springs were subjected to wave action, in many places causing the development of shale nodules which were incorporated in the base of the Merriam. Not only were nodules eroded, but the silt and shale portions of the substratum were separated in places, producing a lag of silt grains with the shale nodules.

As Garrels (1951, p. 95) states, there is almost no loss of energy until the wave breaks and, therefore, inasmuch as little work is done on the bottom between the depth of one-half the wave length and the plunge point, the conglomeratic part of the limestone must represent this portion of the sea floor. Although the region of the plunge point varies somewhat on any shore, a small rise in the level of the Merriam sea would produce a significant change in the position of the wave energy zone on the low gradient slope. A crude approximation of the depth of part of the Merriam sea at this time may be made from Shepard's (1948, p. 47) statement that "important movement of sand during storms appear to be largely confined to depths of about 30 or 40 feet, which is barely outside the breaker zone." Some of the fine clastic material may have been transported into the area and this might be the origin of the chert grains.

The principal faunal remains present in the basal part of the limestone are brachiopods. The most abundant brachiopod present is Composita and commonly the specimens are so abundant as to form an appreciable part of the rock. Menard and Boucot (1951, p. 144) state that the more spherical brachiopods are best adapted to live where the currents are faster because of the greater competent velocity. There may be a relation between faster currents and increased oxygen or food supply. The cause of the local concentration of the whole brachiopod shells might be overcompetition, however this factor does not explain the extreme local nature of the concentration, inasmuch as the main variable factor effecting localization would be the nature of the substratum and the substratum appears to be essentially the same throughout the area. Therefore, the concentration is considered to be the result of local transportation and deposition of the shells. The work of Menard and Boucot has shown that Terebratulina shells are moved by currents incapable of moving the underlying sand grains because of the smaller effective density of the water-filled shells than of the quartz grains. These currents were no faster than those present at a depth of more than 1,000 fathoms in the Pacific Ocean. Possibly the Composita shells were moved by the eddy currents in the slow current of the shallow sea until an area was reached in which the silt grains moved more readily than the shells with the result that the shells were gradually buried. After several specimens had been restricted, the shells might act as traps to stop other shells. The local abundance of only Composita might be due to the abundance of this form over other forms or the sorting might be of species, due to the fact that, as Menard and Boucot (p. 134) state, sorting of species rather than of shapes or sizes will occur "if there is a great difference in the effective densities of species but little difference in shape and size." The orientation of most of the single shells with the convex side upward is also indicative of current action.

Locally, the base of the Merriam is composed of a bluish argillaceous crinoidal limestone with abundant pyrite. Therefore, it is assumed that locally the sea floor was free from strong currents and wave action so that crinoids developed; however, currents of low competency and capacity were present to deposit the argillaceous material and fragmentize the crinoids into columnals and plates. Such bottom conditions evidently formed an environmental niche for the crinoids. Undoubtedly the crinoids were well adapted to the environment, local as it may have been, as is shown by the abundance of specimens. The crinoid remains are probably not a thanatocoenosis as the effective density and size of the fragments is considerably greater than that of the surrounding argillaceous-limy mud and no intermediate size grains are present.

This abundant growth, producing a large amount of organic remains, probably resulted in a large bacteria population, because as ZoBell (1942, p. 128) states, the amount of bacteria seems to be influenced primarily by the amount of organic material present. Also, he points out that bacteria seem to be more abundant in fine and colloidal material than in coarse material. Thus the main conditions are present for the development of a large, probably hederotropic, bacteria population which would produce a reducing environment in the substratum, thereby accounting for the abundant pyrite and the bluish color of the rock. Because the bacteria population decreases greatly with depth, the underlying shale of the Bonner Springs was not so greatly effected. As ZoBell (p. 128) states, some of the enzymes may continue to react with the chemical components of the sediment after the death of the bacteria. As noted previously, pyrite occurs abundantly in the Merriam only in the lower part and only in this part of the area. Inasmuch as calcium and carbonate ions are independent of oxidation-reduction potentials (Krumbein and Garrels, 1952, p. 8), the nature of this environment is not in opposition to the limy composition of the rock.

Pelecypods occur stratigraphically somewhat above the Composita zone and are restricted to the northern part of the area studied and to Missouri. The presence of the pelecypod ~~Myalina~~ (Orthomyalina) ampla Meek and Hayden in only these areas seems to indicate that at this time these portions of the area were no longer subjected to the shallow, turbid waters of the shore zone. According to Newell (1942, p. 18) the myalinas probably indicate relatively quiet water as the animals are found most commonly with the valves in apposition. Although separated valves are found, "these seldom show evidences of markedly turbulent water." It is considered doubtful that the mature animals were powerful enough to drag around the thick, large shells.

The lower part of the lower limestone unit, above the basal layer, indicates a somewhat different environment. The pelecypods are present and crinoids are more common than the local occurence in the basal part, indicating that practically the entire area studies were now below wave action. Arenaceous foraminifers are common throughout the area, however the agglutinated walls are interpreted by several authors as indicating the primitive development of the class rather than cool water. The abundance and degree of preservation of these foraminifers indicate, according to Moore (1929, p. 467), a "relatively quiet environment unaggitated by strong currents." However, in the southern part of the area the tests are present mainly as fragments. The consistant but local occurance of gastropods and ostracodes is of little specific environmental indication, as is the somewhat more common occurance of bryozoans.

Although brachiopods are common in the northern and extreme southern parts of the area, they are rare in the central part. The alga Osagia with its nucleus of shell fragments is abundant in the north but rare in the south. According to Lane (1954) the formation of an Osagia-limestone, or osagite, is due either to vertical sorting which retains the smaller shell fragments that are later encrusted with algae or the shells are broken near the plunge point and the fragments carried out into slightly deeper water. On the basis of other works, Lane concludes that algae are abundant at depths of about 60 feet and with gentle wave action the algae would completely encrust the fragments.

The possibility of mechanical breakage and vertical sorting can be ruled out, as the accompanying faunal remains are not fragmented. If mechanical breakage near the plunge point and lateral sorting into deeper water is the cause, then the abundance of Osagia in the north and the rarity in the south could indicate the area of breakage to be either to the north or south. If the breakage area were to the north, it could be stated that the supply of fragments was greater in the north, thus producing more abundant Osagia. If the breakage area were to the south, it could be stated that although the supply of fragments was greater in the south, the stronger currents and shallower depth prohibited the abundant development of algae in the south.

Mechanical breakage, however, is not the only possible cause of the fragments, inasmuch as, according to Twenhofel (1932, p. 149), on the sea bottom beneath the Gulf Stream off the coast of New England is an abundance of entire and broken shells that are due to fish which crush the shell and excrete the fragments, crustaceans which break shells, and boring sponges and annelids. He also states (p. 151) that unless it can be shown that the comminuted organic matter is due to current or wave action, it should be interpreted as representing the action of abundant scavengers.

The answer to the question seems to be in the lithology of the unit. Throughout most of the area the rock is a fine-grained to aphanitic limestone, however to the south the rock is more argillaceous and farther south the horizon is represented by limy shale. Therefore, the shoreline was probably to the south and the mechanically broken fragments were carried to the north where the habitat with the gentle currents turning over the fragments was more suitable to the algae and, as shown by the presence of Myalina and other forms, strong currents were absent. The action of scavengers might have been responsible for some of the fragments.

The fine-grained texture of the rock also indicates that only gentle currents were present. The fine texture of the rock might also be the result of the large community of benthonic organisms which eat and re-eat the deposited material many times and produce excreta containing material of reduced grain size (Dapples, 1942, p. 124). The finest material might be dissolved or carried away.

Another interesting element of the fauna is the fusulinids. These animals are absent or extremely rare in the north but are common near the south, only to disappear farther south in the limestone. Elias (1937, p. 428) considers the fusulinids of the Lower Permian in Kansas to indicate depths of 160 to 180 feet on the basis of the study of modern large benthonic foraminifers. If the shore of the Merriam sea were to the south, however, it would be impossible to explain the conditions forming the deep water fusulinid community between the shore and the shallow water environment to seaward. Elias points out the greater irregularity of the Pennsylvanian cycles as compared to the Permian and states (p. 427) that certain factors may have shifted the benthos organisms somewhat from the depths which they "normally" occupied. The question arises, however, as to what factors could transport material or environment from a depth of 170 feet to one of

60 feet.

An explanation is offered by Moore (1929, p. 467) who states that the sea floor under very shallow water would be subjected to little wave action and "consequently, depths ranging from 5 to 50 feet may, under certain conditions, afford surroundings quite as favorable to foraminiferal populations as depths of 400 to 500 feet and they may even be more favorable." The beginning of the fusulinid commonness toward the south coincides roughly with the beginning of the Osagia rarity. Therefore, one could conclude that the fusulinids were adapted to an environment which was either too shallow for Osagia development or was one of rapid deposition inasmuch as the only organic remains in the latter environment would be, according to Twenhofel (1942, p. 106), those of forms able to dig themselves out if buried. This environment could not be so shallow as to be near the baselevel of deposition, as Twenhofel (p. 105) states that such an area is one of slow deposition.

Both the shallow and deep water hypotheses consider the depth of water as the principal factor governing distribution, but according to Twenhofel (1932, p. 153) several modern investigations, as in the Irish Sea and Bay of Naples, show that the nature of the substratum is the most important factor determining the distribution of benthonic animals. He concludes that "it is certainly more important than mere depth (of water)." It is possible, then, that the fusulinids could better adapt to this particular environment because of the nature of the substratum.

Because the localities of common fusulinids rarely contain significant amounts of any other animal remains, except the ubiquitous crinoid, it seems probable that the sea in general was shallow and that locally the nature of the substratum was such as to permit the establishment and possible dominance of a fusulinid population. It can be concluded, therefore, that although the actual cause of the distribution is not known, the presence of fusulinids near the southern part of the area does not of necessity indicate deeper water.

The main faunal difference of the upper part of the lower limestone unit is in the more common occurence and somewhat more northward extension of the fusulinids, the local presence of calcareous algae and sponges in the north, and of sponges in the south. Also cephalopods are locally present in the north and worm-borings are present in the top of the unit at some localities. Lithologically the upper part of the unit is distinguished by oolitic limestone and local thick sequences composed of cross-beds.

The greater development of the fusulinids merely indicates an extension of the tolerable habitat. The conclusions that can be drawn from the sponges are that they grew in warm, clear, and shallow water. The worm-borings are not indicative of depth. Although the areal and stratigraphic restrictions of the cephalopod shells suggest benthonic forms (Moore, 1929, p. 471), their presence only in the cross-bedded oolitic limestone, which undoubtedly represents the work of local currents, could possibly indicate that the shells were transported from the original habitat; however, inasmuch as the ooliths and small fossils present in the cross-bedded sequence are about the same size, 0.3 millimeter in diameter, it seems unlikely that the large cephalopod shells would be transported by the same current. Perhaps the localization of the animals in the currents was related to the increased nutrient supply. As algae were found in every cyclic limestone studied by Johnson (1946, p. 1108), these plants were adapted to various environments. The only inferences which can be drawn from the presence of the calcareous algae are that the water was clear and a euphotic zone was present.

The origin of ooliths is contraversial. According to Twenhofel (1932, p. 764-769), it is postulated that ooliths are formed by algae, in an ooze or gel, about a colloid, or subaerially. Thiel (1942, p.96) states that the origin of ooliths is in part diagenetic. Transported ooliths are commonly cross-bedded with associated small fossils of about the same size. Therefore, the upper part of the unit contains indigenous and transported ooliths with the source of the latter probably being the areas of indigenous ooliths.

Shale bed. The shale comprising the shale bed is only locally weakly calcareous and therefore the shale is considered to be a masking of the calcium carbonate. Where the influx of fine clastic material was not great enough to completely mask the limestone, the shale bed did not form. The influx of clastic material was not rapid enough to kill the organisms present inasmuch as the shale is composed of thin layers, indicating a slow rate of deposition. Nor was the sea turbid to the extent of preventing life as fossil remains are common to abundant.

The presence of such animals as brachiopods, bryozoans, and rare calcareous foraminifers indicates shallow water. This shallow water probably contained scavengers as is shown by the fragmental nature of the fish and other remains. The action of scavengers also points to a slow rate of deposition, because under such conditions organisms are in contact longer with the water and the scavengers (Twenhofel, 1942, p. 105). Other indications of the slow deposition of the shale bed are the abundance of sedentary benthonic organisms and the presence of ramose bryozoans. According to Stach (1936, p. 62), the zoarium of these bryozoans indicates a habitat of deep or sheltered waters with no wave action and only gentle currents, which would be the habitat of a shallow area of slow deposition. These forms are not distributed throughout the area because of the nature of the bottom. They are more common in more calcareous areas.

The influx of the clay is possibly related to the increased competency and capacity of the subaerial streams to the south and possibly to a slight recession of sealevel. As Moore (1929, p. 483) states, a climatic change producing an increase in precipitation would result in a clastic sequence succeeding limestone. Such a temporary change in climate would not be in opposition with the plant evidence described by Elias (1936). The change from limestone to clay deposition could also be due to an increase in the temperature of the source area, lessening the plant cover, and increasing runoff (Twenhofel, 1932, p. 143). If the sea shallowed somewhat, the clay could have been carried farther north by bypassing the baselevel area of the bottom. Regardless of the cause of the influx, the deposition was slow. The actual flocculation of the clay is related to the electrolytes present in the sea water.

The small folds in the shale in some areas are probably the result of compaction.

Upper limestone unit. The upper limestone unit is the most widespread rock unit in the Merriam and thus indicates that the sea transgressed farther at this time than at any previous time. The result of such an extension of the sea would be a deepening of the water in the north and a cessation of the clastic influx. Although the percent of insoluble material, primarily clay, does not differ appreciably from that of the lower unit, the amount by weight is greatly less; that is, although the same relative percentage of fine clastic material was flocculated in the seas of both limestone units, a smaller amount was flocculated in the sea of the upper limestone unit. The lessening of the clay material suggests deeper water for the upper limestone sea. In southern Kansas the sea was shallow enough to permit the formation of argillaceous and ferruginous limestone.

The predominant elements of the biota are fusulinids and worm borings and the abundance of these two organisms is an inverse proportion. The fusulinids are abundant in the central part of the area where forms, other than crinoids, are only locally common. The fusulinids are most common in the aphanitic lithofacies of the unit and are therefore considered to represent areas which were little disturbed by currents. Aphanitic limestone represents the accumulation of limy mud in a quiet environment and is characterized by a predominance of clay and fine silt as impurities which accumulate in the quiet conditions (Williams, Turner, and Gilbert, 1954, p. 348). The formation of this limestone could be the result of chemical precipitation or of comminution by benthonic organisms. Some of the limestone might be the result of bacterial precipitation of calcium carbonate and these bacteria might have produced the bluish tinge of the rock. The aphanitic texture may also be the result of diagenetic processes.

In the area near the Kansas River the predominance of fusulinids is replaced by a predominance of Osagia, indicating an area of stronger currents than in the fusulinid area; however the currents were only strong enough to periodically overturn the shell fragments on which the algae grew and to transport the sand grains which seem to represent the paths of currents (Fig. 16). The Osagia biofacies is also associated with a less aphanitic and more fine-grained lithofacies.

The worm-borings to the north and south of the fusulinid area seem to indicate a difference in the nature of the substratum rather than a difference in depth. According to Dapples (1942, p. 119), worms prefer mud bottoms with much admixed sand. Although sand is rare in this limestone, it seems that coagulated flocks of clay or silt grains would fulfill the requirement.

The commonness of calcareous algae and brachiopods farther south probably indicates an environment somewhat similar to that of the fusulinid area, but certain environmetal factors may have prevented the adaptation of the fusulinids to this environment. The increase in the diversity and abundance toward the south might be associated with the higher percentage of sand in the calcareous mud of the substratum. The intermixing of brachiopod-fenestrate bryozoan argillaceous limestone and brachiopod-sponge-crinoid ferruginous limestone in southern Kansas indicates two separate types of habitats. The sea was shallow in this part of the region and local clastic influx was abundant but slow. According to Stach (1936, p. 62), the zoarium of fenestrate bryozoans indicates a habitat of strong currents and wave action, which is in accord with the argillaceous nature of the rock. The sponge-crinoid biofacies indicates quieter conditions of clear water. Although the water was clear, it contained ions of ferric oxide in colloidal suspension which were flocculated by electrolytes in this relatively nearshore environment. The silicon dioxide in suspension would be carried farther to sea (Twenhofel, 1942, p. 108) and thus might be represented by the blue chert in Nebraska.

At the top of the upper limestone unit in the northern part of the area is a rubbly limestone with brachiopod and crinoid remains and rare fusulinids. This part of the unit is indicative of a shallowing of the sea and a beginning of the regressive hemicycle of deposition.

The limits of glauconite formation as described by Cloud (1955) indicates that some of the glauconite in the Merriam could have formed in placed, but more likely the mineral was transported into the area.

In summary, the environment of deposition of the Merriam limestone member indicates an unstable shelf association as defined by Krumbein, Sloss, and Dapples (1949, p. 1868). As the sea advanced, erosion of the substratum occured and silt and clay were transported into the area. Brachiopods adapted to the strong currents thrived and in local restricted areas crinoids flourished. As the sea extended itself farther, the shells near the shore were broken and the fragments slowly transported to the north where algae and pelecypods had migrated into the quieter water. During this time a fine mud of calcium carbonate was forming on the sea floor, the fineness possibly due to the actions of benthonic organisms. Perhaps with a slight increase in the depth of water the fusulinids expanded their habitat. In locally more clear water the sponges grew. During this time gentle currents flowed through the area; however near the end of lower limestone unit time fairly strong currents crossed the sea floor, depositing ooliths and small fossils in the channels cut in the bottom of indigenous ooliths. The sea floor was by no means flat since the unit varies locally in thickness.

A slight recession of sealevel or change in climatic factors produced an influx of clastic material over much of the area. As in the lower unit, the material comprising the shale bed was deposited slowly in a region of quiet and shallow water. Local differences in the nature of the substratum effected the distribution of the organisms.

The sea continued transgressing and obtained its greatest extent in upper limestone unit time. Local areas of strong currents and quiet waters were produced in southern Kansas. Although in most parts the area was an environment of deposition of fine mud in quiet water, local areas of somewhat stronger currents were present. The presence of the quiet area in the central part of the region and of less quiet conditions to the south and northeast may indicate the direction and relative nearness of the shorelines. The change in the biofacies and lithofacies from north to south seems to be almost equally the result of location of currents and nature of the substratum as well as the depth of water.

Any inferences of the depth of water during this time are purely conjectural and the use of certain fossils as indicators of depth seems to emphasize depth as the primary ecologic factor effecting the community. Therefore the writer considers it too arbitrary to assign depths of environment in terms of feet; instead a satisfactory determination is possible in terms of zones.

The basal part of the member is considered to be indicative of the eulittoral zone merely shifted farther inland, undoubtedly overiding part of the previous intertidal zone. By comparison with modern seas one is able to roughly estimate the range in depth of water to be between a few feet and 165 feet. At the close of limestone deposition the sea had shallowed to give an environment more representative of the middle part of the eulittoral zone.

A generalized diagram of the environment of deposition during Merriam time is shown in Plate 3.

Hickory Creek shale member

The lower part of the member represents a continuation of the shallowing of the sea but now with an influx of clastic material. Because of the almost level contact between this shale and the underlying limestone, it is assumed that the shallowing of the sea was rapid enough over this low gradient area to prevent the reworking of the underlying material by the incoming clastic flocculants. The locally developed black fissile shale is considered by Moore (1929, p. 465) to possibly represent an environment of "extremely shallow water, with sunlight promoting abundant plant growth (sea weed) and aiding in partial decay, with too little depth for circulation and effective wave or tidal agitation."

Conditions at the time of the Hickory Creek deposition were probably not restricted to the extent of the development of great areas of black mud. After this deposition, the punk bed and its correlative ferruginous limy shales were deposited. These deposits indicate that the supply of clastics was less and that the environment was now one of oxidation and probably somewhat less shallow without much plant growth. The precipitation of the limestone could be the result of an increase in temperature, salinity, or a change in other physico-chemical factors.

The lower units of the Hickory Creek shale member are therefore indicative of a very shallow water environment.

THE MERRIAM CYCLOTHEM

The members of an ideal cyclothem as distinguished by Moore (1936, pp. 24-25) are shown in Fig. 22. The Merriam cyclothem extends from the sandstone or red clay in the Bonner Springs to the top of the upper limestone unit. This cyclothem comprises a cyclothem B of the megacyclothem as it is characterized by a "middle" limestone, the Merriam. The relation of the Merriam sequence to the cyclothemic units is shown in Figure 23. A study of this figure shows that the sequence south of the Kansas River represents a fairly complete cyclothem. The only cyclothem units absent are the upper molluscoid shale and the upper molluscan shale and nonmarine shale. North of the Kansas River the fusulinid and upper molluscan limestones are inseparable and to the south the fusulinid limestone disappears. In southern Kansas the only units present are probably the lower and upper molluscan limestones, i.e., the shallow water phases.

From the study of the cyclothemic units one could conclude that the shore of the Merriam sea was in Oklahoma on one side and somewhere in Iowa on the other side inasmuch as the fusulinid, deep water, phase is absent to the south and becomes indistinguishable to the northeast.

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

FIG. 22. Members of an ideal cyclothem (Modified from Moore 1936).

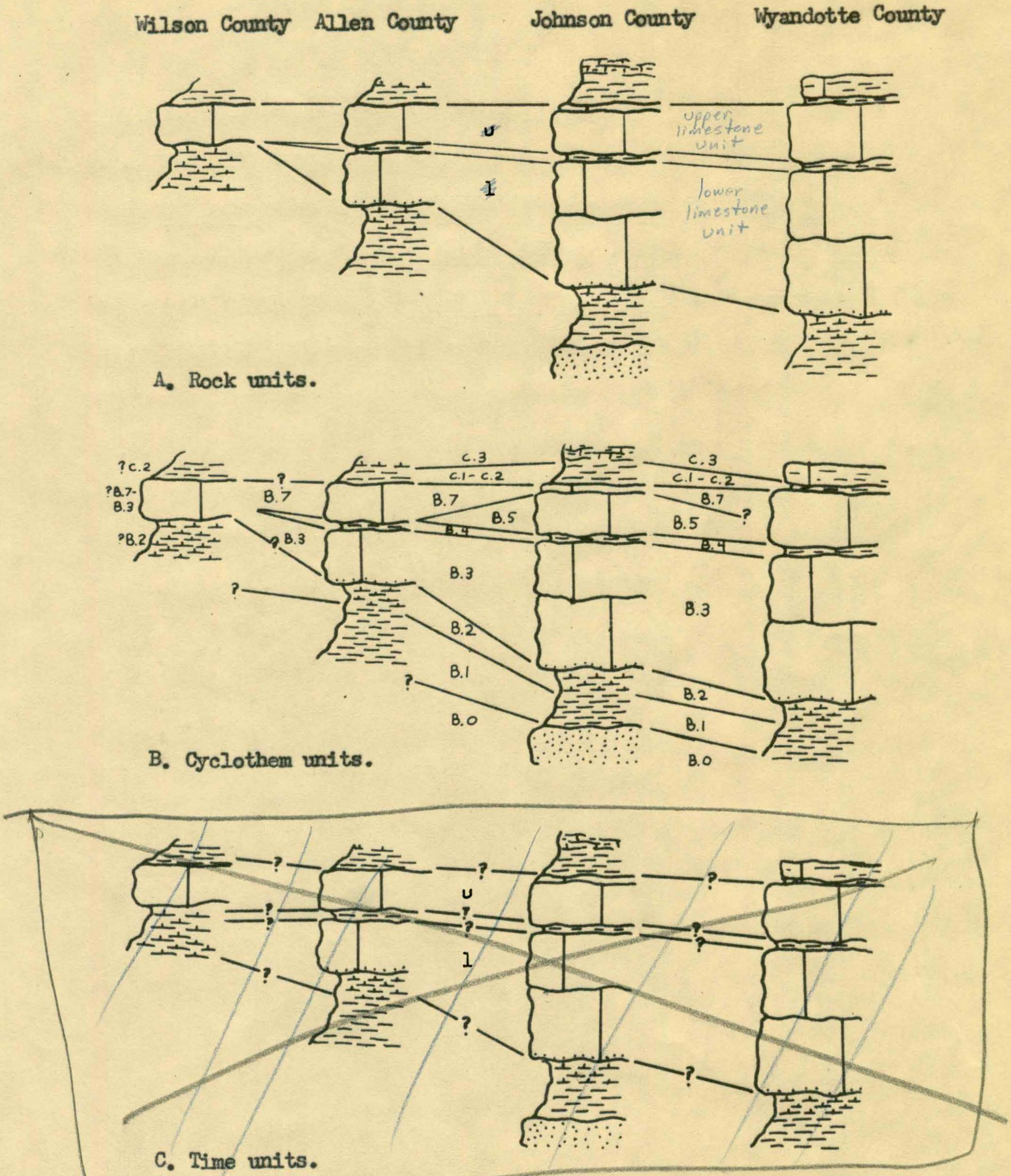


Fig. 6. ~~FIG. 7.~~ ~~FIG. 23.~~ Relation of rock units, and cyclothem units, ~~and time units~~ of the Merriam limestone.

CONCLUSIONS

1. The Merriam limestone member of the Plattsburg formation is divisable into three rock units ---- the lower limestone unit, the shale bed, and the upper limestone unit. Each of these units is distinct in lithologic and biologic character and is identifiable throughout eastern Kansas.

2. Although insoluble residues do not delineate the units of the member to a great extent, acid etched blocks and thin sections show the distinctive features of the units.

3. The lower limestone unit varies greatly in thickness and is absent in some localities. In southern Kansas this horizon is represented by shales.

4. The shale bed is very persistent and may be present in southern Kansas; but if it is, it is indistinguishable from the underlying Lane-Bonner Springs shale.

5. The upper limestone unit is the most persistent unit in the member. In southern Kansas this unit seems to represent the entire member.

6. The Merriam limestone contains several lithofacies and biofacies both vertically and laterally. The greatest lateral change in characteristics occurs in southern Kansas.

7. The various lithofacies and biofacies are results of the different environments of deposition.

8. The Merriam limestone was deposited in shallow water of the eulittoral zone which represents a water depth of a few feet to about

165 feet.

9. The distribution of the biota was primarily the result of the nature of the substratum, location of currents, depth of water, and amount of influx of clastics.

10. Shorelines of the Merriam sea were in Oklahoma and probably in Iowa.

11. The member is indicative of a transgressing sea, and the regressive hemicycle of deposition is poorly represented.

12. The Merriam represents a fairly complete cyclothem in east central Kansas, but farther southward and northeastward fewer cyclothemic units are identifiable.

13. In east central Kansas the cyclothemic units and rock units are closely related, but to the south and northeast the relation is transgressive.

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Only those sections with the Locality number circled will be used in the Appendix. — 5, 7, 10, 14, 16, 24, 27, 30, 39, 42, 44, 46, 48, 54.

APPENDIX A

MEASURED SECTIONS OF THE MERRIAM LIMESTONE IN EASTERN KANSAS

The colors and color symbols used in these sections are from the Rock-color Chart distributed by the Geological Society of America.

Locality 1. SW¼, SE¼, Sec. 25, T. 10 S., R. 23 E., Wyandotte County; measured in cut behind screen of Lakeside Drive-In Theater.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, thin bedded, slabby weathering, mostly eroded	3 +
Hickory Creek shale member	
Shale, dusky yellow, limy, with large limestone nodules .	1.0
Merriam limestone member	
Upper limestone unit	
5. Limestone, medium gray (N5), weathers dusky yellow (5Y6/4); fine- to medium-grained, saccarhoidal texture; massive; osagite; upper contact irregular; *Osagia* abundant; crinoid columnals common	1.7
Lower limestone unit	
4. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); very fine-grained, sub-aphanitic; massive; with small veinlets of dark crystalline dolomite; separated from unit 5 by a 0.1 foot parting of coquinoid limestone similar to that in unit 3; common crinoid columnals, common gastropods near middle of unit, common fenestrate bryozoans and abundant *Composita* at top of unit	0.9

3. Shale, dusky yellow (5Y6/4), weathers same; limy; with nodules of coquinoid limestone; fossils in limestone are mainly crinoid columnals 0.2

2. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); very fine-grained, dense, sub-aphanitic; massive; more crystalline than unit 1; separated from unit 1 by a very thin irregular parting of rubbly shaly limestone, dusky yellow (5Y6/4), with abundant fossil fragments; unit contains common worm borings filled with yellow ferruginous clay; spots and veinlets of dark crystalline dolomite are present in lower three-fourths of unit; abundant brachiopods 0.6

1. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained, dense; massive; lower contact fairly even; large crinoid columnals common in lower one-half of unit, brachiopods abundant at top 0.9

Total Merriam limestone member . . . 4.3

Bonner Springs shale

Shale, moderate yellowish brown (10YR5/4), weathers grayish orange (10YR7/4); sandy; laminated . . . . 25.0+

Locality 2. Center north side of SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 27, T. 11 S., R. 23 E., Wyandotte County; measured in road cut on Camp Naish Road on north side of bend of lower switchback in Boy Scout of America camp one mile east of Bonner Springs.

Thickness
Feet

Plattsburg formation

Hickory Creek shale member

Shale, clayey, very poorly exposed . . . . 1.0±

Merriam limestone member

Upper limestone unit

3. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); osagite; fine-grained; massive; upper contact fairly even; upper 0.1 foot weathers to rubbly fragments; small brachiopods and crinoid columnals common at top, *Osagia* abundant at base . 1.0

Shale bed

2. Shale, pale olive (10Y6/2), covered; limy, papery, laminated; somewhat irregular 0.2

Lower limestone unit

1. Limestone, olive gray (5Y4/1), weathers dusky yellow (5Y6/4); fine- to medium-grained; massive; contains abundant small angular silt pebbles at base; lower contact irregular; *Osagia* abundant throughout unit, *Composita* common throughout unit, *Myalina* rare near the base, brachiopods and crinoid columnals common near the base; some of the small brachiopods largely replaced by ferruginous clay 0.7

Total Merriam limestone member . . . 1.9

Bonner Springs shale

Shale, dusky yellow (5GY5/2), moderate olive brown (5Y4/4) in upper 0.4 foot; clayey; upper 10 feet covered; massive two-foot gray limestone bed exposed below covered interval . . . . 20.0±

Locality 3. SW corner, Sec. 30, T. 11 S., R. 23 E., Wyandotte County; measured in road cut 1.5 miles west of Bonner Springs on Kansas Highway 32.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, thin wavy bedded	10.0±
Hickory Creek shale member	
Shale, dark yellowish orange (10YR6/6) in lower 0.5 foot, light gray in upper part	2.0
Merriam limestone member	
Upper limestone unit	
4. Limestone, light gray (N7), weathers yellowish gray (5Y7/2); fine-grained, dense; massive; abundant small spots of dark crystalline dolomite; upper contact fairly flat; common worm borings filled with ferruginous clay, abundant crinoid columnals, rare brachiopods, rare sponges at base .	0.9
Shale bed	
3. Shale, dark yellow-orange (10YR6/6), weathers same; limy, papery, fissile; apparent gradation into the underlying limestone; contains earthy limestone at base; extremely abundant brachiopod remains	0.3
Lower limestone unit	
2. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); very fine-grained to fine-grained; massive; fairly even upper surface; <u>Osagia</u> abundant, common brachiopods and crinoid columnals	0.9
1. Limestone, yellowish gray (5Y7/2), weathers same; very fine-grained to fine-grained, dense; massive; upper 0.1 foot rubbly and yellow; crinoid columnals common throughout unit, rare <u>Osagia</u> and common spiriferoid brachiopods at top, <u>Composita</u> common at base	0.6
Total Merriam limestone member	2.7
Bonner Springs shale	
Shale, moderate yellow brown (10YR5/4), limy	0.3

Limestone, cross-bedded . . . . unm.

Locality 4. Center west side SW¼, NW¼, NE¼, Sec. 17, T. 12 S., R. 23 E., Johnson County; measured in road cut on west side of Frisbie Road

	Thickness Feet
Plattsburg formation	
Spring Hill limestone and Hickory Creek shale members	
Limestone, mostly covered; and shale, pale olive (10Y6/2), weathers same, limy	8.0±
Merriam limestone member	
Upper limestone unit	
4. Limestone, light gray (N7), weathers olive gray (5Y4/1); fine-grained, dense; massive; upper contact even; abundant spots of dark crystalline dolomite; rare worm borings filled with ferruginous clay; common crinoid columnals, rare <u>Composita</u>, and rare echinoid spines throughout unit, abundant <u>Osagia</u> in lower one-third of unit	1.1
Shale bed	
3. Shale, light olive gray (5Y6/1); covered; silty; laminated; subfissile	0.4
Lower limestone unit	
2. Limestone, light gray (N7), weathers light olive gray (5Y6/1); fine-grained; massive; osagite; rare small light green shaly limestone nodules; similar to unit 1; <u>Osagia</u> abundant with small <u>Osagia</u> resembling ooliths, rare sponges in middle of unit . . .	1.4
1. Limestone, light olive gray (5Y6/1); weathers olive gray (5Y4/1); fine-grained, dense; massive; osagite;	

in places unit weathers with layered relief; Osagia abundant, Myalina common, crinoid columnals common . 1.2

Total Merriam limestone member 4.1

Bonner Springs shale

Shale, covered . . . . 20.0 ±

Locality 5. SE¼, NE¼, NW¼, Sec. 13, T. 12 S., R. 24 E., Johnson County; measured in road cut on west side of U. S. Highways 50 and 169, just south of highway interchange.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, massive to thin bedded, with shale partings . 12.0±

Hickory Creek shale member

2. Shale, mainly pale olive (10Y6/2), laminated, limy . 0.5

1. Limestone, grayish orange (10YR7/4), weathers yellowish gray (5Y7/2); punky, earthy, very weathered appearance; massive; separated from underlying unit by very thin shale parting; common crinoid columnals, rare brachiopods including Composita 0.6

Merriam limestone member

Upper limestone unit

3. Limestone, medium light gray (N6), weathers yellowish gray (5Y7/2); very fine-grained, aphanitic; massive; prominent vertical jointing; common spots

and veinlets of dark crystalline dolomite; rare worm borings filled with yellow ferruginous clay; common crinoid columnals, rare _Osagia_, rare small fusulinids 0.6

Shale bed

2. Shale, mainly pale olive (10Y6/2), weathers same; thinly laminated, papery, fissile, contains rare fossil fragments 0.2

Lower limestone unit

1. Limestone, medium light gray (N6) in lower two-thirds, light gray (N7) in upper one-third, weathers yellowish gray (5Y7/2); fine-grained, oolitic with small ooliths; massive; one bed; fairly prominent vertical jointing; osagite; lower 0.2-0.3 foot is greatly weathered, dark yellowish orange (10YR6/6) on fracture, this lower part contains common fossil fragments; 0.6 foot zone of abundant _Composita_ just above weathered part, brachiopods and _Myalina_ common throughout rest of unit with rare fenestrate bryozoans at top, _Osagia_ more abundant in upper one-third 1.6

Total Merriam limestone member 3.9

Bonner Springs shale

Shale, mostly covered, weathers yellowish gray (5Y7/2) in upper 0.5 foot; hard, limy, laminar blocks; weathers light bluish gray (5B7/1) in lower part, silty, platy . . . . . unm.

Locality 6. Center north side NE¼, Sec. 9, T. 12 S., R. 24 E., Johnson County; measured in road cut on south side of road, 1.7 miles west of Nieman Road on 55th Street, Shawnee.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, covered . . . . 8.0±

Hickory Creek shale member

Shale, black, covered 0.2

Merriam limestone member

Upper limestone unit

3. Limestone, very light gray (N8), weathered surface lichen-covered; fine-grained; massive; upper surface only slightly irregular; abundant *Osagia*, common brachiopods at top; poorly exposed . . . . 0.5±

Lower limestone unit

2. Limestone, medium gray (N5) with faint reddish tinge, weathered surface lichen-covered; fine-grained; massive; abundant *Osagia* . . . . 0.5±

1. Limestone, very light gray (N8), weathers grayish orange (10YR7/4); fine-grained; massive, abundant *Osagia*, common crinoid columnals, and common fenestrate bryozoans throughout unit; abundant *Composita*, common productids, and rare *Myalina*, especially in lower 0.3 foot; poorly exposed . . . . 1.0±

Total Merriam limestone member . . . 2.0±

Bonner Springs shale

Shale, arenaceous, light tan, covered . . . . unm.

Locality 7. Center east side SE¼, Sec. 18, T. 12 S., R. 24 E., Johnson County; measured in road cut on Renner Road 0.3 mile north of Kansas Highway 10.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, weathers yellowish gray (5Y8/1); thin wavy beds; very fossiliferous	3.0±
Hickory Creek shale member	
2. Shale, gray, covered	0.3
1. Limestone, dark yellowish orange (10YR6/6), weathers slightly lighter; punky; massive; weathers to thin irregular beds; upper contact fairly even . . .	1.0
Merriam limestone member	
Upper limestone unit	
2. Limestone, medium light gray (N6), weathers yellowish gray (5Y7/2); medium-grained; massive; prominent vertical jointing continuing into overlying bed; common veinlets of dark crystalline and dense dolomite; rare worm borings filled with ferruginous clay; common fusulinids, common crinoid columnals, rare brachiopods	0.6
Lower limestone unit	
1. Limestone, medium dark gray (N4) in lower 0.3 foot and very light gray (N8) in upper 0.5 foot, weathers yellowish gray (5Y7/2); fine-grained, dense; massive; oolitic with most prominance in middle of bed; abundant limonite alteration at base of bed; bottom surface somewhat irregular, upper surface fairly flat and smooth; unit very fossiliferous, especially in lower and upper one-third; common Osagia, very common in middle one-third of unit; common fenestrate bryozoans in lower one-third; Myalina common, especially in upper 0.3 foot; lower 0.2 foot has brachiopods in weathered relief, especially Composita, Composita also common in upper part of unit	0.8 - 1.3
Total Merriam limestone member	2.4 - 2.9
Bonner Springs shale	

Shale, grayish olive (10Y4/2), weathers pale olive (10Y6/2); laminated; subfissile . . . . unm.

Locality 8. Center north side Sec. 36, T. 12 S., R. 23 E., Johnson County; measured in road cut.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, covered	8.0+
Hickory Creek shale member	
Shale, covered	0.5
Merriam limestone member	
Upper limestone unit	
2. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained, dense; massive; oolitic; abundant <u>Osagia</u>, rare <u>Myalina</u>, rare brachiopods, poorly exposed	0.5
Lower limestone unit	
1. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained; sub-oolitic; massive; contacts uneven; common <u>Osagia</u>, rare <u>Myalina</u>, rare fenestrate bryozoans throughout unit; common small elongate algal masses in middle of unit	1.5
Total Merriam limestone member . . .	2.0
Bonner Springs shale	
Shale, sandy, dusky yellow (5Y6/4); very abundant quartz grains; covered	unm.

Locality 9. SW¼, NW¼, NW¼, Sec. 13, T. 13 S., R. 23 E., Johnson County; measured in road cut in valley side south of bridge.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, thin wavy beds, mostly eroded	4.0+
Hickory Creek shale member	
Shale, covered	3.0
Merriam limestone member	
Upper limestone unit	
4. Limestone, medium light gray (N6), weathers light gray (N7); very fine-grained; contains rare worm borings filled with yellow ferruginous clay; poorly exposed .	1.0
Shale bed	
3. Shale, covered	0.2
Lower limestone unit	
2. Limestone, yellowish gray (5Y7/2), weathers light olive gray (5Y5/2); medium-grained; oolitic; massive; common Osagia, common brachiopods	1.0
1. Limestone, medium light gray (N6), weathers light gray (N7); fine-grained, dense; sub-oolitic; massive; common veinlets of dark crystalline dolomite; rare fairly large cavities filled with yellow ferruginous clay; abundant _Osagia_, abundant _Myalina_, common crinoid columnals	1.0
Total Merriam limestone member	3.2
Bonner Springs shale	
Shale, in upper three feet sandy, dusky yellow (5Y6/4), abundant quartz grains; in lower two feet exposed clayey, laminated, dark greenish gray (5GY4/1)	5.0+

Locality 10. NE$\frac{1}{4}$, SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 28, T. 12 S., R. 22 E., Johnson County; measured in old quarry at northwest corner of De Soto, just north of railroad tracks.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, thin wavy bedded	unm.
Hickory Creek shale member	
Shale, pale olive (10Y6/2), weathers same; limy	unm.
Merriam limestone member	
Upper limestone unit	
5. Limestone, pale olive (10Y6/2), weathers yellowish gray (5Y7/2); fine-grained; very rubbly but hard; resembles a punky limestone; contains irregular thin shale lenses; weathers to frothy appearance; uneven contacts; common brachiopods, common echinoid spines, common crinoid columnals, rare elongate fusulinids .	0.3
4. Limestone, light gray (N7), weathers same; fine-grained, crystalline; common veinlets of dark crystalline dolomite; fairly even contacts; common worm borings filled with yellow ferruginous clay; rare echinoid spines	0.8
Shale bed	
3. Shale, dark yellowish orange (10YR6/6), weathers same; limy; thinly laminated; fissile; abundant brachiopods	0.2
Lower limestone unit	
2. Limestone, yellowish gray (5Y8/1), weathers same; fine-grained, dense, more crystalline than underlying unit; massive; osagite; top of unit is coquinoid with abundant brachiopods and crinoid columnals, crinoid columnals up to 0.5 inch in diameter, also fenestrate bryozoans; separated from underlying unit by thin shale parting; abundant *Osagia* and common crinoid columnals throughout unit, rare ~~*Myalina*~~ Orthomyalina in middle of unit . .	1.1

1. Limestone, light olive gray (5Y6/2), weathers light bluish gray (5B7/1); fine-grained, somewhat sandy; massive; lower 0.4 foot weathers yellowish gray (5Y7/2); fairly even lower contact; Myalina and brachiopods abundant throughout unit, Composita abundant in middle one-third, sponges abundant in upper 0.4 foot 1.6

Total Merriam limestone member 4.0

Bonner Springs shale

Shale, moderate yellowish brown (10YR5/4), weathers yellowish gray (5Y7/2); sandy, laminated, fissile; upper contact only slightly irregular . . . . unm.

Locality 11. NW¼, Sec. 31, T. 12 S., R. 22 E., Johnson County; measured in road cut on east side of Sunflower Road.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, massive to thin bedded . . . . 8.0 +

Hickory Creek shale member

2. Shale, dusky yellow-green (5GY5/2), weathers grayish yellow-green (5GY7/2); laminated 0.4

1. Limestone, moderate yellowish brown (10YR5/4), weathers dark yellowish orange (10YR6/6); punky, fine-grained; weathers to crumbly fragments; separated from underlying bed by weathered parting; abundant crinoid columnals 0.2

Merriam limestone member

Upper limestone unit

5. Limestone, medium light gray (N6), weathers light olive

gray (5Y6/1); aphanitic, dense; massive; abundant dolomite spots and veinlets throughout unit; common Osagia in lower one-third of unit and in places surrounded by limonite; common small brachiopods in lower one-third, also surrounded by limonite; limonite gives mottled appearance to rock 1.0

4. Limestone, medium light gray (N6), weathers light olive gray (5Y6/1); fine-grained; massive; separated from overlying unit by a thin parting of brown shale; common Osagia and common brachiopods 0.3

Shale bed

3. Shale, dark yellow-orange (10YR6/6), weathers light olive gray (5Y5/2); sandy; thickness irregular; grades into underlying unit 0.2

Lower limestone unit

2. Limestone, greenish gray (5GY6/1), weathers same; coquinoid and crystalline with common crinoid columnals and rare brachiopods 0.3

1. Limestone, light olive gray (5Y6/1), weathers same; fine-grained, abundant limonite; apparently massive; crumbly in hand specimen; base not exposed . . . . 0.4+

Total Merriam limestone member . . . 2.4+

Locality 12. 0.4 mile west of NE corner Sec. 4, T. 13 S., R. 22 E., Johnson County; measured on road at east bluff of Kill Creek.

Thickness Feet

Plattsburg formation

Spring Hill limestone member and Hickory Creek shale member

Limestone, erosion remnants, and shale . . . . unm.

Merriam limestone member

Upper limestone unit

4. Limestone, medium light gray (N6), weathers bluish white (5B9/1); very fine-grained, dense; massive; brittle; weathers into angular blocky fragments; common worm borings filled with yellow ferruginous clay; common crinoid columnals and common brachiopods 1.6

Lower limestone unit

3. Limestone, greenish gray (5GY6/1), weathers yellowish gray (5Y7/2); fine-grained, dense, somewhat sandy and orange toward base; thin even beds; common Osagia, common Myalina, common crinoid columnals, rare sponges, rare brachiopods at top 4.3

2. Limestone, pale olive (10Y6/2), weathers grayish orange (10YR7/4); sandy; common crinoid columnals, rare Composita 1.0

1. Limestone, pale olive (10Y6/2), weathers dusky yellow (5Y6/4); sandy; common crinoid columnals, rare fenestrate bryozoans, common Myalina; poorly exposed; units 1 and 2 more closely resemble the underlying Bonner Springs shale in weathering color and type of material than the dense overlying beds of the Merriam 1.0

Total Merriam limestone member . . . 7.9

Bonner Springs shale

Shale, pale olive (10Y6/2); sandy; with limonite stains; poorly exposed 1.0

Limestone, conglomeratic, cross-bedded . . . . unm.

Locality 13. 0.1 mile south of NE corner, Sec. 21, T. 13 S., R. 22 E., Johnson County; measured on road.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, granular 6.5

Hickory Creek shale member

Shale, ferruginous, yellow 0.7

Merriam limestone member

Upper limestone unit

3. Limestone, light gray (N7), weathers light olive gray (5Y6/1); fine-grained, dense; massive; more crystalline than lower units; common worm borings filled with ferruginous clay; abundant limonite at topl rare crinoid columnals, abundant fusulinids at top . . 1.0

Lower limestone unit

2. Limestone, pale yellowish brown (10YR7/2), weathers yellowish gray (5Y7/2); fine-grained; massive; rare crinoid columnals 0.5

1. Limestone, pale yellowish brown (10YR7/2), weathers yellowish gray (5Y7/2); aphanitic, dense; massive; subconchoidal fracture; common worm borings filled with ferruginous clay; poorly fossiliferous 0.5

Total Merriam limestone member . . . 2.0

Bonner Springs shale

Shale, covered . . . . unm.

Locality 14. SE¼, SW¼, SW¼, Sec. 21, T. 13 S., R. 22 E., Johnson County; measured on road.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, covered . . . . 12.0±

Hickory Creek shale member

Shale, limy, poorly exposed 0.2

Merriam limestone member

Upper limestone unit

Limestone, medium light gray (N6), weathers pale yellow-orange (10YR8/6); medium-grained, brittle; massive; common worm borings filled with ferruginous clay; poorly fossiliferous 0.8

Total Merriam limestone member . . . 0.8

Bonner Springs shale

Shale, covered . . . . unm.

Locality 15. 0.1 mile west of NE corner Sec. 30, T. 13 S., R. 23 E., Johnson County; measured on road.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, brown and gray 6.0

Hickory Creek shale member

Shale, brown to gray, ferruginous 1.0

Merriam limestone member

Upper limestone unit

4. Limestone, light gray (N7), weathers yellowish gray (5Y7/2); fine-grained, dense; massive; common veinlets of dark crystalline dolomite; common worm borings filled with ferruginous clay; common crinoid columnals; rare fusulinids 1.3

Shale bed

3. Shale, covered 0.5

Lower limestone unit

2. Limestone, light gray (N7), weathers yellowish gray (5Y7/2); fine- to medium-grained, dense; massive; blocky; oolitic; abundant Osagia, common crinoid columnals, common Myalina 0.3

1. Limestone, light gray (N7), weathers yellowish gray (5Y7/2); fine-grained; abundant Osagia; poorly exposed . . . . 1.0±

Total Merriam limestone member . . . 3.1±

Bonner Springs shale

Shale, covered . . . . unm.

Locality 16. SW¼, SE¼, Sec. 30, T. 13 S., R. 23 E., Johnson County; measured in road cut on hill, west side of bridge over west branch of Cedar Creek.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin wavy beds . . . . unm.

Hickory Creek shale member

Limestone, orange, punky, abundant fusulinids . . . . . . unm.

Merriam limestone member

Upper limestone unit

5. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); very fine-grained; massive; rare _Osagia_; upper part of unit very light gray (N8) with common worm borings filled with ferruginous clay, common spots and veinlets of dark crystalline dolomite, and common robust fusulinids 0.8

Lower limestone unit

4. Limestone, light gray (N7) in upper and lower bed, very light gray (N8) in middle bed; weathers dusky yellow (5Y6/4); fine-grained; each bed massive with slabby weathering along irregular wavy planes; oolitic, ooliths smaller at top of unit; abundant fossil fragments, _Osagia_ abundant, but common near the top of unit; _Myalina_ rare; abundant crinoid columnals; common brachiopods; abundant fenestrate bryozoans . 3.2

3. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); dark brown tinge just beneath weathered surface; fine-grained; oolitic; massive; rare fusulinids and _Osagia_, common crinoid columnals . . 0.3

2. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); dark brown tinge just beneath weathered surface; very fine-grained, dense; massive; prominent vertical jointing; abundant fossil fragments; abundant _Osagia_, abundant brachiopods with common _Composita_, abundant crinoid columnals, common fenestrate bryozoans 0.6

1. Limestone, moderate yellowish brown (10YR5/4), weathers dark yellowish orange (10YR6/6); very fine-grained, earthy throughout but more earthy toward base; abundant fossil fragments; abundant _Myalina_, abundant brachiopods with abundant _Composita_, common fenestrate bryozoans, abundant crinoid columnals 0.5

Total Merriam limestone member . . . 5.4

Bonner Springs shale

Shale, grayish olive (10Y4/2), weathers pale olive (10Y6/2); hard; silty . . . . unm.

Locality 17. NW corner Sec. 16, T. 15 S., R. 23 E., Johnson County; measured in ditch at SE corner of road junction.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, massive, weathers to thin beds	10.0+
Merriam limestone member	
Upper limestone unit	
3. Limestone, yellowish gray (5Y7/2), weathers yellowish gray (5Y8/1); very fine-grained, dense; blocky splitting; massive; common worm borings filled with ferruginous clay at top of unit; common crinoid columnals	1.0
Lower limestone unit	
2. Limestone, medium light gray (N6) to light gray (N7), weathers light gray (N7); fine- to medium-grained; massive; separated from underlying by difference in weathering resistance, appears as one bed in places; abundant _Osagia_, common _Myalina_, common crinoid columnals, rare sponges, rare clusters of calcareous algae, common _Composita_ in lower part	0.6
1. Limestone, medium gray (N5), weathers medium light gray (N6); very fine-grained, dense; massive; abundant limonite gives orange mass color to bed on fresh fracture; abundant _Osagia_	0.4
Total Merriam limestone member . . .	2.0
Bonner Springs shale	
Shale, dark greenish gray (5GY4/1), weathers grayish yellow-green (5GY7/2); clayey, laminated; yellow in upper 0.1 foot	unm.

Locality 18. One-quarter mile north of SE corner, Sec. 19, T. 15 S., R. 23 E., Miami County; measured on road.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member and Hickory Creek shale member	
Limestone, dark yellowish orange (10YR6/6), weathers grayish orange (10YR7/4); earthy, punky; thin bedded .	3.0+
Merriam limestone member	
Upper limestone unit	
Limestone, light gray (N7) and yellowish gray (5Y8/1), weathers yellowish gray (5Y7/2); very fine-grained, dense, blocky splitting; massive; abundant spots and veinlets of dark crystalline dolomite; common small cavities filled with ferruginous clay; common worm borings filled with ferruginous clay; rare crinoid columnals, rare fairly robust fusulinids	1.0+
Total Merriam limestone member . . .	1.0+
Bonner Springs shale	
Shale, covered	unm.

Locality 19. SW corner, NW$\frac{1}{4}$, Sec. 31, T. 15 S., R. 23 E., Miami County; measured on road just north of bend in road.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	

Limestone, yellowish gray (5Y7/2), weathers pale yellowish orange (10YR8/6); very fine-grained, dense; thin bedded; poorly exposed . . . . unm.

Merriam limestone member

Upper limestone unit

3. Limestone, light gray (N7), weathers yellowish gray (5Y8/1); very fine-grained, dense, blocky splitting; massive; abundant spots and veinlets of dark crystalline dolomite; rare cavities filled with orange limonite, limestone is pale red (5R6/2) around these cavities; rare Osagia, common large robust fusulinids, rare crinoid columnals 1.0

Lower limestone unit

2. Limestone, very light gray (N8), weathers yellowish gray (5Y8/1); fine- to medium-grained, oolitic; massive; several beds; poorly exposed in middle of unit; abundant Osagia, rare cephalopods, common crinoid columnals, common Myalina in lower part ... 5.5

1. Limestone, medium gray (N5), weathers light olive gray (5Y6/1); fine-grained, oolitic; massive; lower 0.3 to 0.4 foot mainly limonite replacement as unit 1 of Locality 17; abundant Osagia, common Myalina, common Composita, common crinoid columnals 1.2

Total Merriam limestone member . . . 7.7

Bonner Springs shale

Shale, light olive gray (5Y7/2), weathers same; clayey; about six feet exposed . . . . unm.

Locality 20. SW¼, SW¼, Sec. 9, T. 16 S., R. 23 E., Miami County; measured on road, 100 yards north of road junction.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, eroded rubble . . . . unm.

Hickory Creek shale member

Shale, covered . . . . unm.

Merriam limestone member

Upper limestone unit

3. Limestone, light gray (N7), weathers yellowish gray (5Y8/1); very fine-grained, dense, massive; common spots and veinlets of dark crystalline dolomite; rare worm borings filled with ferruginous clay; common cavities filled with orange limonite; separated from unit 2 by 0.1 foot of slabby limestone; abundant crinoid columnals 1.0

Lower limestone unit

2. Limestone, medium light gray (N6), weathers light olive gray (5Y6/1); fine-grained; oolitic; massive; separated from unit 1 by 0.1 foot shaly limestone; abundant _Osagia_, common brachiopods, common crinoid columnals 0.6

1. Limestone, medium light gray (N6), weathers light olive gray (5Y6/1); fine-grained; massive; abundant limonite replacement; rare _Osagia_, common brachiopods, common _Myalina_, common crinoid columnals . 0.4

Total Merriam limestone member . . . 2.0

Bonner Springs shale

Shale, pale olive (10Y6/2), weathers same; limy, nodular . unm.

Locality 21. NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 23, T. 15 S., R. 22 E., Miami County; measured on road just west of farm house.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, brownish, eroded rubble	unm.
Hickory Creek shale member	
Shale, limy, covered	unm.
Merriam limestone member	
Upper limestone unit	
3. Limestone, medium light gray (N6), weathers light gray (N7); very fine-grained, dense; massive; common spots and veinlets of dark crystalline dolomite; rare worm borings filled with ferruginous clay; common fusulinids, rare crinoid columnals	0.5
Lower limestone unit	
2. Limestone, light gray (N7), weathers very light gray (N8); fine- to medium-grained; massive; several beds, even bedded; oolitic; abundant Osagia, common crinoid columnals, common brachiopods	2.0
1. Limestone, medium light gray (N6), weathers light olive gray (5Y6/1); fine-grained; massive; abundant limonite replacement in lower part; common <u>Osagia</u>, common <u>Composita</u>, common crinoid columnals	1.5
Total Merriam limestone member . . .	4.0
Bonner Springs shale	
Shale, pale olive (10Y6/2), weathers yellowish gray (5Y7/2); nodular, sandy	unm.

Locality 22. NW¼, NW¼, Sec. 5, T. 16 S., R. 22 E., Miami County; measured on road just east of bridge.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, mostly covered	unm.
Hickory Creek shale member	
Shale, yellowish, nodular, marly, overlain by punky limestone bed	1.0±
Merriam limestone member	
Upper limestone unit	
2. Limestone, light gray (N7), weathers light olive gray (5Y6/1); very fine-grained, dense, brittle; massive; abundant spots and veinlets of dark crystalline dolomite; common worm borings filled with ferruginous clay; rare brachiopods, common fusulinids	1.0
Lower limestone unit	
1. Limestone, mottled, medium light gray (N6), pale olive (10Y6/2), yellowish gray (5Y7/2), with abundant limonite, weathers yellowish gray (5Y7/2); fine-grained, dense; massive; slabby weathering; abundant extremely large <u>Osagia</u>, common brachiopods, common crinoid columnals	0.5
Total Merriam limestone member . . .	1.5
Bonner Springs shale	
Shale, pale olive (10Y6/2), weathers yellowish gray (5Y7/2); nodular, sandy; with accessory white quartz grains . . .	unm.

Locality 23. NE corner Sec. 3, T. 17 S., R. 22 E., Miami County; measured in road cut at top of hill just west of road junction.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, weathers light olive gray; thin bedded; eroded rubble	1.0
Hickory Creek shale member	
Shale, covered	1.0
Merriam limestone member	
Upper limestone unit	
3. Limestone, very light gray (N8), weathers light olive gray (5Y6/1); lower part slightly darker gray with orange limonite in cavities; fine- to medium-grained oolitic; massive; upper contact fairly flat; common <u>Osagia</u>, common brachiopods, common crinoid columnals	1.5
Lower limestone unit	
2. Limestone, medium light gray (N6), weathers medium dark gray (N4); fine- to medium-grained, oolitic; massive; cavities filled with orange limonite at top and bottom of unit; separated from unit 3 by a thin and fairly regular shale parting; abundant <u>Osagia</u>, rare <u>Myalina</u>, common <u>Composita</u>, common crinoid columnals	0.6
1. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); medium-grained, granular, suboolitic; massive; separated from unit 2 by a thin irregular shale parting; common <u>Osagia</u>, abundant brachiopods with abundant <u>Composita</u> at the base	0.4
Total Merriam limestone member . . .	2.5
Bonner Springs shale	
Shale, dusky yellow-green (5GY5/2); covered, sandy, hard .	unm.

Locality 24. Center west side of $SW\frac{1}{4}$, Sec. 3, T. S., R. 22 E., Miami County; measured on road, 0.8 mile south of Kansas Highway 68.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, covered	unm.
Hickory Creek shale member	
Limestone, light orange; punky, nodular; very thin bed; abundant crinoid columnals; overlying beds covered . .	unm.
Merriam limestone member	
Upper limestone unit	
3. Limestone, medium light gray (N6) at base and light olive gray (5Y6/1) at top, weathers yellowish gray (5Y8/1); fine-grained at base to very fine-grained at top; massive; slabby weathering more prominent than in unit 1; abundant spots and veinlets of dark crystalline dolomite in middle one-third of unit; worm borings billed with ferruginous clay abundant at top but rare at base of unit; the following fossils are abundant in the lower and upper one-thirds of the unit but are rare in the middle one-third: crinoid columnals, short robust fusulinids, and thin elongate fusulinids	0.7
Lower limestone unit	
2. Limestone, dark yellowish brown (10YR4/2), weathers yellowish gray (5Y8/1); fine-grained; massive; abundant small cavities filled with orange limonite; common <u>Osagia</u>, rare echinoid spines, rare fenestrate bryozoans, common crinoid columnals, rare <u>Composita</u>	0.2
1. Limestone, medium gray (N5) with some small areas of dark gray (N3) and light olive gray (5Y6/1) at the top, weathers yellowish gray (5Y8/1); fine-grained; oolitic with small ooliths; massive; slabby weathering; abundant irregular joints; common limonite weathering; <u>Osagia</u> common at contacts but more abundant in middle of unit, abundant crinoid columnals, rare <u>Myalina</u>, rare fenestrate bryozoans	

in upper one-third, brachiopods with Composita abundant in lower 0.4 foot and common throughout remainder of unit 1.1

Total Merriam limestone member . . . 2.0

Bonner Springs shale

Shale, moderate olive brown (5Y4/4) to olive gray (5Y3/2), weathers pale olive (10Y6/2); silty, papery . . . . unm.

Locality 25. Center east side NE$\frac{1}{4}$, Sec. 8, T. 17 S., R. 22 E., Miami County; measured on road about 0.2 mile south of road junction.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, covered . . . . unm.

Hickory Creek shale member

Shale, yellow, nodular, partly covered . . . . unm.

Merriam limestone member

Upper limestone unit

3. Limestone, medium light gray (N6), weathers yellowish gray (5Y7/2); fine-grained, oolitic; massive; rare Osagia, rare elongate fusulinids, common brachiopods, common crinoid columnals 1.5

Lower limestone unit

2. Limestone, light gray (N7), weathers yellowish gray (5Y7/2); fine- to medium-grained, oolitic; several indistinct beds, low angle cross-bedding; abundant Osagia becoming common toward top, common crinoid

columnals, common brachiopods 3.0

1. Limestone, medium light gray (N6), weathers yellowish gray (5Y7/2); fine-grained, oolitic; massive; lower 0.6 foot with abundant limonite replacement; separated from unit 2 by a thin shale parting; common crinoid columnals, abundant _Osagia_, common _Myalina_, abundant _Composita_ with common other brachiopods 1.0

Total Merriam limestone member . . . 5.5

Bonner Springs shale

Shale, moderate olive brown (5Y4/4) to olive gray (5Y3/2), weathers pale olive (10Y6/2); silty, papery . . . . unm.

Locality 26. Center north side NE¼, Sec. 13, T. 17 S., R. 21 E., Miami County; measured on road about 250 yards west of road junction.

Thickness Feet

Plattsburg formation

Spring Hill limestone member and Hickory Creek shale member

Limestone, lower part yellow, shaly, punky . . . . unm.

Merriam limestone member

Upper limestone unit

5. Limestone, yellowish gray (5Y7/2), weathers very pale orange (10YR8/2); very fine-grained, dense; blocky splitting; massive; common spots and veinlets of dark crystalline dolomite; common worm borings filled with ferruginous clay; rare _Osagia_, abundant robust fusulinids, abundant brachiopods, common fenestrate bryozoans, common crinoid columnals 1.0

Shale bed

4. Shale, dusky yellow green (5GY5/2), weathers same; at top is moderate yellowish brown (10YR5/4); limy; common brachiopods, common crinoid columnals . . . 0.2

Lower limestone unit

3. Limestone, medium light gray (N6), weathers very light gray (N8); medium-grained, very granular; massive; abundant fossil fragments; abundant crinoid columnals, common Osagia, rare fenestrate bryozoans, rare Composita 0.7

2. Limestone, very light gray (N8), weathers yellowish gray (5Y8/1); very fine-grained, dense, brittle; massive; abundant spots and veinlets of dark crystalline dolomite; rare brachiopods but extremely abundant Composita 1.0

1. Limestone, medium gray (N5), weathers light gray (N7); fine-grained, oolitic; massive; common crinoid columnals, abundant Osagia, rare ~~Myalina~~ 0.2

Total Merriam limestone member . . . 3.1

Bonner Springs shale

Shale, dusky yellow green (5GY5/2), weathers grayish yellow green (5GY7/2); nodular, hard . . . . unm.

Locality 27. NW¼, NW¼, Sec. 34, T. 16 S., R. 21 E., Franklin County; measured on Kansas Highway 68 just west of Turkey Creek bridge.

Thickness
Feet

Plattsburg formation

Hickory Creek shale member

Shale, yellow, limy, nodular . . . . unm.

Merriam limestone member

Upper limestone unit

5. Limestone, light gray (N7), weathers medium light gray (N6); very fine-grained, dense; massive; common veinlets of dense gray dolomite; upper contact fairly flat; separated from underlying unit by a thin to 0.1 foot shale parting similar to unit 3 but with no limestone nodules; rare small worm borings filled with ferruginous clay; common crinoid columnals, common echinoid spines, rare fusulinids 0.4

Lower limestone unit

4. Limestone, light gray (N7) in upper one-third, white (N9) in middle, and very light gray (N8) in lower one-third, weathers medium light grey (N6); fine-grained; oolitic, with larger ooliths toward the top; obscure cross-bedding of low angle, bedding irregular and thin but unit has massive appearance in places; common brachiopods, Osagia common in lower and middle one-thirds and abundant in upper one-third 6.5

3. Shale, dark yellowish orange (10YR6/6), weathers slightly lighter; limy, papery; very thin irregular bed with limestone nodules; limestone is medium gray (N5), weathers grayish orange (10YR7/4) and dark yellowish brown (10YR4/2); fine-grained, dense; very similar to underlying unit 0.1

2. Limestone, yellowish gray (5Y8/1), weathers grayish orange (10YR7/4) and dark yellowish brown (10YR4/2) beneath surface; very fine-grained, dense; massive; common veinlets of dense gray dolomite; prominent vertical jointing; common crinoid columnals, common brachiopods with very abundant Composita becoming less abundant at top 1.6

1. Limestone, moderate yellowish brown (10YR5/4), weathers same; very fine-grained, earthy, rubbly; rare brachiopods; poorly exposed 0.3

Total Merriam limestone member . . . 8.9

Bonner Springs shale

Shale, light olive gray (5Y5/2), weathers pale olive (10Y6/2); silty, laminated . . . . unm.

Locality 28. SW¼, SE¼, Sec. 29, T. 16 S., R. 21 E., Franklin County; measured in road cut 100 yards east of Hickory Creek bridge on Kansas Highways 33 and 68.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, light olive gray (5Y6/1) and yellowish gray (5Y8/1) mottled, weathers dusky yellow (5Y6/4); fine-grained, suggary; lower three feet massive but weathers to thin irregular beds; yellow punky limestone in lower part; common fusulinids, common brachiopods, common crinoid columnals up to 0.5 inch in diameter . . . . . 3.0+

Hickory Creek shale member

Shale, grayish olive (10Y4/2), weathers pale olive (10Y6/2); clayey, laminated; yellow punky limestone bed 0.3 foot thick and 0.05 foot above base of unit; shale below punky limestone bed is carbonaceous in placed 0.8

Merriam limestone member

Upper limestone unit

3. Limestone, yellowish gray (5Y7/2), weathers yellowish gray (5Y8/1; fine-grained; massive; upper contact even, lower contact very irregular; common spots and veinlets of dark crystalline dolomite and dense gray dolomite; common worm borings filled with ferruginous clay; common fusulinids, common crinoid columnals, rare <u>Composita</u> 0.3

2. Limestone, pale yellowish brown (10YR6/2), weathers yellowish gray (5Y8/1); fine-grained; massive; very irregular bed; separated from slabby top of underlying unit by very irregular plane; abundant spots and veinlets of dark crystalline dolomite; common worm borings filled with ferruginous clay; very common fusulinids, common crinoid columnals 0.2

Lower limestone unit

1. Limestone, light olive gray (5Y6/1) in lower 0.2 foot, light gray (N7) in remainder of unit, weathers

yellowish gray (5Y8/1); upper 0.8 foot very fine-grained, dense, brittle; abundant veinlets of dense gray dolomite; abundant worm borings filled with ferruginous clay at top of unit; lower 0.2 foot oolitic; common *Osagia*, common ramose bryozoans, and common brachiopods in lower 0.2 foot, common fusulinids in remainder of unit, common crinoid columnals throughout unit 1.0

Lower limestone unit

1. Limestone, light olive gray (5Y6/1) in lower 0.2 foot, light gray (N7) in remainder of unit, weathers yellowish gray (5Y8/1); upper 0.8 foot very fine-grained, dense, brittle; abundant veinlets of dense gray dolomite; abundant worm borings filled with ferruginous clay at top of unit; lower 0.2 foot oolitic; common *Osagia*, common ramose bryozoans, and common brachiopods in lower 0.2 foot, common fusulinids in remainder of unit, common crinoid columnals throughout unit 1.0

Total Merriam limestone member . . . 1.5

Bonner Springs shale

Shale, sandy, moderate yellowish brown (10YR5/4) at top, weathers yellowish gray (5Y8/1); remainder of unit is dark greenish gray (5GY4/1); weathers light greenish gray (5G8/1), five feet exposed . . . . unm.

Locality 29. Center east side NE$\frac{1}{4}$, Sec. 15, T. 17 S., R. 20 E., Franklin County; measured in road cut 0.4 mile south of railroad crossing.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, light olive gray (5Y6/1), pinkish in lower part, weathers dusky yellow (5Y6/4); thin irregular beds . . . . 8.0±

Hickory Creek shale member

Shale, grayish olive (10Y4/2), weathers pale olive (10Y6/2); yellow in places; limy; laminated; limestone, punky, yellow, 0.4 foot thick, less than 0.1 foot above base of unit 0.7

Merriam limestone member

Upper limestone unit

3. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); fine-grained; massive; common small spots and veinlets of dark crystalline dolomite; upper surface fairly even; common <u>Osagia</u>, rare robust fusulinids, common crinoid columnals 0.4

Lower limestone unit

2. Limestone, medium light gray (N6), with olive gray tinge, weathers dusky yellow (5Y6/4); fine-grained; massive; upper surface very irregular; common crinoid columnals throughout unit, rare <u>Osagia</u> in lower 0.1 foot, rare robust fusulinids in remainder of bed, abundant worm borings filled with ferruginous clay in upper one-half of unit 0.6

1. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); fine-grained, oolitic; massive; both contacts fairly even; lower 0.1 foot contains small flat shale pebbles only slightly lighter in color than the underlying shale; common <u>Myalina</u>, common crinoid columnals, <u>Osagia</u> abundant near base and very common throughout rest of bed 1.4

Total Merriam limestone member . . . 2.4

Bonner Springs shale

Shale, grayish olive (10Y5/4), weathers pale olive (10Y6/2); sandy, blocky; top of unit is 9.5 feet above top of maroon shale . . . . 9.5±

Locality 30. SW corner SE$\frac{1}{4}$, Sec. 23, T. 17 S., R. 20 E., Franklin County; measured in road cut east of bridge.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); thin irregular beds	8.0+
Hickory Creek shale member	
Shale, covered	0.4
Merriam limestone member	
Upper limestone unit	
4. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained, dense, brittle; massive; more common spots and veinlets of dark crystalline dolomite than in underlying unit; rare worm borings filled with ferruginous clay; common fusulinids, rare _Osagia_, common crinoid columnals	0.5
Lower limestone unit	
3. Limestone, light olive gray (5Y6/1); weathers dusky yellow (5Y6/4); aphanitic, dense, brittle; massive; at places seemingly continuous with either adjacent unit, common robust fusulinids	0.4
2. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); very fine-grained, dense; massive; abundant spots and veinlets of dark crystalline dolomite and dense gray dolomite; rare robust fusulinids, common crinoid columnals	0.4
1. Limestone, medium light gray (N6), weathers olive gray (5Y3/2); fine- to medium-grained, granular, oolitic; massive; common small flat shale pebbles in lower 0.1 foot; common _Osagia_, common crinoid columnals, common brachiopods with common _Composita_	0.7
Total Merriam limestone member . . .	2.0
Bonner Springs shale	

A-10

Shale, grayish olive (10Y5/4), weathers pale olive (10Y6/2); sandy, blocky 5.0/

Locality 31. SE corner, NE$\frac{1}{4}$, Sec. 25, T. 17 S., R. 20 E., Franklin County; measured in road cut, 0.4 mile south of Rantoul Road.

Thickness Feet

Plattsburg formation

Spring Hill limestone member and Hickory Creek shale member

2. Limestone, thin irregular beds, yellowish gray, with punky appearance at base; common fossil fragments . 4.0/

1. Limestone, yellow, punky, thin irregular beds; with thin olive gray and yellow papery shale above . . . 1.3

Merriam limestone member

Upper limestone unit (0.5 foot) and lower limestone unit (0.8 foot)

2. Limestone, yellowish gray (5Y7/2) in upper part and medium gray (N5) in lower part, weathers dusky yellow (5Y6/4); very fine-grained, dense, brittle; massive; upper part about 0.5 foot thick, lower part about 0.8 foot thick; common spots of dark crystalline dolomite; rare worm borings filled with ferruginous clay at top of unit; common crinoid columnals, rare fusulinids 1.3

1. Limestone, yellowish gray (5Y7/2) and pale olive (10Y6/2), weathers dusky yellow (5Y6/4); very fine-grained, dense; massive; abundant veinlets of dense gray dolomite; oolitic in places near the veinlets where rare fusulinids are present; common crinoid columnals, common Composita 0.8

Total Merriam limestone member . . . 2.1

Bonner Springs shale

Shale, medium bluish gray (5B5/1), weathers light bluish gray (5B7/1); silty, thinly laminated; yellow and limy in upper one foot 10.0/

Locality 32. NE corner, SE$\frac{1}{4}$, Sec. 32, T. 17 S., R. 21 E., Franklin County; measured in road cut, 1.6 miles south of Rantoul.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); aphanitic, dense, brittle; thin irregular beds; crinoid columnals up to 0.5 inch in diameter 5.0/

Merriam limestone member

Upper limestone unit

3. Limestone, yellowish gray (5Y8/1), weathers dusky yellow (5Y6/4); fine-grained, oolitic with small ooliths; massive; thickness very irregular but for most part upper surface only slightly irregular; common crinoid columnals, abundant Osagia, rare fusulinids, locally very abundant small brachiopods at base 0.4

Lower limestone unit

2. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); medium-grained, very oolitic; massive; upper surface very irregular; common small cavities filled with orange limonite; rare large veinlets of dark crystalline dolomite; common crinoid columnals, abundant Osagia, rare fusulinids, common ramose and fenestrate bryozoans, rare Composita 0.7

1. Limestone, medium light gray (N6), lower 0.1 foot dark yellowish orange (10YR6/6), weathers dusky yellow

(5Y6/4); lower part punky, pale yellowish brown (10YR6/2) beneath surface, oolitic, abundant <u>Composita</u>; entire bed fine-grained, oolitic with very small ooliths which are somewhat coarser at top of unit, brittle; massive; <u>Osagia</u> common in middle and abundant at top, rare fusulinids at top, common crinoid columnals 1.3

Total Merriam limestone member . . . 2.4

Bonner Springs shale

Shale, grayish olive (10Y5/4), weathers pale olive (10Y6/2); sandy, blocky; 11 feet from top of unit to top of maroon shale . . . . 11.0+

Locality 33. SE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 9, T. 18 S., R. 21 E., Franklin County; measured in road cut on hill east of bridge.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained; thin irregular beds, punky at base . . . . 1.5+

Hickory Creek shale member

Shale, dark yellowish orange (10Y6/6), covered; near base is slabby punky limestone bed 0.3 foot thick 2.5

Merriam limestone member

Upper limestone unit

5. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); very fine-grained, dense, brittle; massive; prominent vertical jointing; common spots

and veinlets of dark crystalline dolomite; common robust fusulinids 1.0

Lower limestone unit

4. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); medium-grained, granular, sub-oolitic; massive; common vertical jointing; finer grained at top; common Osagia, common fenestrate bryozoans, common crinoid columnals, rare (?)Composita at base 0.9

3. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained, crystalline; massive; irregular contacts; abundant veinlets of dense gray dolomite; common Composita, rare fusulinids 0.7

2. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); aphanitic, dense; massive; common veinlets of dense gray dolomite; punky weathering at base with common Composita 0.6

1. Limestone, brownish gray (5YR4/1), weathers dusky yellow (5Y6/4); medium-grained, suboolitic; massive; slabby and shaly at top below 0.1 foot limy shale; common greenish gray (5GY6/1) shale pebbles; abundant Osagia, common crinoid columnals 0.5

Total Merriam limestone member . . . 3.7

Bonner Springs shale

Shale, grayish olive (10Y5/4), weathers pale olive (10Y6/2); sandy, blocky; top of unit is 8.0 feet above top of maroon shale . . . . 8.0+

Locality 34. NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 16, T. 18 S., R. 21 E., Franklin County;

measured in road cut south of bridge.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, light olive gray (5Y6/1), weathers dark yellowish orange (10YR6/6) and pale yellowish orange (10YR8/6); fine-grained; thin irregular beds; common brachiopods . . . . 4.0+

Hickory Creek shale member (?)

Shale, limy and shaly limestone, dark yellowish orange (10 YR6/6) and dark yellowish brown (10YR4/2), covered; similar to other shale partings but is slightly thicker and more persistant, also it divides two weathering colors of the limestones 0.1

Merriam limestone member

Upper limestone unit

3. Limestone, greatly weathered, mottling of light olive gray (5Y6/1), dark yellowish orange (10YR6/6), grayish orange (10YR7/4), and very pale orange (10YR8/2), weathers yellowish gray (5Y7/2); fine-grained, suggary texture; massive; top contact very even; common spots and veinlets of dark crystalline dolomite and dense gray dolomite; common echinoid spines, common brachiopods, rare Osagia, common crinoid columnals, common very robust fusulinids . 0.8

Lower limestone unit

2. Limestone, light olive gray (5Y6/1), weathers yellowish gray (5Y7/2); fine-grained, dense; massive; irregular contacts; separated from unit 3 by local shale parting; common spots and veinlets of dark crystalline dolomite; common brachiopods, very rare Osagia . . 0.5

1. Limestone, greatly weathered, pale yellowish brown (10YR6/2) and grayish orange (10YR7/4), weathers yellowish gray (5Y7/2); very fine-grained, suggary texture; massive; may weather into three or four beds; prominent vertical jointing; common brachiopods with rare Composita, common crinoid columnals . . . 2.0

Total Merriam limestone member . . . 3.3

Bonner Springs shale

Shale, moderate olive brown (5Y4/4), weathers pale olive

(10Y6/2); sandy, upper ten feet with hard thin to thick beds of fine-grained gray sandstone . . . . 20.0+

Locality 35. $SE\frac{1}{4}$, $SE\frac{1}{4}$, Sec. 30, T. 18 S., R. 21 E., Franklin County; measured on road just west of bridge.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, brown, very slabby and shaly; partly covered; weathers to very thin irregular flaky slabs	1.0+
Merriam limestone member	
Upper limestone unit	
3. Limestone, grayish orange (10YR7/4), weathers dusky yellow (5Y6/4); fine-grained, suggary texture; massive; at places continuous with unit 2; common spots and veinlets of dark crystalline dolomite; common large robust fusulinids, common <u>Composita</u>, common crinoid columnals	0.9
Lower limestone unit	
2. Limestone, pale yellowish brown (10YR6/2), weathers dusky yellow (5Y6/4); very fine-grained, dense, suggary texture; abundant limonite weathering; common veinlets of dark crystalline dolomite; common robust fusulinids, common horn corals, common crinoid columnals	1.1
1. Limestone, light gray (N7), weathers olive gray (5Y3/2); very fine-grained, dense; massive; continuous with overlying unit; rare horn corals, common crinoid columnals	0.8
Total Merriam limestone member . . .	2.8

Bonner Springs shale

Shale, covered . . . . unm.

Locality 36. NE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 16, T. 19 S., R. 21 E., Franklin County; measured in road cut just southwest of road junction on U. S. 169.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

2. Limestone, dark yellowish brown (10YR4/2), weathers moderate yellowish brown (10YR5/4); thin irregular beds of slabby erosion remnant . . . . 0.5+

1. Limestone, dark yellowish brown (10YR4/2), weathers same; very thin irregular slabby beds, fairly persistant 0.2

Merriam limestone member

Upper limestone unit

2. Limestone, yellowish gray (5Y8/1), weathers very light gray (N8); fine-grained, suggary texture; massive but weathers into thin irregular beds; upper contact fairly even, lower contact obscure in places; common veinlets of dense gray dolomite; common echinoid spines, rare Osagia, very abundant extremely large robust fusulinids, common crinoid columnals, rare horn corals in lower part, common Composita in remainder of unit above horn coral zone, common brachiopods at top of unit 1.5

Lower limestone unit

1. Limestone, pale yellowish brown (10YR6/2), weathers dusky yellow (5Y6/4); fine-grained, dense; massive; common spots and veinlets of dark crystalline dolomite;

lower 0.5 foot is brownish, hard, weathers yellow, punky; less fossiliferous than overlying unit; common crinoid columnals, rare brachiopods, rare extremely large robust fusulinids except in lower 0.5 foot . . 2.5

Total Merriam limestone member . . . 4.0

Bonner Springs shale

Shale, greenish gray (5GY6/1), weathers yellowish gray (5Y8/1) in upper six feet; silty, blocky; with abundant brachiopods near top underlain by dark greenish gray (5GY8/1) silty laminated shale weathering light bluish gray (5B7/1) . . 15.0+

Locality 37. NW¼, SE¼, Sec. 15, T. 19 S., R. 20 E., Franklin County; measured on road at bend from north-south to northwest-southeast.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member and (?) Hickory Creek shale member

Limestone, yellow, punky greatly weathered, mostly covered . . . . 1.0+

Merriam limestone member

Upper limestone unit

3. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4; aphanitic, dense, brittle; massive; common worm borings filled with ferruginous clay; common spots and veinlets of dark crystalline dolomite; rare fusulinids, rare crinoid columnals . 0.9

Lower limestone unit

2. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); fine-grained, suggary texture, brittle; massive; common spots of dark crystalline dolomite; rare fusulinids, common crinoid columnals, common

Osagia near middle of unit; traverse made 50 feet to north-northwest on this unit 1.4

1. Limestone, upper 0.5 foot light gray (N7, lower 0.6 foot light olive gray (5Y6/1) probably due to weathering, weathers dusky yellow (5Y6/4); very fine-grained, dense, somewhat brittle; massive; common veinlets of dense gray dolomite as at Locality 31 with associated oolitic patches and rare fusulinids; common Composita, common crinoid columnals 1.1

Total Merriam limestone member . . . 3.4

Bonner Springs

Shale, dark greenish gray (5GY4/1), weathers light greenish gray (5G8/1); hard, nodular, sandy . . . . 8.0+

Locality 38. SW¼, SW¼, Sec. 9, T. 19 S., R. 20 E., Franklin County:

measured in old quarry just west of bridge.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, very light gray (N8), weathers dusky yellow (5Y6/4); fine-grained; massive but weathers into thin irregular beds; abundant fossil fragments . . . . 5.0+

Hickory Creek shale member

Shale, grayish olive (10Y4/2), moderate yellowish brown (10YR5/4) near surface, weathers greenish gray (5GY6/1); laminated, clayey; yellow punky limestone bed 0.5 foot thick near base 1.1

Merriam limestone member

Upper limestone unit -

4. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); very fine-grained, dense, brittle; massive; common spots and veinlets of dark crystalline dolomite, veinlets at places grouped into a curving swarm or set; common worm borings filled with ferruginous clay, more abundant at top; common small fusulinids, rare brachiopods 1.1

Lower limestone unit

3. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); very fine-grained, dense, suggary texture, brittle; massive; common spots and veinlets of dark crystalline dolomite; commonly weathers even with overlying unit; rare small brachiopods and rare Composita, common small robust fusulinids in upper part 0.5

2. Shale, olive gray (5Y4/1), weathers yellowish gray (5Y7/2); very thinly laminated, papery, silty; upper part with limestone nodules; bed of about constant thickness but slightly irregular in position . . . 0.1

1. Limestone, light gray (N7), weathers light olive gray (5Y5/2); medium-grained, granular; massive; lower part poorly exposed; common Osagia, rare fusulinids, common crinoid columnals 0.5

Total Merriam limestone member . . . 2.2

Bonner Springs shale

Shale, dark greenish gray (5G4/1), weathers light greenish gray (5G8/1); hard, silty, thinly laminated; top of unit is 5.5 feet above top of fine-grained brown-weathering sandstone . . . . 5.5+

Locality 39. NE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 29, T. 19 S., R. 20 E., Anderson County; measured in road cut on east-west road 0.2 mile east of junction.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, light gray (N7), weathers olive gray (5Y4/1); fine-grained, thin irregular beds; abundant fossils including large crinoid columnals 4.0/

Hickory Creek shale member

Shale, covered, yellow, limy, nodular 3.5

Merriam limestone member

Upper limestone unit

2. Limestone, light olive gray (5Y6/1), light gray (N7) in middle, weathers olive gray (5Y4/1); very fine-grained, dense; massive; common worm borings filled with ferruginous clay at top of unit; common spots and veinlets of dark crystalline dolomite; prominent vertical jointing; separated from unit 1 by a 0.1 foot slabby limestone; rare brachiopods near top, rare _Osagia_ in middle, common robust fusulinids in upper two-thirds 1.4

Lower limestone unit

A-11

1. Limestone, light olive gray (5Y6/1), weathers olive gray (5Y4/1); very fine-grained; massive; abundant spots and veinlets of dark crystalline dolomite; middle one-third of bed more grayish, fine-grained but more granular, common robust fusulinids and rare _Osagia_; lower 0.2 foot very shaly, greatly weathered; common crinoid columnals, common _Composita_, other brachiopods common at top 0.8

Total Merriam limestone member . . . 2.2

Bonner Springs shale

Shale, light olive gray (5Y5/2), but limonite-stained greenish gray (5G6/1) near top, weathers light greenish gray (5G8/1); hard, silty, laminated near top; top of unit about 17 feet above greenish gray fine-grained sandstone 17.0/

Locality 40. $SE\frac{1}{4}$, $SE\frac{1}{4}$, Sec. 34, T. 19 S., R. 19 E., Anderson County; measured in road cut.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, yellowish gray, weathers lighter than lower limestones; lower 1.5 feet massive but weathers to thin irregular beds as overlying limestone; at base is 0.1 foot fossiliferous yellow shaly-weathering limestone; at places separated from underlying unit by less than one inch of brown shale; common large brachiopods, rare crinoid columnals	5.0+
Merriam limestone member	
Upper limestone unit	
2. Limestone, yellowish gray (5Y8/1), weathers light gray (N7) and yellowish gray (5Y8/1); medium-grained; massive; flat upper contact; very rare <u>Osagia</u>, rare elongate and robust fusulinids, abundant crinoid columnals, common brachiopods near top	0.9
Lower limestone unit	
1. Limestone, medium gray (N5), weathers medium light gray (N6) and yellowish gray (5Y7/2); medium-grained; massive; in places continuous with unit 2; light brownish gray (5YR6/1) just under surface; common veinlets of dark dolomite; rare <u>Osagia</u>, common crinoid columnals, rare horn corals near top	0.8
Total Merriam limestone member . . .	1.7
Bonner Springs shale	
Shale, dark gray (N3), weathers light bluish gray (5B7/1); silty; upper two feet covered, moderate yellowish brown (10YR5/4), silty; massive sandstone occurs in middle of unit	40.0+

Locality 41. NW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 3, T. 20 S., R. 21 E., Anderson County: measured in road cut.

Thickness Feet

Plattsburg formation

Spring Hill limestone member and (?) Hickory Creek shale member

2. Limestone, thin bedded, slabby weathering . . . . . . 3.0+

1. Covered . . . . 3.0+

Merriam limestone member

Upper limestone unit

2. Limestone, light gray (N7), weathers medium light gray (N6); very fine-grained, dense, brittle; massive; prominent vertical jointing; common spots of dark crystalline dolomite; rare worm borings filled with ferruginous clay; rare crinoid columnals 1.2

Lower limestone unit

1. Limestone, medium light gray (N6), weathers light olive gray (5Y6/1); pale red tinge at top due to weathering; fine-grained, oolitic; massive; prominent vertical jointing; rare Osagia, common brachiopods including common Composita, common Myalina in lower part; Myalina and brachiopods most common in zone 0.4 foot above base of unit 2.4

Total Merriam limestone member . . . 3.6

Bonner Springs shale

Shale, greenish gray (5GY6/1), weathers light greenish gray (5GY8/1): very platy, hard, sandy . . . . 10.0+

Locality 42. SE$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 7, T. 20 S., R. 21 E., Anderson County; measured on road at road junction.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member and Hickory Creek shale member	
Limestone, thin bedded, two-foot erosion remnant; underlain by 0.8 foot covered interval and 0.4 foot punky limestone	3.2+
Merriam limestone member	
Upper limestone unit	
6. Limestone, medium light gray (N6), weathers light gray (N7); aphanitic, dense, brittle; massive; somewhat granular around abundant worm borings filled with ferruginous clay; pitted weathering; even upper contact; common veinlets of dark crystalline dolomite; common crinoid columnals, rare brachiopods in lower one-half.	1.2
Shale bed	
5. Shale, olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4), not interlaminated, weathers light olive gray (5Y6/1); limy papery; common small symmetrical open folds with vertical planes; upper 0.05 foot yellow with limestone nodules; rare brachiopods	0.1
Lower limestone unit	
4. Limestone, light gray (N7), weathers very light gray (N8); fine-grained, somewhat granular; massive; common brachiopods, common crinoid columnals . . .	0.5
3. Limestone, light gray (N7), weathers very light gray (N8); fine-grained, suggary texture; massive; prominent vertical jointing; common small fusulinids, common *Osagia*, common crinoid columnals	0.9
2. Limestone, very light gray (N8), weathers light gray (N7); fine-grained; massive; rare brachiopods, rare small robust fusulinids, common crinoid columnals	0.9

A-12

1. Limestone, light gray (N7), weathers dark yellowish orange (10YR6/6); very fine-grained; massive; greatly weathered; abundant brachiopods including abundant Composita, rare ~~Myalina~~, common crinoid columnals 1.1

Total Merriam limestone member . . . 4.7

Bonner Springs shale

Shale, greenish gray (5GY6/1), weathers light greenish gray (5GY8/1); very platy, hard, sandy . . . . 10.0+

Locality 43. SE¼, NE¼, SW¼, Sec. 20, T. 20 S., R. 21 E., Anderson County; measured on road.

Thickness Feet

Plattsburg formation

Spring Hill limestone member and (?) Hickory Creek shale member

2. Limestone, thin irregular beds, abundantly fossiliferous . . . . 1.0+

1. Limestone, shaly, yellow, and limy yellow shale . . . 0.4

Merriam limestone member

Upper limestone unit

3. Limestone, medium dark gray (N4) at base and medium light gray (N6) at top, weathers dusky yellow (5Y6/4); aphanitic, dense, brittle; massive; common spots of dark crystalline dolomite; common worm borings filled with ferruginous clay; common crinoid columnals, rare small thin fusulinids in upper part, rare Osagia near base 0.8

Lower limestone unit

2. Limestone, medium gray (N5), weathers dusky yellow

(5Y6/4); very fine-grained, dense, brittle; massive; common veinlets of dark crystalline dolomite; common small fusulinids, common crinoid columnals 0.6

1. Limestone, medium light gray (N6), weathers medium gray (N5) to dusky yellow (5Y6/4); medium-grained, oolitic; massive; greatly weathered; common *Osagia*, common crinoid columnals, rare brachiopods 0.9

Total Merriam limestone member . . . 2.3

Bonner Springs shale

Shale, dusky yellow green (5GY5/2), weathers light greenish gray (5GY8/1); sandy, laminated . . . . 20.0+

Locality 44. SW¼, SE¼, SE¼, Sec. 30, T. 20 S., R. 21 E., Anderson County; measured in road cut just east of road junction.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin to thick irregular beds, abundantly fossiliferous with large brachiopods at base . . . . . 12.0+

Hickory Creek shale member

Shale, dark greenish gray (5GY4/1) and dark yellowish orange (10YR6/6); laminated, limy; shale in upper 0.4 foot and lower 0.1 foot separated by yellow thin bedded punky limestone 2.0

Merriam limestone member

Upper limestone unit

4. Limestone, light gray (N7), weathers light olive gray (5Y6/1); very fine-grained, dense, brittle; massive

continuous with underlying unit; common spots and veinlets of dark crystalline dolomite; rare worm borings filled with ferruginous clay; upper contact even; prominent vertical jointing; common crinoid columnals, rare Composita 1.0

Lower limestone unit

3. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); very fine-grained, dense; massive; continuous with overlying unit; prominent vertical jointing; common crinoid columnals, very rare Osagia 0.5

2. Limestone, very slabby and shaly weathering, is actually only the upper part of unit 1; at places complete gradation from unit 1 to unit 4 . . . . . . 0.1

1. Limestone, mottled by weathering, medium light gray (N6), light greenish gray (5GY8/1), and moderate yellowish brown (10YR5/4), weathers dusky yellow (5Y6/4); medium-grained; crinoidal limestone; massive but with laminated appearance; contains pebbles of hard light greenish gray shale up to one inch in diameter; very abundant crinoid columnals 0.3

Total Merriam limestone member . . . 1.9

Bonner Springs shale

Shale, greenish gray (5GY6/1) in upper part, weathers light greenish gray (5GY8/1); dark gray (N4) with bluish tinge in lower part, weathers light bluish gray (5B7/1); very platy, hard, sandy in upper part; the platy sandy shale occurs as beds throughout the blue more clayey laminated shale . . . . 10.0+

Locality 45. SW¼, NW¼, SE¼, Sec. 4, T. 20 S., R. 20 E., Anderson County; measured on road at top of hill.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member and (?) Hickory Creek shale member	
2. Limestone, thin bedded, fossiliferous with large crinoid columnals, top eroded	2.0+
1. Limestone, punky, very fossiliferous, crumbly weathering	0.5
Merriam limestone member	
Upper limestone unit	
4. Limestone, light olive gray (5Y6/1), weathers medium light gray (N6); fine-grained, dense, suggary texture; massive; two beds; common spots and veinlets of dark crystalline dolomite; common worm borings filled with ferruginous clay; common crinoid columnals, common brachiopods in upper one-third, common robust fusulinids near top	1.4
Lower limestone unit	
3. Limestone, light gray (N7), weathers medium light gray (N6); fine-grained, dense, suggary texture; massive; common veinlets of dense gray dolomite; prominent vertical jointing; common crinoid columnals	0.8
2. Limestone, dark yellowish orange (10YR6/6), weathers light olive gray (5Y5/2); punky, slabby; greatly weathered; fairly persistent bed but locally thins.	0.2
1. Limestone, light olive gray (5Y6/1), weathers medium light gray (N6) with yellow stain from overlying slabby limestone; very fine-grained, dense, more granular toward top; massive with yellow shale parting in middle; lower part greatly weathered, grayish orange (10YR7/4) on fracture; common crinoid columnals, rare fusulinids in lower two-thirds of unit	1.3
Total Merriam limestone member . . .	3.7
Bonner Springs shale	
Shale, olive gray (5Y4/1), weathers light olive gray (5Y6/1),	

weathers moderate yellowish brown (10YR5/4) at top; very sandy, laminated, with thin bedded sandstone in lower half 20.0/

Locality 46. NE$\frac{1}{4}$, SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 26, T. 20 S., R. 20 E. Anderson County: measured in road cut just west of bend in road.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, light olive gray, thin bedded with massive lower 1.5 feet, very fossiliferous	unm.
Hickory Creek shale member	
Shale, olive green, underlain by blue shale, at base is 0.3 foot punky limestone bed	2.5
Merriam limestone member	A-14
Upper limestone unit	
5. Limestone, medium dark gray (N4), weathers medium light gray (N6); aphanitic, dense, brittle; massive; abundant worm borings filled with ferruginous clay; common crinoid columnals, rare brachiopods in lower half	1.1
Shale bed	
4. Shale, olive gray (5Y4/1), weathers light olive gray (5Y6/1); limy, papery; common fusulinids, common brachiopods, common crinoid columnals	0.2
Lower limestone unit	
3. Limestone, medium light gray (N6), weathers dusky	

yellow (5Y6/4); fine-grained, granular; massive; at places seemingly continuous with lower two units; upper contacts of units 2, 3, and 5 are flat; common crinoid columnals, rare fusulinids, very rare Osagia 0.7

2. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); aphanitic, dense; massive; locally difficult to distinguish from unit 1 by weathering; abundant swirls of dark crystalline dolomite; common calcite vugs; rare thin fusulinids, common crinoid columnals, common brachiopods, rare ~~Myalina~~ [illegible] myalina 1.2

1. Limestone, medium light gray (N6), weathers dark yellowish brown (10YR4/2) but appears dusky yellow (5Y6/4) on outcrop; aphanitic, dense, brittle; massive; rare small fusulinids, common crinoid columnals, common brachiopods, rare fenestrate bryozoans in upper half 1.3

Total Merriam limestone member . . . 4.5

Bonner Springs shale

Shale, dark gray (N3), weathers light bluish gray (5B7/1); sandy, laminated, platy; locally interbedded with dark olive green sandy shale . . . . 6.0+

Locality 47. SW¼, SW¼, Sec. 35, T. 20 S., R. 20 E., Anderson County; measured on road.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin bedded . . . . 2.0+

Hickory Creek shale member

Shale, olive green, with thin punky limestone at base . . 2.5

Merriam limestone member

Upper limestone unit

4. Limestone, medium dark gray (N4), weathers medium gray (N5); very fine-grained, dense; massive; common worm borings filled with ferruginous clay; common crinoid columnals 1.2

Shale bed

3. Shale, olive gray (5Y4/1), weathers light olive gray (5Y6/1); limy, papery; rare brachiopods 0.2

Lower limestone unit

2. Limestone, medium light gray (N6), weathers medium dark gray (N4); fine-grained, dense; massive; upper contact even; common crinoid columnals, rare fusulinids 1.2

1. Limestone, medium light gray (N6) weathers medium dark gray (N4); aphanitic, dense; massive; common veinlets of dense gray dolomite; common crinoid columnals, rare thin fusulinids, common brachiopods 2.6

Total Merriam limestone member . . . 5.2

Bonner Springs shale

Shale, olive green, sandy, laminated . . . . 40.0+

Locality 48. NE¼, SW¼, Sec. 34, T. 20 S., R. 19 E., Anderson County; measured in road cut on new road northeast of bridge.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin bedded in upper three feet; massive, very fine-grained, dense, fossiliferous in lower 1.1 feet; weathers dusky yellow (5Y6/4) 4.1

Hickory Creek shale member

Shale, upper half dark yellowish orange (10 YR6/6), weathers grayish orange (10YR7/4); lower half olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4) not interlaminated; weathers light olive gray (5Y6/1); limy, papery 0.4

Merriam limestone member

Upper limestone unit

3. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); aphanitic, dense; massive; upper contact even; common worm borings filled with ferruginous clay; common veinlets of dense gray dolomite; common crinoid columnals 0.4

Shale bed

2. Shale, moderate yellowish brown (10YR5/4), weathers moderate yellow (5Y7/6); limy, hard, irregular limestone stringer at top of unit becomes lower half of unit 3 at places; lower 0.1 foot olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4) not interlaminated, weathers light olive gray (5Y6/1); limy 0.4

Lower limestone unit

1. Limestone, light gray (N7) in upper two-thirds, lower one-third greatly weathered, weathers dusky yellow (5Y6/4); fine- to medium-grained; massive; common veinlets of dense gray dolomite; prominent vertical jointing; moderate yellowish brown (10YR5/4) clay pebbles common throughout unit giving pitted weathering in places; lower 0.1 foot conglomeratic and grading into underlying unit; abundant crinoid columnals, rare fusulinids, rare brachiopods at top of unit; unit thins to shaly rubbly limestone and limy shale . . . . 1.5 - 0.2

Total Merriam limestone member . . . 2.3 - 1.0

Bonner Springs shale

Shale, pale olive (10Y6/2), weathers same; laminated, sandy; with some interlaminated blue shale 15.0

Locality 49. SE¼, SE¼, Sec. 4, T. 21 S., R. 19 E., Anderson County;
measured in road cut just east of creek.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, light olive gray; thin irregular beds; very fossiliferous, especially crinoid columnals	15.0+
Hickory Creek shale member	
Shale, moderate yellowish brown (10YR5/4), weathers pale olive (10Y6/2); limy, papery	0.7
Merriam limestone member	
Upper limestone unit	
4. Limestone, light gray (N7), weathers very light gray (N8); very fine-grained; massive but appears nodular from blasting; abundant worm borings filled with ferruginous clay; abundant veinlets of dark crystalline dolomite; rare crinoid columnals; poorly exposed	1.0
Shale bed	
3. Shale, moderate yellowish brown (10YR5/4), weathers pale olive (10Y6/2); limy, papery; poorly exposed .	0.2
Lower limestone unit	
2. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained; massive; common robust fusulinids, common crinoid columnals	0.5

1. Limestone, light gray (N7) in upper part, medium light gray (N6) in lower part, weathers dusky yellow (5Y6/4); upper part aphanitic, dense; abundant veinlets of dark crystalline dolomite; rare fusulinids, common brachiopods; lower part fine- to medium-grained, suboolitic; common Osagia; unit massive with prominent vertical jointing; crinoid columnals abundant near base and common in rest of unit 1.1

Total Merriam limestone member . . . 2.8

Bonner Springs shale

Shale, pale olive (10Y6/2), weathers same; sandy, laminated; five feet below top of unit is interbedded sandy shale and massive to thin bedded sandstone about 30 feet thick. 35.0+

Locality 50. SW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 13, T. 21 S., R. 19 E., Anderson County; measured in road cut south of bridge.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, brittle, weathers white; thin irregular beds; lower 0.8 foot weathers dusky yellow (5Y6/4); fine-grained, somewhat earthy; very fossiliferous . . . . . . 3.0+

Hickory Creek shale member

Shale, moderate yellowish brown (10YR5/4); covered, clayey 0.1

Merriam limestone member

Upper limestone unit

5. Limestone, light olive gray (5Y6/1), weathers mainly

light gray (N7); aphanitic, dense; massive; abundant worm borings filled with ferruginous clay; pitted weathering; common small grains of dense gray dolomite; rare brachiopods, common crinoid columnals . . 0.5

Shale bed

4. Shale, olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4) not interlaminated, weathers light olive gray (5Y6/1); limy, papery; poorly exposed 0.3

Lower limestone unit

3. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4) and medium gray (N5); aphanitic, dense; massive; common vertical jointing; common spots and veinlets of dark crystalline dolomite; common worm borings filled with ferruginous clay at top of unit; abundant fusulinids, common horn corals, common crinoid columnals 0.4

2. Limestone, light olive gray (5Y6/1), weathers dusky yellow (5Y6/4); fine-grained; massive; very abundant small robust fusulinids, abundant crinoid columnals 0.3

1. Limestone, medium gray (N5), weathers dusky yellow (5Y6/4); fine- to medium-grained; massive; prominent vertical jointing; contacts fairly even; rare ramose bryozoans, abundant crinoid columnals, small robust fusulinids common at base but rare in remainder of unit, common Osagia at top; unit poorly exposed 1.0

Total Merriam limestone member . . . 2.5

Bonner Springs shale

Shale, medium bluish gray (5B5/1), weathers light bluish gray (5B7/1); silty, hard; upper three feet grayish olive (10Y4/2), covered, sandy, hard . . . . 10.0+

Locality 51. $NW\frac{1}{4}$, $SE\frac{1}{4}$, Sec. 6, T. 21 S., R. 20 E., Anderson County; measured in road cut on U. S. Highways 59 and 169 just south of bridge.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, light gray (N7), weathers olive gray (5Y4/1) to grayish orange (10YR7/4); massive but weathers into thin to thick irregular beds with the shale parting above lower 1.5 foot bed; abundantly fossiliferous 15.0/

Hickory Creek shale member

Shale, olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4) not interlaminated, weathers light olive gray (5Y6/1); limy, papery; one inch punky limestone stringer near top 0.3

Merriam limestone member

Upper limestone unit

3. Limestone, light olive gray (5Y6/1) in upper part, medium gray (N5) in lower part, weathers yellowish gray (5Y7/2); aphanitic, dense; massive; pitted weathering; upper contact fairly flat; common spots and veinlets of dark crystalline dolomite; abundant worm borings filled with ferruginous clay; rare elongate fusulinids, common crinoid columnals, common small brachiopods 1.0

Shale bed

2. Shale, olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4) not interlaminated, weathers light olive gray (5Y6/1); limy, papery; common small open folds with vertical planes; lower contact even, upper contact only slightly irregular 0.2

Lower limestone unit

1. Limestone, light gray (N7) in upper one-half, medium dark gray (N4) in lower one-half, weathers yellowish gray (5Y7/2), commonly yellowish brown beneath the surface especially in lower half of

unit; very fine-grained, dense; massive; prominent vertical jointing; suggary texture in middle and somewhat granular at top; common spots of dark crystalline dolomite near top; lower 0.1 foot slightly conglomeratic with small sandy shale pebbles, grades into underlying unit; rare brachiopods, common crinoid columnals, common small fusulinids in lower part and near top of unit, common Osagia above middle of unit 2.2

Total Merriam limestone member . . . 3.4

Bonner Springs shale

Shale, medium bluish gray (5B5/1), weathers light bluish gray (5B7/1); silty, laminated; upper 0.4 foot is dusky yellow green (5GY5/2), weathers light greenish gray (5GY8/1); silty, laminated . . . . 15.0+

Locality 52. SE$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 17, T. 21 S., R. 20 E., Anderson County; measured in road cut just north of road junction.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin to thick irregular beds, abundantly fossiliferous . . . . 8.0+

Hickory Creek shale member

Shale, covered, yellow, limy 0.3

Merriam limestone member

Upper limestone unit

4. Limestone, olive gray (5Y6/1), weathers dusky yellow (5Y6/4); aphanitic, dense; massive; abundant veinlets

of dark crystalline dolomite; abundant worm borings filled with ferruginous clay; common crinoid columnals 0.7

Shale bed

3. Shale, olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4) not interlaminated, weathers light olive gray (5Y6/1); limy, papery; common small open folds with vertical planes 0.2

Lower limestone unit

2. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); very fine-grained, somewhat granular; massive; rare worm borings filled with ferruginous clay; common fusulinids, common crinoid columnals . 0.4

1. Limestone, light gray (N7), weathers dusky yellow (5Y6/4); very fine-grained, dense; massive; prominent vertical jointing; common veinlets of dark crystalline dolomite; common small fusulinids, rare _Osagia_, common crinoid columnals 1.2

Total Merriam limestone member . . . 2.5

Bonner Springs shale

Shale, covered, interlaminated dusky yellow green and blue, silty, laminated . . . . 10.0+

Locality 53. SE¼, SW¼, SE¼, Sec. 35, T. 21.S., R. 20 E., Anderson County; measured on gravel road 0.35 mile west of dirt road.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin irregular beds . . . . unm.

Hickory Creek shale member

Shale, covered . . . . unm.

Merriam limestone member

Upper limestone unit

4. Limestone, light gray (N7), weathers very light gray (N8); fine-grained, dense; massive but weathers to nodular rubble; pitted weathering; common veinlets of dark crystalline dolomite; abundant worm borings filled with ferruginous clay; common crinoid columnals 1.0

Shale bed

3. Shale, covered . . . . 0.1±

Lower limestone unit

2. Limestone, medium light gray (N6), weathers olive gray (5Y4/1); fine- to medium-grained, somewhat granular; massive; common vertical jointing; upper contact fairly irregular; common small robust fusulinids, abundant crinoid columnals, rare <u>Osagia</u> in upper part 2.2

1. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); fine-grained, somewhat earthy, suggary texture; massive; distinctly separated from overlying unit; even contacts; common crinoid columnals, rare horn corals near top 0.7

Total Merriam limestone member . . . 4.0

Bonner Springs shale

Shale, olive gray, with sandstone in upper part; blue in lower part 10.0/

Locality 54. SW¼, SW¼, Sec. 7, T. 22 S., R. 21 E., Anderson County; measured in road cut 0.3 mile north of road junction.

	Thickness Feet
Plattsburg formation	
Spring Hill limestone member	
Limestone, light olive gray, weathers light gray (N7); thin irregular beds, abundantly fossiliferous	6.0+
Hickory Creek shale member	
Shale, light olive gray; limy, papery; punky yellow limestone 0.4 foot thick at base	0.8
Merriam limestone member	
Upper limestone unit	
3. Limestone, light gray (N6) in upper half, medium light gray (N7) in lower half, weathers light gray (N7); aphanitic, dense; massive; pitted weathering in places; common spots and veinlets of dark crystalline dolomite in upper part; common worm borings filled with ferruginous clay especially in lower part of unit; rare small robust fusulinids, common crinoid columnals, very rare *Osagia* at top .	1.3
Shale bed	
2. Shale, olive gray (5Y4/1), light greenish gray (5G8/1), and moderate olive brown (5Y4/4) not interlaminated, weathers light olive gray (5Y6/1); limy, papery; common small symmetrical folds with vertical planes; rare brachiopods and limestone nodules in upper 0.05 foot	0.2
Lower limestone unit	
1. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); fine-grained, more granular toward base; weathers to yellowish brown beneath surface; common small robust fusulinids, common *Osagia* at top; upper 0.4 foot with *Osagia* weathers somewhat differently and lighter; lower 0.1 foot slabby, conglomeratic with a sandy shale pebbles	1.6
Total Merriam limestone member . . .	3.1

Bonner Springs shale A-17

Shale, upper 5.5 feet with olive gray (5Y4/1) silty shale at top weathering light olive gray, underlain by thin bedded ripple-marked sandstone; remainder of unit is shale, medium bluish gray (5B5/1), weathers light bluish gray (5B7/1); silty, platy . . . . 18.0±

Locality 55. SE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 25, T. 22 S., R. 20 E., Anderson County;

measured in road cut 0.2 mile north of road junction.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin irregular beds, very fossiliferous, abundant brachiopods at the base . . . . 4.0±

Hickory Creek shale member

Shale, light olive gray; papery, limy; weathers to papery froth; at base is punky limestone 0.2 foot thick, weathers to nodular rubble 0.8

Merriam limestone member

Upper limestone unit

3. Limestone, medium light gray (N6), weathers light gray (N7) and dusky yellow (5Y6/4); aphanitic, dense; massive; prominent vertical jointing; common veinlets of dense gray dolomite; abundant worm borings filled with ferruginous clay; common crinoid columnals, common brachiopods in lower one-third of unit 1.2

Shale bed

2. Shale, olive gray (5Y4/1), light greenish gray

(5G8/1), and moderate olive brown (5Y4/4) not interlaminated, weathers light olive gray (5Y6/1); limy, papery; poorly exposed 0.2

Lower limestone unit

1. Limestone, medium light gray (N6), weathers light gray (N7); very fine-grained, dense, more granular at base; massive; vertical jointing not prominent; upper contact even; common crinoid columnals, small robust fusulinids very abundant at base and common throughout rest of unit 1.9

Total Merriam limestone member . . . 3.3

Bonner Springs shale

Shale, blue and olive gray with thin bedded sandstone in upper part as at Locality 54; upper two feet covered . . 10.0+

Locality 56. SW¼, SW¼, Sec. 8, T. 23 S., R. 19 E., Anderson County; measured on road.

Thickness Feet

Plattsburg formation

Spring Hill limestone member and Hickory Creek shale member

Covered . . . . unm.

Merriam limestone member

Upper limestone unit

3. Limestone, very light gray (N8), weathers light gray (N7); very fine-grained, dense, suggary texture; massive but weathers to thin irregular beds; lower and upper contacts concealed; common veinlets of dark crystalline dolomite; rare worm borings filled

with ferruginous clay; common crinoid columnals, common brachiopods . . . . 1.6±

Shale bed

2. Shale, covered . . . . 0.2±

Lower limestone unit

1. Limestone, medium light gray (N6), weathers dark yellowish orange (10YR6/6); fine-grained, more granular toward base; massive; common veinlets of dark crystalline dolomite; common <u>Osagia</u>, rare brachiopods, poorly exposed 1.6

Total Merriam limestone member . . . 3.4±

Bonner Springs shale

Shale, dusky yellow green (5GY5/2), weathers light greenish gray (5GY8/1); silty, laminated; five feet exposed . . . unm.

Locality 57. Center NW$\frac{1}{4}$, Sec. 20, T. 24 S., R. 18 E., Allen County; measured in road cut at road junction.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin bedded, slabby . . . . 2.0±

Hickory Creek shale member

Shale, covered, yellow, nodular 2.5

Merriam limestone member

Upper limestone unit

2. Limestone, medium light gray (N6), weathers light gray (N7) and dusky yellow (5Y6/4); fine- to medium-grained granular in places; massive; abundant thin irregular close-spaced layers of yellow ferruginous clay give laminated appearance to rock; at top of unit is thin slabby weathering zone; common brachiopods, common crinoid columnals; poorly exposed . . . . 1.0±

Lower limestone unit

1. Limestone, light olive gray (5Y6/1), weathers light gray (N7); medium-grained, granular; massive; common irregular yellow clay laminae throughout; rare brachiopods, common crinoid columnals; poorly exposed . . . . 1.0±

Total Merriam limestone member . . . 2.0±

Bonner Springs shale

Shale, covered . . . . unm.

Locality 58. Northwest corner Sec. 2, T. 25 S., R. 18 E., Allen County; measured in old shale quarry (Lake Bassola), Basset, Kansas.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thin to thick irregular beds; very fossiliferous with sponges in lower part; common shaly partings . . . 3.0±

Hickory Creek shale member

Shale, blue, papery, limy, in upper 0.8 foot; limestone, shaly, platy, rubbly, in lower 0.5 foot 1.3

Merriam limestone member -

Upper limestone unit

3. Limestone, medium light gray (N6), weathers dusky yellow (5Y6/4); aphanitic, dense; massive; common spots of dark crystalline dolomite; prominent vertical jointing; common small worm borings filled with ferruginous clay; abundant large crinoid columnals, common brachiopods, common calcareous algae 0.7

Shale bed

2. Shale, moderate yellowish brown (10YR5/4), weathers yellowish gray (5Y7/2); limy, papery; common small marly limestone nodules; common nodules of clay shale 0.2

Lower limestone unit

1. Limestone, moderate yellowish brown (10YR5/4) in upper half, greenish gray (5GY8/1) in lower half, weathers dusky yellow (5Y6/4); upper half fine-grained, dense; somewhat slabby weathering, greatly weathered; lower half marly, continuous with upper half of unit and grades into underlying unit; abundant crinoid columnals, common brachiopods, rare sponges only locally common 0.7

Total Merriam limestone member . . . 1.6

Bonner Springs shale

Shale, light bluish gray (5B7/1), weathers same; silty; upper 0.3 foot limy with limestone nodules . . . . 35.0+

Locality 59. NE$\frac{1}{4}$, Sec. 18, T. 29 S., R. 16 E., Wilson County; measured in lower road cut on Kansas Highway 47 west of Altoona.

Thickness Feet

Plattsburg formation

Spring Hill limestone member

Limestone, massive, thick irregular beds; very fossiliferous with abundant sponges . . . . unm.

Hickory Creek shale member

Limestone, thin bedded with shale partings, in the upper part; shale, blue, papery, in middle of unit; and shale, blue, very limy and fossiliferous, in lower part . . . unm.

Merriam limestone member

Upper limestone unit

Limestone, medium gray (N5), weathers dusky yellow (5Y6/4); fine-grained; massive; weathers to earthy appearance; fossiliferous with common brachiopods, common crinoid columnals, common fenestrate and ramose bryozoans; bed is very irregular in thickness and stratigraphic position . . . . 0.8 - 0.2

Total Merriam limestone member . . . 0.8 - 0.2

Bonner Springs shale

Shale, medium dark gray (N4), weathers light bluish gray (5B7/1); silty, nodular; common limestone nodules near top . . . . 15.0+

Locality 60. SW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 23, T. 30 S., R. 15 E., Wilson County; measured in road cut on Kansas Highway 96.

Thickness
Feet

Plattsburg formation

Spring Hill limestone member

Limestone, thick bedded; poorly fossiliferous; shaly limestone in lower part, very fossiliferous with abundant sponges; poorly exposed 40.0/

Hickory Creek shale member

Shale, gray, calcareous; common interbedded shaly limestone; fossiliferous; poorly exposed 10.0/

Merriam limestone member

Upper limestone unit

Limestone, dark yellowish brown (10YR4/2), weathers grayish orange (10YR7/4); aphanitic, dense; weathers slabby; very fossiliferous with abundant sponges, abundant crinoid columnals, common brachiopods, and rare fenestrate bryozoans; contacts concealed; poorly exposed 1.0/

Bonner Springs shale

Shale, light tan, silty, unfossiliferous . . . . unm.

Only the circled samples will be used, as they are from the sections remaining in Appendix A —

APPENDIX B

CONSTITUENTS OF THE COARSE FRACTIONS OF THE INSOLUBLE RESIDUES FROM THE MERRIAM LIMESTONE MEMBER

1B	90%	arenaceous foraminifer tests and fragments
	10%	quartz sand grains, loose, subrounded to angular, etched, milky and orange, up to 0.1 millimeter in diameter
	Rare	quartz, clear, anhedral, loose, up to one millimeter in diameter
		interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
		chert, blue, smooth, ordinary, unmodified
		glauconite.
2A	50%	arenaceous foraminifer tests and fragments
	40%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.45 millimeter in diameter
	10%	chert, white, smooth, porcelaneous, unmodified
		chert, milky, smooth, chalcedonic, dolomorphic
		chert, gray, smooth, chalcedonic, unmodified
		beekite, white, replacement of discoid foraminifers
		quartz, clear, subhedral to anhedral, loose
		white mica, small flakes.
2B	50%	arenaceous foraminifer tests and fragments
	40%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.45 millimeter in diameter
	10%	chert, white, smooth, porcelaneous, unmodified
		beekite, white, replacement of discoid foraminifers
		quartz, clear, anhedral, loose
		mica flakes, clear
		mica flakes, black
		silt aggregates.
2Ca	95%	silt aggregates, mostly discoid, rarely bean-shaped, diameter up to 0.25 millimeter, length up to 0.45 millimeter
	3%	arenaceous foraminifer tests and fragments
	2%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.45 millimeter in diameter
	Rare	brachiopod spines.
2Cb	50%	silt aggregates, mostly discoid, some irregular
	40%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.45 millimeter in diameter
	10%	arenaceous foraminifer tests and fragments

Rare quartz, clear, anhedral, loose
chert, blue, smooth, ordinary, unmodified.

3A
50% arenaceous foraminifer tests and fragments
40% quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.15 millimeter in diameter
10% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
Rare white mica flakes
quartz, clear, anhedral loose
beekite, white, nodular and discoid.

3B
70% arenaceous foraminifer tests and fragments
10% quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.25 millimeter in diameter
10% beekite, white, nodular
10% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
Rare quartz, clear, anhedral, loose
white mica flakes
pyrite fragments.

3C
80% arenaceous foraminifer tests and fragments
10% quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.1 millimeter in diameter
5% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
5% beekite, white, nodular
Rare quartz, clear, anhedral, loose
silt aggregates
brachiopod spines
glauconite.

4A
70% arenaceous foraminifer tests and fragments
20% quartz sand grains, loose, subrounded to angular, etched, milky and rarely orange, up to 0.3 millimeter in diameter
5% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
3% quartz, clear and orange, anhedral, loose
2% beekite, white, fossil replacement
silt aggregates.

4B
70% arenaceous foraminifer tests and fragments
20% quartz sand grains, loose, subrounded to angular, etched, milky and orange, up to 0.2 millimeter in diameter
10% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
Rare quartz, clear, anhedral, loose
beekite, white, replacement of discoid foraminifers
silt aggregates
chert, smooth, chalcedonic, unmodified.

4C	80%	arenaceous foraminifer tests and fragments
	15%	quartz sand grains, loose, subrounded to angular, etched, milky and orange, up to 0.1 millimeter in diameter
	5%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	Rare	quartz, clear, anhedral, loose
		beekite, white, fossil replacement
		white mica flakes
		silt aggregates.
5AB	75%	silt aggregates, dark brown, up to 0.6 millimeter in diameter
	20%	arenaceous foraminifer tests and fragments
	5%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.2 millimeter in diameter
	Rare	quartz, clear, subhedral to anhedral, loose
		chert, blue, smooth, ordinary, unmodified.
5C	80%	silt aggregates, light brown, up to 0.5 millimeter in diameter
	20%	arenaceous foraminifer tests and fragments
	Rare	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.1 millimeter in diameter
		white mica flakes
		pyrite, botryoidal
		chert, blue, smooth, ordinary, etched.
5D*	90%	silt aggregates, white, up to one millimeter in diameter
	10%	arenaceous foraminifer tests and fragments
	Rare	white mica flakes.
6B	80%	arenaceous foraminifer tests and fragments
	10%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.25 millimeter in diameter
	3%	beekite, white, fossil replacement, especially discoid foraminifers
	2%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	5%	quartz, clear, anhedral, loose
		white mica flakes
		silt aggregates
6C	75%	quartz sand grains, loose, subrounded to angular, etched, milky and orange, up to 0.1 millimeter in diameter
	10%	arenaceous foraminifer tests and fragments
	10%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	5%	beekite, white, replacement of discoid foraminifers
	Rare	quartz, clear, anhedral, loose, up to 0.5 millimeter in diameter
		silt aggregates

chert, blue, smooth, ordinary, unmodified.

7AB	80%	silt aggregates
	10%	arenaceous foraminifer tests and fragments
	10%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.1 millimeter in diameter
	Rare	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds.
9A	80%	silt aggregates
	10%	arenaceous foraminifer tests and fragments
	10%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.3 millimeter in diameter
	Rare	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
		white mica flakes
		chert, dark yellow, anhedral, loose, 0.1 millimeter long.
11C	60%	arenaceous foraminifer tests and fragments
	20%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	10%	quartz sand grains, loose, subrounded to angular, etched, milky and orange, up to 0.25 millimeter in diameter
	5%	silt aggregates
	5%	quartz, clear and orange, anhedral, loose, up to 0.25 millimeter in diameter
		white mica flakes
		pyrite, botryoidal
		glauconite
		chert, blue, smooth, ordinary, unmodified.
11D*	60%	beekite, white, nodules and fossil replacement
	20%	arenaceous foraminifer tests and fragments
	20%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	Rare	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.1 millimeter in diameter.
16A	60%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.3 millimeter in diameter
	20%	arenaceous foraminifer tests and fragments
	20%	silt aggregates
	Rare	quartz, clear, anhedral, loose
		chert, red, smooth, ordinary, etched.
16Ba	50%	silt aggregates
	30%	quartz sand grains, loose, subrounded to angular, etched
	20%	arenaceous foraminifer tests and fragments
	Rare	interstitial silica, white, dolomoldic, with scattered dolomolds

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white mica flakes
chert, blue, smooth, ordinary, unmodified.

16Bb	80%	silt aggregates
	19%	quartz sand grains, loose, subrounded to angular, etched, milky, up to 0.3 millimeter in diameter
	1%	arenaceous foraminifer tests and fragments
	Rare	chert, white, smooth, ordinary, dolomoldic, with scattered dolomolds
		chert, blue, smooth, ordinary, unmodified.
16Bc	60%	arenaceous foraminifer tests and fragments
	35%	quartz sand grains, loose, subrounded to subangular, subspherical, etched, milky, up to 0.3 millimeter in diameter
	5%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
		white mica flakes
		silt aggregates.
16C	50%	arenaceous foraminifer tests and fragments
	50%	silt aggregates
	Rare	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter.

17A	60%	silt aggregates
	25%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.3 millimeter in diameter
	15%	arenaceous foraminifer tests and fragments
	Rare	chert, white, smooth, ordinary, unmodified.
17B	90%	arenaceous foraminifer tests and fragments
	8%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.3 millimeter in diameter
	2%	silt aggregates
	Rare	white mica flakes
		glauconite
		chert, blue to black, smooth, ordinary, unmodified.
17C	95%	arenaceous foraminifer tests and fragments
	4%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	1%	chert, blue, smooth, ordinary, unmodified
	Rare	quartz, clear, anhedral, loose
		glauconite.
20A	70%	arenaceous foraminifer tests and fragments
	10%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.5 millimeter in diameter

	10%	pyrite, crystals and cubes as botryoidal masses, also as small fragments adhering to foraminifer tests and sand grains
	10%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
		quartz, clear, anhedral, loose
		beekite, white, replacement of discoid foraminifers
		white mica flakes.
20B	50%	silt aggregates
	30%	arenaceous foraminifer tests and fragments
	15%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.4 millimeter in diameter
	5%	quartz, clear, subhedral to anhedral, loose
		beekite, white, replacement of foraminifers
		white mica flakes
		glauconite
		pyrite aggregates.
20C	60%	silt aggregates
	30%	arenaceous foraminifer fragments
	10%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.2 millimeter in diameter
	Rare	quartz, clear, anhedral, loose
		chert, blue, smooth, ordinary, unmodified
		pyrite aggregates.
23A	85%	arenaceous foraminifer tests and fragments
	10%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.3 millimeter in diameter
	5%	beekite, white, fossil replacement
		white mica flakes
		chert, smoky, smooth, ordinary, unmodified
		quartz, clear, anhedral, loose
		carbonaceous material fragment.
23B	50%	arenaceous foraminifer fragments with some tests
	50%	quartz sand grains, loose, subrounded to subangular, etched, milky up to 0.3 millimeter in diameter
	Rare	white mica flakes
		glauconite
		quartz, clear, anhedral, loose
		chert, white to red, smooth, ordinary, unmodified
		chert, smoky, smooth, ordinary, unmodified.
23C	50%	arenaceous foraminifer tests and fragments
	50%	quartz sand grains, loose, subrounded to subangular, etched, milky to clear, up to 0.4 millimeter in diameter
	Rare	white mica flakes
		beekite, white, replacement of discoid foraminifers
		glauconite

chert, white to red, smooth, ordinary, unmodified
chert, brown, smooth, ordinary, unmodified
chert, blue, smooth, ordinary, unmodified.

26Aa 99% arenaceous foraminifer tests and fragments
1% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.25 millimeter in diameter
glauconite
white mica flakes.

26Ab 50% arenaceous foraminifer tests and fragments
50% silt aggregates
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
white mica flakes
interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds.

26B 85% arenaceous foraminifer tests and fragments
5% beekite, white, fossil replacement
5% quartz sand grains, loose, subrounded to subangular, etched, milky to clear, up to 0.2 millimeter in diameter
5% pyrite, botryoidal aggregates
interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds.

26C 50% arenaceous foraminifer tests and fragments
40% quartz sand grains, loose, subrounded to subangular, etched, milky to clear, up to 0.1 millimeter in diameter
10% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
Rare glauconite
pyrite, replacement of small tubular organisms.

27B 88% silt aggregates
10% quartz sand grains, loose, subrounded to subangular, etched, milky to clear, up to 0.1 millimeter in diameter
2% arenaceous foraminifer tests and fragments
Rare interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
white mica flakes.

27C 99% silt aggregates
1% arenaceous foraminifer tests and fragments
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
pyrite, small grains
white mica flakes
glauconite.

28AB 99% silt aggregates
1% arenaceous foraminifer tests and fragments
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter
white mica flakes.

28Ca 99% silt aggregates
1% arenaceous foraminifer tests and fragments
Rare chert, red, smooth, ordinary, unmodified.

28Cb 95% silt aggregates
5% arenaceous foraminifer tests and fragments
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.5 millimeter in diameter
white mica flakes.

28S** 90% silt aggregates
5% arenaceous foraminifer tests and fragments
5% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
Rare quartz sand grains, loose, subrounded to subangular, etched, milky up to 0.1 millimeter in diameter.

29A 80% silt aggregates, up to 0.5 millimeter in diameter
10% arenaceous foraminifer tests and fragments
10% quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.3 millimeter in diameter
Rare quartz, clear, anhedral, loose, etched, up to 0.5 millimeter in diameter
chert, gray, smooth, ordinary, etched
white mica flakes.

29B 95% silt aggregates
5% arenaceous foraminifer tests and fragments
Rare quartz grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds.

29C 95% silt aggregates
5% arenaceous foraminifer tests and fragments
Rare quartz sand grains, loose, subrounded to subangular, etched, milky up to 0.1 millimeter in diameter
interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
glauconite
chert, green, smooth, ordinary, unmodified
chert, blue, smooth, ordinary, unmodified.

31A 50% silt aggregates, up to 0.2 millimeter in diameter, light brown

	50%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
	Rare	quartz, clear, anhedral, loose
		white mica flakes.
31B	95%	silt aggregates, dark brown, up to 0.4 millimeter in diameter
	5%	arenaceous foraminifer tests and fragments
	Rare	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter.
31C	95%	silt aggregates, dark brown, up to 0.4 millimeter in diameter
	5%	interstitial silica, white, fine-grained, dolomoldic, with abundant to scattered dolomolds
		beekite, white, replacement of small crinoid stems
	Rare	arenaceous foraminifer tests and fragments
		quartz, clear, subhedral to anhedral, loose
		brown chitinous-like material
		chert, blue, smooth, ordinary, unmodified.
32A	60%	silt aggregates
	35%	arenaceous foraminifer tests and fragments
	5%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.4 millimeter in diameter
	Rare	white mica flakes
32B	50%	silt aggregates
	35%	arenaceous foraminifer tests and fragments
	10%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.2 millimeter in diameter
	5%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	Rare	white mica flakes.
32C	70%	silt aggregates
	25%	arenaceous foraminifer tests and fragments
	5%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.2 millimeter in diameter
	Rare	quartz, clear, loose, anhedral
		white mica flakes
		interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds.
33Aa	40%	arenaceous foraminifer tests and fragments
	40%	quartz sand grains, loose, subrounded to subangular, etched. milky, up to 0.2 millimeter in diameter
	10%	pyrite, pyritohedrons, cubes, and aggregates, loose grains, also adheres to some foraminifer tests
	5%	white mica flakes
	5%	interstitial silica, white, fine-grained, dolomoldic, with

scattered dolomolds
quartz, clear, anhedral, loose

33Ab 50% silt aggregates
40% arenaceous foraminifer tests and fragments
10% quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
Rare white mica flakes.

33B 85% silt aggregates
10% arenaceous foraminifer tests and fragments
5% pyrite, botryoidal aggregates of samll grains
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.2 millimeter in diameter
beekite, white, fossil replacement.

33C 90% silt aggregates, up to 0.8 millimeter in diameter
5% arenaceous foraminifer tests and fragments
5% pyrite, botryoidal masses, and small tubes which are probably crinoid stems
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.2 millimeter in diameter
beekite, white, fossil replacement
chert, green, smooth, ordinary, unmodified.

43A 55% arenaceous foraminifer fragments
40% pyrite, octohedrons, cubes, aggregates of grains up to four millimeters in length
5% quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.2 millimeter in diameter
Rare white mica flakes.

43B 95% silt aggregates, light brown, up to 0.5 millimeter in diameter
5% arenaceous foraminifer tests and fragments and interstitial silica, white, dolomoldic, with scattered dolomolds
Rare white mica flakes.

43C 90% silt aggregates, light brown, up to 0.3 millimeter in diameter
5% arenaceous foraminifer tests and fragments and interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
5% pyrite, aggregates of grains and small thin tubes
Rare quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.5 millimeter in diameter
brown chitinous-like material
chert, blue, smooth, ordinary, unmodified.

44AB 55% arenaceous foraminifer tests and fragments and interstitial

silica, white, fine-grained, dolomoldic, with scattered dolomolds
40% pyrite, aggregates of cubes and crystals
5% quartz sand grains, loose, subrounded to subangular, etched, milky to clear, up to 0.1 millimeter in diameter
Rare chert, white, smooth, ordinary, unmodified
white mica flakes.

44C 95% silt aggregates A-19
5% interstitial silica, white, fine-grained, dolomoldic, with scattered to abundant dolomolds
Rare arenaceous foraminifer tests and fragments.

44S** 95% silt aggregates
5% arenaceous foraminifer tests and fragments
interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
brown chitinous-like material.

45A 80% silt aggregates, light brown, up to 0.1 millimeter in diameter
10% quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter
5% interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds and arenaceous foraminifer tests and fragments
5% pyrite, laminar and as aggregates
Rare white mica flakes.

45B 35% silt aggregates, light brown, up to 0.2 millimeter in diameter
35% quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
20% arenaceous foraminifer tests and fragments
10% white mica flakes
Rare chert, red, smooth, ordinary, unmodified
brown chitinous-like material
black mica flakes.

45C 95% silt aggregates, dark brown, up to 0.6 millimeter in diameter
5% arenaceous foraminifer tests and fragments and interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
Rare white mica flakes
pyrite grains
quartz sand, grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter
chert, blue, smooth, ordinary, unmodified.

46A	30%	silt aggregates, light brown, up to 0.3 millimeter in diameter
	30%	arenaceous foraminifer tests and fragments and interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	30%	pyrite, small tubes, aggregates up to one millimeter in length
	10%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
	Rare	white mica flakes
		brown chitinous-like material.
46B	60%	arenaceous foraminifer tests and fragments
	30%	silt aggregates, large, dark brown, and small, light brown
	10%	pyrite, botryoidal aggregates and laminar
	Rare	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter.
46C	70%	silt aggregates, light brown, up to 0.2 millimeter in diameter
	20%	arenaceous foraminifer tests and fragments
	10%	pyrite, aggregates, botryoidal masses, and tubes
	Rare	white mica flakes
		brown chitinous-like material.
48AB1***		
	90%	quartz sand grains, loose, subrounded to angular, etched, mainly white but also yellow and red stained, up to 0.1 millimeter in diameter
	5%	white mica flakes
	5%	chert, white to gray, smooth, ordinary, etched
	Rare	glauconite
		chert, brown, smooth, ordinary, unmodified.
48C1	90%	silt aggregates, light brown, up to 0.3 millimeter in diameter
	5%	arenaceous foraminifer fragments and interstitial silica, white, dolomoldic, fine-grained, with scattered dolomolds
	5%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter
		pyrite aggregates
		sponge spicules.

48AB2 This fraction differs from that of sample 48AB1 only in the presence of rare arenaceous foraminifer tests and rare light brown silt aggregates.

48C2 This fraction is the same as that of sample 48C1.

49A	85%	silt aggregates, light brown, up to 0.1 millimeter in diameter

	15%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter
	Rare	white mica flakes glauconite.
50A	55%	silt aggregates, light brown, up to 0.5 millimeter in diameter
	20%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
	15%	pyrite, aggregates, botryoidal masses, thin tubes
	10%	arenaceous foraminifer tests
	Rare	white mica flakes brown chitinous-like material.
50Bb	85%	silt aggregates, light brown, up to 0.2 millimeter in diameter
	10%	arenaceous foraminifer fragments and interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	5%	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter
	Rare	pyrite aggregates white mica flakes.
50C	80%	silt aggregates, light brown, up to 0.1 millimeter in diameter
	20%	arenaceous foraminifer fragments
	Rare	pyrite aggregates white mica flakes.
54AB	60%	silt aggregates, light brown, up to 0.2 millimeter in diameter
	30%	arenaceous foraminifer tests, mainly tubular forms
	10%	interstitial silica, white, fine-grained, dolomoldic, with scattered dolomolds
	Rare	quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.1 millimeter in diameter white mica flakes.
54C	89%	silt aggregates, light brown, up to 0.2 millimeter in diameter
	10%	arenaceous foraminifer fragments
	1%	chert, blue, smooth, ordinary, unmodified
	Rare	beekite, white, fossil replacement.
58C	85%	silt aggregates, light brown, up to 0.3 millimeter in diameter
	10%	arenaceous foraminifer fragments and tubular tests
	5%	white mica flakes

A-20

59C 90% arenaceous foraminifer tests and fragments
10% quartz sand grains, loose, subrounded to subangular, etched, milky, up to 0.05 millimeter in diameter
Rare pyrite aggregates and octohedron
white mica flakes.

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* Residue from limestone bed in the Hickory Creek member. ~~For explanation of symbols see page 51.~~

** Residue from Spring Hill limestone member.

*** Residues 48AB1 and 48C1 are from the thick section of the Merriam at Locality 48, whereas residues 48AB2 and 48C2 are from the thin section at the same locality. See ~~text for details~~ Plate 3.

In the sample numbers the arabic numeral refers to the measured section, the capital letters A and B refer to the lower and upper part of the lower limestone unit and the capital letter C refers to the upper limestone unit; the small letters are subdivisions.

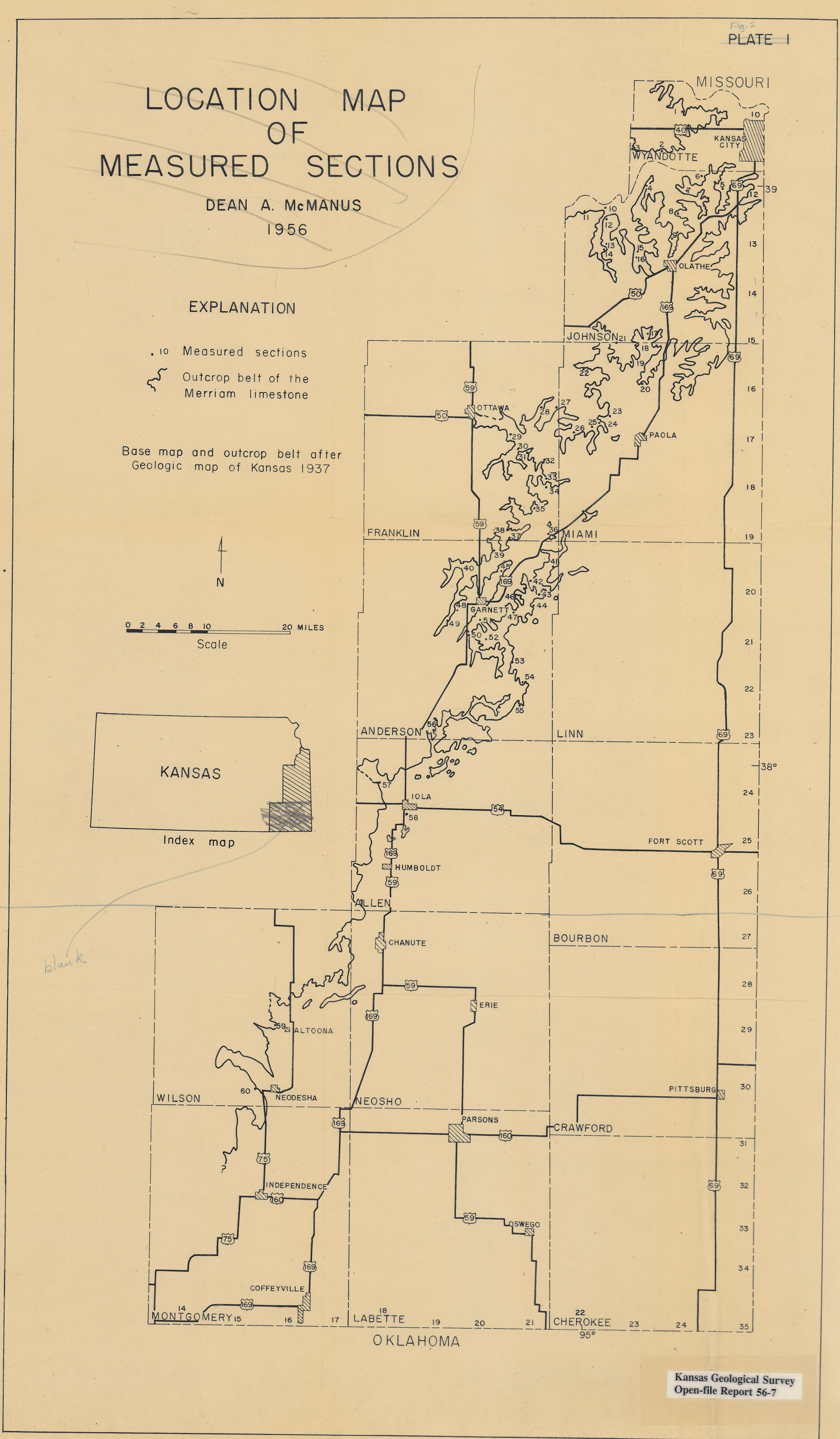
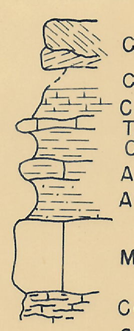


PLATE I
LOCATION MAP OF MEASURED SECTIONS
DEAN A. McMANUS
1956
EXPLANATION
10 Measured sections
Outcrop belt of the Merriam limestone
Base map and outcrop belt after Geologic map of Kansas 1937
N
0 2 4 6 8 10 20 MILES
Scale
KANSAS
Index map
MISSOURI
KANSAS CITY
WYANDOTTE
OLATHE
JOHNSON
OTTAWA
PAOLA
FRANKLIN
MIAMI
GARNETT
ANDERSON
LINN
IOLA
HUMBOLDT
FORT SCOTT
ALLEN
CHANUTE
BOURBON
ERIE
ALTOONA
WILSON
NEODESHA
NEOSHO
PARSONS
CRAWFORD
PITTSBURG
INDEPENDENCE
OSWEGO
COFFEYVILLE
MONTGOMERY
LABETTE
CHEROKEE
OKLAHOMA
39
38°
95°

CORRELATED SECTIONS OF THE MERRIAM LIMESTONE IN EASTERN KANSAS

By
Dean A. McManus
1956

EXPLANATION

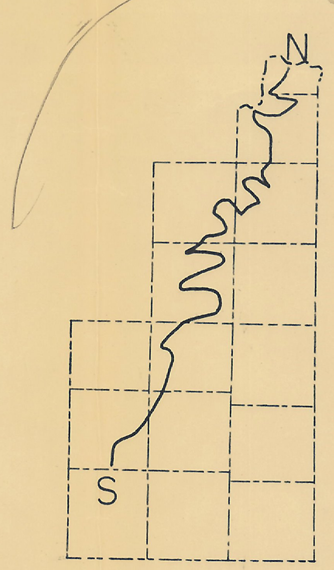


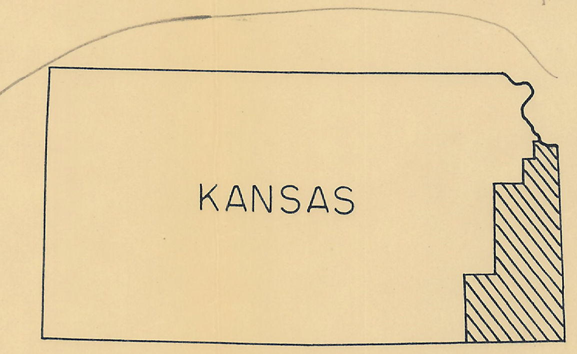
Cross-bedded limestone
Covered interval
Calcareous shale
Thin-bedded limestone
Clay shale
Argillaceous limestone
Arenaceous shale
Massive limestone
Calcareous shale and argillaceous limestone

/ — worm-borings
— fusulinids
* — Osagia
M — Myalina
C — Composita
— Brachiopods (in shale beds)

a — abundant
c — common
r — rare

vertical scale — 1 inch = 1 foot
no horizontal scale

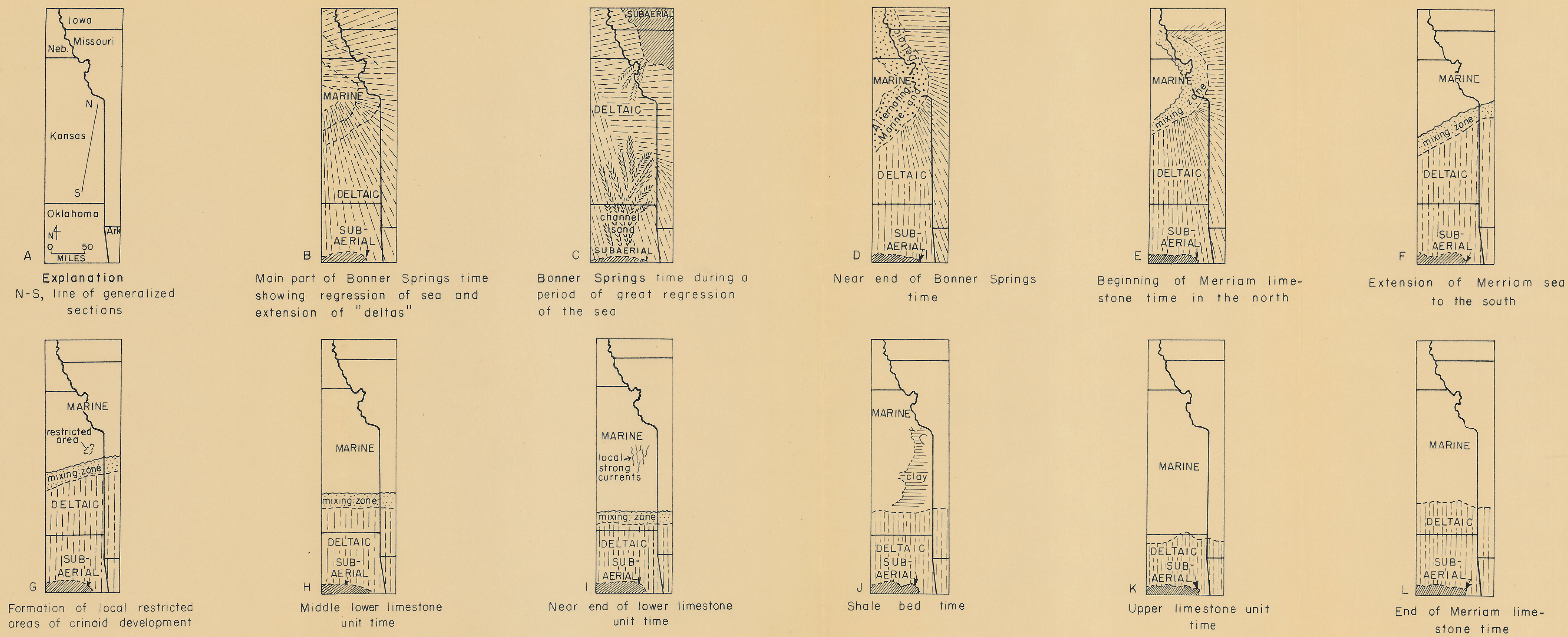




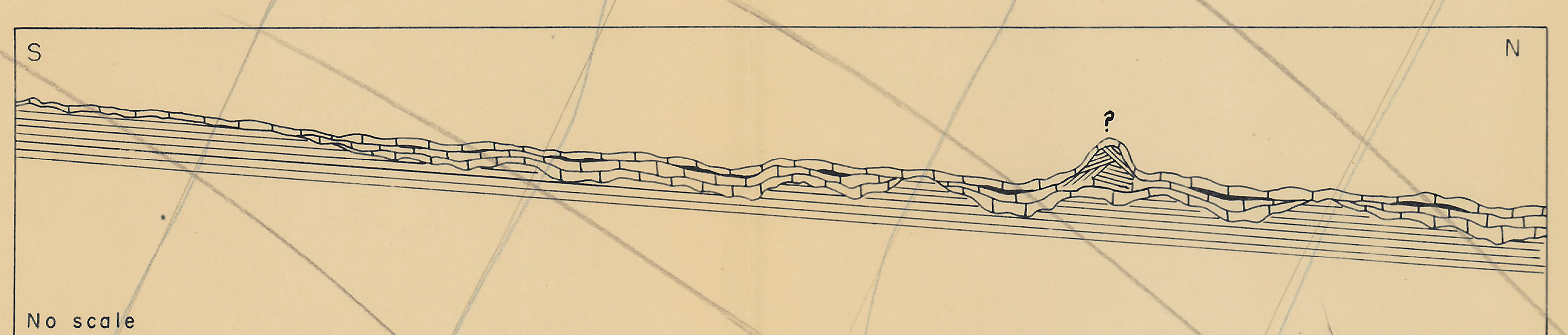
INDEX MAP

Kansas Geological Survey
Open-file Report 56-7

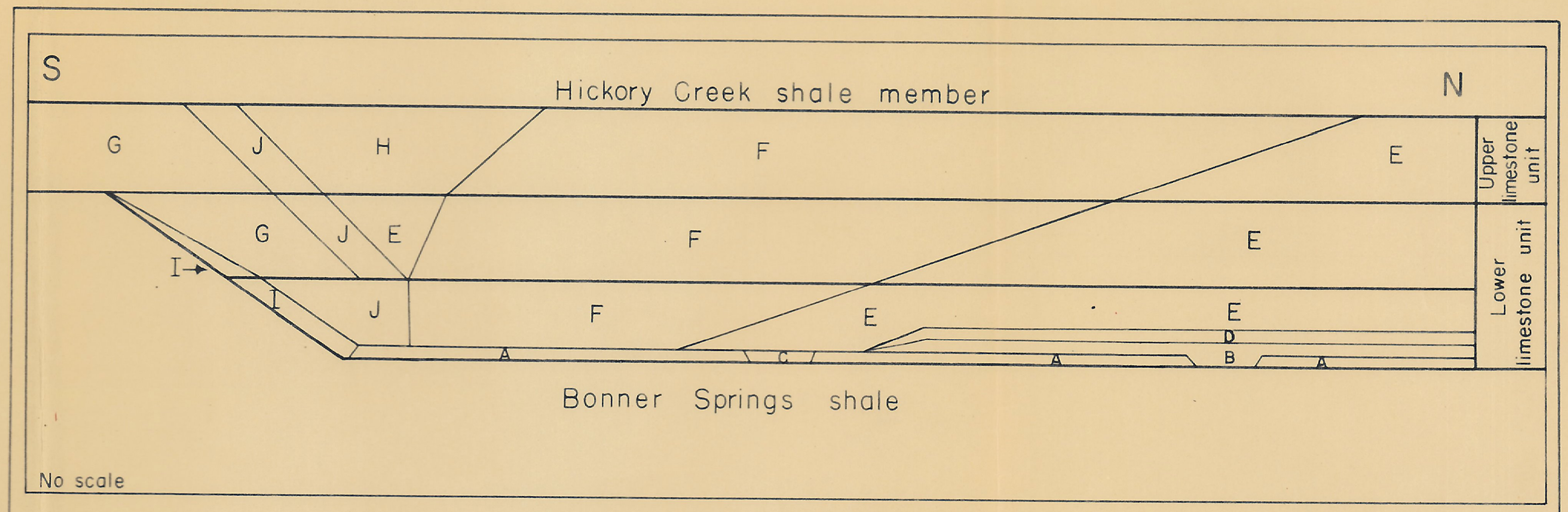
Fig. 4



Paleogeographic Maps of Merriam Time in Eastern Kansas



Generalized Stratigraphic Section of Merriam Limestone in Eastern Kansas



ENVIRONMENTS

- A — Strong wave and current action, shallow water, mixing zone
- B — Moderately strong currents, sandy bottom, shallow water (Composita zone)
- C — Local reducing environment, very gentle currents, bottom below wave base
- D — Quiet, clear, shallow water with gentle currents (~~Myalina~~ orthomyalina zone)
- E — Clear shallow water with gentle currents, bottom of limy muds or ooliths (Osagia)
- F — Quiet water to gentle currents, moderately shallow to deep water, primarily bottoms of limy muds, in places possibly dominated by fusulinids
- G — Clear water, bottom below wave base (sponge - crinoid community)
- H — Gentle currents to quiet water, algal habitat
- I — Influx of ~~clastic~~ argillaceous material
- J — Moderately strong currents, shallow water, molluscoid community

Generalized Paleoecologic Section of the Merriam Limestone in Eastern Kansas

Fig. 5