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Stratigraphy of the Kereford Limestone in Eastern Kansas

by

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STRATIGRAPHY OF THE KEREFORD LIMESTONE IN

EASTERN KANSAS

by

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Note: All figures subsequent to and including Figure 12, are photographs of sections measured and located in Appendix A. Where referred to in the text their page number may be found from the above list of illustrations.

ABSTRACT

A study was made of the stratigraphy of the Kereford Limestone member of the Oread Limestone (Shawnee Group; Virgilian Series, Upper Pennsylvanian) in eastern Kansas from outcrops whose localities range from Doniphan County in the north to Elk County in the south. Laboratory investigation of this limestone was conducted with the aid of etched blocks and thin sections and using the classification of Folk (1959). The unit is extremely variable in all characteristics. It is most constant in character in the northern part of the outcrop from Doniphan to Douglas Counties, consisting of an upper part with a high concentration of fusulinids and a lower part with a fauna which varies greatly in diversity and abundance. In the central part of the outcrop, in Franklin, Osage and Coffey Counties, the unit is much thicker and consists dominantly of a micrite which becomes increasingly more sandy southwards. The top of the unit in both areas shows evidence of having been deposited in a higher energy environment than the remainder. The unit in the southern part of the outcrop, from Woodson to Elk Counties is highly variable and appears to be the product of an environment where the energy levels were higher than those which existed in the basin of deposition in the north. The unit is interpreted as being deposited during a halt or slight transgression in the overall regression towards the end of the Oread megacyclothem.

INTRODUCTION

General Statements

This report on the stratigraphy of the Kereford Limestone in eastern Kansas is to record in some detail the distribution, lithologic and paleontologic features. The ultimate aim is to interpret environmental conditions extant during the deposition of the Kereford Limestone in this area.

The area studied in this report is located in eastern Kansas, in the physiographic division known as the Interior Lowland Province (Fenneman, 1938). North of the Kansas River the area is included in the Dissected Till Plain section of the Province, south of the river in the Osage Section. Exposures of the unit occur in Doniphan, Atchison, Leavenworth, Jefferson, Douglas, Franklin, Osage, Coffey, Woodson, Greenwood and Elk Counties. More detailed locations are shown in Fig. 1, and map references in Appendix A.

The Kereford Limestone, by virtue of its position as the uppermost member of the Oread Formation (Fig. 2) and its thinness in relation to the other members of the formation, rarely has any marked topographic expression, and almost all exposures of the Kereford Limestone lie well back from the Oread escarpment, which is usually formed by the thicker, more resistant, Plattsmouth Limestone. In the central part of the outcrop area in central Coffey County, where the underlying Heumader Shale is thick, the Kereford is unusually thick and is commonly associated with sandstones which locally are massive. There the member may form a scarp well above

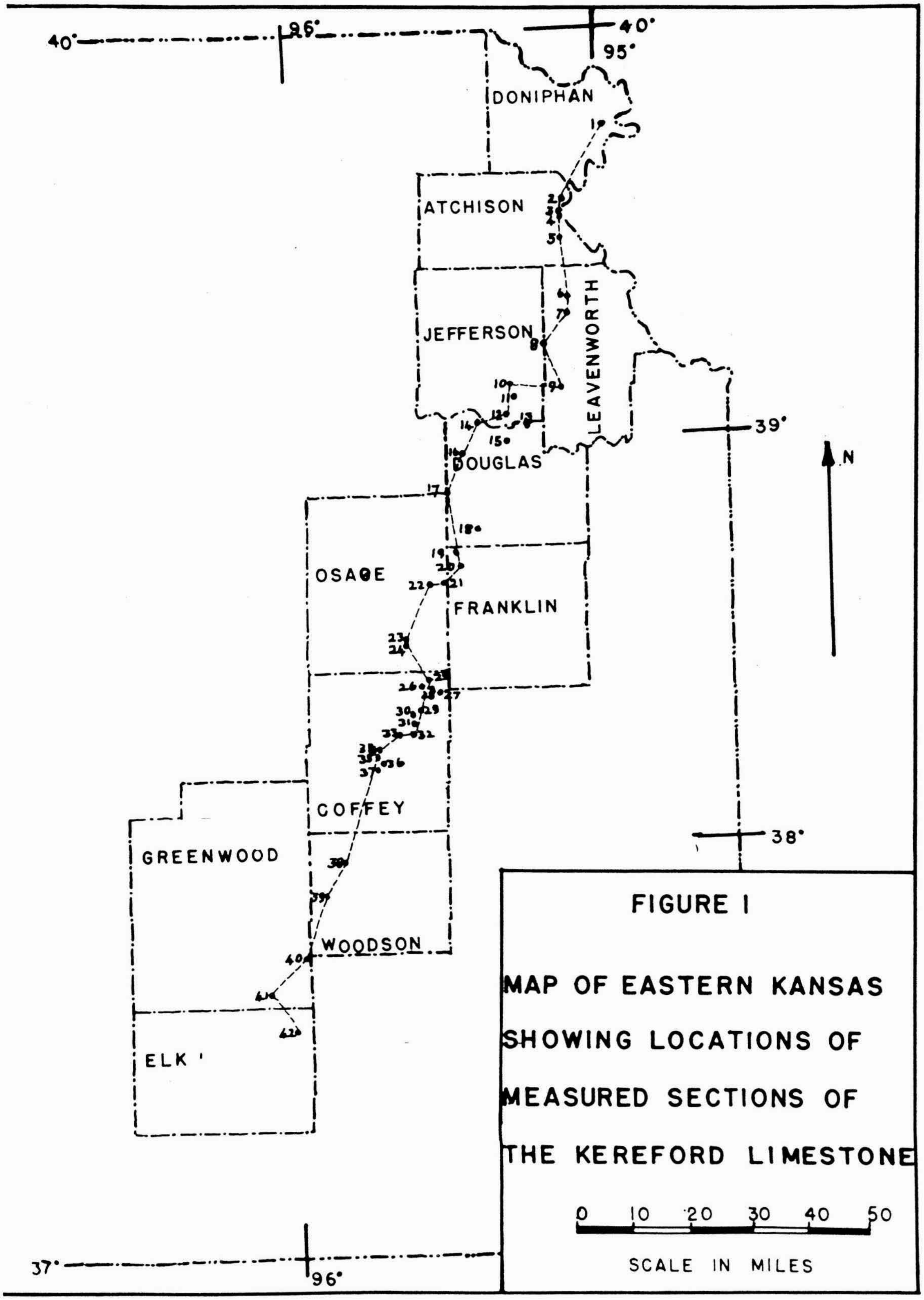

FIGURE I

MAP OF EASTERN KANSAS SHOWING LOCATIONS OF MEASURED SECTIONS OF THE KEREFORD LIMESTONE the Plattsmouth Limestone, and the sandstones appear to have a marked impression on the topography, producing treeless, rolling uplands.

Field Investigation

Outcrops of the Kereford Limestone were located mainly by reference to the stratigraphic section books in the files of the State Geological Survey. The geochemical branch of the Survey furnished the location of many exposures, which, inasmuch as they had been recently studied, were in excellent condition. In contrast, some of the exposures obtained from the stratigraphic section books were found to be covered or destroyed. Where information was poor, or more detailed correlation required, outcrops were found by driving county roads and by studying geological and topographic maps. Reference was also made to various theses.

The majority of outcrops visited were measured and described using the schedule proposed by Goldman (1923) and the terminology of McKee (1953). Where outcrops were found to be poor or fragmentary, note was made of the lithology and fossil content, mainly for use in correlation.

Vertically oriented samples were collected, commonly from 1 foot intervals and also from zones where significant changes in lithology or fossil content occurred. Very thick, apparently homogeneous units were sampled at intervals of 2 to 4 feet. Fossils were collected for more detailed identification.

Appendix A gives the detailed location and description of measured sections. Photographs at each locality are included in the appendix rather than distributed in the text; this arrangement was judged to be more useful to the reader. In each case the outcrop of Kereford is shown between lines.

Laboratory Analysis

Etched Block Study

The use of the classification of Folk (1959) determined the method of lithological investigation. Folk considers that only by the use of thin sections can carbonate rocks be accurately described and calssified. However, he claims that 80 percent accuracy can be obtained by the use of etched surfaces. The amount of time necessary for the preparation of thin sections was considered to be excessive, and so thin sections were made only as an initial control, or where an apparently significant lithological type was found, and in cases where identification and classification were doubtful.

The limestone samples were sawed in a vertical direction and the flat surface placed in a solution of 10 percent hydrochloric acid for up to 5 minutes, (the amount of etching that occurs is determined by the density of the limestone). Frequent examination of the surface with a hand lens, during the process, determined the optimum amount of etching. Ives (1954) gives a detailed discussion of the use of etched blocks. Study of the etched surface was made under a binocular microscope, and with practice it was found that in most cases the limestone could readily be classified.

Acetate Peel Study

Folk (1959) states that a similar level of accuracy of identification can be obtained either with acetate peels or etched blocks. Peels have the disadvantage that the distribution and identification of insoluble constituents cannot be determined, and the advantage that grain size and texture can be better seen. Commonly the Kereford Limestone has a high content of insoluble material so acetate peels are used mainly for illustration purposes, rather than as an aid in studying lithologies. Owen (1959) gives a description of the methods used in preparing the peels.

Insoluble Residue Study

The method, with a few modifications, follows that of Fisher (1958), who used that originally developed by Ireland (1951). Samples of limestone weighing 20 grams were dissolved in 10 percent hydrochloric acid. Coarse fractions were retained for subsequent study. The coarse fraction of samples from one locality where the limestone was highly arenaceous were sieved in order to determine the grain size. As the Kereford commonly has a high content of insoluble material it was felt that a study of the nature of this materia was necessary. Results of this investigation are shown in Appendix B.

Choice of Classification

The classification of limestones of Folk (1959) was chosen as it is felt that it gives more precision in the description of a limestone than any other classification, and also that the concepts underlying the classification are extremely useful in interpreting the conditions of deposition of the unit. It was not used in the field, although, according to Folk this can be done. Sucessful use of this classification is found to be very much a matter of experie-nce.

Previous Work

No detailed study has been carried out on the Kereford Limestone alone, but it is mentioned in numerous reports which are concerned with either larger groupings of rocks, or in studies of localized areas.

First reference to the unit probably was made by Bennett (1896, p.115) who, in a description of a section in the quarry at Lecompton, Kansas, states:

> "Above this, the [Plattsmouth Limestone] lies 1 foot of blue clay shales; [the Heumader Shale] then 6 feet of shelly, nodular limestone, with heavy clay partings abounding in well-preserved fossils,................"

Hinds and Green (1915, p.171) in their classification of the Oread Limestone mention that above the "upper limestone" of the Oread is the so-called "Waverly Flagging". Condra (1927, p.45) considered the name "Waverly Flagging" a non-geographic term, and first applied the name Kereford Limestone to a limestone which he describes as being:

> "dense, somewhat arenaceous, in part oolitic, and quite fossiliferous".

The type locality is the Kerford Quarry, just south of Atchison.

Further reference to the stratigraphy of the Kereford Limestone in localized areas may be found in several unpublished Masters' theses

(Laughlin, 1957; McLaren, 1958) and in the State Geological Survey reports on Osage County (O'Connor, 1955), Elk County (Verville, 1958), Douglas County (O'Connor, 1960), and also U.S. Geological Survey geologic map of the Fredonia Quadrangle (Wagner, 1954).

The general paleontology of the Oread Limestone has been studied by Delo (1928) and reference to it has been made in more specialized studies; for example, Ireland (1956) arenaceous Foraminifera; Squires (1952) bryozoans; the insoluble residues of the Shawnee Group have been studied by Perkins (1952).

Acknowledgements

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Thanks are also due to Mr. Stanton Ball and Mr. Walter Hill of the Geological Survey, for many stimulating discussions and to my wife, Jacqueline, for the typing of this thesis.

STRATIGRAPHY

General Statements

The Kereford Limestone is the topmost or "super" limestone of the Oread Limestone formation, a division of the Shawnee Group (Fig. 2).

A fairly detailed study of the development of the stratigraphic classification of the Kereford Limestone is given by Moore (1935).

The Oread Formation was originally classed as the topmost limestone member of the Douglas Formation of Haworth (1898, p.93). Moore (1932, pp.93-94) excluded the Oread Limestone from the (reclassified) Douglas Group on the basis that it is more related to the cyclic shale-limestone sequence of the overlying Shawnee Group than the predominantly clastic Douglas Group. In addition, the more readily mappable boundary occurs at the base of the Oread rather than at the top.

The name Oread Limestone was applied by Haworth (1894, p.123) in Moore, 1935 to the massive limestone now known as the Toronto Limestone immediately overlying the Lawrence Shale. This terminology is synonymous with the "lower Oread" of later workers. In 1895 Haworth (p.461) applied the name to two limestones, probably the "lower" and "upper Oread" of later usage. The limestone subsequently called Kereford was probably included in the latter, as it was by Bennett (1896, p.114). Hinds and Green (1915, p.31) recognised four limestone beds which included the limestone above the "upper" member, this limestone being the Kereford Limestone.

Moore (1935, p. 161) crystallized the classification of the Oread Limestone into its present form with four limestone members, and three intercalated shale members; these are respectively Toronto Limestone (base), Snyderville Shale, Leavenworth Limestone, Heebner Shale, Plattsmouth Limestone, Heumader Shale, Kereford Limestone (top).

Laughlin (1957) noted that the spelling of Kereford Limestone member by Condra (1927) differed from the spelling of the name of the type locality, the Kerford Quarry, in Atchison. Moore (1952, p. 366) considers that:

> "Stratigraphic names established by uniform usage in several publications shall not be subject to change in spelling, whatever the origin of these names or the advocated reason for change in orthography shall be."

The spelling of the word Kereford, as proposed by Condra in 1927 and used in subsequent literature, is therefore retained.

The Kereford Limestone in the Northern Part of the Outcrop in Eastern Kansas

The Kereford Limestone in eastern Kansas exhibits great variation in appearance, lithologic type and thickness. In the northern part of the outcrop, in Doniphan, Atchison, Leavenworth Jefferson and Douglas Counties, the unit is more constant in its features than in any other part of eastern Kansas; even here, however, there is considerable variation.

The thickness of the unit ranges from 8.6 feet at Locality 4 in the Kerford Quarry south of Atchison, to 1.6 feet at Locality 2, 2 miles north of Atchison. The unit in both localities , is rather abnormal in character, and generally the thickness decreases northwards. The thickness ranges from about 7 feet in Douglas, Jefferson and Leavenworth Counties, to 3 feet in Atchison and Doniphan Counties, although, as is shown above, there may be considerable variation in thickness within a few miles (Plate 1).

The appearance of the Kereford Limestone is relatively constant throughout the area. The lower part has thin slabby beds about 2 to 4 inches thick and is regularly bedded, often with a rather nodular appearance, and thin calcareous shale partings. In some exposures, as at Locality 7, just east of Easton, in northern Leavenworth County, the thicknesses of the interbedded shale and limestone may be sub-equal. At other exposures, for example at Locality 16, Douglas County, any semblance of regular bedding is lost, and the shale partings appear to be completely gradational into the limestone. This thin slabby part of the Kereford is completely absent from Locality 1, in northern Doniphan County.

The upper part of the Kereford approaches massive bedding, being usually a single thick, slabby or blocky bed about 2 feet thick. In any vertical exposure (Fig.22) it tends to be more prominent than the remainder of the unit. This rather massive, outstanding appearance disappears in central Douglas County (Fig.23), although the upper part is commonly thicker bedded than the underlying part of the member. Though the upper part of the Kereford is usually a single 2 foot bed in the northern part of the outcrop, in Jefferson and Douglas Counties it is a minor, though prominent part of the unit (which has a total thickness of about 7 feet), in the north, where the total thickness is much less, it may comprise virtually the whole of the unit (Fig. 15) with the underlying slabby limestone being reduced to one or two thin, rather nodular beds. Towards the top of this massive unit thin stringers of sorted shell material are seen, which, owing to differential weathering, tend to stand out. At Locality 4, in the Kerford Quarry south of Atchison, cross-stratification is seen near the top of the member.

Commonly, the contact of the Kereford Limestone with the overlying Jackson Park Shale is marked by a thin platy zone of coquinal limestone. The lower contact is usually sharp, although locally thin stringers of limestone are seen in the top of the underlying Heumader Shale. At Locality 6, the upper contact is marked in some places by a thin, (0.1 feet) layer of fibrous calcite, with the fibers normal to the bedding plane. This layer shows some of the features of cone-in-cone structure, and is believed to be post-diagenetic. At the same locality, 0.5 feet below the base of the Kereford, similar fibrous calcite occurs, separating yellow, very calcareous shale from a gray shale.

On fresh surfaces, the color of the limestone is generally light gray, or buff-gray, with the interbedded shales being a darker color. Commonly it weathers to a yellow-buff color, although in some exposures, as at Locality 3, in Jackson Park at Atchison, the color of the exposed surface is due to limonitic clay which has been washed down from the shale and sand of the overlying Jackson Park Shale.

In many outcrops, the lower slabby-bedded limestone appears very argillaceous. Examination of insoluble residues indicates a high content of clastic material (commonly about 20 percent). (Appendix B). In Locality 4, the limestone can only be distinguished from the over- and underlying shale by its lighter color; here the unit contains some 40 to 50 percent clastic material. The insoluble residue content of the more massive upper unit, where evidence of sorting is seen, is low. (Fig. 2). Locally pyrite is observed, and may be quite abundant in the insoluble residue.

The lower slabby limestone is commonly a fossiliferous micrite, however all gradations from a micrite to a biomicrudite were observed. In some exposures, notably Localities 12 and 15, an extremely high concentration of "algal material" may produce an algal biolithite near the base of the unit.

In Douglas County the upper, more massive part of the unit is almost entirely a fusulinid biomicrudite. Towards the top of this, thin stringers of reworked fossil material appear, and the upper surface of the member is commonly a "coquina" of fossil material. In some exposures, as at Locality 16 near Stull in Douglas County, this "coquina" has been called "oatmeal rock" by Jewett (personal communication) and it is separated from the top of the unit by a thin shale zone. On going northwards the ratio of the sorted shelly material to the fusulinid biomicrudite increases, until, in Atchison County, virtually the whole of the thick upper bed is composed of this material, and it is rarely a good biosparrudite as commonly the sorted shell fragments are in a micrite matrix. Oolites may be seen in some exposures, but only in Locality 4 d o they occur in sufficient quantity for the rock to warrant the appellation of "oosparite".

The fauna of the lower part of Kereford varies considerably both in variety of fossil types and in amount of fossil material. Generally, in the southern part of the area, the basal beds of the Kereford may be very fossiliferous, almost "reef-like", and the fossil content decreases sharply up to the upper fusulinid biomicrudite. In northern Leavenworth, Atchison and Doniphan Counties there is commonly a very sparse fauna in the lower part of the Kereford. Three phyla appear to be dominant, algae, bryozoans and brachiopods. In the south "Ottonosia" is very abundant near the base. Both ramose and fenestrellate bryozoans, often well preserved, are generally distributed throughout the lower unit. The brachiopods are very diverse, and are locally very abundant, as in Locality 18, near Globe in southern Douglas County. Composita is probably the most abundant genus in any one locality. Minor fossils are the pelecypods, chiefly Myalina (which is very abundant near the base of the Kereford in some exposures), although other pelecypod genera are seen; tabulate corals, ostracodes, snails (usually small), and crinoids, the latter usually occurring as articulated columnals. Triticites may be seen in this lower part, but it is generally very rare. (Fig. 2).

The upper, fusulinid biomicrudite, has a restricted but abundant fauna of Triticites, minor gastropods commonly of the bellerophontid type, and very rare brachiopods. Towards the top, in the sorted shelly material, the fauna becomes more diverse with Osagia, some

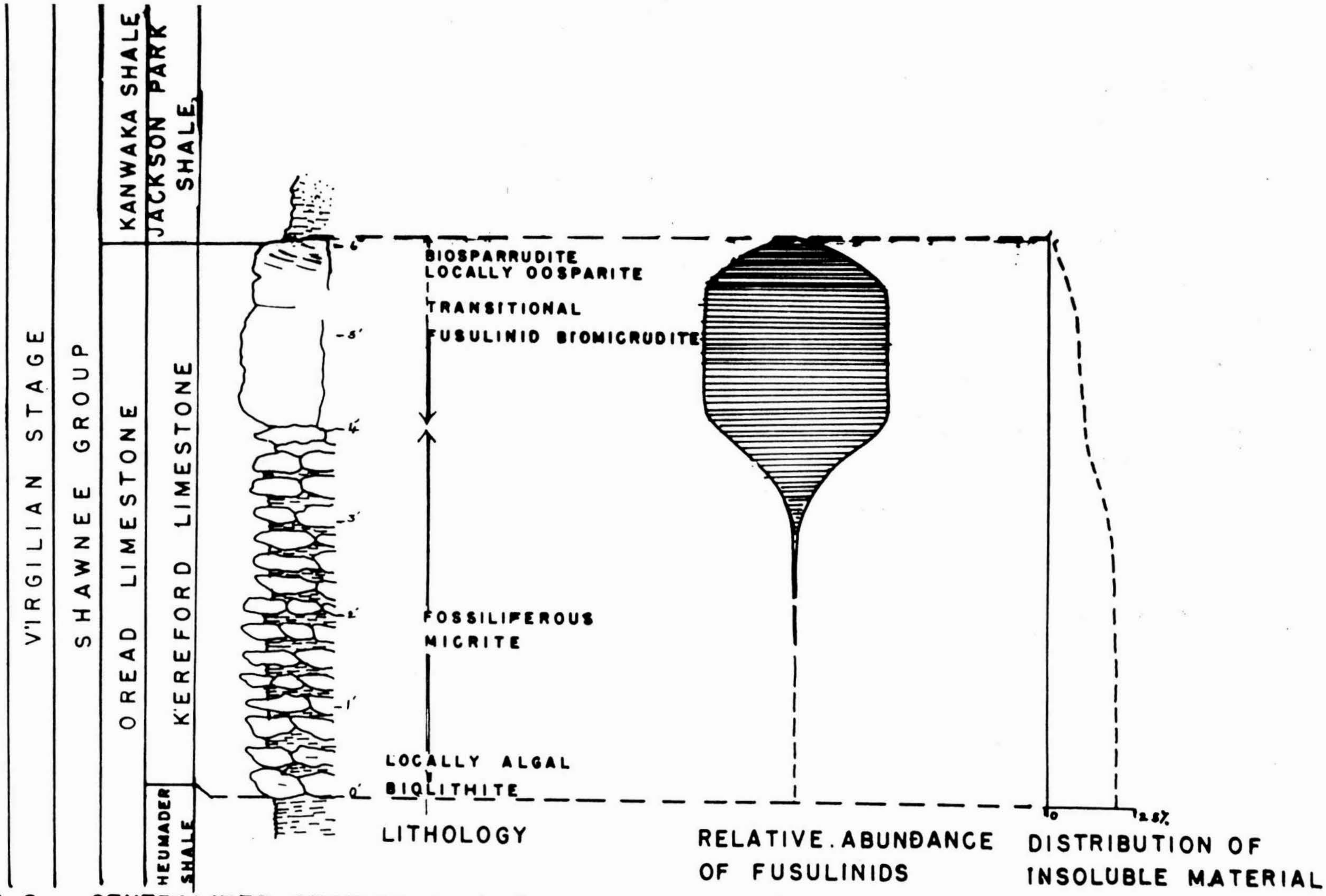

FIGURE 2 GENERALIZED SECTION OF KEREFORD LIMESTONE IN THE NORTHERN PART OF THE OUTCROP IN KANSAS

Triticites, bryozoans (usually ramose), shell fragments and disarticulated crinoid ossicles; occasionally, well preserved brachiopods occur on the upper surface.

Arenaceous Foraminifera are generally fairly equally distributed throughout.

The Kereford Limestone in the Central Part of the Outcrop

In Franklin, Osage and Coffey Counties the Kereford Limestone shows greater variation in lithologic type and thickness than anywhere else in eastern Kansas. What appears to be a gradual change of the unit in these characters can be traced from southern Douglas County into northern Franklin and Osage Counties. The word "appears" is used, as in southern Douglas County the upper part of the Kereford in the exposures seen, has been removed by erosion. Detailed correlation of the member in southern Coffey County with the unit further south is difficult, owing to the paucity of good exposures, and/or the absence of recognizable Kereford in the extreme south of Coffey County and northern Woodson County.

The member reaches the maximum thickness in this area. About 25 feet of Kereford are seen at Melvern in southern Osage County, and approximately 30 feet near Waverly in northern Coffey County. The thickness of the unit is reduced to 5 feet in the vicinity of Burlington, central Coffey County.

Two lithologic types occur which are not found in the northern part of the outcrop in eastern Kansas. In Franklin and Osage Counties a thick sequence of flaggy, rather regular bedded, unfossiliferous "lithographic limestone" occurs on top of the basal fossiliferous part of the unit. Farther south, in northern and central Coffey County, this "lithographic limestone" or micrite grades laterally into an arenaceous limestone or a calcareous, very fine-grained sandstone, which, as in Locality 31, changes upwards into a massive, scarp forming, fine-grained, non-calcareous sandstone.

As noted above, in southern Douglas County, the Kereford Limestone consists of a lower, slabby bedded, fossiliferous micrite and an upper fusulinid biomicrudite, with a total thickness of about 7 feet. In northern Franklin County, at Locality 2[illegible], this fossiliferous sequence becomes condensed down to about 3 feet, with essentially the same fossil distribution remaining. Overlying this is the micrite, which forms the major part of the Kereford Limestone in Osage County. Therefore, from evidence of fossils, this minor, lower part would appear to be equivalent to almost the entire Kereford in the north. At Locality 23, the lower fossiliferous part is unusually well developed but it is only 7 feet thick compared to a thickness of about 26 feet for the complete Kereford at this locality. It is commonly rather irregular and slabby-bedded and has calcareous shale partings. In some exposures the Kereford appears to be gradational into the underlying Heumader Shale. The upper contact is manifested by the more flaggy, regularly bedded, characteristically weathering micrite above, and by the remarkably sharp transition from a fossiliferous to a completely unfossiliferous micrite. Apart from the absence of fossils in the micrite, there are no marked changes in texture or in the content of insoluble material at this boundary. (See Appendix B).

This lower fossiliferous part is not found further south than Waverly and even here (Locality 26) it is a very minor part of the member.

Commonly it is a fossiliferous micrite; at Melvern, where there is an abundance of fossil material it is a biomicrudite.

Generally the relationship seen in the northern part of the outcrop with fusulinids in the upper part of the member and other fossils in the lower part, is repeated in the "condensed sequence" in the central area. The abundance of Triticites decreases southwards, until at Melvern, only a few scattered fusulinids are seen in the upper part of the lower fossiliferous zone.

The fossil content of the lower part of the Kereford in this area varies considerably in diversity and abundance. At Locality 24 there is a wide variety of forms, "algal material", sparse fusulinids, abundant horn corals, tabulate corals, diverse brachiopods, and crinoid ossicles. The fauna may be sparse elsewhere. Myalina is commonly found near the base of the unit, commonly associated with Juresania and Derbya. The forms occur at the top of the lower fossiliferous zone at Locality 24, and also Myalina is found with some brachiopods at the extreme southern extent of this lower fossiliferous zone in northern Coffey County where it is very thin in relation to the total thickness of the unit.

Overlying the lower fossiliferous part of the Kereford in Osage County, and the extreme north of Coffey County is the unfossiliferous, flaggy micrite. This forms the major part of the Kereford in Osage

County. Southwards in Coffey County, the arenaceous lateral equivalent of this micrite forms the dominant part of the member. In Osage County this part of the Kereford is a thick (16 feet) sequence of light-gray, hard, flaggy, and regular-bedded micrite, which becomes slabby towards the top. The micrite weathers into characteristic sharp-edged slabs. Between the flaggy beds are thin partings of what appear to be very finely laminated limestone rather than shale. The micrite in Osage County has an insoluble content of about 10 percent, mainly argillaceous material (Appendix B), but with a small amount of very fine sand and mica particles.

In northern Coffey County there is a change in this basic lithology. At Locality 25, 2 miles east and 1 mile north of Waverly, the average amount of insoluble material in the micrite is little more than in Osage County (Appendix B), but it becomes more shaly and silty towards the base. Near Waverly (Locality 26) the member appears very silty; this is especially apparent on the bedding surfaces, which are commonly very micaceous. The name "Waverly Flagging" of Hinds and Green (1915), probably originates from this. At this locality ripple marks (Fig. 3) with north-south trending axes are observed on some bedding surfaces where the amount of arenaceous material is fairly high. To the south as well as to the east of Waverly the lower part of this sequence becomes very sandy, and the upper part becomes a sandstone, as at Locality 27, 4 miles east of Waverly. At Locality 29, 4.5 miles south of Waverly, it is a micrite, containing some oolites and with a fairly low insoluble residue content. In some exposures the lower part of the Kereford below the micrite

FIG. 3. Locality 26. Coffey County. Apparent ripple markings on bedding surfaces of the Kereford Limestone.

is represented by stringers of sandy limestones in a calcareous shale. It is significant that this limestone-shale sequence occurs around the fringes of the area having a large sandstone content. South and east of Waverly the lower part of the Kereford is typically a very thin-bedded to laminated series of interbedded arenaceous limestones (arenaceous or quartzose micrite), calcareous sandstones, and quartzose sandstones. This is well seen at Locality 29 where the top of the underlying Heumader Shale also contains a few stringers of similar material in the shale.

Farther south and west, as in the exposure at Locality 32, any semblance of the flaggy-bedded sequence is lost. The basal part of the Kereford is a calcareous sandstone with very disturbed bedding, which grades upwards into a massive, blocky, or slabby fine-grained sandstone, which produces a fairly prominent scarp in the area.

The whole sequence of the Kereford in Coffey County is essentially unfossiliferous. Rare, well preserved Linoproductus, still with the spines attached, and long crinoid stems were found in a horizon towards the top of the exposure at Locality 25. (Appendix A). Fucoidal markings or worm borings occur in these lower flaggy beds. The disturbed bedding in Locality 32 may be due to an enfauna associated with the fucoid markings.

The basal part of the Kereford is seen about 2.8 miles west of Locality 32, in the vicinity of Sharpe in Coffey County. It is still arenaceous (about 30 percent insoluble material) but is a slabby, light-gray limestone, with fucoid markings, Linoproductus and crinoid ossicles. It is very similar in appearance to the weathered outcrop of Kereford at Locality 37 (Pecke's Quarry near Burlington) although at Burlington the clastic content is extremely low.

The Kereford near Burlington is about 5 feet thick, with thick slabby bedding and a sparse, diverse, fauna of "algal material", bryozoans, various brachiopods, and Myalina. A borehole drilled by the corps of army engineers in this vicinity showed that the shale below the Kereford contained thin bands of siliceous limestone, as in Locality 29, near Waverly.

For about 5 miles south of Burlington scattered incomplete outcrops of Kereford occur, which are similar in appearance and lithology to the unit at Burlington, but commonly are more fossiliferous.

Overlying the micrite at Melvern, southern Osage County, is a slabby locally cross-stratified oolitic limestone, about 2 feet thick. The lithology varies from an oosparrudite to a biosparrudite. The top part is coquinoidal with abundant brachiopods and pelecypods. It is not seen in northern Osage County at the Pomona Dam Site (Locality 22), but is well developed at the top of the Kereford in the vicinity of Waverly (Locality 25). South of Waverly at Locality 29 a thick (12 feet) sequence of micrite, containing stringers of oolites in a micrite matrix occurs on top of the sandy, flaggy lower Kereford. A similar sequence is observed in all other exposures in this area, except where the massive sandstone is developed on top of the Kereford.

The Kereford Limestone in the Southern Part of the Outcrop

Exposures of the Kereford Limestone in Woodson, Greenwood and Coffey Counties are not as abundant as in the area to the north. No exposures of Kereford were found in an area extending from a point about 5 miles south of Burlington, to five miles south of the Coffey-Woodson County line. Although it is possible to suggest the relation between the Kereford in these two areas, no detailed correlation can be made.

The member ranges in thickness from about 9 feet at Locality 40 in east-central Greenwood County, down to a feather edge in northern Elk County. There are no great changes in thickness, such as in the area to the north.

In Woodson County the Kereford can be divided into three parts, which tend to merge into one another southward. The lower part is a flaggy to slabby, locally cross-stratified, sandy biosparrudite to a biomicrudite. At Locality 39 (in central Woodson County) this lower part contains abundant Triticites; on the basis of this, and the type of lithology it is probably equivalent to most of the Kereford further south, where a fusulinid biosparrudite to biomicrudite comprises most of the unit. Osagia, fenestrellate and ramose bryozoans, Juresania, other brachiopods and Myalina are found in the lower part of the Kereford at this locality.

At Locality 40 (Greenwood County) the basal part of the Kereford is a fossiliferous micrite with sparse Triticites and Linoproductus which grades upwards into a fusulinid biomicrudite to biosparrudite.

The middle part of the Kereford in Woodson County is a slabby-bedded, highly arenaceous micrite or calcareous sandstone. The only evidence of fossils in this part are fucoid markings or worm borings. This rather minor part of the Kereford is possibly the equivalent of the entire Kereford to the north in Coffey County.

The upper part of the Kereford is a highly variable unit. In Woodson County it lies on the middle arenaceous micrite and in Greenwood County on the lower fusulinid limestone. In northern Woodson County it is an oomicrite and in central Woodson County it is a "reef-like" biolithite with abundant fossils, that comprise a locally well sorted biosparrudite. This may be reef debris. In Greenwood County this upper unit is a biosparrudite with locally abundant oolites.

The fauna of this upper unit is very variable; Osagia, Myalina, and shell fragments are fairly abundant. At Locality 39, central Woodson County, Syringopora occurs in the biolithite.

Wagner (1954) notes Kereford in the extreme northwestern corner of Wilson County. It is about 5 feet thick, with a lower fossiliferous part, a middle sandy part, and an upper sandy, rather unfossiliferous part. This would appear to be essentially similar to the Kereford in Greenwood County.

The Kereford continues to be a fusulinid biosparrudite micrite in northeastern Elk County, where it feathers out.

The lower contact of the Kereford is usually sharp. The upper contact may be an erosional interface. At Locality 43 (Fig.) a massive channel sandstone lies on an erosion surface in the Kereford. This sandstone, which is probably correlated with the Elgin sandstone

(Wagner, 1954), may locally be in a channel eroded down as far as the Plattsmouth. A similar erosional surface probably occurs at Locality 39.

INTERPRETATION OF LITHOLOGIC TYPES IN THE KEREFORD LIMESTONE

Keller (1954, p.61) considers that the two primary factors in the sedimentary process are the materials involved and the amount of energy available. McManus (1959, pp.58-59) gives a fairly detailed discussion of the importance of the concept of energy-levels. The limestone classification of Folk (1959) is fundamentally related to this concept. Two out of the three end members upon which the classification is based, the sparry calcite cement and the microcrystalline calcite ooze, according to Folk are a direct consequence of the energy levels extant at the time of deposition of the sediment. Evidence has been presented (Mamet and Berry, 1961) that at least in some localities the presence of micrite may not be due to differences in physico-chemical factors related to rates of accretion of calcium carbonate, and to the presence or absence of suitable nuclei for deposition. However the interpretation of Folk's classification in terms of energy levels appears to be valid, from field evidence, for the Kereford Limestone.

Microcrystalline Rocks

Micrite

In Osage County micrite forms the major part of the Kereford Limestone. The rock is a microcrystalline calcite ooze with a minor amount (about 10 percent) of terriginous material, mainly clay, but with some silt-sized quartz grains and muscovite.

Folk (1959,p. 12) considers that microcrystalline calcite ooze is formed by rapid biochemical or chemical precipitation in the absence of persistent strong currents, and can be formed in deep water or very shallow sheltered areas. The thicker sections of the Kereford Limestone in eastern Kansas consist dominantly of micrite. If approximate time equivalence can be assumed for the accumulation of the unit, then the micrite would appear to have been deposited rapidly. Weller (1960, p.168) infers that limestones formed in deep water accumulate slowly. This would seem to indicate that the micrite in the Kereford member in Osage County has been formed in shallow water. Near Waverly, in Coffey County, the sandy equivalent of the micrite has apparent ripple markings on some of the more highly silty bedding surfaces; the presence of these probably indicates shallow water. Ripple markings are not seen in Osage County in the micrite probably owing to the mechanical properties of fine calcareous ooze.

Microcrystalline Terriginous Rocks

Quartzose micrite to calcareous sandstone

This rock is composed of material which ranges from very fine sand to silt-sized (62 micron fraction dominant) angular, sub-equant, quartz grains and very minor amounts of clay material and muscovite, all set in a recrystallized micrite matrix. (See Fig. 4). Evidence of recrystallization of the calcite is provided on examination of thin sections by the shiny appearance of fractured surfaces, and the patchy undulose extinction of the calcite over fairly large areas in which many quartz grains are included. Insoluble residues indicate that the quartz grains make up about 50 percent by weight of the rock. This, plus evidence from thin sections, shows that the amount of quartz present is not sufficient to form a self-supporting framework whose pore spaces could be filled in later by cement. The quartz grains are so loosely packed that they must have been deposited together with microcrystalline calcite ooze in relatively quiet waters, where the ooze would not likely be removed by current action. Field evidence, provided by the thinly laminated regular bedding, absence of cross-stratification, and the slight amount of clay material present support the idea of fine sand settling out along with the calcite ooze in a low energy environment. Deposition seems to have occurred in relatively shallow water. It is suggested that the slight gradations in the sand:carbonate ratio, and the apparently greater concentration of sand on the bedding surfaces, are due either to slight changes of current, possibly microcrystalline calcite ooze being partially removed, or fluctuations in the amount of sand brought from the source area. The latter suggestion would appear more likely, as, in some localities the quartzose micrite grades up into an apparently non-calcareous, fine-grained sandstone, which shows no cross-stratification at any of the exposures examined.

The source of this sand would appear to lie to the south east. This conclusion is based on the fact that a lower concentration of sand occurs in exposures lying north and west of the sandy Kereford in Coffey County.

Microcrystalline Allochemical Rocks

Fossiliferous Micrite and Biomicrite

These allochemical rocks differ only from micrite in that they contain fossils in varying percentages. The dividing line between a fossiliferous micrite (1 to 10 percent allochems) (Fig. 5) and a biomicrite (greater than 10 percent allochems) (Fig. 6) is purely arbitrary, and all gradations are found in the Kereford Limestone. In a biomicrite, fossil material, in greater or smaller amounts, occurs in a matrix of microcrystalline ooze. This relationship indicates that the lithologic type is deposited in an area of little current action. In the Kereford Limestone there is some gradation into rocks which indicate a greater amount of current action. This will be discussed below.

Biomicrites are probably the most abundant rock type in the Kereford Limestone in eastern Kansas, being found in most localities. In Douglas, Jefferson and Leavenworth Counties, almost the entire Kereford unit is composed of this lithologic type. (As the size of the fossil material in these rocks is commonly greater than 1 mm., they are classified as biomicrudites).

Argillaceous material is the most common impurity in the Kereford biomicrudites, and locally this may be quite high.

Oomicrite

Folk (1959, p.22) states that oomicrite is an unusual lithologic type, being composed of oolites found in a high energy environment, and enclosed in a micrite matrix, the product of a low energy environment.

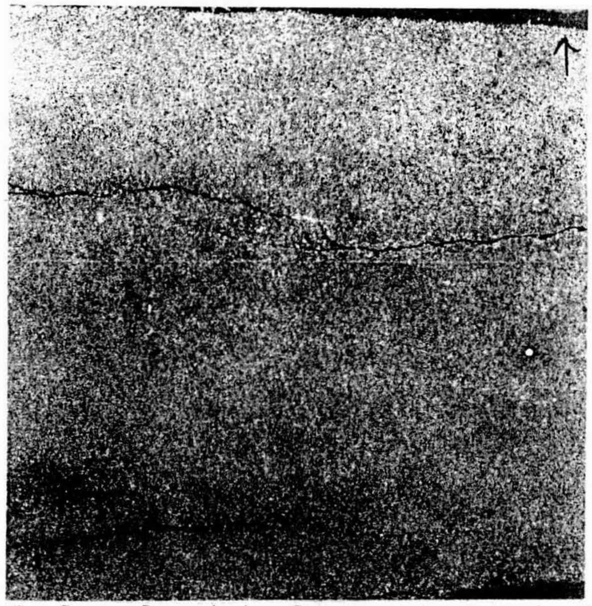

FIG. 4. Vertical peel-print of a quartzose micrite to calcareous sandstone, composed of about equal amounts of very fine sand sized to silt sized quartz grains set in a micrite matrix. Loc. 27 near base. (X2).

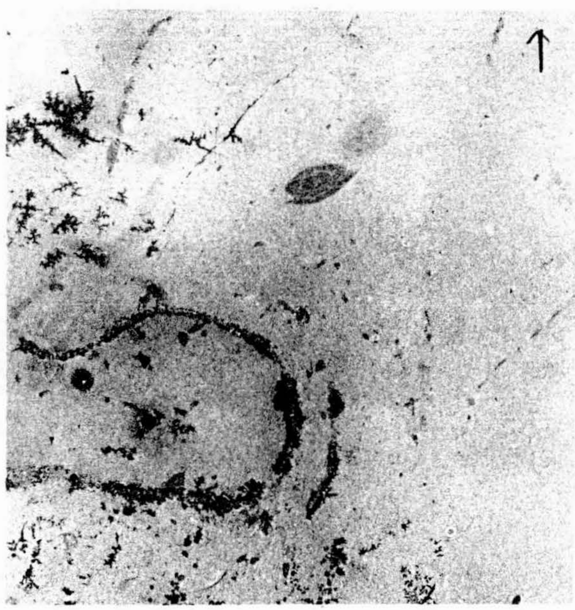

FIG. 5. Vertical peel-print of a fossiliferous micrite to a micrite. Note fine grained texture, and presence of pyritized shell material. Loc. 12,2 feet above base. (X2).

The oolites may be fairly abundant, but not present in sufficient quantities to form a self-supporting lattice, which subsequently could be filled with sparry calcite cement. Folk (p.22) considers that this rock might be formed in an area where two different energy levels occurred adjacent to one another, such as where channels with rapid currents protected marine flats.

This lithologic type is only seen well in one exposure (Locality 38) (Fig. 7) in northern Woodson County where it occurs at the top of the member.

Algal Biolithite

The term biolithite is a convenient one, used when the fossils are not disturbed from the position that they occupied in life. Biolithites grade into biomicrites. Algal biolithite is fairly abundant in several localities, particularly in the basal part of the Kereford Limestone in Douglas County. (Fig. 8).

Sparry Allochemical Rocks

These rocks consist of allochems, in the case of the Kereford Limestone these are fossils and/or oolites, cemented by a sparry calcite cement. Rocks of this type are indicative of a high energy environment, where any microcrystalline ooze deposited together with the allochems has been washed out by strong currents. There are few good examples of sparites in the Kereford Limestone because most of the rocks have features indicating a higher energy environment, such as sorted shell fragments, somewhat transitional between the micrites and the sparites. Folk (1961) would probably describe them as poorly

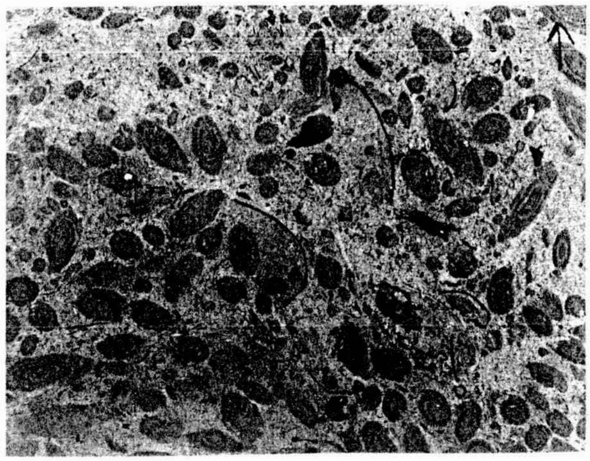

FIG. 6. Vertical peel-print of a fusulinid biomicrudite. Note apparent random orientation of Triticites. Loc. 16, 5 feet from base. (X2).

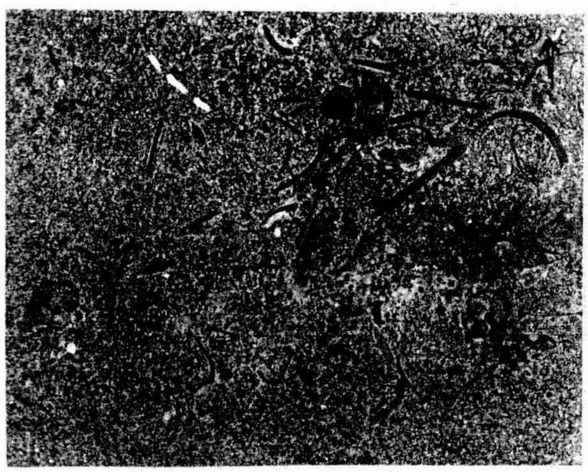

FIG. 7. Vertical peel-print of an oomicrite which is rather transitional to an oosparite. Note fine grained nature of matrix at top. Loc. 38, near top of unit. (X2).

FIG. 8. Vertical peel-print of a highly algal limestone, probably an algal biolithite. Note lamination of encrusting shells and areas of fine grained calcite ooze. Loc. 12, 1 foot from base. (X2).

washed biosparites.

The relative positions occupied by the limestone types indicative of high energy and low energy in the environment of deposition are constant in the northern and central part of the outcrop in eastern Kansas, with the high energy rock occurring invariably in the upper part of the member. This relationship is not followed in the south. In Woodson County lithologic types indicative of a higher energy environment occupy the upper and lower parts of the unit with a micrite separating them. Further south the micrite appears to pinch out and the whole member shows features of a high energy environment.

Biosparite

As is indicated above, good biosparite is rare in the Kereford Limestone. What has been called a "biomicrite-biosparite transition" in the descriptions of outcrops is an intermediate type between the two, probably corresponding to the new term of "poorly washed biosparite" (Folk, 1961). The fossil material is frequently indicative of sorting and current action, such as Osagia encrusting shell fragments (Fig. 9), size-sorted shell fragments, and disarticulated crinoid columnals (Fig. 10, 11), all of which may show rounding. Commonly many of these are packed tightly enough, as in the "oatmeal rock" in Douglas County, to form a lattice capable of supporting itself, yet the interstitial material is commonly micrite and possibly a slight amount of argillaceous material. However in general, the clay content of this rock is considerably lower than that of biomicrite.

Commonly, in the Kereford Limestone, the fossil material is greater than 1 mm in diameter, thus the appelation biosparrudite is used.

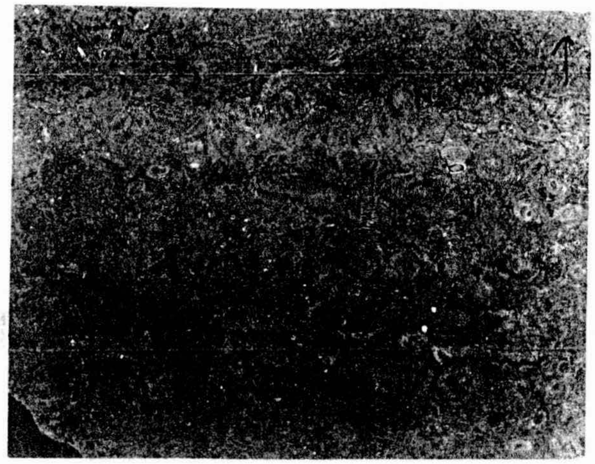

FIG. 9. Vertical peel-print of a limestone transitional between a biosparite and biomicrite, or a "poorly worked biosparite". Note presence of Osagia. Loc. 1, near top. (X2).

FIG. 10. Vertical peel-print of a brachiopod biomicrudite. Note brachiopod fragments, showing some evidence of sorting, set in a fine grained calcite ooze matrix. Loc. 3, 1.4 feet from base. (X2).

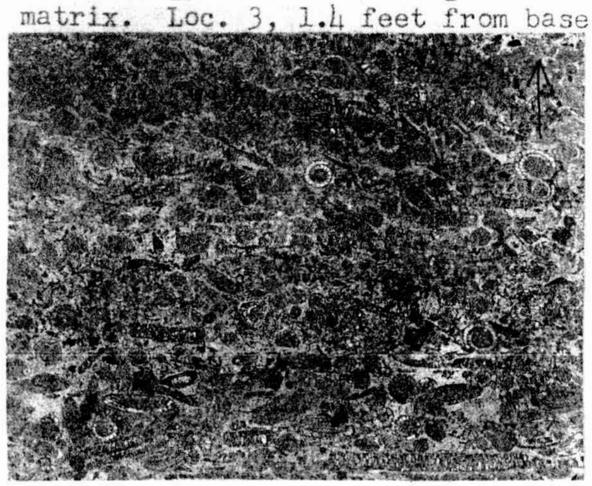

FIG. 11. Vertical peel-print of a fusulinid biomicrudite. Note similar orientation of Triticites and close packing, suggesting some sorting. Loc. 42. (X2).

Oosparite

Oosparite is not as common as the biosparite-biomicrite in the Kereford Limestone. Commonly some oolites are seen in the sorted shell-fragment limestone, but rarely in such abundance as to name the rock an oosparite. Where abundant oolites occur the rock usually has a sparry calcite matrix, this being in contrast to what is generally seen in limestones of sorted fossil fragments. Also cross-stratification, where seen, is much better developed in the biosparrudites. This may result from the fact that the small spherical oolites are possibly better adapted for sorting and clean-washing than the irregular fossil fragments, rather than that oolites indicate a higher energy environment.

There appears to be a very broad and general relationship between these two lithological types which show sorting, and the underlying rock. In much of the northern part of the outcrop, as in Douglas County, where the rock below the sorted material is very fossiliferous, the upper rock tends to be a biosparite. In Osage and Coffey Counties, where the underlying rock is a micrite, oosparites are dominant.

Very rarely, oomicrites are seen composing rock as noted above, but stringers of oolitic material may be found in a micrite, below overlying oosparite, which indicates the gradual approach of a higher energy environment.

These sorted rocks would appear to vary considerably in thickness over short distances. At Locality 3 about 1 foot of sorted shell material occurs, compared with about 7.4 feet at Locality 4, only 0.4

miles away. This would appear to indicate an environment with localized strong currents, possibly channeling and piling up material.

Areal Distribution of Different Lithologic Types

In the northern part of the outcrop in eastern Kansas the biomicrite and fossiliferous micrite found in the lower part of the member are indicative of low energy conditions. In the extreme north, in Doniphan and Atchison Counties, rocks of this lithological type are only a very minor part of the unit; further south, in Douglas and Jefferson Counties, they comprise almost the entire unit. The lithology in this area changes upward into a biosparite-biomicrite or even an oosparite, and cross-stratification is seen in some localities. This is indicative of an environment with a fairly high energy level. The change from one lithologic type to the other is generally transitional, stringers or sorted material occurring in a micrite matrix, though in south-central Douglas County, the sorted material occurs above a shale break and the underlying unit shows no indication of any change of energy levels.

In the central part of the outcrop area in Osage and Woodson Counties there is a marked increase in thickness of the unit, and an increase in clastic material, which tends to complicate the relatively simple picture in the north. In Osage County, and northern Coffey County, a well-developed oosparite with cross-stratification occurs above the dominant micrite. Even where there is a high sand content in the micrite, as in central Coffey County, in the exposures where the limestone is seen above the quartzose micrite, there is evidence that a high energy environment existed in the vicinity, as oolites and some layers of coquinoidal material occur in a dominantly micrite matrix.

The lithology of the member in the southern part of the outcrop, with the exception of the middle part of the unit in Woodson County, shows evidence of being deposited in a high energy environment.

PALEONTOLOGY AND ENVIRONMENTAL INTERPRETATION

The fauna of the Kereford Limestone is very diverse and locally abundant. There appears to be a close relationship between the lithology of the unit and its faunal content, and many of the changes of lithology seen can only be explained by reference to the paleontology.

Proposed attempts to measure quantitatively some selected fauna were not carried out, but some idea of the abundance of the fauna and the size of the individual fossils, may be obtained from the lithologic classification.

Many groups are represented in this member; algae, foraminifera, sponges, coelenterates, bryozoans, brachiopods, pelecypods, crinoids, ostracods and conodonts. Of these, probably the algae, foraminifera and brachiopods are the dominant groups.

Algae

Algal structures are locally very abundant, especially in some localities in the northern part of the outcrop. Here, in the basal part of the member in some localities, the algal material is so plentiful that the rock may be named an algal biolithite. The dominant genus is Ottonosia, but in any one locality, what has been referred to as "algal material" in the appendix may be more abundant. This consists of irregularly encrusted allochems, and also what appears to be sediment binding algae. In some instances the algal laminae are separated by sparry calcite. Harbaugh (1961) suggests that the laminae may enclose spaces which are consequently filled up by calcite cement, immediately subsequent to, or during, burial. These algae, found in the lower part of the Kereford appear to have a wide tolerance to oxidizing and reducing conditions. In some localities the laminations of the algae are replaced by pyrite.

In the sorted shell fragment limestones, which are indicative of a higher energy environment Osagia may be quite abundant.

In some exposures, as in Locality 34, small (about 1 cm. in diameter) irregular patches or sparry material occur in the laminae. These in some cases appear to have laminae associated with, and accordingly are labelled "algal material".

Lime secreting algae seem to be confined to the depths of less than 200 feet (Twenhofel, in Elias, 1937, p.420). On faunal evidence Elias (p.410) would place the environment of the calcareous algae at a shallower depth than most other contemporary forms.

In the Kereford they are found most commonly associated with brachiopods, especially Composita, less commonly with mollusks, and bryozoans. Osagia may occur with Triticites and various other shell fragments.

Foraminifera

Two groups of Foraminifera appear in the Kereford Limestone, the major one being the fusulinids, represented by Triticites. This, in respect to numbers is probably the most abundant form in the Kereford Limestone, occurring in most exposures, with the exception of those in Coffey County, although the abundance varies considerably. Triticites is extremely abundant in the south of the outcrop in eastern Kansas, being found as far south as the unit feathers out in Elk County. In northern Kansas it is abundant towards the top of the unit in Douglas, Jefferson and Leavenworth Counties. In these two areas the lithology of the rock containing Triticites is different. In the south and extreme north, in Doniphan and Atchison Counties, the lithology is indicative of a fairly high energy environment. In Douglas, Jefferson and Leavenworth Counties it is the reverse. Elias (1937, p.425) considered, on the basis of faunal evidence that the fusulinids occupy rather deeper water than the remainder of the contemporary biota: this would appear to be rather difficult to reconcile with the above facts of fusulinids being found in both a high and low energy environment.

In Douglas, Jefferson and Leavenworth Counties there is a marked relationship between abundance of fusulinids and the lithology of the rock. Much of the member in this area consists of thin limestones interbedded with shale, and containing rare, if any, Triticites. Where abundant fusulinids occur the shale partings are absent, or much fewer, and the rock has a more massive appearance. The amount of argillaceous material in these fusulinid biomicrudites is slightly lower. This would appear to indicate that the fusulinid biomicrudite was deposited further from shore than the limestones and interbedded shales. Towards the top of the more massive part of the Kereford in this area, where evidence of a higher energy environment becomes apparent, the fusulinid content decreases slowly. Triticites may be found in the lower part of the member, but it is very rare, and in one locality a few were found in the top of the Heumader Shale.

Where the fusulinids are abundant other groups are absent or very rare. Gastropods, in particular bellerophontid gastropods occur in the fusulinid biomicrudite but are not abundant. In the fusulinid biomicrudite-biosparites, _Osagia_ is quite abundant.

Arenaceous Foraminifera are found in most localities where the member is fossiliferous. _Ammovertella_ is commonly the most abundant genus, but locally _Ammodiscus_ or _Tolypammina_ may be dominant. They do not appear to be restricted to any particular lithology.

Sponges

Sponge spicules are not very common in the Kereford Limestone, but are found in insoluble residue and observed in thin section from some localities. These sponge spicules are of the simple monaxonid type.

Coelenterates

Both tabulate and rugose corals are found in the Kereford Limestone, although they are nowhere very abundant, and occur only locally.

Syringopora occurs in the basal part of the member in Douglas County, near Melvern, in Osage County and in Woodson County. _Lophophyllum_ is found at Melvern.

The corals occur in the unit only where there is an abundant biota, this would indicate that they are only found where very favorable environmental conditions existed.

Wells (1957) notes that most Paleozoic corals were not attached in the adult stage, hence few Paleozoic forms were adapted to a reef environment, near the surface of the sea, where the current action would be expected to be strong and also there is no evidence that they favored deep water, and on the basis of this, suggests that they lived in a similar ecologic niche to that occupied by present day sheltered, lagoonal corals growing in warm, fairly shallow, well oxygenated water.

The horn corals at Melvern are almost invariably lying sub-parallel to the bedding, and occur in the shale partings in the unit, as well as the limestone. Weller (1960, p.197) notes that horn corals are common in argillaceous sediments, whereas colonial corals tend to occur much more commonly in limestones, although at Locality 17, in Douglas County, one specimen of Syringopora was found in the top of the Heumader Shale, just below the limestone.

Bryozoans

Fenestrellate and ramose bryozoans are very abundant in the Kereford Limestone. Probably the commonest type are fenestrellate, and in some localities, as in the basal part of the unit in Douglas County, are very well preserved. Ramose bryozoans, notably Rhombopora appear to be the dominant type in the sorted shelly limestones, although this may be due to their greater resistance to fragmentation. Fistulipora is seen at one locality in Jefferson County.

The environmental significance of bryozoans is treated fairly fully by Duncan (1957) and evidence is presented that bryozoans did not occupy deep (probably less that 200 feet), or extremely shallow water (above wave base), although encrusting bryozoans, such as Fistulipora can occur in very shallow water. Some fenestrellate and ramose bryozoans were found in the top of the underlying Heuader Shale.

Fucoid Markings or Worm Borings

These are most abundant in the sandy phase of the Kereford Limestone.

Brachiopods

These are abundant and diverse, although few specific genera appear to have environmental significance.

Probably the most abundant genera are Composita and Dielasma, which may locally form almost a "coquina" exclusive of other brachiopods. Other genera are Hustedia, Wellerella (rare), Neospirifer, Punctospirifer (rare), Marginifera, Echinoconchus, Derbyia, Derbyoides, Juresania and Linoproductus.

The last four genera appear to have some environmental significance. Derbyia, and the closely related Derbyoides are frequently found in the more argillaceous part of the unit, and at some localities in the shale below the member. The association of Juresania with molluskan faunas is noted by Elias (1937, p.409) and this is seen in several exposures in the Kereford Limestone, Juresania occurring with Myalina at the base of the unit, and also near Melvern, being very abundant together with Myalina and Derbyia just below the micrite.

Linoproductus also appears to be able to occupy ecological niches which are not available to other genera, being found (together with rare crinoid stems) in the micrite phase of the Kereford in northern Coffey County. (Similarly Linoproductus oklahomae is found to the near exclusion of other forms in the Elgin Sandstone, (personal communication, Stanton Ball)). This genus may have a particularly wide tolerance to certain conditions.

Pelecypods

These usually do not occur in great numbers, and appear to be rather restricted.

Myalina is by far the most abundant genus, being found in many localities. Newell (1942, p.19) considers that the Mytilacea favored conditions similar to those of modern Mytilidae, which are found in the littoral and shallow neritic zones, and are able to withstand considerable variation in salinity. Myalina occurs commonly at the base of the Kereford, and may be present in the underlying shale. In some localities it occurs at the top, although this is rare. The association of Myalina with Juresania is noted above.

Other genera of pelecypods found in this formation are Chaenomya, Cardiomorpha, Allorisma (?) and Aviculopecten. Aviculopecten occurs either at the base of the unit, or in the upper, sorted, shell fragment limestone.

Commonly the pelecypods show evidence of recrystallization to sparry calcite. At one locality silicification had taken place almost exclusively among the mollusks. This is probably due to the metastable aragonite shell of the pelecypods being altered to calcite, or being silicified in preference to the calcite brachiopod shells.

Gastropods

These are a minor, but fairly common element in the Kereford biota. Small high and low spired gastropods occur in most of the lithologies. Bellerophontid gastropods are observed commonly in the fusulinid biomicrudite in the northern part of the area, and may rarely be found in the lower part of the member. At one locality a large euomphalid gastropod was found in the basal part of the unit.

Ostracodes

Cavalina was found at one locality, fairly well distributed throughout the unit, the shells being heavily pyritized and being observed in the insoluble residues. Possibly many of the small shell fragments observed in the etched blocks belong to ostracodes.

Crinoids

No crinoid calices were found, although crinoid ossicles may be fairly abundant in some localities, particularly in the rocks which indicate a higher energy environment. The amount of articulation or disarticulation of the crinoid stems probably provides a good indication of the energy level in the environment or deposition.

Conodonts

One conodont was found near the base of the unit at the same locality as the heavily pyritized ostracodes above.

ENVIRONMENT OF DEPOSITION OF THE KEREFORD LIMESTONE IN EASTERN KANSAS

The results of a report of this nature, based on the study of an essentially linear outcrop pattern along the strike of the unit, provide rather limited sources for the interpretation of the environment of depostion.

As stated above, the two most important factors in the sedimentary process are materials and energy. Therefore a consideration of the energy levels extant in the environment of depostion is of considerable value in interpretation. Lithological evidence indicates that during the depostion of the lower part of the member in the northern and central part of the outcrop in eastern Kansas, a low energy level, with little or no strong current action was maintained in the basin of deposition. A high energy level with strong current action prevailed during the depostion of the upper part of the unit in the north and central part of the outcrop, and for the whole of the unit in the south.

Consideration of the theory of cyclothems and the position of the Kereford Limestone at the top of the "Oread" megacyclothem provides an explanation for these differences in lithology. The Kereford unit was deposited during the overall regressive phase of the "Oread" megacyclothem. It is believed that the member was deposited as a result of a halt in the general regression, which would probably cause a decrease in the amount of clastic sediment being brought into the basin of deposition, or else a slight transgression. This was then followed by a marked regression as the continuation of the regressive phase of the "Oread" megacyclothem.

In the northern part of the outcrop, where the unit displays more constancy in its characteristics than elsewhere, the transgression would appear to have been slight, as can possibly be deduced from the abundant shale partings characteristically seen in the lower part of the unit, and also, in the extreme north of the area, the gradation of shale into the limestone seen in some localities. The lithology indicates that these lower sediments were deposited during quiescent conditions. The shallowing of the sea during the regressive phase caused the depostion of the upper part of the limestone to occur above wave base, causing sorting, and winnowing much of the microcrystalline calcite ooze. In some localities the current action appears to have been strong, causing cross-stratification, and probably the piling up of shell fragments and oolites into shoals as shown by the exposures at Localities 3 and 4 where the sorted material increases from about 1 foot to 7.4 feet over a distance of 0.4 miles.

The member in the southern part of the outcrop does not follow this pattern of initial quiet deposition and later strong current action, but appears to have been affected by current action during the whole of the time the Kereford was being depositied. It can only be suggested that the sea was initially much shallower, and at all times the depostion was above wave base.

Evidence provided by the underlying Heumader Shale and overlying Jackson Park Shale seems to support this idea of an interruption in the regressive phase of the "Oread" megacyclothem. There is no evidence that the entire Heumader Shale was deposited in brackish water although there are indications that in some localities it may have been formed fairly near the shore. In some localities a fauna considered to be typically marine (ramose and fenestrellate bryozoans, Derbyia and rarely Syringopora, crinoid columnals and Triticites), is found at the top of the shale. At other localities, generally where the shale appears gradational into the limestone, Myalina with associated Juresania and Derbyia occurs. This fauna is regarded as being indicative of a near shore environment. It is to be emphasised that the number of localities where fossils occur in the Heumader Shale is limited, and the fossils are usually only found in the extreme top of the unit; generally at these localities the overlying Kereford Limestone is also extremely fossiliferous. Sand is only found in the Heumader Shale at the extreme southern extent of the Kereford outcrop. All indications point to the fact that the Heumader Shale is a marine deposit; possibly some of it may have been deposited in brackish water and the environment of deposition continued into the Kereford. In contrast the overlying Jackson Park Shale indicates a marked regression. It is typically sandy, and in several localities plant remains are found, and may have accumulated at or above sea level.

It would appear that the surface upon which the Kereford was deposited varied considerably in character. Faunal associations in the basal part of the Kereford Limestone indicate that in many places initial deposition of the unit occurred a long way from shore. In Douglas, Jefferson and Leavenworth and Osage Counties commonly an abundant marine fauna is found immediately above the base of the unit. If the underlying Heumader Shale had been a brackish water deposit this would not be expected; instead a brackish water fauna would probably occur at the base of the limestone. However, in the extreme northern part of the outcrop, and in central Coffey County these lower limestones are essestially unfossiliferous. At some localities, particularly in Jefferson County, the basal part of the Kereford is very pyritic and may have a less abundant fauna. The sea floor, prior to deposition of the Kereford may have been so irregular that isolated areas occurred where reducing conditions may have existed. This irregular surface may have provided protection from wave action giving quiescent conditions for the initial deposition of the Kereford.

The greatest transgression of the sea is possibly marked by the level of greatest abundance of Triticites in the member. As noted above, where fusulinid concentration is high the amount of clastic material shown tends to be low. The content of clastic material in the limestone probably decreases with distance from shore. As abundant fusulinids are found in lithologic types which are the products of high energy levels in the basin of depostion, as in the south of the outcrop in Kansas, and also low energy levels, as in the north, it would appear that if the energy levels in an environment are an indication of water depth then the presence of abundant fusulinids are an indication of distance from shore rather than depth of water.

In the central part of the outcrop, the great thickening of the unit, produced by the related micrite and quartzose micrite is superimposed upon the general picture of transgression and regression.

As noted above, the source of the terriginous material seems to have been to the southeast, and it appears to have been deposited under quiet conditions, possibly in fairly shallow water. The fine-grained sand and silt are visualized as settling out together with the calcareous ooze. Possibly the sand may have have been brought into the basin of depostion by fresh water, thus creating a brackish water environment. This could explain the faunal assemblages which are found immediately below the micrite in Osage and Coffey Counties. Myalina, often large, together with Juresania and Derbyia, are locally very abundant. No changes in texture or insoluble residue content are noted, merely a very abrupt lack of fossils. This can only be explained by a change in salinity of the water. The rare occurrence of Linoproductus and crinoid stems indicate that the environment of depostion of the micrite was not completely inimical to marine life at all times.

The sands in the arenaceous micrite are well sorted, both mechanically and chemically. It may be noted that the Bourbon Arch (Jewett, 1951) passes through the area where the sands are concentrated. Possibly this influx of clastic material is associated with the presence of this structure.

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APPENDIX A

MEASURED SECTIONS OF THE KEREFORD LIMESTONE MEMBER IN EASTERN KANSAS

Locality 1

SE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 19, T. 3 S., R. 22 E., Doniphan County. Section measured in Everett's Quarry, just south of U.S. Highway 36, 2 miles northwest of Wathena (Fig. 12).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (approx. 20.0')

5. Shale, gray, weathering buff, seemingly unfossiliferous..20.0'

Oread Limestone Formation

Kereford Limestone Member (3.0')

4. Biosparrudite-biomicrudite transition, light-gray, locally weathering tan, slabby, slightly pyritic, upper contact sharp with a few thin limestone stringers in the immediately superjacent shale, lower contact marked by a thin calcareous shale parting, *Osagia*, rare *Triticites*...1.1'

3. Fossiliferous micrite, light-gray, slabby, slightly pyritic, fossils irregularly distributed and not abundant, "algal material", arenaceous Foraminifera, mainly *Ammodiscus*, ramose bryozoans, shell fragments, spicules, *Marginifera*, *Myalina*..........................0.9'

2. Fossiliferous micrite, light-gray, slabby, slightly pyritic, lower contact sharp, "algal material", arenaceous Foraminifera, mainly *Ammodiscus*, shell fragments, spicules, *Myalina*..............................1.0'

Heumader Shale Member (2.7')

1. Shale, medium gray, calcareous, *Myalina* at top...........2.7'

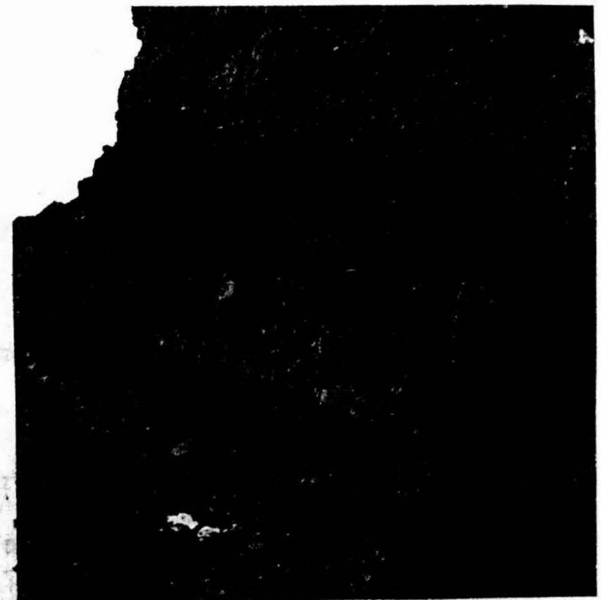


FIG. 12. Exposure of the Kereford Limestone at Locality 1, Atchison County. Unit consists of three, thick slabby beds.

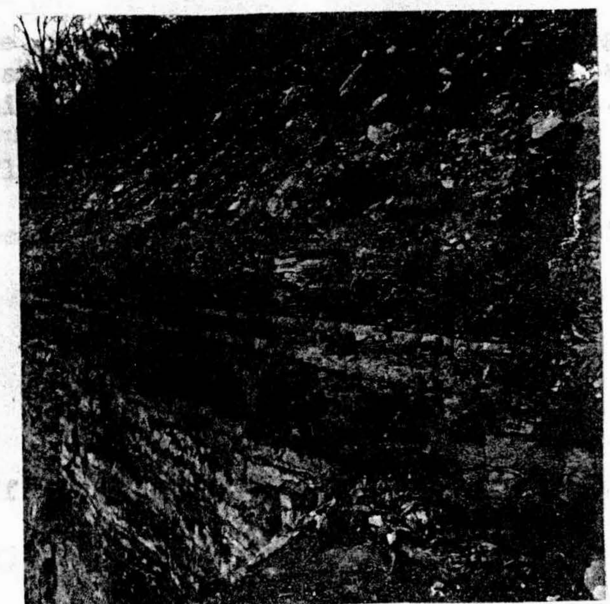


FIG. 13. Exposure of the Kereford Limestone at Locality 2, Atchison County. Note that the member can only be distinguished from the over- and underlying shale by its lighter color and slightly thicker bedding.

Locality 2

SW¼, Sec. 18, T. 5 S., R. 21 E., Atchison County. Section measured in quarry, east side of read, 2 miles north of Atchison (Fig. 13).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (15.0')

5. Shale, gray, weathering buff, shaly, silty.........approx. 15.0'

Oread Limestone Formation

Kereford Limestone Member (1.6')

4. Argillaceous micrite-calcareous shale, light-gray, slabby, slightly gradational with shale..................0.6'

3. Shale, calcareous, shaly to flaggy, unfossiliferous.......0.6'

2. Argillaceous micrite-calcareous shale, light-gray, slabby, slightly pyritic, gradational contacts, unfossiliferous......................................0.4'

Heumader Shale Member (2.0')

1. Shale, medium gray, shaly, calcareous, unfossiliferous....2.0'

Locality 3

SE¼, Sec. 7, T. 6 S., R. 21 E., Atchison County. Section measured in quarry in bluffs above river, in southeast part of Jackson Park, Atchison (Fig. 14).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (10.0 +)

4. Shale, limonitic, shaly to flaggy, silty, apparently unfossiliferous....................................10.0+

Oread Limestone Formation

Kereford Limestone Member (3.8')

3. Fossiliferous micrite to biomicrudite near base, grading upwards into a biomicrudite-biosparrudite transition with some oolites near top, light-gray, limonite stained, blocky, upper contact is sharp with a few thin stringers of flaggy, cross-bedded oosparite in the shale immediately superjacent to the unit; lower contact is sharp, with an undulating bedding surface. Fossil distribution is irregular near base of unit stringers of abundant fossils are interlayered with fossiliferous micrite; rare Triticites, ramose bryozoans, shell fragments, small high-spired gastropods, disarticulated crinoid ossicles..2.4'

2. Fossiliferous micrite grading into a micrite near base, with a brachiopod biomicrudite immediately subjacent to the overlying unit, medium gray, limonite stained, slabby to flaggy, rather irregularly bedded, interbedded with limonitic, calcareous unfossiliferous shale; lower contact sharp, with very thin stringers of micrite immediately subjacent; fossil content low and irregularly distributed, mainly spicules, shell fragments, at top layer of abundant brachiopod shells, oriented sub-parallel to bedding, Composita..............1.4'

Heumader Shale Member (5.6')

1. Shale, light-gray, limonitic, seemingly unfossiliferous...5.6'

Locality 4

NE$\frac{1}{4}$, WE$\frac{1}{4}$, Sec. 18, T. 6 S., R. 13 E., Atchison County. Section measured in Kerford Quarry, approximately 0.4 miles south of Locality 3. (Fig. 15).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (approx. 10.0')

4. Shale, medium gray, clayey to shaly................approx. 10.0'

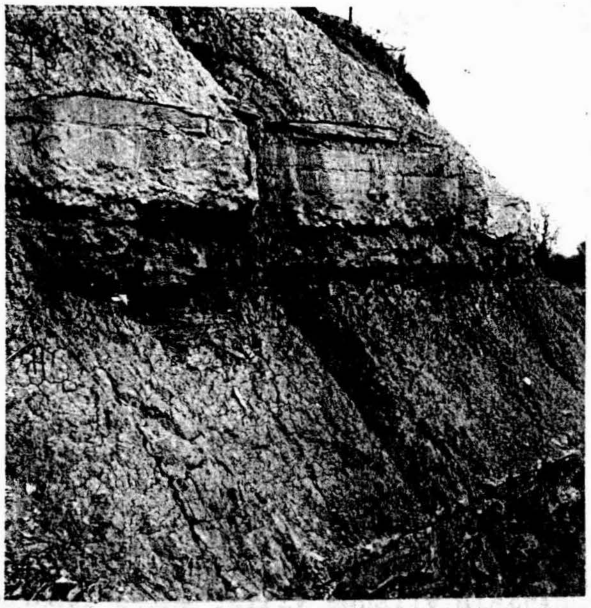


FIG. 14. Exposure of the Kereford Limestone at Locality 3, Atchison County. Note the flaggy, rather nodular limestones in the lower part and the more massive upper part, typical of the Kereford Limestone in the northern part of the outcrop.

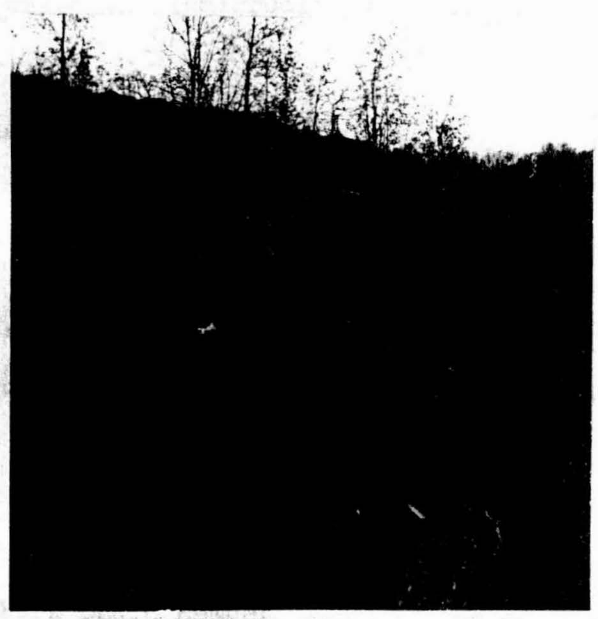


FIG. 15. Exposure of the Kereford Limestone at Locality 4, in the Kerford Quarry, Atchison County. This is the type section of the member. Note the thickness of the upper part of the unit, compared to that in Fig. 3, only 0.4 miles away.

Oread Limestone Formation

Kereford Limestone Member (7.4')

3. Oosparite-oomicrite at top, grading into biosparrudite and oosparite lower down, to a fossiliferous micrite at base; buff, tan weathering; unit composed of four slabby units of sub-equal thickness separated by almost plane partings without shale, undulating bedding surfaces within the unit indicated by differential weathering of shell fragment layers, slight cross-stratification at top, sharp contacts at top and base, spicules and small sorted shell fragments in discontinuous stringers near base, Osagia, fairly abundant Triticites and disarticulaed crinoid ossicles higher up, small algal encrusted shell fragments and rhomboporoid bryozoans at top, with Ammovertella and Ammodiscus being fairly equally distributed throughout....6.2'

2. Micrite with brachiopod biomicrudite immediately subjacent to the overlying unit; medium gray, flaggy to slabby, rather nodular, interbedded with calcareous shale, slightly gradational contact with shale below, few algal (?) structures seen near base, abundant Composita in biomicrudite at top........................1.2'

Heumader Shale Member (5.2')

1. Shale, gray, seemingly unfossiliferous..................5.2'

Locality 5

SW¼, NW¼, Sec. 32, T. 6 S., R. 21 E., Atchison County. Section measured in quarry, 3/8 mile west of State Highway 7, 4 miles south of Atchison.

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member

3. Shale and sandstone, yellow, platy to flaggy.............._____

Oread Limestone Formation

Kereford Limestone Member (2.6')

2. Micrite, at top fossiliferous micrite; buff, flaggy to slabby, with interbedded calcareous shale partings, slightly wavy bedding surfaces, upper contact sharp, lower contact gradational; uppermost bed with zone of disarticulated crinoid ossicles and small shell fragments sub-parallel to bedding, Composita, Aviculopecten (?), fucoidal markings or worm borings.....2.6'

Heumader Shale Member (6.1')

1. Shale, medium gray, thin calcareous zone at top, unfossiliferous..6.1'

Locality 6

NW¼, NW¼, Sec. 20, T. 8 S., R. 21 E., Leavenworth County. Section measured in quarry, 0.5 miles east of Easton (Fig. 16).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member

5. Shale, yellow, interbedded with flaggy to slabby sandstone..

Oread Limestone Formation

Kereford Limestone Member (6.4')

4. Biomicrudite to biosparrudite, buff, yellow weathering, blocky, bedding surfaces within the unit indicated by differential weathering of shell fragment layers, upper contact locally marked by a layer of fibrous calcite, 0.1' thick, fibers normal to bedding planes, lower contact slightly irregular but sharp, Osagia, Triticites, spicules, brachiopod fragments, bellerophontic gastropods, crinoid ossicles..................................2.1'

3. Micrite, buff, flaggy to slabby, rather nodular, interbedded with approximately equal thickness of yellow, calcareous shale, lower contact sharp, rare Derbyia.......4.3'

Heumader Shale Member (3.8')

2. Shale, yellow, earthy, limonitic and calcareous, lower contact locally marked by a fibrous calcite layer...0.5'

1. Shale, medium gray, shaly..............................3.3'

Locality 7

SW¼, Sec. 32, T. 8 S., R. 21 E., Leavenworth County. Section measured in road cut on north side of county road, near top of hill.

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (3.0')

3. Sandstone, buff-colored, cross-stratified, lower contact possibly erosional..............................3.0'

Oread Limestone Formation

Kereford Limestone Member (2.0')

2. Micrite, light-gray, weathers buff, slabby to flaggy, argillaceous, lower contact sharp, sparse shell fragments, Triticites..............................2.0'

Heumader Shale Member (6.0')

1. Shale, yellow, limonitic, clayey..............................6.0'

Locality 8

SE corner, Sec. 28, T. 9 S., R. 20 E., Jefferson County. Section measured in stream bank, adjacent to farm roadway, 50 yards west of Leavenworth-Jefferson County line (Fig. 17).

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (6.5')

3. Fusulinid biomicrudite, locally biosparrudite at top, brown-gray, slabby, weathering flaggy with wavy bedding, uppermost contact not seen, lower contact

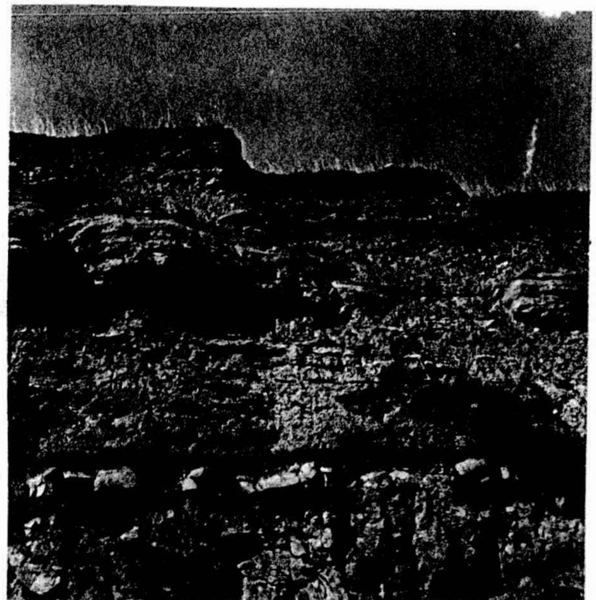


FIG. 16. Exposure of the Kereford Limestone at Locality 6, Leavenworth County. Note lower part, with flaggy, rather nodular limestones and intercalated with sub-equal thicknesses of shale.

FIG. 17. Exposure of the Kereford Limestone at Locality 8, Jefferson County. Upper bed with fusulinids, normally rather massive, is here weathered to platy fragments.

irregular but sharp, extremely abundant Triticites, maximum fusulinid concentration seen near center of unit, Osagia near top....................................1.8'

2. Micrite to fossiliferous micrite, light-gray, light-gray to buff weathering, slabby to flaggy, argillaceous, fenestrellate and ramose bryozoans, brachiopods, bellerophontid gastropods in upper part, "algal material", Linoproductus, lower part..........................4.7'

Heumader Shale Member

1. Shale, medium gray....................................____

Locality 9

Center of east line, SE¼, Sec. 36, T. 10 S., R. 20 E., Leavenworth County. Section measured in quarry, west side of Highway 16 (Fig. 18).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member

6. Shale, gray-tan, clayey....................................____

Oread Limestone Formation

Kereford Limestone Member (6.1')

5. Fusulinid biomicrudite, light-gray, buff weathering, slabby, towards top, bedding manifested differential weathering of thin stringers of sorted shell fragments and crinoid ossicles; upper contact sharp, top being a thin, platy, shell fragment zone; abundant Triticites, maximum concentration of fusulinids near middle of unit and decreasing sharply 0.5' from top, Ammovertella, Marginifera, Juresania, Linoproductus, small high-spired bellerophontid gastropods..................................2.8'

4. Fossiliferous micrite, light-gray, weathers buff, slabby, uneven bedding, slightly pyritic, sparsely fossiliferous, fossils unevenly clustered, Triticites, arenaceous Foraminifera, small gastropods.................1.5'

FIG. 18. Exposure of the Kereford Limestone at Locality 9, Leavenworth County. Showing the upper massive bed and lower thinner bedded limestone.

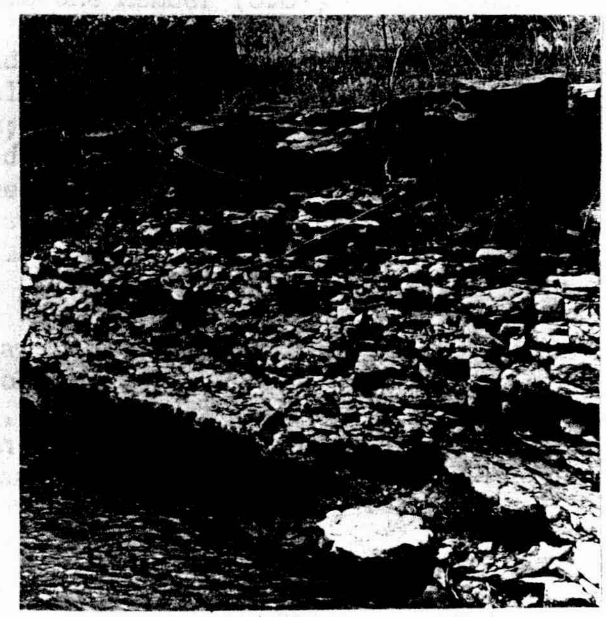


FIG. 19. Exposure of the Kereford Limestone at Locality 10, Jefferson County. Note upper rather platy weathering fusulinid bed.

3. Shale, calcareous..0.1-0.2'

2. Micrite, buff, slabby, uneven bedding, pyritic rare"algal material", Ammovertella, shell fragments, spicules..1.6'

Heumader Shale Member (3.5')

1. Shale, medium gray, unfossiliferous..........................3.5'

Locality 10

SW¼, Sec. 33, T. 10 S., R. 19 E., Jefferson County. Section measured on west bank of Buck Creek, west of north-south county road (Fig. 19).

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (6.0')

3. Fusulinid biomicrudite, light-gray, brown weathering, slabby to flaggy, very irregular bedding surfaces; upper contact not seen, (evidence from displaced material indicated a platy, shell fragment zone at top); abundant Triticites, often algal coated, fusulinids concentrated in lower and middle parts of unit, rare Neospirifer, bellerophontid gastropods..2.0'

2. Micrite and fossiliferous micrite; locally at base algal biolithite, gray, slabby to flaggy, shale partings, somewhat pyritic, pyrite usually concentrated in the algal structures, irregularly distributed fauna, usually sparse, Ottosonia at base locally abundant rare Triticites, fenestrellate bryozoans, often well preserved, Composita, Derbyia, Hustedia, high-spired gastropods, crinoid ossicles........4.0'

Heumader Shale Member

1. Shale, medium gray, seemingly unfossiliferous.............approx. 3.0'

Locality 11

Center north line SW¼, Sec. 14, T. 11 S., R. 19 E., Jefferson County. Section measured on road-cut, north side of east-west county road, near top of hill (Fig. 20).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member

6. Shale, gray-tan..._____

Oread Limestone Formation

Kereford Limestone Member (6.6')

5. Biosparrudite-biomicrudite, platy, upper contact sharp; lower contact covered; very low fusulinid concentration, fragmental ramose bryozoans, shell fragments, crinoid ossicles..............................0.4'

4. Covered, possibly shale...0.3'

3. Biomicrudite and fossiliferous micrite; light-gray, buff weathering, slabby, upper contact covered, lower contact rather arbitrary, being determined by the sudden decrease in fusulinid concentration and more flaggy bedding below, abundant Triticites, Fistulipora, fenestrellate bryozoans, and bellerophontid gastropods in lower part; towards top, fossil content decreases, giving a fossiliferous micrite, Osagia, few Triticites, small high-spired gastropods, this sorted fossiliferous material being concentrated in stringers...2.9'

2. Fossiliferous micrite, light-gray, buff weathering, slabby to flaggy, weathering to give a rather nodular appearance, lower contact sharp, Ottosonia near base, rare Triticites, abundant fenestrellate bryozoans, Composita, Derbyia, fairly abundant Myalina...3.0'

Heumader Shale Member (2.4')

1. Shale, yellow-gray, apparently unfossiliferous.............2.4'

Locality 12

$NW\frac{1}{4}$, $NE\frac{1}{4}$, Sec. 29, T. 11 S., R. 19 E., Jefferson County. Section measured in Hamm's Quarry, north side of U.S. 59, 0.5 miles east of Williamstown (Fig. 21).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (20.0')

6. Shale, siltstone above, light-gray, buff weathering, shaly to flaggy, carbonaceous material on bedding planes..20.0'

Oread Limestone Formation

Kereford Limestone Member (7.5')

5. Fusulinid biomicrudite; light-gray, weathering buff, blocky, becoming slabby towards top where weathered-out stringers of sorted shelly material are seen; slightly pyritic; upper contact is sharp and is marked by a thin, platy, argillaceous zone of small, rounded shell fragments and spicules; lower contact is rather arbitrary, based on the sudden decrease in fusulinid content, slabby to flaggy bedding, and shaly partings below; abundant <u>Triticites</u> concentrated in lower and middle part of unit, arenaceous Foraminifera, mainly <u>Tolypammina</u>, rare pyritized <u>Cavalina</u>, brachiopod spines, small low and high-spired gastropods, bellerophontid gastropods; <u>Rhombopora</u>, sorted shell fragments, spines, crinoid ossicles; towards top fusulinid concentration decreases.......................4.5'

4. Fossiliferous micrite, light-gray, slabby to flaggy; <u>Triticites</u>, <u>Ammodiscus</u>, <u>Tolypammina</u>, rare pyritised <u>Cavalina</u>....................................0.9'

3. Shale, calcareous..0.1'

2. Fossiliferous micrite, locally an algal biolithite, light-grey, slabby, rather nodular in appearance, plane, slightly undulating bedding, lower contact sharp, with a few, very thin, stringers of algal limestone in the immediately subjacent shale, fossils decrease in abundance towards top of the unit,

FIG. 20. Exposure of the Kereford Limestone at Locality 20, Jefferson County.

FIG. 21. Exposure of the Kereford Limestone at Locality 12, Jefferson County.

Ottonosia in lower part, growth lines heavily pyritized, rare pyritized Triticites, Ammodiscus, Tolypammina, pyritized Cavalina, conodonts, ramose bryozoans, Echinoconchus, Neospirifer, Linoproductus, Marginifera, Hustedia, Composita, brachiopod fragments and spines, commonly algal encrusted, Chaenomya, silicified pelecypod and gastropod fragments, crinoid ossicles......................................2.0'

Heumader Shale Member (1.5')

1. Shale, medium gray, highly calcareous, slightly pyritic and fossiliferous immediately subjacent to limestone; rare, flattened and silicified fusulinids, Tolypammina and Ammodiscus, rhombop- oroid and fenestrellate bryozoans, Derbyia, crinoid columnals, lower part unfossiliferous....................1.5'

Locality 13

SE¼, Sec. 1, T. 12 S., R. 19 E., Douglas County. Section measured in [illegible]ford's Quarry, north of U.S. Highway 24.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (approx. 4.0')

3. Biomicrudite-fossiliferous micrite, buff, yellow weathering, slabby, irregularly bedded; upper contact not seen; lower contact arbitrarily determined by the decrease of fusulinids, Triticites, bellerophontid gastropods........................1.0'

2. Fossiliferous micrite, locally an algal biolithite, buff, yellow weathering, slabby to flaggy, irregularly bedded, shaly bedding surfaces, lower part more fossiliferous with Ottonosia, fenestrellate bryozoans, Composita, Derbyia, Linoproductus, Cardiomorpha, Allorisma (?), high and trochoid-spired gastropods; towards top rare Triticites........3.0'

Heumader Shale Member (1.6')

1. Shale, light-gray to buff; fossiliferous at top with Foraminifera, Derbyia, Astartella...................1.6'

Locality 14

SW corner, Sec. 35, T. 12 S., R. 18 E., Douglas County. Section measured in quarry at Lecompton, just south of Santa Fe railroad (Fig. 22).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (approx. 20.0')

4. Shale, yellow silty, seemingly unfossiliferous.......approx.20.0'

Oread Limestone Formation

Kereford Limestone Member (7.0')

3. Biomicrudite, light-gray, yellow weathering, slabby; upper contact sharp, top marked by a platy, argillaceous sorted shell fragment zone; lower contact by a decrease in fusulinid content and more flaggy bedding, with shale partings, below, abundant Triticites, bellerophontid gastropods in lower part of unit, towards top fusulinids become less abundant, shell fragments, crinoid columnals, at top Osagia, rare Triticites, Dielasma, small gastropods, spines....................................2.0'

2. Fossiliferous micrite, locally biomicrudite, light-gray, yellow weathering, flaggy to slabby, rather nodular in appearance, interbedded with calcareous shale, Ottonosia, "Marksia", near base, rare Triticites, increasing in number towards top, fenestrellate bryozoans, Linoproductus, Hustedia, Dielasma, crinoid ossicles...5.0'

Heumader Shale Member (2.0')

1. Shale, light-gray..2.0'

Locality 15

SE corner SE$\frac{1}{4}$, Sec. 7, T. 12 S., R. 19 E.. Douglas County.

Section measured a few yards west of Bridge No. 257, on north side of Turnpike. Poor exposure, basal Kereford only.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (1.0'+)

2. Biomicrudite, algal biolithite, yellow, slabby to flaggy, with very irregular bedding, highly weathered, upper contact missing, lower contact sharp, highly fossiliferous, abundant Ottonosia, sparse Triticites, Syringopora, fenestrellate and ramose bryozoans, fairly abundant Composita, Juresania, (with well-preserved spines) Derbyia, Wellerella, articulated crinoid stems, large Myalinas, often algal encrusted, high-spired and bellerophontid gastropods.................................1.0'+

Heumader Shale Member (approx. 4.0')

1. Shale, gray, mostly covered.........................approx. 4.0'

Locality 16

Center south line of SW$\frac{1}{4}$, Sec. 30, T. 12 S., R. 18 E., Douglas County. Section measured in stream bank, north side of county road, 3/8 mile east of Stull (Fig. 23).

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (7.8')

6. Biomicrudite-biosparrudite, "Oatmeal rock", gray-brown, buff weathering, slabby, plane bedding surfaces locally absent, sharp upper and lower contact, well-developed WNW directed vertical jointing, rock consists almost entirely of well sorted shelly material, commonly oriented parallel to bedding plane, with a small amount of interstitial micrite and argillaceous material, Osagia, Triticites, arenaceous

Foraminifera, reworked, algal encrusted, shell fragments and spicules..............................0.4'

5. Shale, yellow, weathered, clayey, seemingly unfossiliferous..0.8'

4. Fusulinid biomicrudite, buff, yellow weathering, two slabby units, separated by a thin yellow calcareous shale parting, upper contact sharp, lower contact marked by a shale break and decrease in fusulinid content, abundant Triticites in lower unit, less in upper unit, Ammovertella, brachiopod shell fragments, crinoid ossicles........................1.6'

3. Micrite, fossiliferous micrite, light-gray, slabby to flaggy, argillaceous, pyritic, irregular, more shaly bedding planes, lower contact marked by an increase in fossil content, and more slabby bedding, lower part essentially a micrite, sparse fossil content, Triticites, concentration increasing towards top, Ammovertella, Linoproductus, Dictyoclostus, Neospirifer, crinoid stems, bellerophontid gastropods.....3.0'

2. Biomicrudite, locally algal biolithite, light-gray, buff-gray weathering, slabby, very irregular bedding surfaces, slightly pyritic, locally very abundant Ottonosia, rare Triticites, Ammovertella, Tolypammina, Rhombopora, fenestrellate bryozoans, Composita, Derbyia, Linoproductus, Juresania, Neospirifer, Punctospirifer, articulated crinoid stems..................2.0'

Heumader Shale Member

1. Shale, medium gray......................................____

Locality 17

Center E line, Sec. 35, T. 13 S., R. 17 E., Douglas County.

Section measured in stream bed, under bridge on Shawnee-Douglas County line.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (6.9')

5. Biomicrudite, "Oatmeal rock", brown-gray, slabby,

FIG. 22. Exposure of the Kereford Limestone at Locality 14, Douglas County. This shows well the lower flaggy to slabby bedded part and the upper more massive limestone.

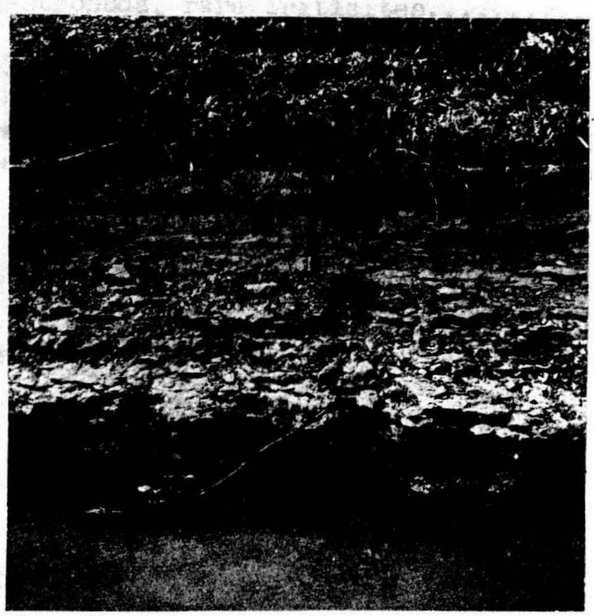


FIG. 23. Exposure of the Kereford Limestone at Locality 16, Douglas County. Note the upper part of the member on this exposure. The topmost bed, "Oatmeal rock" is not present in this figure.

argillaceous, upper and lower contact sharp, unit composed of sorted reworked Triticites, arenaceous Foraminifera, shell fragments and spicules, commonly algal encrusted, slight interstitial micrite and argillaceous material.................................0.4'

4. Shale, brown, earthy, unfossiliferous.......................1.0'

3. Fossiliferous micrite, locally biomicrudite, weathering tan-brown, flaggy bedded, wavy bedding planes, upper contact sharp, lower contact arbitrary, determined by more slabby bedding below, and increase in fossil content; Triticites abundant towards top, rare Osagia, large fenestrellate bryozoans near base, Linoproductus, Echinoconchus, Neospirifer, crinoid ossicles............................2.9'

2. Biomicrudite, gray, yellow-brown weathering, slabby, very irregularly bedded, lower contact sharp, with some thin limestone stringers in shale immediately subjacent to the unit, basal limestone shaly with a sparse fauna; abundant fauna above base with Syringopora, fenestrellate bryozoans, Composita, Derbyia, Marginifera, Juresania, Hustedia, high-spired gastropods, rare Triticites........................2.6'

Heumader Shale Member

1. Shale, medium gray, shaly, top calcareous and fossiliferous, Syringopora in shale below limestone.......____

Locality 18

NW corner, Sec. 3, T. 15 S., R. 18 E., Douglas County.

Exposure in ditch on south side of U.S. Highway 50 and in north-south county road, 0.5 mile west of Globe.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (2.0')

1. Biomicrudite, light-gray, buff weathering, rubbly very weathered, abundant fauna, algal material commonly encrusting shells, Syringopora, fenestrellate bryozoans, abundant Composita, Dielasma, Hustedia, Derbyia, oriented sub-parallel to bedding planes, large euomphalid gastropods, high-spired gastropods.............2.0'

Locality 19

Center NE¼, Sec. 24, T. 15 S., R. 17 E., Franklin County. Section measured at top of quarry in Plattsmouth Limestone. Very poor exposure.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (approx. 1.0')

2. Algal biolithite-biomicrudite, yellow-cream, very badly weathered, rubbly, algal material weathering out, Syringopora, fenestrellate and ramose bryozoans, brachiopods, undisassociated crinoid stems.......................................approx. 1.0'

Heumader Shale Member (12.0')

1. Shale, red-gray, earthy, clayey, unfossiliferous..........12.0'

Locality 20

Extreme SW corner, Sec. 8, T. 16 S., R. 18 E., Franklin County. Section measured on east side of north-south county road and around corner to east.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (3.5')

4. Micrite, light-gray, hard, flaggy, planar slightly undulating bedding; upper contact missing, lower contact determined by more slabby irregular bedding and presence of fossils below...........................0.5'

3. Biomicrudite, light-gray, buff weathering, flaggy to slabby irregular bedding; lower contact determined by a marked decrease in fusulinid content below, abundant Triticites.....................................1.5'

2. Biomicrudite, similar to above but more slabby, abundant diverse fauna, Ottonosia, algal "binding" material, rare fusulinids, abundant ramose and

fenestrellate bryozoans, abundant weathered-out brachiopods Composita, Dielasma, Marginifera, Hustedia, Derbyia, Neospirifer, Punctospirifer, high-spired gastropods.................................1.6'

Heumader Shale Member (27.0')

1. Shale, yellow, calcareous.................................27.0'

Locality 21

Center S line, SE¼, Sec. 10, T. 16 S., R. 17 E., Osage County. Section measured in road-cut, on east-west county road, on hill above bridge.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (10.4')

6. Micrite, light-gray, buff weathering, hard, flaggy, planar bedding surfaces, weathers into angular sharp edged slabs, upper contact missing..................5.5'

5. Biomicrudite-fossiliferous micrite, light-gray, yellow weathering, slabby to flaggy, irregularly bedded; upper contact marked by the abrupt disappearance of fossils and the overlying regular bedding, encrusting algae, Triticites, Juresania, Dielasma, Marginifera..1.5'

4. Shale, yellow, calcareous.................................0.5'

3. Fossiliferous micrite-biomicrudite similar to limestone above; Ottonosia, rare Triticites, bryozoans, Juresania, Myalina at base, more diverse fauna upwards with Juresania, Dielasma, Neospirifer.....................1.5'

2. Argillaceous fossiliferous micrite, grading downwards into a very calcareous shale transitional to shale below; upper contact transitional; Juresania, Composita, Derbyia, Marginifera, Neospirifer, abundant Myalina, Aviculopecten..................................1.4'

Heumader Shale Member (approx. 40.0')

1. Shale, medium gray, seemingly unfossiliferous...........approx.40.0'

FIG. 24. Exposure of the Kereford Limestone at Locality 22, Osage County. Foot of figure marks base of unit, hands mark the top of fossiliferous part. Note characteristically weathering micrite, which forms dominant part of the unit.

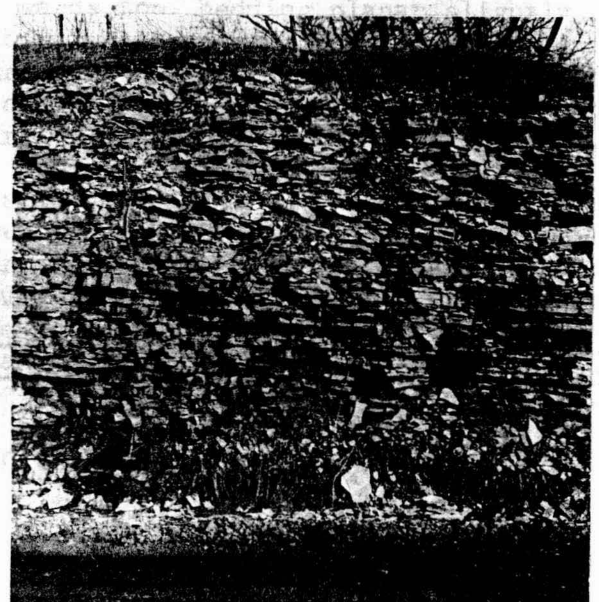


FIG. 25. Exposure of the Kereford Limestone at Locality 23, Osage County. Hammer marks the top of fossiliferous zone. Note regular bedding of the micrite, which comprises almost whole of unit seen in this figure.

Locality 22

SW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 20, T. 16 S., R. 17 E., Osage County. Limestone section measured about 200 yards to northwest of spillway of Pomona Dam, at road side as road bends round bluff. Shale sections above and below the Kereford were measured above the spillway. (Fig. 24).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (approx. 30.0')

1. Shale, gray, sandy with mica flakes................approx. 30.0'

Oread Limestone Formation

Kereford Limestone Member (20.0')

7. Micrite, light-gray, hard, flaggy, becoming more slabby towards top, bedding planar slightly undulating, thin calcareous shale of finely laminated limestone partings; upper contact very sharp; lower contact determined by presence of fossils and more slabby irregular bedding below..........................16.2'

6. Fossiliferous micrite, light-gray, slabby, thin calcareous shale partings, unit essentially similar in texture to micrite above; lower contact marked by a shale unit; sparse but diverse fauna, algal encrusted Triticites, Composita, Marginifera, Linoproductus, Juresania (?), Derbyia, Wellerella, Echinoconchus, crinoid columnals....................................2.3'

5. Shale, gray, calcareous, seemingly unfossiliferous......0.2-0.3'

4. Fossiliferous micrite, biomicrudite, flaggy to slabby, fairly abundant Triticites, small gastropods......0.2'

3. Shale, gray, calcareous, seemingly unfossiliferous.....0.2-0.3'

2. Fossiliferous micrite-micrite, slabby to flaggy, thin shale partings, algal material, crinoid ossicles.....0.9'

Heumader Shale Member (approx. 30.0')

1. Shale, medium gray, clayey, unfossiliferous..........approx.30.0'

Locality 23

West line NW¼, Sec. 3, T. 18 S., R. 16 E., Osage County. Section measured in road-cut just north of Melvern (Fig. 25).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member

5. Shale, yellow, clayey.......................................______

Oread Limestone Formation

Kereford Limestone Member (25.6')

4. Oosparrudite-biosparrudite, brown-gray, slabby, some cross-stratification, flaggy at extreme top with thin stringers of coarser allochems, mainly shell fragments in the dominant oosparite; upper contact sharp marked by abundant fossils on bedding planes at extreme top, ramose bryozoans, small brachiopods, Composita, Derbyia, Myalina, Aviculopecten (?), Allorisma, small high and low-spired gastropods..2.0'

3. Shale, brown, clayey...0.2'

2. Micrite, light-gray, weathering yellow gray, flaggy to slabby towards top, very regular bedding with slightly undulating bedding planes separated by thin shale or finely laminated micrite; lower contact sharp marked by presence of fossils and less regular bedding below..16.4'

1. Biomicrudite, very similar to the fossiliferous part of the section of Locality 24, not so well exposed..approx.7.0'

Locality 24

NW¼, NW¼, Sec. 10, and center east line NE¼, Sec. 9, T. 18 S., R. 16 E., Osage County. Section measured in Santa Fe railroad cut, at Melvern (Fig. 26).

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (17.8')

5. Micrite, light-gray, yellow-cream weathering, slabby to flaggy regular bedding with planar slightly undulating bedding surfaces separated by finely laminated micrite; top missing; lower contact marked by appearance of fossils and more irregular bedding..............approx.9.0'

4. Biomicrudite-fossiliferous micrite, light-gray, yellow-weathering, slabby undulating bedding surfaces with thin calcareous shale partings; lower contact marked by a prominent shaly zone, "algal material", sparse Triticites, which occur in small clusters near base of unit; Tolypammina, small horn corals, abundant Composita, also Dielasma, Dictyoclostus, Hustedia, Juresania, Derbyia, Echinoconchus (?), abundant crinoid ossicles; at top of unit abundant fauna consisting of Juresania, large Derbyia, Punctospirifer, Myalina, gastropods.......................4.6'

3. Shale with lenses of fossiliferous micrite, yellow-gray, fairly abundant horn corals, (Lophophyllidium) both in shale and limestone lenses, corallites commonly oriented sub-parallel to bedding....................0.8'

2. Biomicrudite, locally algal biolithite, light-gray, weathering yellow, flaggy to slabby, wavy irregular bedding planes with thin calcareous shale partings; lower part highly algal, in places an algal mat lying sub-parallel to bedding; Tolypammina, Lophophyllidium, Syringopora, abundant Composita, Dielasma, Echinoconchus, Hustedia, crinoid ossicles.........................3.4'

Heumader Shale Member (4.0')

1. Shale, medium gray, weathering gray-yellow; very fossiliferous at top; abundant Derbyoides, rhomboporoid bryozoans, fenestrellate bryozoans, Neospirifer, Punctospirifer, Hustedia, small trochoid gastropods, lower part seemingly unfossiliferous..........4.0'

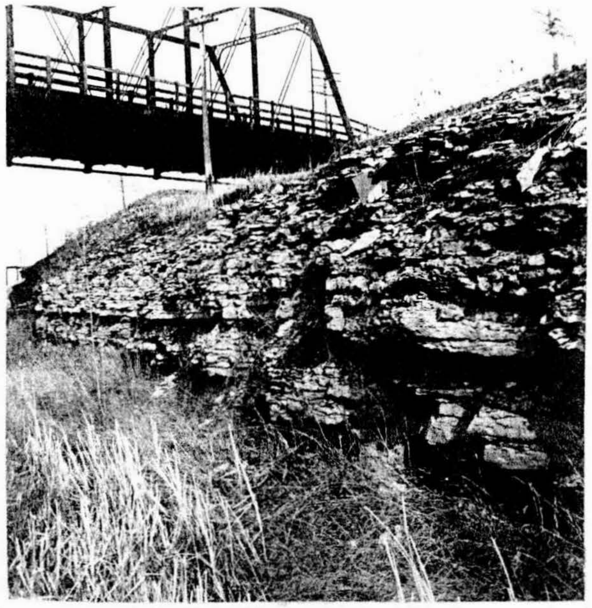


FIG. 26. Exposure of the Kereford Limestone at Locality 24, Osage County. This is the lower, fossiliferous part of member. Note irregular bedding compared to Fig. 25.

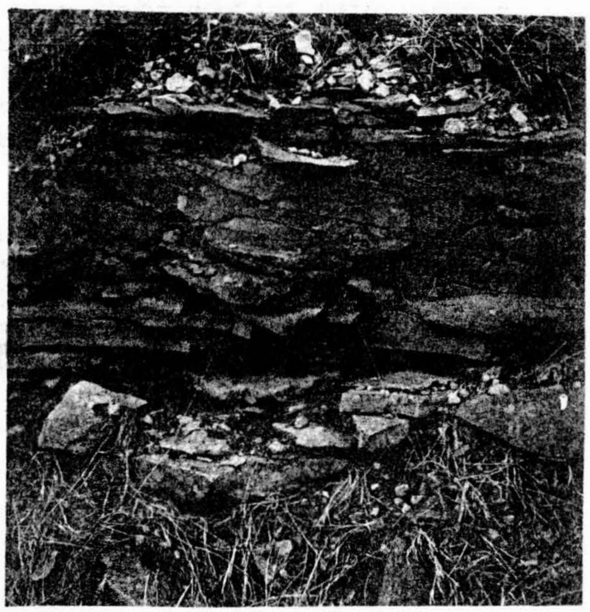


FIG. 27. Exposure of the Kereford Limestone at Locality 25, Coffey County. This is the oolitic top of the member, showing the cross-stratification.

Locality 25

Extreme NE corner Sec. 18, and S line of SE¼, Sec. 7, T. 19 S., R. 17 E., Coffey County. Section measured starting in old quarry to south of U.S. Highway 50S, lower part seen on north side of road (Fig. 27).

	Thickness Feet Inches
Oread Limestone Formation	
Kereford Limestone Member (17.2')	
4. Oosparite-oosparrudite, light-gray, tan weathering, flaggy, locally cross-stratified; extreme to absent, dominantly oosparite; towards base locally oosparrudite; lower contact transitional over 0.2' with stringers of oosparite in a dominantly micrite matrix; some shell fragments, spines, small high-spired gastropods.....	1.9'
3. Micrite, light-gray, weathering buff-gray, flaggy silty, slightly wavy-bedded with shaly or finely laminated limestone partings, more shaly and silty towards base; lower contact determined by presence of fossils and more irregular and slabby bedding below; a very sparse fauna was found about 7' below unit above containing <u>Linoproductus</u> with spines attached, undissociated crinoid stems and fucoidal markings or worm borings..................................	14.0'
2. Fossiliferous micrite, weathers yellow, slabby, silty, irregular bedding; lower contact sharp; algal material, fenestrellate bryozoans, <u>Rhombopora</u>, <u>Composita</u>, <u>Punctospirifer</u>, <u>Myalina</u>, undissociated crinoid ossicles...........................	1.3'
Heumader Shale Member	
1. Shale, yellow-gray, apparently unfossiliferous............	_____

Locality 26

N line of NE¼, NW¼, Sec. 24, T. 19 S., R. 16 E., Coffey County. Section measured along stream bed, and in road ditch, 0.2 to 0.5 mile east of Waverly (Fig. 28).

	Thickness Feet Inches
Oread Limestone Formation	

FIG. 28. Exposure of the Kereford Limestone at Locality 26, Coffey County. This is the silty "Waverly Flagging".

Kereford Limestone Member (approx. 31.0')

3. Oosparite, fragmental....................................______

2. Micrite, arenaceous, light-gray, weathering buff-gray, flaggy, slightly wavy-bedded (some bedding surfaces appear ripple marked) with micaceous silty bedding surfaces, rare fucoidal markings or worm borings....................................approx. 30.0'

1. Fossiliferous micrite, light-gray, flaggy to slabby, slightly pyritic; distinguished from unit above by presence of fossils; sparse but diverse fauna, Ottonosia, fenestrellate bryozoans, Hustedia, Neospirifer, Myalina, crinoid ossicles...............approx. 1.0'

Locality 27

Center S line SE$\frac{1}{4}$, Sec. 21, T. 19 S., R. 17 E., Coffey County,

Section measured on east-west railroad, and in field to south.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (9.4')

3. Sandstone, fine, buff, yellow-tan weathering, flaggy to slabby, unfossiliferous..........................6.0'

2. Arenaceous micrite or microsparite, calcareous sandstone, light gray-brown, tan weathering, flaggy, very thin-bedded to laminated, interbedded with more sandy beds, micaceous on bedding planes, essentially small (62 micron fraction dominant) angular quartz grains in a microsparite matrix; unfossiliferous, rare fucoid markings or worm borings observed on some bedding surfaces.............3.4'

Heumader Shale Member (approx. 60.0')

1. Shale, yellow-gray, clayey, earthy, with thin lenses of calcareous sandstone at top...............approx. 60.0'

Locality 28

Center of N side, Sec. 21, T. 19 S., R. 17 E., Coffey County.

Section measured in ditch on north side of road. Incomplete exposure.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (6.0')

2. Micrite, basal part a white-cream, flaggy, unfossiliferous; upper contact nor seen; thin (0.2 feet) biomicrudite or biosparrudite zone of sorted shell fragments, Linoproductus, Marginifera...2.0'

1. Shale, yellow-gray, calcareous, containing numerous flaggy wavy-bedded stringers of arenaceous micrite-calcareous arenite, micaceous on bedding surfaces; fucoid markings or worm borings.........4.0'

Locality 29

Center of E line, Sec. 11, T. 20 S., R. 16 E., Coffey County.

Section measured in road-cut, west side of road, 4.5 miles due south of Waverly.

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (approx. 30.0')

4. Shale, yellow-gray, mostly covered, overlain by a sandstone..................................approx. 30.0'

Oread Limestone Formation

Kereford Limestone Member (approx. 23')

3. Micrite-oomicrite, cream, flaggy to slabby; partly covered, oomicrite near base; rare stringers of oolites in micrite throughout; towards top rare Linoproductus..................................approx. 12.0'

2. Arenaceous micrite to calcarenite-arenite, gray-brown, weathering tan, flaggy, laminated alternating between highly arenaceous micrite (approx. 50 percent sand) and arenite; bedding surfaces with occasional fucoid markings, lower contact transitional...11.6'

Heumader Shale Member

1. Shale, gray weathering yellow; upper part containing lenses of limestone stringers; base not seen...............____

Locality 30

Center of S line SE¼, SE¼, Sec. 19, T. 20 S., R. 16 E., Coffey County. Section measured on east side of stream bank and along east-west county road, near bridge.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (21.0+')

3. Oosparite-oomicrite-micrite, white, slabby, slightly irregular bedding; upper contact missing; lower contact marked by a basal biosparrudite with bryozoans, brachiopod and gastropod fragments.......................................11.0+'

2. Calcarenite, arenaceous micrite, arenite, buff-gray, yellow weathering, thin-bedded, flaggy, all gradations from an arenaceous micrite to an arenite; unfossiliferous..................................10.0+'

Heumader Shale Member

1. Shale, gray, clayey, base not seen.....................____

Locality 31

Center S line, SW¼, Sec. 22, T. 20 S., R. 16 E., Coffey County.

Section measured at top of hill on east-west county road (Fig. 29).

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (16.5')

6. Sandstone, yellow-buff, gray-buff weathering, flaggy, plane bedding surfaces, unfossiliferous...........6.4'

5. Covered, sandstone fragments...........................2.4'

4. Sandstone, yellow-buff, gray-buff weathering, massive to slabby, unfossiliferous.......................5.7'

3. Covered..1.8'

2. Arenaceous micrite-calcareous sandstone, gray, weathers gray-buff; flaggy, thin irregular bedding with sandstones along bedding planes....................0.2'

Heumader Shale Member

1. Shale, yellow-gray, with thin lenses of siltstone; base not seen....................................

Locality 32

North line of NE¼, Sec. 34, T. 20 S., R. 16 E., Coffey County.

Section measured near top of hill to the top, on south side of east-west county road.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (28.9')

5. Sandstone, gray-buff, tan weathering, slabby; only partially exposed..................................26.0'

4. Calcarenite-arenite, buff-gray, buff weathering; slabby, irregular disturbed bedding grading into an argillaceous micrite near base; fucoid markings or

worm borings seen on upper surface (borings may be responsible for the distorted bedding); rare bryozoans, carbonaceous material........................1.6'

3. Covered..1.0'

2. Arenaceous micrite, calcareous arenite, buff-gray, buff weathering, slabby, thin, irregular distorted bedding..0.3'

Heumader Shale Member (40.0')

1. Shale, yellow-gray, clayey, mostly covered...............40.0'

Locality 33

Center of N line of NW¼, NW¼, Sec. 32, T. 20, S., R. 16 E., Coffey County. Section measured in stream bank, south of west-east county road, about 0.75 mile east of Sharpe (Fig. 30).

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (1.0+')

2. Fossiliferous micrite to micrite; arenaceous, light-gray, weathering buff, weathering into platy fragments, disturbed bedding, slightly micaceous, good vertical NE-SW and NW-SE jointing; fucoid markings or worm borings on some bedding planes, Linoproductus, crinoid ossicles..........1.0+'

Heumader Shale Member

1. Shale, yellow-gray, clayey, silty, calcareous............._____

Locality 34

SE¼, SW¼, Sec. 2, T. 21 S., R. 15 E., Coffey County. Section measured in Nelson's Quarry (Fig. 31).

Thickness
Feet Inches

Kanwaka Shale Formation

FIG. 29. Exposure of the Kereford Limestone at Locality 31, Coffey County. Hammer rests on calcareous bed at base, massive sandstone at top.

FIG. 30. Exposure of the Kereford Limestone at Locality 33, Coffey County, Base of Kereford only.

Jackson Park Shale Member (13.0')

5. Sandstone, tan-brown, thin-bedded, flaggy to slabby, fine-grained, ripple marks, micaceous on bedding surfaces; lower boundary rather transitional with unit becoming laminated then shaly; plant fossils..............4.0'

4. Shale, silty, yellow-gray, shaly, seemingly unfossiliferous..9.0'

Oread Limestone Formation

Kereford Limestone Member (4.5')

3. Fossiliferous micrite to micrite, medium gray, weathering brown-gray, slabby, slightly pyritic; upper contact sharp with top being a thin (0.2 foot) zone of shaly biomicrudite; lower contact sharp but irregular; rare fucoid markings or worm borings, "algal material" associated with sparry cement, spicules, crinoid ossicles, upper surface with ramose bryozoans, Derbyia, Composita, Myalina, crinoid ossicles..1.7'

2. Micrite to fossiliferous micrite, medium gray, brown weathering, rather rubbly; crinoid ossicles. This bed appears to be only locally present................1.1'

1. Fossiliferous micrite, medium gray, slabby; base not seen; "algal material", rare brachiopod fragments, Composita, slight amount of carbonaceous material..1.7'

Locality 35

135' S, 350' W of NE corner of Sec. 11, T. 21 S., R. 15 E., Coffey County. Borehole, Corps of Engineers, John Redmond Dam.

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member (13.1')

5. Sandstone, soft, weathered, micaceous, with shale streaks, tan..5.4'

4. Shale, moderately soft, weathered, gray..................7.7'

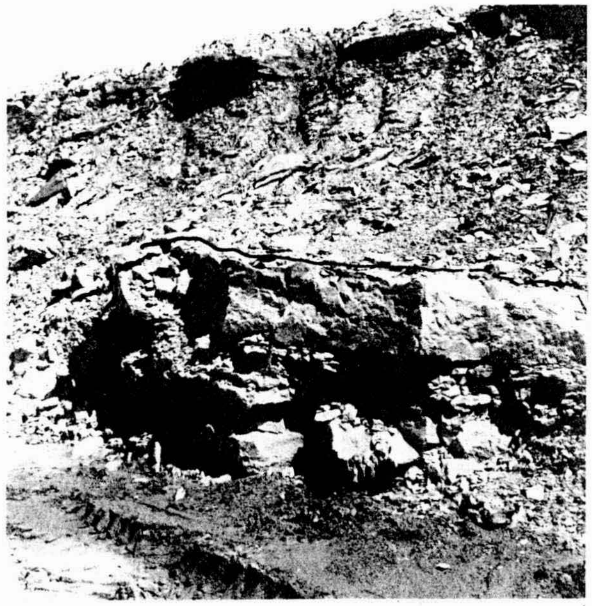


FIG. 31. Exposure of the Kereford Limestone at Locality 34, Coffey County. Note massive appearance and thin-bedded sandstone in overlying Jackson Park Shale containing plant fossils.

FIG. 32. Exposure of Kereford Limestone at Locality 36, Coffey County. The rather massive appearance is characteristic of exposures of the Kereford Limestone in the vicinity of Burlington.

Oread Limestone Formation

Kereford Limestone Member (8.1')

3. Limestone, moderately hard, fossiliferous, gray, towards base irregularly bedded shale streaks..............5.3'

2. Shale, very hard, with alternating bands of siliceous limestone, fossiliferous........................2.8'

Heumader Shale (30.0')

1. Shale, moderately hard to moderately soft, gray, fossiliferous towards base.............................30.0'

Locality 36

SW¼, SW¼, Sec. 11, T. 21 S., R. 15 E., Coffey County. Section measured at junction of east-west county road, with east side of U.S. Highway 75 just 0.5 mile north of Burlington.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member

1. Fossiliferous micrite, grey-tan, weathering tan-yellow, slabby to flaggy; fucoid markings or worm borings, Juresania, Composita, fenestrellate bryozoans, Myalina, crinoid ossicles..............____

Locality 37

Center Sec. 14, T. 21 S., R. 15 E., Coffey County. Section measured at top of hill, above Pecker's Quarry, near Burlington.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (4.0')

2. Fossiliferous micrite, tan-gray, slabby, weathers platy; top and base not seen; sparse fauna, fucoid markings or worm borings, "algal material", brachiopods, Myalina, crinoid ossicles..................4.0'

Heumader Shale member (60.0')

1. Shale, yellow, calcareous, clayey, mostly covered..........60.0'

Locality 38

Center N line, $NW\frac{1}{4}$, $SW\frac{1}{4}$, Sec. 14, T. 24 S., R. 14 E. Woodson County. Section measured in ditch on south side of east-west county road.

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member

7. Sandstone, red-tan weathering, fine-grained, slabby, about 10 feet above limestone, and below a covered zone probably shale..........................____

Oread Limestone Formation

Kereford Limestone Member (approx. 7.3')

6. Micrite, oomicrite, white, tan weathering, rubbly, top contact missing, Ammovertella..........................approx. 1.0'

5. Covered, shale break?..0.3'

4. Oomicrite, tan, flaggy to slabby; lower contact determined by absence of oolites and the thicker slabby bedding below; sparse fauna, Triticites, crinoid ossicles..approx. 3.0'

3. Arenaceous micrite to calcareous sandstone; medium gray, slabby, irregular bedding, slump structure (?); incompletely exposed, lower contact determined by the presence of fossils and higher shale content below; fucoid markings or worm borings..................1.5'

2. Biosparrudite-biomicrudite, arenaceous, light-gray, weathers buff, flaggy to slabby, irregularly bedded with yellow calcareous shale partings, locally cross-stratification; lower contact sharp; highly fossiliferous, fenestrellate and ramose bryozoans, Juresania, Myalina, Aviculopecten, Nuculana (?), disarticulated crinoid ossicles..1.5'

Heumader Shale Member

1. Shale, yellow-gray, calcareous, with thin stringers of limestone subjacent to overlying unit..................____

Locality 39

Center S line, SW¼, SE¼, Sec. 7, T. 25, S., R. 14 E., Woodson County. Section measured at top of hill on east-west county road, 3 miles north and 2 miles east of Batesville.

	Thickness Feet Inches
Kanwaka Shale Formation	
Jackson Park Shale Member	
5. Sandstone, slabby, tan weathering, 3-4 feet above underlying limestone, locally in erosional (?) contact	____
Oread Limestone Formation	
Kereford Limestone Member (5.6')	
4. Biolithite, locally biosparrudite, yellow weathering, slabby to flaggy; highly fossiliferous, "algal material", *Ammovertella*, *Syringopora*, *Myalina*, locally large crinoid ossicles set in a sparry matrix	2.0'
3. Arenaceous micrite to calcarenite, yellow weathering, slabby to flaggy; upper contact determined by more slabby beds and fossils below; fucoid markings or worm borings	1.6'
2. Biosparrudite, locally an oosparite, medium gray, weathering tan, slabby, irregularly bedded; *Osagia*. abundant *Triticites*, shell fragments, *Myalina*	2.0'
Heumader Shale Member	
1. Shale, gray, weathering yellow, clayey	____

Locality 40

N line of NW¼, NW¼, Sec. 17, T. 26 S., R. 13 E., Greenwood County. Section measured on north side of east-west county road, near top of hill (Fig. 33).

	Thickness Feet Inches
Oread Limestone Formation	

FIG. 33. Exposure of the Kereford Limestone at Locality 40, Greenwood County.

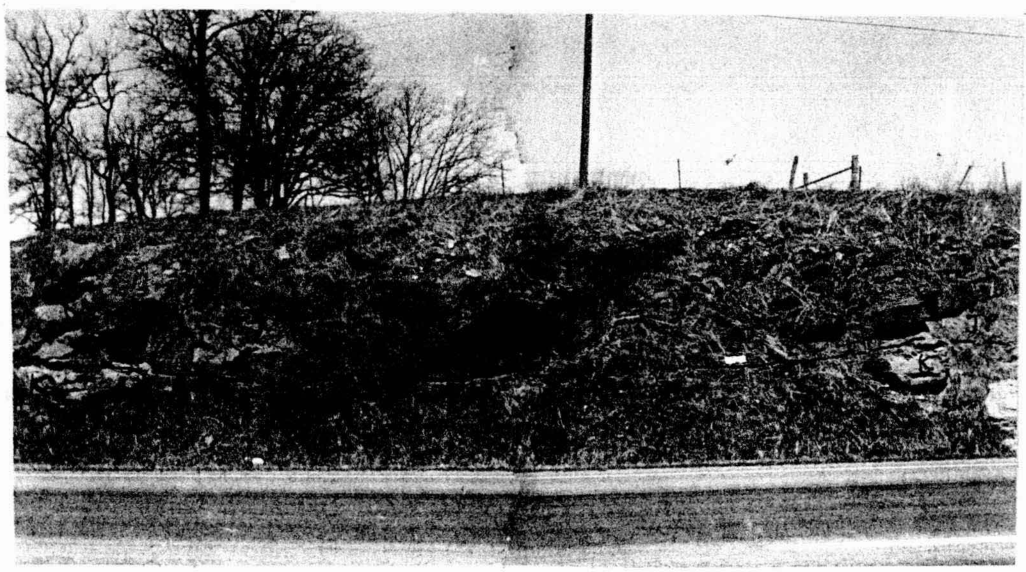


FIG. 34. Exposure of the Kereford Limestone at Locality 41, Greenwood County. Note the massive Elgin (?) Sandstone, lying in a channel cut in both the Kereford and the overlying Jackson Park Shale.

Kereford Limestone Member (9.3')

4. Biosparrudite, locally oosparite, tan weathering, flaggy, slightly irregular bedding; partly covered, upper contact nor seen; lower contact manifested by marked increase of fusulinids below; Osagia, rare Triticites, arenaceous Foraminifera, ramose bryozoans, shell fragments, spines, Juresania, Myalina, crinoid ossicles..............................3.5'

3. Biomicrudite, biosparrudite, medium gray, weathering tan to buff, flaggy to slabby, irregular bedding surfaces; partially covered, lower contact determined by sharp decrease in abundance of fusulinids and increased shale content below, abundant Triticites, fucoidal markings or worm borings on bedding planes......................................2.4'

2. Fossiliferous micrite, arenaceous and argillaceous, medium gray color, tan-buff weathering, flaggy to slabby very irregular bedding surfaces with shaly partings; rare Triticites, Linoproductus..................3.4'

Heumader Shale Member (30.0')

1. Shale, yellow, seemingly unfossiliferous..................30.0'

Locality 41

Center S line, SW¼, NW¼, Sec. 10, T. 28 S., R. 12 E., Greenwood County. Section measured in road-cut, on State Highway 96, 2.5 miles west of Fall River bridge (Fig. 34).

Thickness
Feet Inches

Kanwaka Shale Formation

Jackson Park Shale Member

4. Sandstone, tan weathering, massive, probably Elgin Sandstone resting in some places on an erosional surface of the Kereford, and on lower part of Jackson Park Shale which is here yellow-gray and sandy..______

Oread Limestone Formation

Kereford Limestone Member (2.6')

3. Oosparite-oomicrite, silty, buff-gray, flaggy to shaly, irregular shale partings; upper surface sharp, in part an erosional surface below a massive sandstone which may replace this unit altogether, reducing total thickness of Kereford to 1.3 feet, or the surface may be a depositional contact with the shale above; some fucoid markings, rare Triticites, Ammovertella, Ammodiscus................0.6'

2. Biomicrudite-biosparrudite, gray-buff, limonitic, buff weathering, blocky to slabby, irregular bedding; upper contact erosional or usually marked by increase of shale content; lower contact sharp; very fossiliferous, "algal material", Osagia, abundant Triticites in middle part of unit, arenaceous Foraminifera, Ammovertella, Ammodiscus,........ shell fragments, Myalina near base, disassociated crinoid ossicles...2.0'

Heumader Shale Member

1. Shale, gray, weathering yellow.............................____

Locality h2

SW corner, NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 5, T. 29, S., R. 13 E., Elk County.

Section measured at top of hill along east-west county road.

Thickness
Feet Inches

Oread Limestone Formation

Kereford Limestone Member (0.6')

2. Biomicrudite-biosparrudite, two thin flaggy beds separated by a gray shale, regular bedding planes abundant Triticites both in limestone and shale, arenaceous Foraminifera, brachiopod fragments, ramose and fenestrellate bryozoans, Derbyia, Myalina.............0.6'

Heumader Shale Member

1. Shale, gray, yellow, slightly sandy, apparently unfossiliferous...____

APPENDIX B

PERCENTAGES OF THE INSOLUBLE RESIDUES OF THE KEREFORD LIMESTONE AND CONSTITUENTS OF THE COARSE FRACTION

Locality	Distance from base of unit	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
1	+0	1	22	23	Mainly arenaceous Foraminifera, *Ammodiscus*, rare *Ammovertella*, some pyrite.
1	1.5	1	14	15	Subequal amounts of pyrite and arenaceous Foraminifera, mainly *Ammodiscus*, rare *Amovertella*.
1	2.5	1	4	5	Mainly pyrite, pyritized spines, some chert, Foraminifera fragments.
2	+0	1	39	40	Pyrite.
4	+0	1	14	15	Arenaceous Foraminifera, mainly *Ammodiscus*, some pyrite.
4	1	0	11	11	Rare *Ammodiscus*, pyrite.

Locality	Distance from base of unit feet	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
4	1.5	0	4	4	Rare arenaceous Foraminifera, some pyrite.
4	4	0	2	2	Rare arenaceous Foraminifera.
4	6	2	3	5	Lacy chert, silicified *Triticites*, *Ammodiscus*.
4	7	1	3	4	Oomoldic chert, *Ammovertella*.
6	+0	1	15	16	Pyrite, lacy chert.
6	2	0	9	9	———————
6	5	1	3	4	Lacy chert, pyrite, pyritized Triticites.
9	+0	2	8	10	Pyrite, arenaceous Foraminifera, mainly *Ammovertella*, spicules, pyritized rhomboporoid bryozoans.
9	1	0	23	23	Rare pyrite.
9	2.5	0	16	16	Rare arenaceous Foraminifera, pyritized spicules.
9	4	3	9	12	Lacy chert, rare Foraminifera, mainly *Ammovertella*.
9	6	2	12	14	Lacy chert, rare *Ammovertella*.

Locality	Distance from base of unit feet	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
12	-0	7	40	47	Silicified gastropods and pelecypod fragments, *Triticites*, arenaceous Foraminifera, mainly *Tolypammina*, *Ammodiscus*, spicules, slight pyrite.
12	+0	4	16	20	Pyrite, pyritized *Cavalina*, bryozoans, ramose and fenestrellate, *Ammodiscus*.
12	1	1	12	13	Mainly arenaceous Foraminifera and fragments, *Ammodiscus*, *Tolypammina*, *Ammovertella*, spicules, pyritized *Cavalina*, conodonts.
12	3	2	16	18	Pyritized *Triticites*, *Cavalina*, some *Ammodiscus*, *Tolypammina*.
12	4	1	13	14	Mainly clay-silt, some pyrite, *Tolypammina* and other Foraminifera fragments.
12	6	0	33	33	Largely fragmentary arenaceous Foraminifera, *Tolypammina*, pyrite *Cavalina*.

Locality	Distance from base of unit Feet	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
12	7	1	15	16	Broken arenaceous Foraminifera, some clay-silt.
16	+0	2	16	18	Mainly arenaceous Foraminifera, largely *Ammovertella*, some pyrite.
16	1	2	18	20	Mainly arenaceous Foraminifera, *Tolypammina*, *Ammovertella*, some pyrite.
16	2	0	21	21	Some arenaceous Foraminifera.
16	3	2	21	23	Subequal pyrite, arenaceous Foraminifera, mainly *Ammovertella*, rare *Triticites*, some spicules.
16	4.5	1	24	25	Some pyrite, *Ammovertella*.
16	5.5	2	21	23	Mainly pyrite.
16	6	1	18	19	Rare *Ammovertella*, some pyrite.
16	7.5	1	6	7	Fragmental arenaceous Foraminifera.
17	+0	2	13	15	Arenaceous Foraminifera, mainly *Tolypammina*, some clay.
17	3	0	17	17	————
17	5	0	18	18	————

Locality	Distance from base of unit feet	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
17	6.5	0.1	5	6	Broken arenaceous Foraminifera, rare limonite.
22	.5	1	22	23	Rare, arenaceous Foraminifera, spicules.
22	2.5	0	6	6	————————
22	3	0	6	6	Arenaceous Foraminifera, spicules, rare muscovite.
22	4	0	7	7	Fine quartz sand to silt, some muscovite.
22	16	0	6	6	Same as above.
23	7	1	7	8	Same as above.
23	11	1	9	10	Same as above.
23	15	1	11	12	Same as above.
23	19	1	10	11	Same as above.
23	23	2	10	12	Fine quartz sand to silt, some muscovite.
23	24	2	5	7	Arenaceous Foraminifera, spicules, some silt.

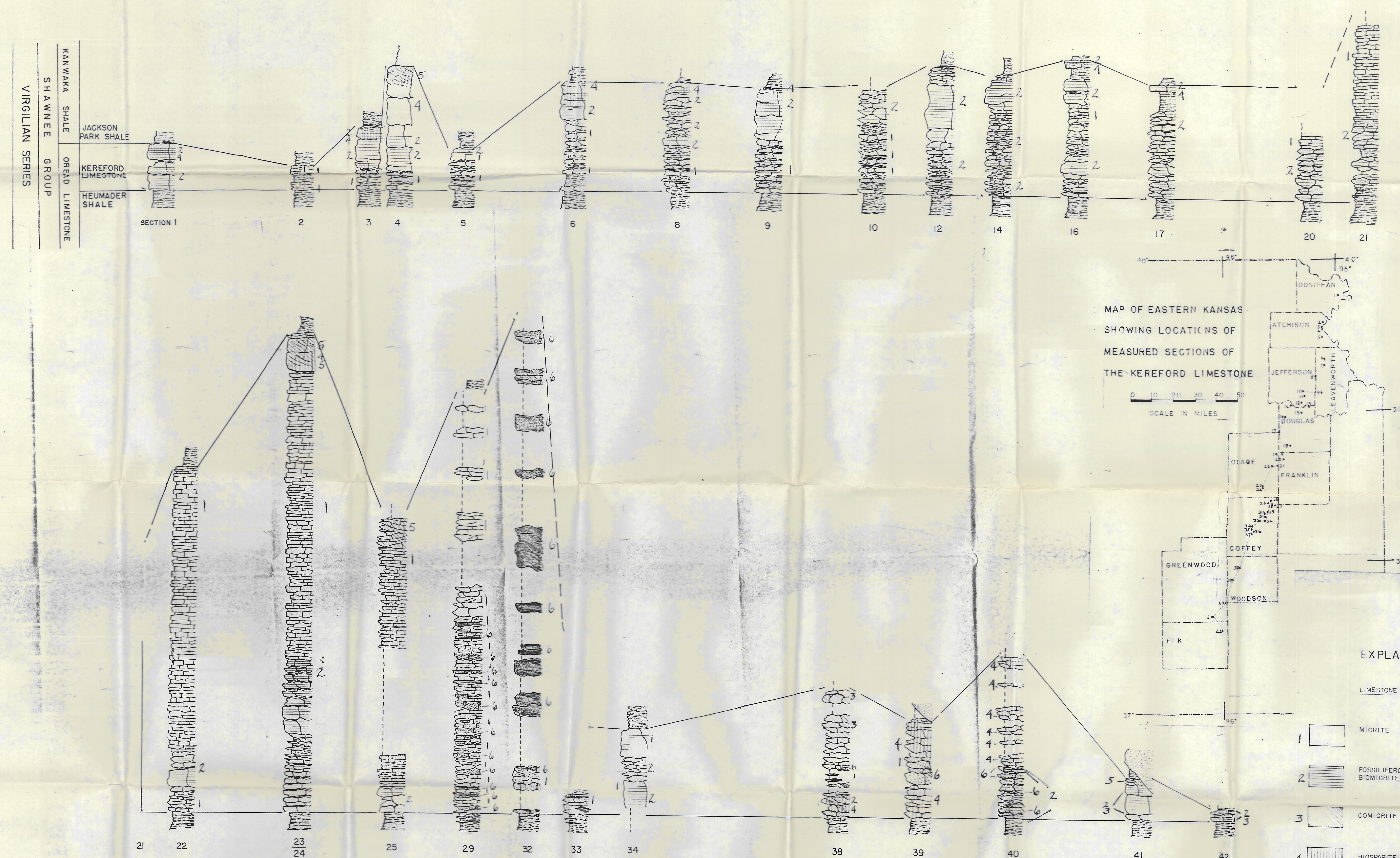
Locality	Distance from base of unit feet	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
23	25	1	2	3	Arenaceous Foraminifera, Tolypammina, Ammodiscus, some silt muscovite.
24	+0	0	10	10	Arenaceous Foraminifera, some silty clay material.
24	1	1	5	6	Arenaceous Foraminifera, Tolypammina, slight biotite, muscovite.
24	2	0	7	7	Rare arenaceous Foraminifera, mainly Tolypammina.
24	3	0	8	8	Rare arenaceous Foraminifera, spicules, some muscovite.
24	4.5	1	11	12	Rare arenaceous Foraminifera, some limonite.
24	6.5	0	9	9	————
24	8	0	6	6	Fine quartz sand to silt, some muscovite.
25	1.3	0	10	10	Slight amount of fine quartz sand to silt, some muscovite.
25	1.4	0	19	19	Fine quartz sand to silt.
25	4	1	15	16	Same as above.
25	10	1	10	11	Same as above.

Locality	Distance from base of unit feet	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
25	15	3	6	9	Same as above.
25	15.5	2	4	6	Fine quartz sand to silt, muscovite, slight amount of carbonaceous material.
25	17	1	2	4	Fine quartz sand to silt, some muscovite, rare *Tolypammina*.
29	+0	45	15	60	Fine sand to silt quartz fragments, subangular, 62 micron size dominant, some muscovite.
29	3	44	5	49	Quartz sand to silt, muscovite, small amount of carbonaceous material.
29	6	49	7	56	Quartz sand to silt, slight amount of muscovite.
29	12	4	12	16	Quartz sand to silt, some *Ammovertella*.
29	16	0	4	4	Fine quartz sand to silt, muscovite.
29	18	0	4	4	Same as above.
29	22	2	10	12	Same as above.
33	+0	14	9	23	Fine quartz sand to silt, some muscovite, carbonaceous material.
34	0.5	2	2	4	Fine quartz sand to silt, small amount of pyrite, carbonaceous (?) material.

Locality	Distance from base of unit feet	Coarse fraction percent	Fine fraction percent	Total percent of insoluble residue	Constituents of coarse fraction
34	2	0	5	5	Fine quartz sand to silt.
34	4	1	3	4	Fine quartz sand to silt, small amount of muscovite.
38	0	15	5	20	Fine quartz sand to sandstone, some muscovite, rare arenaceous Foraminifera, *Ammovertella*.
38	3	37	16	55	Fine quartz sand to silt, some muscovite.
38	6	10	9	19	Fine quartz sand to silt, rare arenaceous Foraminifera, *Ammovertella*.
39	1	3	18	21	Fine quartz sand to silt, some muscovite, limonitic *Triticites*.
39	3	46	1	47	Fine quartz sand to silt, some muscovite.
39	5	3	7	10	Fine quartz sand to silt, *Tolypammina*, *Ammovertella*.
41	+0	1.6	10	26	Fine quartz sand to silt, arenaceous Foraminifera, *Ammovertella*, *Ammodiscus*.
41	0.7	2	10	12	Arenaceous Foraminifera, *Ammovertella*.
41	2.4	16	5	21	Fine quartz sandstone to silt, some muscovite, arenaceous Foraminifera, *Ammovertella*.

PLATE I

STRATIGRAPHY OF THE KEREFORD LIMESTONE IN EASTERN KANSAS



EXPLANATION

LIMESTONE LITHOLOGIES

1 MICRITE

2 FOSSILIFEROUS MICRITE, BIOMICRITE, BIOMICRUDITE

3 COMICRITE

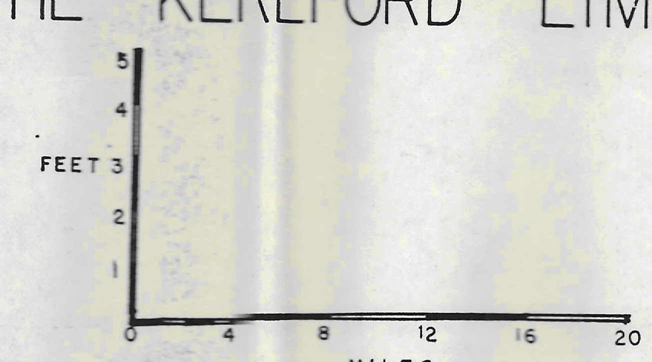
4 BIOSPARITE, BIOSPARRUDITE

5 OOSPARITE

6 QUARTZOSE ARENITE

CORRELATION CHART OF THE KEREFORD LIMESTONE

DATUM: BASE OF KEREFORD
HORIZONTAL SCALE, 1 INCH = 4 MILES
VERTICAL SCALE, 1 INCH = 2 FEET
LINE OF SECTION GIVEN ON FIGURE 1.



J. W. H. MONGER
JULY, 1961