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Microfossil Distribution In The Hickory Creek Shale, Wilson, Montgomery Counties Kansas

THEODORE E. JACQUES

1964

MICROFOSSIL DISTRIBUTION IN THE HICKORY CREEK SHALE, WILSON, MONTGOMERY COUNTIES KANSAS

by

Theodore E. Jacques
B. S., The University of Wisconsin, 1961

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

R C Moore
Instructor in charge

William H. Merrill
For the department

August, 1964

Frank C. Foley

J M Jewett

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ABSTRACT

A study of microfossil distribution in the Hickory Creek Shale at Brickton and Altoona, Kansas, is conducted in an attempt to correlate divisions within the shale. Abundances of foraminifers, ostracodes, holothurian sclerites, sponge spicules, immature brachiopods, pelecypods, gastropods, and trilobites are found to vary considerably in a vertical direction and to have similarities at the two localities both in location and intensities of occurrence highs.

Although not conclusive, a correlation is made between the shale at Altoona and the botton 7+ feet at Brickton.

Numbers and kinds of microfossils are used in interpreting the history of the geologic development of the large shale mound centered at Brickton.

INTRODUCTION

The Hickory Creek Shale is the middle member of the Plattsburg Limestone and lies between the Merriam Limestone Member, below, and the Spring Hill Limestone Member, above (Fig. 1). In northeastern Kansas the unit is typically grey or yellowish, relatively unfossiliferous (Moore, 1935, p. 129) and except for a few local thickenings, such as near De Soto (Newell, 1935, p. 69), where it is 20 feet thick, the unit is seldom more than a few tenths of a foot thick.

In Wilson and Montgomery Counties, in the area ruled diagonally in Figure 2, the Plattsburg Limestone thickens into what has been interpreted as a barrier reef (Davis, 1959) or marine bank (Harbaugh, 1959). An isopach map of the Hickory Creek Shale (Fig. 3) shows that this unit also thickens from its normal thin development to a shale bank that is greater than 40 feet thick locally. In its thickest development, the shale accounts for almost all of the Plattsburg Formation. The Hickory Creek Shale forms an arcuate bank in the area from Fredonia to Altoona in an east-west direction, and from Altoona to Sycamore in a north-south direction, (Fig. 3). The bank was studied along its outcrop and is also known to be present in the subsurface to the west. It is inferred to have extended several miles east where rocks of the Plattsburg have been removed by erosion.

Besides departure from normal thickness, the Hickory Creek changes in color, lithology, and paleontology in the area of the "buildup." The shale is consistently dark grey, and except

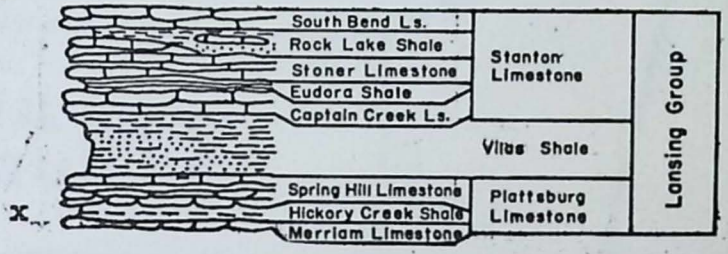


Figure 1.-Stratigraphic column of Lansing Group (Pennsylvanian) with position of Hickory Creek Shale marked by x. (from Jewett, 1959).

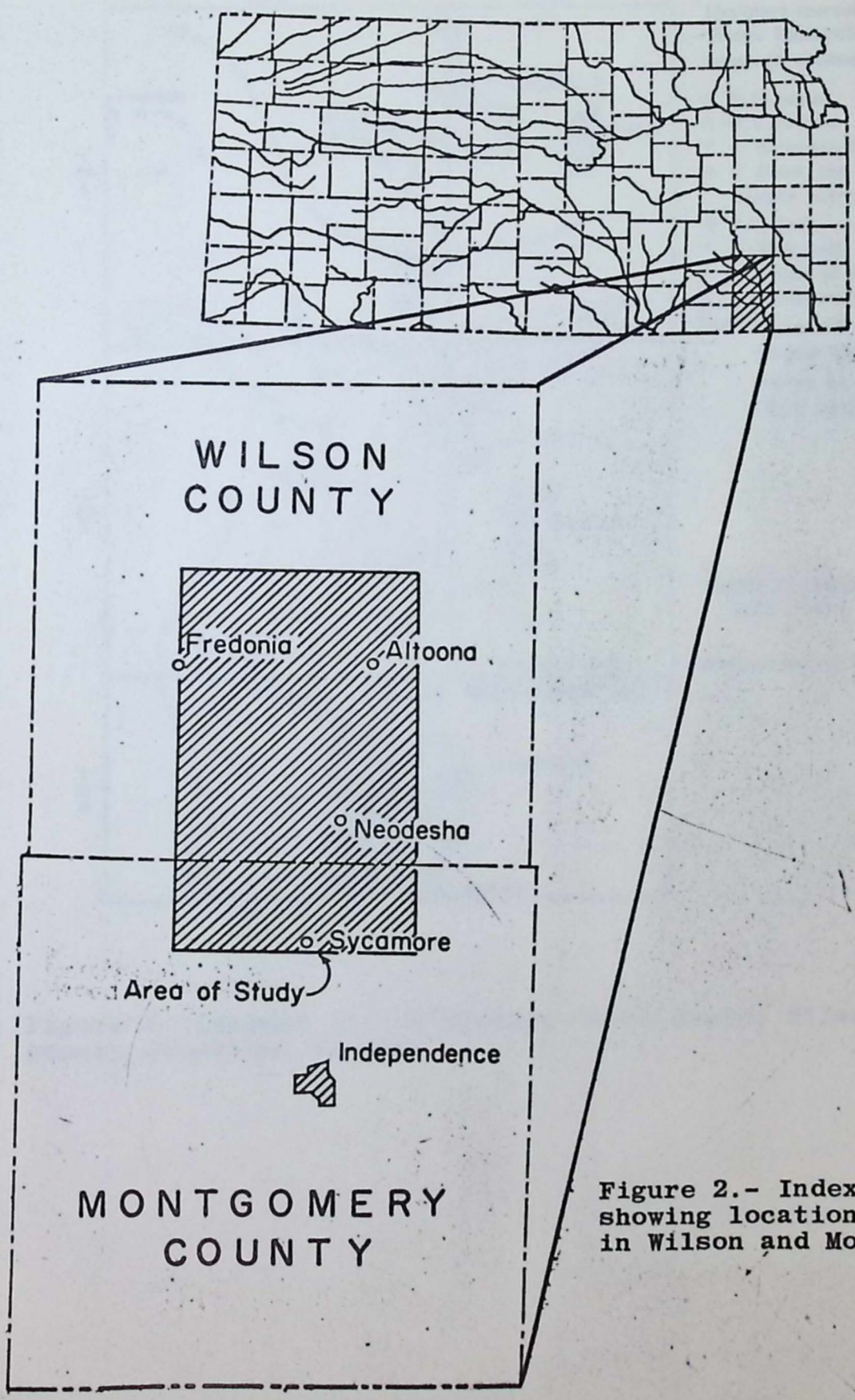


Figure 2.- Index map of Kansas showing location of study area in Wilson and Montgomery Counties.

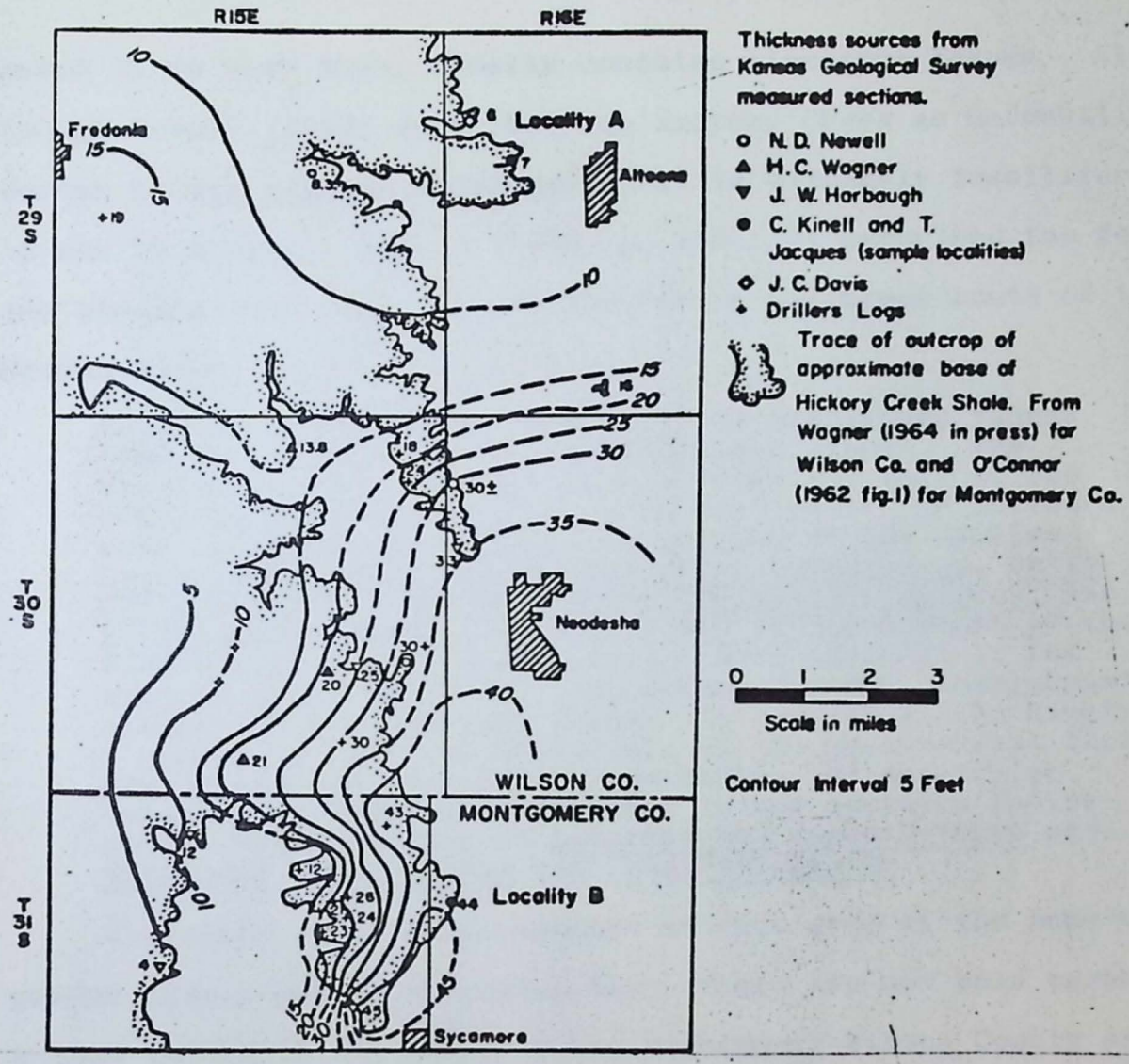


Figure 3.-Isopach map of Hickory Creek Shale, Wilson, Montgomery Counties, Kansas.

where it is very thin, usually contains limestone lenses. Although Newell (1935) described the Hickory Creek as unfossiliferous in its typical development, it is extremely fossiliferous in the bank area. Newell (1933, p. 129-130) described the following changes that occur in the Plattsburg Limestone south of the Neosho River:

> South of Neosho River, however, the Plattsburg faunas take on a striking and very different aspect. The Merriam member loses the worm borings and many of the other fossils that characterize the bed in the northern area. A great development of sponges of the species Girtycoelia benjamini, Maeandrostia kansasensis, Heliospongia ramosa, and especially Coelocladia spinosa, and Heterocoelia beedei, occurs in all of the members of the Plattsburg, but they are particularly abundant in the Hickory Creek Shale . . .the productids are conspicuously absent in this southern fauna. In central Wilson County, a number of mollusks definitely of the geosynclinal facies are introduced into the sponge fauna. Of particular note is the occurrence together in the southern facies of the Hickory Creek of Leiorhynchus rockymontanus and Enteletes hemiplicatus var. plattsburgensis.

The shale in a fresh exposure is dark grey at the base but grades upward into a yellowish hue. There are no thin carbonaceous layers in the shale of the Montgomery-Wilson County area, such as occur in northern Kansas, but instead, stringers and lenses of marine limestone with considerable initial dip are found in the shale, especially where it is thick (Fig. 4, 5, 6).

The Spring Hill Limestone of the Plattsburg Formation and the limestones of the Stanton Formation also participate in "buildups" in Wilson and Montgomery Counties. One interesting and genetically significant aspect of the relationship of the thickness of the Vilas Shale to the thickness of the Plattsburg Limestone is the fact that the shale is thickest where

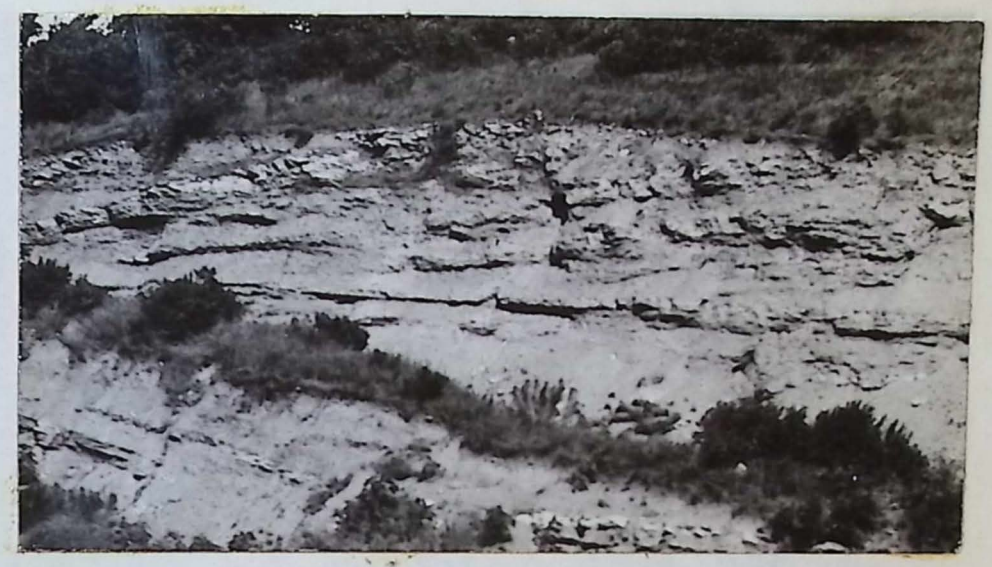


Figure 4.- Photograph of Hickory Creek Shale in SW$\frac{1}{4}$ sec. 17, T 31 S., R 16 E. (Locality B). Interbedded limestone lenses dip toward the south (left edge of photograph) at considerable dips. (Photograph courtesy of J. W. Harbaugh).

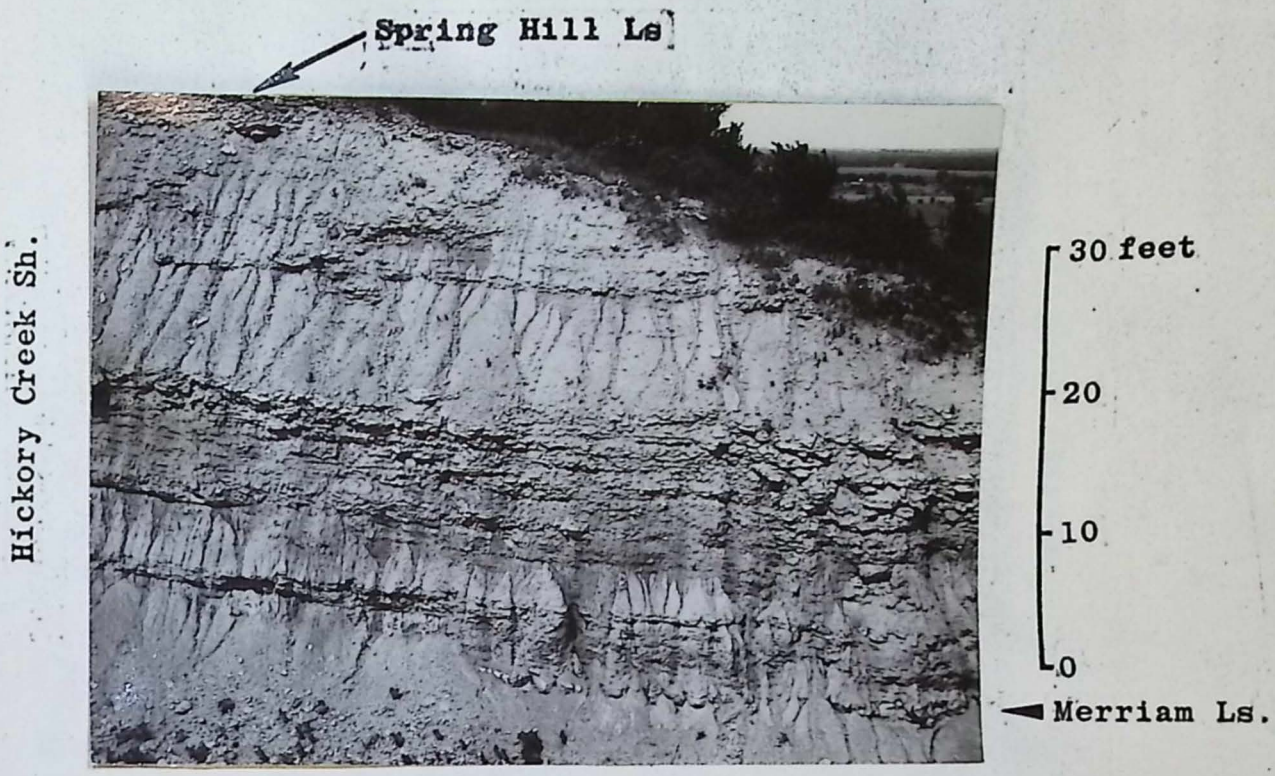


Figure 5.-Photograph of Plattsburg Limestone at Locality B showing thickest development of Hickory Creek Shale Member. Note numerous limestone stringers and the gradational boundary between the Hickory Creek Shale and Spring Hill Limestone Member.

Figure 6.-Photograph of Plattsburg Limestone at Locality A showing limestone lenses interbedded with Hickory Creek Shale Member.

the limestone below is thin and vice versa. Harbaugh (1959) has explained this relationship as a sediment fill between mounds of limestone during the development of the buildup. Chelikowsky and Burgat (1947) suggested that differential compaction of the shale and normal sedimentary processes caused variation in thicknesses.

The marine banks have received much attention because similar buried marine banks are potential traps for oil (Merriam, 1963, p. 119), and because "buildups" near the surface are choice sites for limestone quarries (Harbaugh, 1959, p. 314-315). Newell (1933), Davis (1959), Chelikowsky and Burgat (1947), and others have described the stratigraphic and petrographic aspects of these marine banks in the Stanton and Plattsburg Formations. However, little research has been done on the invertebrate paleontology, especially of the shales. For example, little is known about the relationship of the fossil content to the sedimentation and development of these peculiar anomalies.

Purpose of Study

The principal purpose of this study is to determine whether different kinds of microfossils and their abundances can be used in making zonal correlations within a formation that displays variability in thickness, lithology, and other physical and chemical properties. I propose to examine the usefulness of relative microfossil abundances to determine if divisions of the shale away from the "buildup" can be placed in the proper vertical position in the thick section at Brickton. This type

of correlation is based on the assumption that similar environments over large areas of the bank may enable one to correlate environmental horizons by comparing fossil abundances which reflect these environments.

It was hoped that four or five complete sections of the Hickory Creek could be sampled across the bank at regular intervals from the area of maximum thickness to an off-bank outcrop. Excellent exposures are available in an abandoned shale pit at Brickton, Kansas (Fig. 5) and in a road cut on Kansas Highway 47, just west of Altoona, Kansas (Fig. 6) These outcrops provided unweathered samples for the end points along the proposed north-south section through the bank. However, samples of fresh shale between these localities were impossible to obtain because of weathering and inaccessibility due to heavy brush cover. The Altoona locality is here designated as Locality A, and the Brickton locality as Locality B. Both sampling stations are indicated in Figure 7. Samples are referred to by locality letter and are numbered from the base of the shale upward. For example, sample A1 is located at the bottom of the shale at Altoona.

Field Procedures

Although more control points were not secured, the two sampled sections provided an opportunity to study the shale in two extremes of thickness. At Locality B, 44 feet of shale was sampled. At Locality A, 7 feet of Hickory Creek was measured and sampled. These two sections of the Hickory Creek are approximately 12 miles apart.

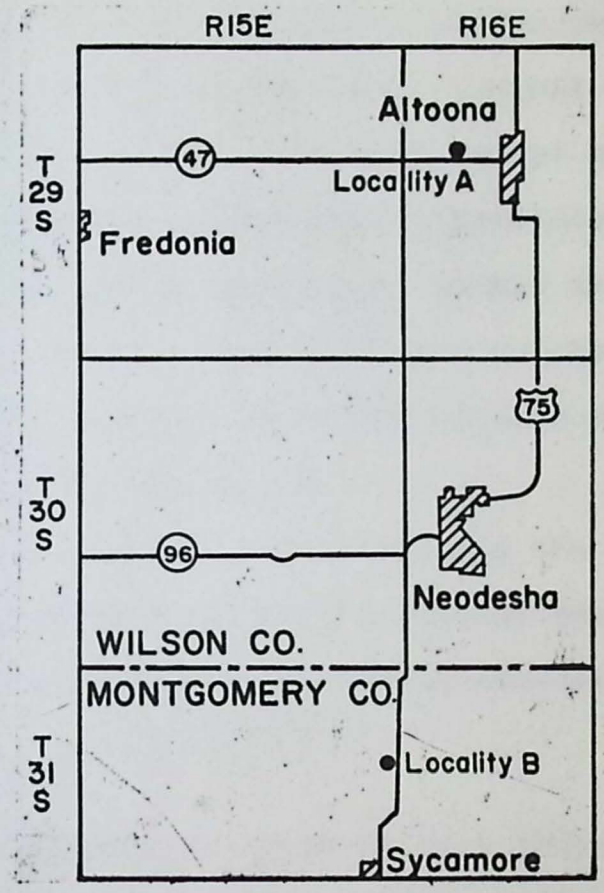


Figure 7.-Index map of Wilson and Montgomery Counties, Kansas showing location of sampling localities.

The sections were sampled by removing about five pounds of shale between 1-foot marks painted on the outcrop face. This method called for digging a continuous channel and provided samples of a complete section of shale except where limestone stringers were present in the Brickton locality. It is desirable to sample these limestones by another method because lithologic transitions are probably closely related to changes in the fossil content. It was not within the scope of this study, however, to sample or study the limestones.

Field work was completed by recording the lithology of the two sections which hopefully will establish some relationship between lithology and changes in fossil abundances.

Laboratory Procedures

Each 2.3-kg. sample was reduced to a 500-gram sample by splitting. This material was placed in 1-liter beakers and washed repeatedly with tap water to disaggregate the shale, remove the clay, and free the microfossils. The shale disintegrated so easily that further treatment was not needed except for boiling. Ultrasonic vibration of the calcareous residue completed the cleaning operation.

The residue was dried, weighed, and separated into three fractions by sieving through number 35, 60, and 120 standard sieves. (Standard sieve numbers referred to in this report and mesh size in mm are:

ss120 = 0.125mm
ss 60 = 0.246mm
ss 35 = 0.417mm

This procedure greatly facilitated the counting process because it eliminated the need for continual refocusing of the binocular microscope, and helped to concentrate microfossils into groups of similar taxonomy. For example, most of the Nodosinella foraminifers were concentrated in the number 120 sieve.

Because the residue from the 500-gram portion of the shale sample yielded 100 to 300 grams of fossil-rich residue, it was necessary to reduce the amount of material further, so that the sample could be handled in a reasonable amount of time. Sample size was critical because it had to be large enough to be statistically representative, yet small enough to be handled in a relatively short period of time, so that many samples could be treated. After experimenting with several larger sample sizes, it was decided that a 10-gram sample would be most suitable. The three sieve sizes from each sample interval were split until the combined sample weight was approximately 10 grams. This method of reducing the sample maintained the original ratio among the three sieve sizes and therefore among the numbers of fossils contained in each. The weight of each split sample was recorded and the sample consisting of three sieved portions prepared for examination by cleaning in the ultrasonic vibrator.

Counting Procedures

Each sieve size portion of the sample was sprinkled into a small, shallow plastic container partitioned into 24 compartments. The material in each compartment was examined for microfossils and these were tabulated at the generic and class levels.

It was thought that this method of handling small amounts of sample, although tedious, did produce accurate results and avoided duplication in counting.

Data Presentation

The sample weights and microfossils counted are recorded in Table 1. In order to permit visual comparison of the abundance data from sample to sample, the number of individuals and the sample weights were converted to a common reference weight of 10 grams. These data were used to construct abundance curves (Plate I) for the taxa counted.

Acknowledgments

Financial support for the project was furnished by the Kansas Geological Survey. Dr. John W. Harbaugh of Stanford guided me to several exposures in the field, and Carl Kinell assisted me in measuring sections and collecting samples. Dr. Daniel F. Merriam offered continued support and encouragement. I am grateful for assistance given by Dr. William C. Pearn in the statistical analysis of data, and in preparing computer programs. Appreciation is expressed to my wife, Vicki, for editing the manuscript and for suggestions that greatly improved the manuscript. Dr. C. W. Pitrat advised me during the early stage of the study and Dr. R. C. Moore offered valuable suggestions and criticisms in the final preparation of the manuscript.

DESCRIPTION AND DISTRIBUTION OF MICROFOSSILS

Microfossils identified and counted are:

FORAMINIFERA

- *Ammobaculites*
- *Ammodiscus*
- *Endothyra*
- *Endothyranella*
- *Glyphostomella*
- *Nodosinella*
- *Spiroplectammina*
- *Tetrataxis*

OSTRACODES

- *Amphissites*
- *Bairdia*
- *Bythocypris*
- *Cavellina*
- *Healdia*
- *Hollinella*
- *Kirkbya*
- *Macrocypris*
- *Monoceratina*
- *Selenites*
- *Ulrichia*

CONODONTS

- *Hindeodella*
- *Streptognathodus*

HOLOTHURIAN OSSICLES

- *Ancistrum*
- *Protocaudina*
- *Thuroholia*

GASTROPODS

- High- and low-spired forms (*Pseudozygopleura*)

PELECYPODS

- pectinids and myalinids

SPONGE SPICULES

IMMATURE BRACHIOPODS

Megafossils identified from the outcrops are:

BRACHIOPODS

Hustedia
Composita
Juresania
Punctospirifer
Neospirifer
Neochonetes
Dictyoclostus
* *Rhipidomella*

SPONGES

Girtyocoelia
Heliospongia

BRYOZOANS

* *Sulcoretipora*
Rhombocladia
* *Fenestella*
Fistulipora
* *Rhombopora*
** *Polypora*
Penniretepora
Minilyia

GASTROPODS

Pseudozygopleura

VERTEBRATE

Sharks' teeth

ECHINOIDS

Spines and plates

CRINOIDS

* Plates and columnals
Calyces

Apographiocrinus typicalis Moore and Plummer
Plaxocrinus perundatus Moore and Plummer
Stellarocrinus geometricus Moore and Plummer
Perimestocrinus impressus Moore and Plummer
Erisocrinus propinquus Miller

(These beautifully preserved calyces were found in a zone about 35 feet above the base of the shale on a north-facing slope adjacent to the quarry at Locality B).

* abundant
** very abundant

OSTRACODES

Bairdia. The largest and most abundant ostracode present, Bairdia, shows a great variety of shapes, indicating the presence of many species. Although it was not within the scope of this study to describe the distribution of species of the various genera, it probably would be profitable and desirable to note the occurrence of some of the more distinctive species of Bairdia since species are much more sensitive to environmental change than the group as a whole. Elongate forms that are assignable to B. peracuta (Harlton, 1928) occur in samples B8, B13, B16, B17, B19, B29, B35, B40.

At Locality A, Bairdia was not identified in the samples A1 and A2 because of poor preservation of the ostracodes. Coatings of clay and other material obscured outlines of the carapaces. The specimens that were identified as Bairdia in samples A6 and A7 gradually increase upward in abundance from sample A1 to a maximum occurrence in A6.

At Locality B, Bairdia is present in every sample but is especially abundant in samples B15 through B20.

Most of the individuals of Bairdia were collected in ss60 although frequently very large individuals were noted in ss35. The majority of the specimens consisted of both valves. Internal features of the valves were visible where valves occurred singly.

Amphissites. This second most abundant ostracode shows a variety of surface ornamentation and shape. Most specimens have as the obvious feature a central node. Lateral carinae

in other individuals are subdued and the only surface ornamentation is a reticulate network. At least four species were tentatively identified according to variations in ornamentation; A. centronotus, A. roundyi, A. carinotus, and A. dattonensis. Amphissites rarely occurs as a complete carapace, and is usually amber-colored or dark grey.

At Locality B, Amphissites is most abundant in sample B20 and becomes less abundant upward in the section.

At Locality A, Amphissites is most abundant in sample A7 and increases in abundance upward in the section. Amphissites has an abundance curve similar to Bairdia although changes are not as great.

The following ostracode genera were not included in Plate I because their occurrence is too sparse to be plotted on a scale comparable to the other taxa. They were difficult to identify because of coatings of clay which obscured shell outlines and surface details.

Bythocypris is most abundant in sample B15. At Locality A Bythocypris occurs in greatest numbers in samples A6 and A7. Although Bythocypris probably is present in samples A1 and A2, none were identified because of poor preservation of the less distinctive ostracodes.

Healdia. In the Hickory Creek Shale, this small, nondescript ostracode occurs sporadically and in small numbers. It is relatively minor in total number of individuals. Generally, only one or two specimens per sample were recorded from Locality B. Healdia is more abundant in samples from Locality A.

Cavellina. The ostracode is most abundant in sample B20 and A7. It is distributed discontinuously and represented by six or seven specimens per 10-gram sample. Cavellina is slightly more abundant at Locality A.

Specimens of Selenites were gathered in the ss60 and ss35 sieve. The genus is easily distinguished by its large size and distinctive shape. It is abundant in samples B19 and B20 with maximum occurrence of about seven individuals in sample B20. Selenites carapaces are rare or lacking in most samples from Locality A.

Hollinella, Monoceratina, Macrocypris, Kirkbya, and Ulrichia. These genera are easily identified but generally are very rare in the samples. The occurrence of Hollinella is less than two specimens per sample. It occurs in only 14 of the 46 samples, of both localities. Specimens are commonly dark grey and invariably the valves are disarticulated. The specimens were very large compared to the other ostracodes and were conveniently gathered in the ss120 and ss35 sieves.

Monoceratina is easily recognized by its distinctive caudal process and the single spine on each valve. It is rare or lacking in samples from Locality A and is only present in small numbers at Locality B. In sample B39 it reaches a maximum of eight individuals. Most specimens are small and disarticulated.

Ulrichia is found in 18 samples from both localities. Only one or two specimens per sample were counted in these but in sample B20 an unusually high count of 22 individuals was recorded. Complete carapaces were usually found.

Kirkbya is extremely rare in the two sections of the Hickory Creek Shale occurring in only seven of the 46 samples, with one or two specimens per sample. Complete carapaces were usually observed for this genus.

FORAMINIFERA

Foraminifers far outnumber all other microfossils in the Hickory Creek Shale. In sample B1, more than 2200 individuals were counted. At Locality A the foraminifers also dominate the other fossils with a maximum occurrence of 1289 individuals in sample A2. The abundance pattern shows that the greatest concentration of foraminifers occurs at or near the base of the shale. At Locality B there is a tapering off of the curve after this flood of population in B1. There are similar explosions in the foraminiferal population in samples B5 and B6, followed by a rather constant occurrence until the final burst at the top of the section in sample B40.

Ammodiscus. By far the most abundant of the microfossils, this genus occurs in greatest numbers in the bottom samples of both sections. At Locality B its maximum occurrence is in sample B1. Numbers of Ammodiscus decrease above sample B6 and it is relatively unimportant in the rest of the section, with an average occurrence of one or two individuals in each sample. At Locality A, the maximum occurrence of Ammodiscus is slightly diminished with respect to section B in that the maximum occurs not in sample A1, but in sample A2.

Ammodiscus is a little less important in terms of total numbers in samples of Locality A than in those of Locality B. At Locality A, Ammodiscus gradually decreases in numbers upward so that near the top of the section Ammodiscus is not a major part of the microfossil population.

There is some question as to whether Cornuspira and Ammodiscus should be considered distinctive genera. Ireland (1956, p. 839) thought these genera were isomorphs and similar in all respects except for the material the organisms used in constructing their tests. This selective use of available construction materials was judged by him to be a significant reason for recognizing two distinct genera; Ammodiscus being the name applied to the isomorph using siliceous material and Cornuspira for the calcareous form. Both forms are recognized in the Hickory Creek by performing a simple test with acetic acid. Upon contact with the acid, some of the specimens dissolved completely while others produced a siliceous residue. This criterion for distinguishing the two genera could not be used in this study because of the time involved in testing every individual with a discoidal shape. Therefore, all discoidal foraminifers were tallied under Ammodiscus, regardless of chemical makeup.

The Nodosinella-Nodosaria isomorphs were treated similarly; all Nodosinella-like forms were counted as Nodosinella.

The surface of Ammodiscus is coarsely granular. Some specimens are transparent and have a vitreous luster. Other specimens have a porcellaneous luster and are milky-white. The

surface of the latter specimens is glossy and quite unlike those with a granular textured surface. Difference in appearance probably reflects the difference in the material used in the construction of the tests, the glossy ones being calcareous and assignable to the genus Cornuspira and the granular ones siliceous and referable to the genus Ammodiscus. But without the acid test, these features were too subtle to be used effectively in this study to separate the two genera.

Most of the specimens were collected in the ss120 sieve but those having less than three or so whorls were probably lost. However, occasional checks in the contents of the bottom pan of the sieve column for Ammodiscus showed that significant amounts were not lost.

Nodosinella. Nodosinella is the second most abundant microfossil found in the Hickory Creek Shale. Several species are probably represented in the samples although no attempt was made to recognize them. Tests of Nodosinella range in texture from glossy to coarsely granular. Like Ammodiscus, the calcareous and siliceous isomorphs known as Nodosaria and Nodosinella, respectively, are probably present, as suggested by this difference in texture. Both forms were tallied and considered graphically as Nodosinella.

The gently curved linear-seried tests of Nodosinella have variation in the appearance of the sutures that is noteworthy and probably of value in speciation. In some individuals the suture is indented so that the arrangement of the chambers resembles stacked beads. In others the indentation of suture is so subdued that the walls of the test are perfectly straight.

It was often difficult to distinguish the final uniserial portion of Endothyranella and Ammobaculites from Nodosinella. However, in the latter genus the chambers increase in size with age so that the test is slightly conical, whereas in the former the uniserial chambers are of nearly equal size. The genera could be distinguished on this basis.

Nodosinella has a maximum occurrence at Locality B in sample B5 with 687 specimens and fluctuates in abundance from sample B7 to B20. It is rare from samples B26 to B41, and at the top of the section, but there is a large increase in samples B41 and B42.

Ammobaculites-Endothyranella. These coiled-uniserial foraminifers are light amber-colored and have a smooth, non-granular texture. The two forms are distinguished from each other because Endothyranella has the straight uniserial portion of the test tangential to the coiled portion whereas Ammobaculites has its serial chambers aligned at right angles to the circumference of the earlier coiled portion. Endothyranella appears to be an intermediate form between Endothyra and Ammobaculites because it is one stage past Endothyra in evolution in being uncoiled and not yet having erect uniserial portion like Ammobaculites.

Using this criterion, Endothyranella and Ammobaculites were easily differentiated. However, where only the final uniserial portion of a broken test was found, identification was not possible and these were tallied with Ammobaculites because this genus is generally more abundant.

Ammobaculites fluctuates from 25 to 50 individuals per sample at Locality A and has similar variability in samples of Locality B. At Locality B the population gradually decreases upward and finally becomes numerically insignificant near the top of the section.

Endothyranella was not positively identified at Locality A although some of the uniserial fragments assigned to Ammobaculites are undoubtedly referable to it. At Locality B the genus is very sparsely distributed and is missing from samples B1, B4, B10, B13, B15, B26, B30, and B42. At its maximum occurrence in sample B5, the genus is represented by six individuals.

Spiroplectammina. The coiled, biserial foraminifer is extremely variable in abundance and is scattered throughout section B. This sporadic distribution is reflected in the numerous "kicks" of the distribution curve. At Locality B it varies from a maximum of 55 specimens in B24 to none in samples B1-B4, B10, B20, and B30. The genus is much less abundant at Locality A where the greatest occurrence is in sample A7 which contains 18 individuals.

Spiroplectammina usually occurs as whole tests although broken tests are numerous. The texture of the surface is very granular. This fact made recognition of the genus difficult because most of the light was reflected so that chambers were not visible. Most of the specimens were collected in the ss120 sieve.

Endothyra. The pattern of distribution of Endothyra is very similar to that for Ammobaculites at Locality A and resembles that for Nodosinella and total foraminifers at Locality B. Maximum occurrence is in sample B5 which has 123 individuals. Large numbers are found at the bottom of the section in sample B1 but except for those two samples, Endothyra has less than 50 individuals per sample.

The test of Endothyra is amber-colored. Endothyra is usually found in ss120 and frequently in ss60. The texture of the surface is semi-glossy and preservation is excellent. There is no sign of wear by transport.

Tetrataxis. Tetrataxis is very well preserved and exhibits a variety of shapes that indicate the presence of several species. Forms with high and low apical angles are present, the latter being more common. This foraminifer is quite large and numerous individuals were found in the ss60 sieve. The surface texture is very finely granular and the color is commonly cream.

The distribution of Tetrataxis is very similar to that of Spiroplectammina. At Locality B the abundance varies from zero to 25 individuals per sample. Maximum occurrence at Locality B is in sample B43 near the top of the section. At Locality A, Tetrataxis is most abundant near the top of the shale and is relatively rare near the bottom as at Locality B.

TRILOBITES

Ditomopyge. Ditomopyge was identified from fragments of the cephalon such as free cheeks, genal spines and parts of the brim.

The characteristic double spine at the posterior extremity of the pygidium clearly indicated a juvenile of Ditomopyge. Since it is probable that one individual contributed not more than one fragment (because of chance preservation as fossils), each fragment was counted as an individual. The fragments are grey and show few signs of transport. Although most of the fragments were judged to be parts of immature individuals of Ditomopyge, very large genal spine fragments were found in ss35 and were probably derived from mature specimens.

Most specimens counted come from Locality A and most of these are confined to the bottom three feet of the section. Twenty-eight fragments were counted in sample A2 and above this interval the abundance sharply tapers off.

SPONGE SPICULES

One type of spicule having eight or more rays was found. The heteractinellid sponge spicules were very large and were collected in ss60 sieve. Spicules smaller than 0.264 mm were not common. Fragments of the rays were probably present in the smaller sieves but were not identified.

Sponge spicules are very rare in the Hickory Creek Shale. At Locality B, fewer than half the samples contained spicules and of these only six contained more than ten fragments. Maximum occurrence of 20 specimens is in sample B30. There is a sharp increase in abundance of spicules from samples B27 to B30 at Locality B. Spicules are much less important as a contributor to the total population than most other organisms, although

fragments of sponges such as Girtyocoelia and Heliospongia are abundant on the weathered surface of the shale.

HOLOTHURIANS

Holothurian ossicles of three general types were identified and tabulated. The most common sclerite is the perforated plate called Thuroholia (Gutschick, 1958). This genus occurs in 25 samples, with maximum occurrence of ten individuals in sample B41. The average occurrence of this genus is one or two specimens per sample.

Protocaudina is the name proposed by Croneis and MacCormack (1932) to include holothurian sclerites that are shaped like spoked wheels having an outer rim with eight or ten perforations and a central hub with four pores. At least two species of this genus are represented in the samples of Hickory Creek. One is called Protocaudina hannai for wheels with eight perforations in the outer rim and the other called Protocaudina kansasensis, which has ten perforations in the outer rim.

These wheel-shaped sclerites are most abundant in sample B41 which contains eight individuals. The distribution of the sclerites is fairly uniform throughout the section at both localities. At Locality B maximum occurrence is in the top of the shale in samples B39 and B41.

The third type of sclerite is exceedingly rare and is found in only four samples. In three of these samples it occurs singly. In sample A5 there are four of these sclerites. Ancistrum was originally applied to two types of sclerites,

those that are hooklike and those that resemble perforated plates. This name was restricted by Croneis (1932) to include only forms that were hook-shaped. This restriction left the perforated plates without designation until 1953 when Gutschick erected the genus Thuroholia to embrace this type of sclerite. In the samples of Hickory Creek studied, the only portion of this sclerite that was recognized and tallied was the part of the hook having the eyelet.

CONODONTS

The two Hickory Creek genera that were identified in this study are both bar types. Hindeodella and Streptognathodus are very well preserved and commonly amber-colored. Some specimens of Streptognathodus are dark grey and most specimens are so that either the single bladelike portion or the heavy denticulated bar was found. This genus occurs in all of the samples from Locality A and in 24 of the samples from Locality B. Maximum occurrence of 22 specimens is in sample A7. The average number of specimens is three per sample.

Hindeodella is rarer in occurrence than Streptognathodus. It appears in only 12 of the samples from both localities and reaches maximum abundance in sample B7.

This conodont consists of short pieces of the bar having one or two series of alternating short teeth and one long tooth.

GASTROPODS

Juvenile stages of several types of gastropods were tabulated. For convenience in counting, they were grouped into

two categories on the simple qualification of having high or low spires. The genus identified with certainty is Pseudozygopleura. This form accounts for the majority of gastropods in the high-spired group. Within the low-spired group is a number of planispiral bellerophontid gastropods and one or two other low-spired gastropod genera which were not identified. Ornamentation is not developed on most of the juveniles so that genera except for Pseudozygopleura are not recognized.

At Locality B there is a gradual increase in numbers of gastropods upward, except for several minor decreases. Climax of numbers is reached in sample B41. At Locality A the occurrence of gastropods is fairly constant, with bursts in populations in sample A5 and A7. Gastropods are much less numerous at Locality A than at Locality B. Also, at Locality A the abundance of gastropods decreases upward in the section whereas in the samples of Locality B there is an increase in numbers upward.

PELECYPODS

Genera of pelecypods were not identified because ornamentation and distinctive shell shapes are not developed. Pectinids and myalinids are represented by juvenile shells, most of which are unornamented single valves. Several open, articulated valves were noted. This condition may signify quiet water.

The distribution of this group in both localities is very discontinuous. At Locality A there are only one or two individuals per sample. At Locality B, pelecypods do not occur in significant numbers below B27. Culmination of pelecypod populations occurs in sample B41 with a small decrease following the climax.

BRACHIOPODS

Several growth stages of at least one identified brachiopod genus are recognized as contributing to the immature brachiopod population. Rhipidomella is identified from internal characters such as the teeth and pallial markings. Other brachiopods probably represented in the microfossil population are: the productids Dictyoclostus, Juresania; the spirifers, Neospirifer, Punctospirifer, Composita, and Hustedia, and the chonetid, Neochonetes. These genera are all identified on the weathered outcrop face but are not recognized in juvenile stages. Productid spines and lamellar shell fragments indicated the presence of some of these genera in the adult stage. At Locality B, maximum occurrence of about 130 specimens is in sample B2 which is followed upward by a very gradual and discontinuous decrease in number of individuals. At Locality A maximum occurrence is in A2 followed by a rather rapid decrease in numbers and a sharp increase in the final sample.

ANALYSIS OF ABUNDANCE DATA

Index of Affinity

For use in paleontologic interpretation the above described taxa were arranged into groups whose members "frequently occurred together in the samples /and/ were a nearly constant part of each other's biological environment." (Fager, 1957, p. 586).

A statistical device proposed by Fager and McGowan (1963) and used by Lane (in press) is the index of affinity given as

$$(J/(N_A - N_B)^{\frac{1}{2}}) - 1/2(N_B)^{\frac{1}{2}}$$

where J is the number of joint occurrences, N_A is the total number of occurrences of taxon A, N_B the total occurrence of taxon B.

$N_A \leq N_B$ is a necessary requirement. Taxonomic categories higher than genera were rejected for this procedure because they are ubiquitous and would produce meaningless results.

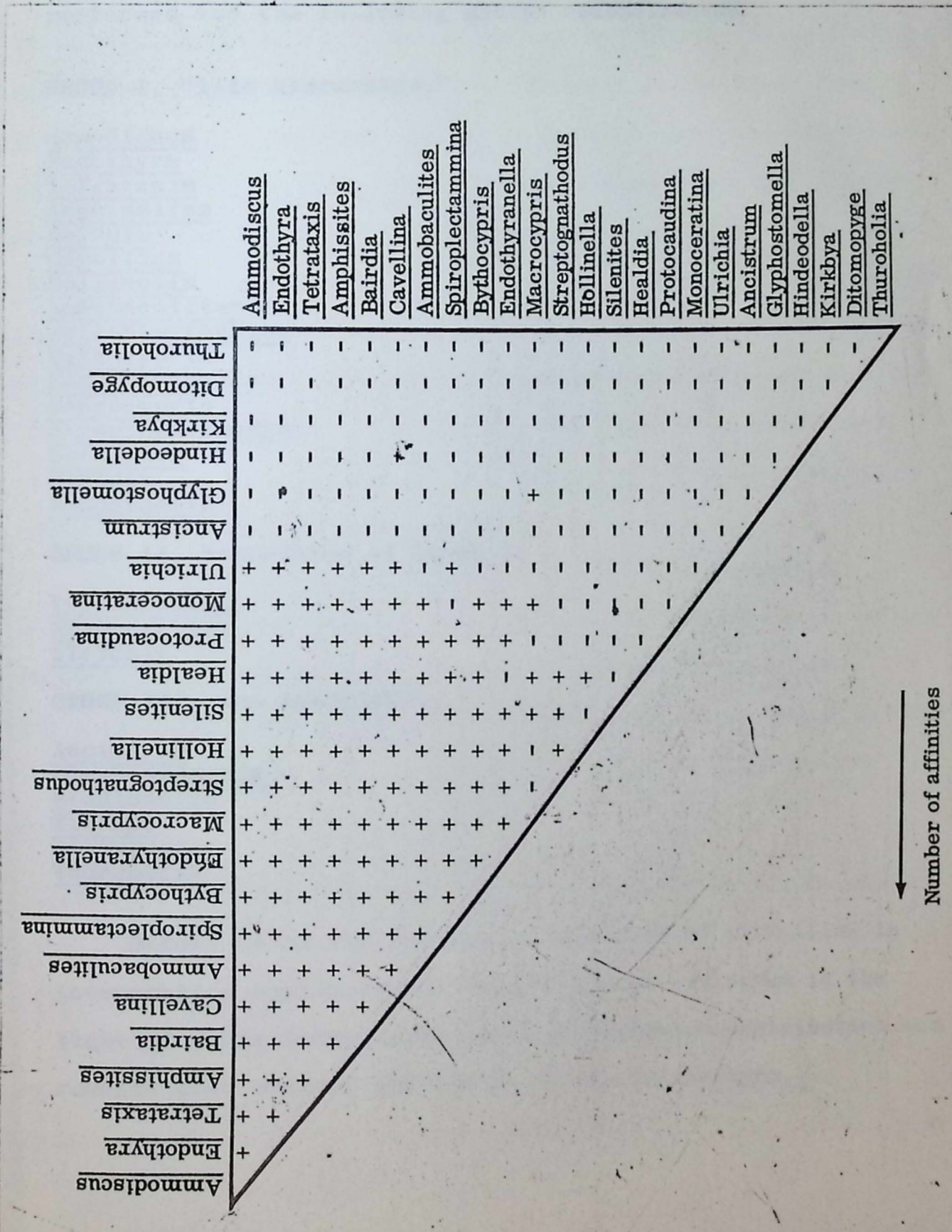
The affinity equation was performed using the data of Table 1 on all possible pairs of selected microfossils by means of a computer program, written by William C. Pearn. Separate calculations were made for the data from the two localities. Because the confidence of the index as a measure of association is directly proportional to the number of samples, the indices obtained for Locality B are judged to be more reliable than those for Locality A. After indices from Locality B were obtained, the taxa were arranged in descending order of numbers of affinities (Table 2).

A cutoff value of 0.500 was used in this study for the reason presented by Fager (1963, p. 454) in a study of living populations:

> This breakpoint was chosen because it was felt that /taxa/ should be found together in somewhat more than half their recorded occurrences if they are to be grouped together.

A somewhat lower value should probably have been selected to take into account processes that tend to destroy organisms after death. Pairs of taxa with indices above 0.500 are considered here to have been negatively associated.

Table 2.- Contingency table for all possible pairs of selected Hickory Creek Shale microfossils. Affinities above .500 designated by plus (+); those below .500 by minus (-).



Fager's (1957) method for grouping the pairs of taxa into life assemblages after obtaining the index of affinity was performed and the following groups reconstructed.

GROUP I, "life assemblage."

Ammodiscus
Endothyra
Tetrataxis
Amphissites
Bairdia
Cavellina
Hollinella
Ammobaculites
Spiroplectammina
Bythocypris
Endothyranella
Macrocypris
Streptognathodus
Selenites
Heoldia
Nodosinella

GROUP II, associates of Group I.

Protocaudina
Monoceratina
Ulrichia

GROUP III, non associates.

Ancistrum
Glyphostomella
Hindiodella
Kirkbya
Ditomopyge
Thuroholia

Before using the results of this test of affinities in interpretive applications, they should be evaluated in the light of other information, such as abundance distribution and results from studies of similar fossil assemblages.

Lane's study (in press) of the microfossils of the Council Grove Group (Permian) included a grouping of fossils into what he considered living units. His fossils include many of those identified in this study but microfossils that are members of several different groups in his study are included in the large Group I of this report. In other words, in Group I there are microfossils that do not belong to a life assemblage with other microfossils of this artificial unit. This group contains members that were brought together after death and because of their numerous occurrences together have high indices of affinity. The test of affinity does not guarantee that pairs having 0.500 or better indices were symbiotic. The evidence of current action (limestone cross beds) also suggests that mixing of fossils in situ and transporting of fossils took place at Locality B.

The highly variable nature of the abundance curves of Locality A and the lack of distinct inverse relationships further suggests that the physical aspects of sedimentary processes had more control in distribution of microfossils at Brickton than at Altoona and that many organisms now found at Brickton are not in situ.

INTERPRETATION OF GEOLOGICAL HISTORY OF THE HICKORY CREEK SHALE BANK

Interpretation of Data

Imbrie (1955b) concluded his preliminary report on the Florena Shale (Council Grove Group, Wolfcampian) with the comment that, "under favorable conditions the methods of analysis

here exemplified represent a useful approach to many biostratigraphic problems." One of the stratigraphic problems presented by the great differences in thickness in sections of the Hickory Creek Shale is the correlation of thin "off-bank" shale layers at Locality A with the thick shale outcrop at Locality B. Use of microfossil abundances as time correlation indices is based upon the observations of Imbrie (1955b) and Dietsch (1956) that microfossil and megafossil abundances are strikingly similar at widely spaced observation points. This lateral persistency suggests that perhaps equal numbers of fossils were deposited over large areas synchronously in some formations.

It is upon this observation of lateral homogeneity in distribution that correlation within the Hickory Creek Shale was attempted with the use of abundance data.

One approach to the problem was to analyze the data statistically using a chi-square test programmed for the electronic computer by William C. Pearn. His procedures and results are as follows:

> Numbers of fossils in each of the recognized taxons for all the samples in a stratigraphic section comprise the entries in an R X C contingency table, in which R (rows) is the number of samples used and C (columns) is the number of distinct taxons. This immediately suggests the use of the chi-square statistic in analysis of the data.
>
> Unfortunately, the usual multinomial hypothesis testable by the use of chi-square in the complete R X C table is of no particular interest with reference to the data at hand. Using the data at hand, an attempt was made to divide the table into natural groups of rows (samples) within which the hypothesis of same multinomial distribution would be accepted and between which the corresponding hypotheses would be rejected.

> The objective was to obtain in this quantitative manner a number of row-groups (corresponding to environments of deposition?) which could then become the basis of stratigraphic correlation. The first step was to calculate chi-square for all adjacent pairs of samples, i.e., row-groups of size two. It was hoped that some of these chi-squares would lead to rejection of the multinomial hypothesis and others would allow acceptance.
>
> Between the samples for which pair-wise chi-squares rejected, lines of demarcation would then have been drawn and subsequent runs of the chi-square computer program would have combined the rows between provisional lines of demarcation into larger row-groups. The process would have continued until the final objective was attained. However, the process never really got started. At the first step, all pair-wise chi-squares led to rejection! Another tack will be taken on this problem. (William C. Pearn, written communication).

Although this method failed, another approach was tried. The data (Table 1) were transposed into a graph portraying abundances (Plate I) so that visual comparison of the two localities could be made. This comparison of the population curves revealed several similarities that are the basis of my correlations.

For many taxa the maximum occurrences are at the base of the shale at both localities. At Locality B, this peak occurs in sample B1 but is slightly retarded at Locality A where it occurs at A2. The implication of this similarity is that initial flooding of sediment and organisms over Merriam Limestone occurred essentially at the same time at both localities. The intensity of the peak suggests that this influx was rapid. Therefore, the basal layers of the Hickory Creek Shale are considered to be essentially time correlative.

For Nodosinella, Tetrataxis, gastropoda, foraminifera and Ammodiscus there is a peak near the top of the section at both

localities. For Ammodiscus, Endothyra, Endothyranella, and Nodosinella, there is another high in B5. The significance of the two upper peaks of Locality B must be evaluated in order to determine which peak is most similar to the terminal peak of Locality A.

If only the numerically most important taxon (foraminifers) is considered, the peak at A7 matches fairly well with B5. The peaks for Endothyranella and Nodosinella in B5 are also the closest match to A7.

Significant departures from this trend are the curves for Ammodiscus which has no second large increase in numbers at Locality A, and the two peaks for the ostracodes which do not coincide with either B5 or B7.

Evidence that tends to reject the peaks near the top of section B as correlative to those of the top of section A is the greatly subdued nature of the pelecypod curve at Locality A and the explosion of population at Locality B. The bottom of section B has a pelecypod curve similar to that of section A which is additional evidence of the correlation of the lower layers.

There are significant differences in the abundance curves for the lower seven samples that must be taken into account in any interpretation of the environmental history which proposes the correlation of the lower seven feet of shale.

For several of the taxa, there is a great difference in the number of individuals in the samples from both localities. Ditomopyge is almost absent at Locality B but quite abundant at

Locality A especially in sample A1. There are large numbers of gastropods in samples A1 through A7, but few in samples B1 through B7. Endothyranella is entirely absent from Locality A but present in moderate amounts at Locality B. These differences in distribution may be due to errors in counting or sampling, but if the errors are not the cause of this anomaly then ecological factors operating differentially at both localities may have been responsible.

In considering the distributions of Ditomopyge, the answer to the difference may lie in the observation that Ditomopyge does not have positive affinity for any other organism. Its distribution is probably controlled by a discrete set of ecological circumstances rather than by random physical conditions. Gastropods and pelecypods are thought to be found more or less in the place of origin. The absence of wear and presence of many articulated and opened valves corroborate this theory.

Discrepancy in the numbers of Endothyranella from the two localities is probably due to the error in not recognizing this intermediate form when I first started counting the samples of Locality A.

Curves of Nodosinella, Tetrataxis, Amphissites, and Bairdia are closely similar in that they increase upward and are opposite in shape to the curves of Ammodiscus and Ditomopyge, which decrease upward. This inverse relationship is apparent at Locality A, but subtle at Locality B. The entire section of Locality A, however, displays gross inverse relationships.

Several reasons may be offered for the difference in the regular, almost linear, inverse relationship of abundances at Locality A and the obscure relationships of Locality B. Ecological factors such as salinity, depth of water and temperature, may have been more important in controlling distributions at Locality A than at Locality B. The assemblages of fossils at Locality A might more nearly be life assemblages in which increases and decreases in numbers of individuals are a result of symbiosis and commensalism. Although the index of affinity indicates associations among fossil assemblages, it does not reflect the ways in which positively associated pairs wax and wane in numbers relative to one another in response to ecological changes.

These ecological factors may have been less important at Locality B where physical conditions, such as currents, gradient and rate of sedimentation may have been more important in controlling populations. These physical conditions were accentuated and modified by the topographic high centered around Brickton.

Although the evidence for abundance correlation is not conclusive I submit that the bottom seven plus or minus feet of Hickory Creek Shale was deposited more or less simultaneously over both localities and therefore that most of the shale at Brickton was deposited after the shale at Altoona.

The following summary of the depositional history of the shale bank is not entirely original in that it is taken from the studies of Newell, Davis, and Harbaugh. However, fossil evidence presented in this study adds more detail to the historical geology and adds weight to sedimentary and petrologic evidence of previous interpretations.

Geologic Development of the Bank

Merriam Limestone deposition ended in southeastern Kansas in clear waters with the sea floor below wave base (McManus, 1956, p. 55). The bottom of the shallow sea is inferred to have been relatively flat because of the sharp and relatively flat contact between the Merriam and the Hickory Creek. Judging from the sharp nature of the contact (Fig. 8) and the intense initial peaks for many of the microfossils, influx of sediment and marine fossils was sudden. An alternate suggestion is that deposition of everything except microfossil material ceased for a period following the deposition of the Merriam Limestone.

Cessation of sedimentation permitted semi-consolidation of the Merriam Limestone, before the influx of Hickory Creek clastics and accounts for the sharp contact and the lack of intermixing of the lithologies at the base of the Hickory Creek. This hiatus also resulted in concentration of microfossils in the earliest Hickory Creek sediments.

For some reason, perhaps biological, perhaps physical, (e.g., sedimentational) trilobites of the genus Ditomopyge thrived at Altoona, but were relatively rare at Brickton during early Hickory Creek time. Brachiopods, foraminifers, and ostracods thrived in the waters over both localities. Large numbers of pedunculate brachiopod juveniles suggest a firm, somewhat stabilized substratum.

Most organisms diminished in numbers at Brickton and Altoona as the lower seven plus or minus feet of sediment was deposited. A large burst of population occurred at Altoona just

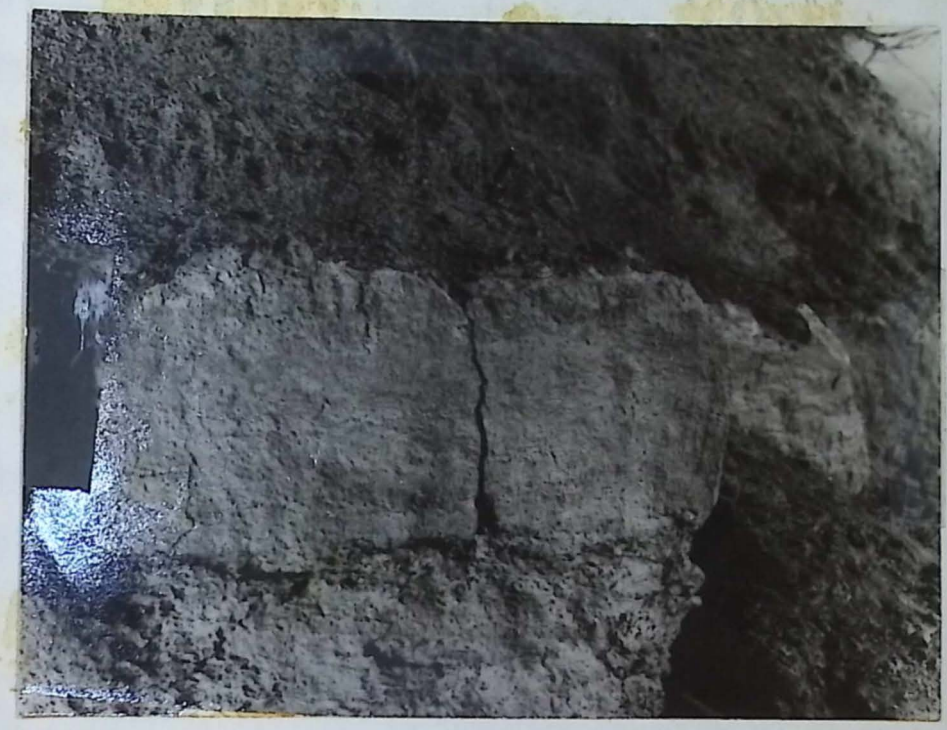


Figure 8.-Photograph of Merriam Limestone in sharp contact with Hickory Creek Shale above in shale quarry at Locality B (Brickton, Kansas). (Photograph courtesy of D. F. Merriam).

prior to the initial deposition of Spring Hill Limestone. Clay continued to accumulate at Locality B in a large, low drift that had a steep southern face and a gentle northern slope. $CaCO_3$ and clay were deposited simultaneously at both localities, in what Newell (1933, p. 54) calls "a complementary replacement of the Spring Hill." In other words, the Spring Hill thins southward as it is replaced below by the Hickory Creek so that much of the latter member at Sycamore (location B) is equivalent in age to part of the Spring Hill.

Numerous fenestrate bryozoans at Brickton acted as baffles to sediments that was being carried northward and trapped it in an area around Brickton. Once a low drift of clay particles was built, continued development of the bank was insured by a self-perpetuating process as long as the environment remained favorable for the growth of bryozoans and other sessile organisms which reduce the velocity of sediment-carrying currents and cause deposition.

Davis (1959) thought that the sediments of the Hickory Creek and Spring Hill south of Neodesha were deposited in a lagoon during early Hickory Creek time, although no evidence is found for a lagoonal environment. According to him, the Hickory Creek at Brickton became a submarine platform upon which the reef proper began to form in the middle of Spring Hill time. Calcareous clay continued to be deposited at Brickton until clastics were no longer available or currents were too weak to transport them from the source area to the south. During the period of nondeposition of clay, clastic limestone lenses were

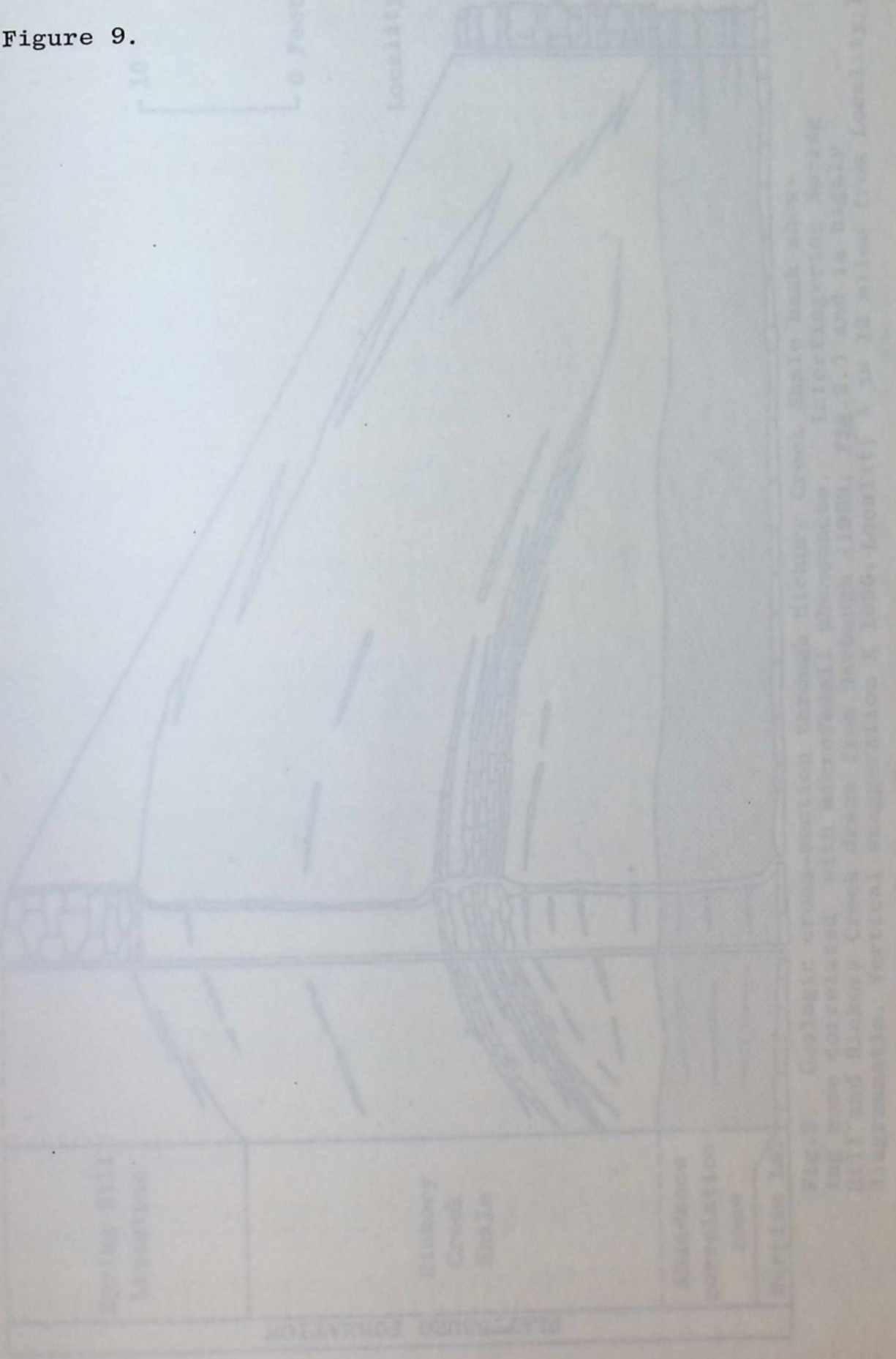
formed from locally derived material such as sponges, crinoids, bryozoans and similar organisms.

Harbaugh interpreted these lenses, which have dips up to 7^{o}, to be equivalent to the lower Spring Hill flanking the bank. The lenses are of similar petrography, although the age correlations with lower Spring Hill Limestone are yet to be demonstrated. It appears that a limestone sheet was draped over the Brickton clay mound at the same time a similar sheet was being deposited at Altoona. Sponges became firmly established during this time at Brickton as indicated by numerous spicules from samples B26 through B30. Clastic limestone lenses are indicators of substantial currents which mixed fossils on the growing mound.

Continuation of the sponge, bryozoan and crinoid assemblage after deposition of the limestone lenses suggests that there were no intolerable ecological changes. Low sedimentation rates are suggested by the large numbers of sponges (suggested by spicule "highs") which would not have thrived in roiled waters.

Pelecypods and gastropods gradually replaced brachiopods in increasing numbers as foraminifers (except Nodosinella) rapidly declined in population. Mollusks climaxed as deposition of clay sedimentation was slowly brought to an end and limestone deposition of the Spring Hill began. The change from Hickory Creek deposition to Spring Hill was not as abrupt as the change from the Merriam to Hickory Creek. The boundary between members is gradational and the changes in abundance of gastropods and pelecypods, which are judged to have grown in place, are more gradual than elsewhere in the section.

The interpretation presented above is presented graphically in Figure 9.



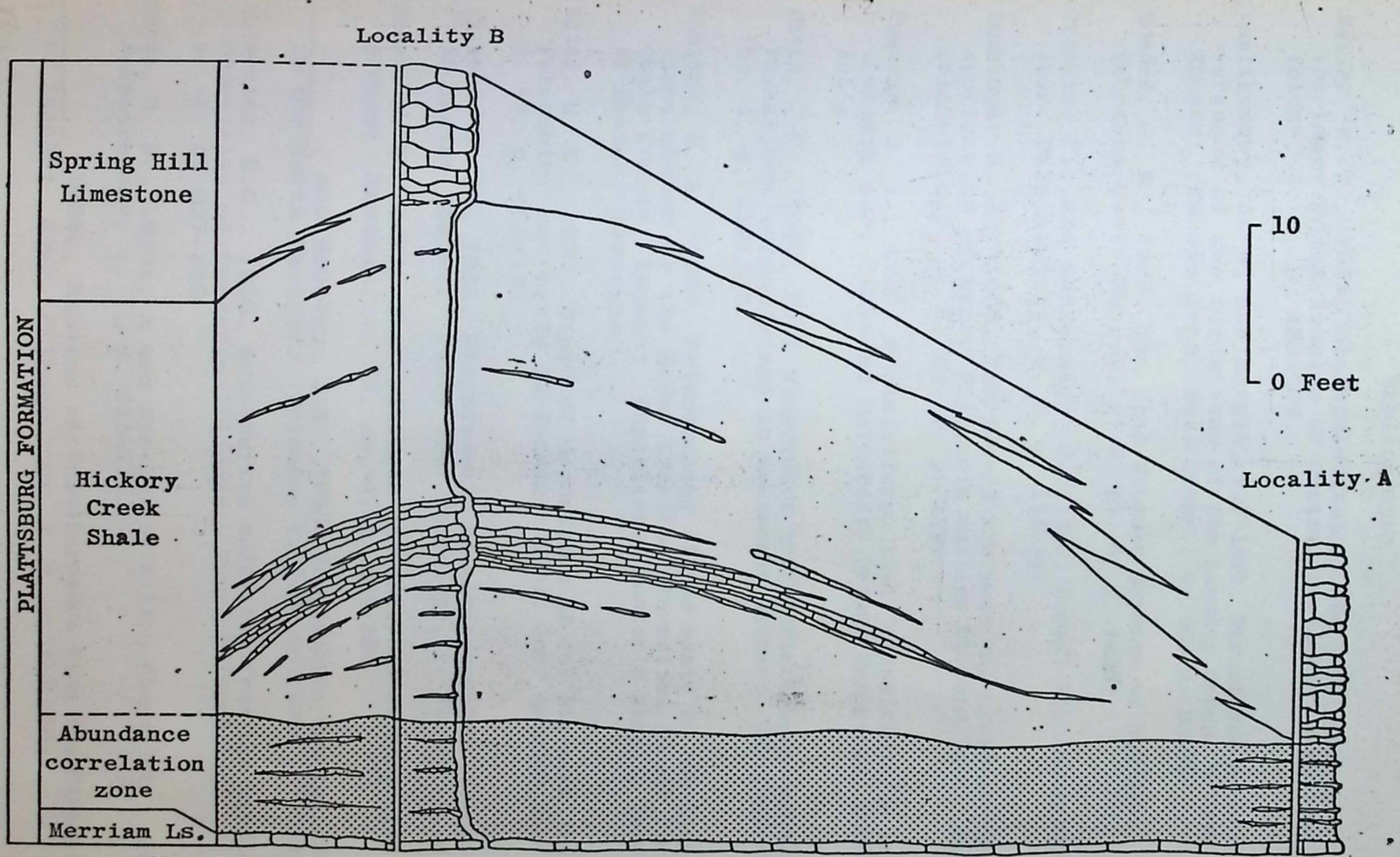


Fig.9. Geologic cross-section through Hickory Creek Shale bank showing zone correlated with microfossil abundances. Interfingering Spring Hill and Hickory Creek drawn from Harbaugh (1959, fig.2.) and is highly diagrammatic. Vertical exaggeration X 1056. Locality A is 12 miles from Locality B.

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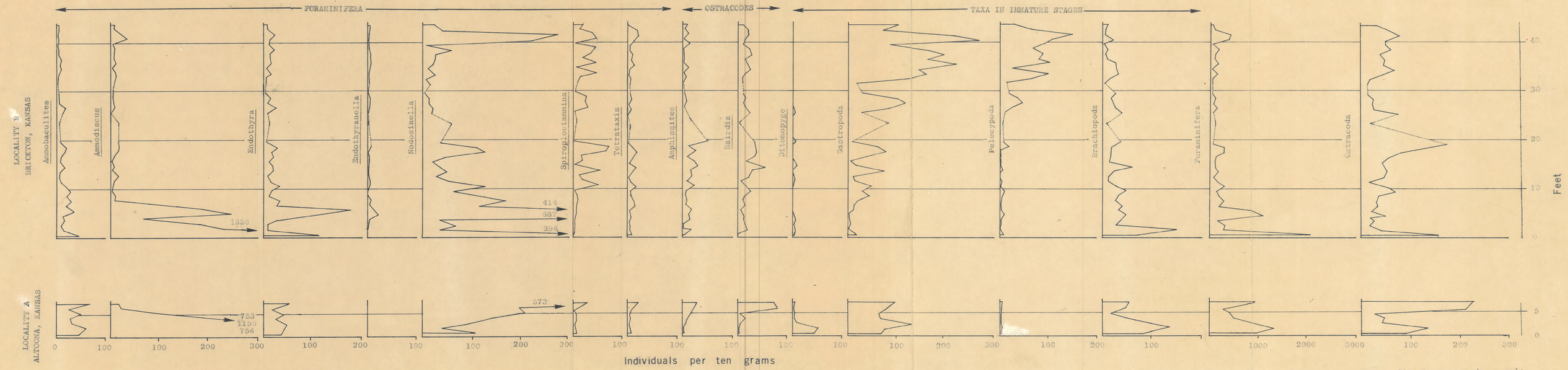
TABLE I. Abundance of microfossils in Hickory Creek Shale Member, from localities A and B, measured at one foot intervals.
(Gastropods, pelecypods, brachiopods, and *Ditomopyge* counted in juvenile stage.)

	Locality B Brickton, Kansas																																			Locality A ¼ miles west Altoona, Kansas						
Sample Number	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B24	B26	B27	B28	B29	B30	B32	B33	B34	B35	B36	B37	B38	B39	B40	B41	B42	B43	B44	A1	A2	A3	A4	A5	A6	A7
Sample Weight (gms)	8.45	9.47	9.87	6.40	9.00	3.74	4.64	7.38	7.03	8.48	8.00	10.92	7.02	10.90	5.60	12.37	9.77	6.32	5.14	10.82	4.66	10.00	10.48	13.94	8.90	7.11	10.81	7.45	8.86	10.86	10.00	9.01	5.30	8.98	5.81	8.63	4.37	8.57	11.26	10.38	5.47	9.35	7.61	3.95	4.00	5.86
Ammobaculites	35	13	7	8	10	12	8	20	12	20	14	8	3	7	7	7	8	10	9	5	2	10	15	4	3	1		1	3	8	5	7	2	4		3		1	1	44	27	27	19	17	8	35
Ammodiscus	1399	214	177	42	219	69	1	7	4		2	6	9	2	2	1	5	8	8	14	5	2	5	4	1	1	3		8	3	9	3	3	7		31	10	2	6	783	629	704	183	39	8	8
Endothyra	91	6	7	14	97	64	11	22	6	12	25	13	4	18	10	13	16	9	14	5	5	5	26	9	10	1	4	3	12	3	12	11	6	19	6	10	9	7	6	35	22	45	20	16	6	28
Endothyranella				3	19	4	1	5	1		2	4		1		3	3	1	4		1		3	6	5		2		1		6	5	3	1		1	1	3	2							
Glyphostomella	1							1															1	6	1						4	4		3	5	3		2	3			1				
Nodosinella	335	35	64	21	619	155	54	122	87	52	101	67	19	52	19	23	44	79	56	37	27	18	19	17	12	3	17	3	25	9	20	21	13	52	2	194	120	33	26	106	22	87	108	82	79	336
Spiroplectammina		1	1		3	2	2	6	3		39	16	6	55		19	13	47	36		2		30	31	21		7	8	40	3	42	16	18	36	1	39	16	9	20	4	1	2	4	2		11
Tetrataxis	6	1	4		3	1	6	8	4	2	11	7		9	9	2	9	11	5	1	1	1	7	6	8	4	2	4	2	3	13	7	5	4	3	10	9	16	3	4	1	5	3	1	3	10
Total Foraminifera	1867	270	260	88	970	307	83	191	117	86	194	121	41	144	47	68	98	165	132	62	43	36	106	83	61	10	35	19	91	29	111	74	50	126	17	291	165	73	67	976	702	871	337	157	104	428
Amphissites		13		7	9	6	2	6	2	4	17	4	12	15	16	24	9	15	5	53	6	8	2	9	3	1	1	3	3	10	2	1	1	3	7	1	5	4	9			5	9	5	8	16
Bairdia		19	13	7	1	2	7	6	10	21	13	6	14	32	31	21	30	23	17	37	1	21	15	12	10	6	7	4	9	22	14	9	12	18	2	9	8	13	6			4	10	1	32	45
Bythocypris		4			4		5	9	9	20	13		3	7	20	1	6	9	5	36		25	1	3	2	3				6	20	5	2	5	1	6	3	9	3			9	4	1	17	16
Cavellina		2	6	4	19		1	1	2	13	1	3	3	1	7	2	1	4	4	20	1	9	4	5	5	1	2		1	20	2	2	1	12	15	10	5	4	3			7	2	1	8	32
Healdia							1	1	2	1	1	1		1	2		1	1		1		1			1				1	4	1			1			1	4			3	5		7	5
Hollinella			1							2	1		1									1							2				1		2		1		1			2		1		1
Kirkbya															1						1			1											2							1	1			1
Macrocypris				1						3		1			5	2	2			8		6	1	1	1	1			3	8	5	6	1	2	2	1	1	2	1			1	1	2	3
Monoceratina		1			2			1		1			1	2	1		2		2	5		2	1	1					3	6	3	2		6	2	3	2	2				2		4	2
Silenites					1					4		3	1		5	1	2	3		5	7	1	1	3		2			3		1		1			2	1	1				1			1
Ulrichia		1		1					1	1	2			1	3					2	23		2				1				1			1				1			3	1			
Total Ostracodes	134	40	20	20	45	8	16	24	26	70	48	17	35	56	87	52	54	52	40	190	10	76	27	32	24	12	16	19	39	78	49	45	19	51	33	45	36	45	37	95	74	39	35	10	84	132
Hindeodella		1			4	3		2				1		2		1																		1		1	2						8	1	2	10
Streptognathodus	5	2			7	3	1	6	2			2	4	2			1	1		3		1	2	1	1		1		1		1	1			1			1	1	4	3	6	3	2	2	13
Ancistrum						1																							1											1		4				
Protocaudina		2				1		2	1		1	1			1	1		1	2		1	1	1			1	2	1		1				4		7	1				11	1				1
Thuroholia	8	1			1		3	3	1			1						2	1	7	2		3	2					5		1				9				1	1	1		1		1
Ditomopyge	1	1		1								1			2	1				2								6											43	25	4				1
Sponge Spicules														2		1	1						11	18	16		2	11	10		8		1	1	2	5	1			1		1	1	1		
Total Brachiopods	62	141	22	21	38	10	17	17	21	38	18	12	8	25		14	13	8	8	38	4	38	29	29		20	7	11	28	32	28	9	2	9	2	19	3	8	11	98	72	93	33	6	18	30
Gastropods (High Spired)	7		3	1		3	2	6	14		11	5	4	47	4	2	17	20	17		26		62	129	62		7	68	81		120	101	51	101	25	129	53	31	68	49	22	69	27	12	17	81
Gastropods (Low Spired)	6		1	1			3	7	15		29	8	2	32	4	1	17	26	11		10		25	32	23		6	28	60		99	46	51	48	22	96	40	26	44	19	18	57	24	13	16	99
Total Gastropods	13		4	2		3	5	13	29	22	40	13	6	79	8	3	34	46	28	7	36	26	87	161	85	18	13	96	141	155	219	147	102	149	47	225	93	57	112	68	40	126	51	25	33	180
Total Pelecypods					7		1		3	4				2					1	5			24	57	29	12	12	46	86	24	99	69	44	68	1	89	63	55	35	1	2	1				

Plate 1

Quantitative abundance curves for Hickory Creek Shale microfossils, Southeast Kansas



Dotted line indicates limestone occupying sample interval or missing sample.