ENVIRONMENTAL CONTROL OF CONODONT DISTRIBUTION IN THE SHAWNEE GROUP (UPPER PENNSYLVANIAN) OF EASTERN KANSAS

by

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The recognition of more than one hundred cyclothems in the Pennsylvanian and Lower Permian rock succession of Kansas, each containing a number of distinctive types of deposits and varied assemblages of organic remains, provides opportunity for paleoecological observations and interpretations which may come to be accepted as specially trustworthy.

The purpose of writing about repetition of paleobiotopes and various kinds of organic communities in Kansas is to point out the value of classifying them in types which seem to have similar characters and then of comparing the examples of each with one another.

R. C. Moore (1964)

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ABSTRACT

Biofacies analysis of Upper Pennsylvanian conodont faunas from the classic Shawnee Group cyclothems of eastern Kansas by means of intuitive empirical methods and by relative abundance and cluster analysis demonstrates the existence of conodont biofacies in the Upper Pennsylvanian and supports Merrill (1962, et seq.) in his contention that the distribution of some conodont bearing animals in Pennsylvanian seas was to a degree environmentally controlled.

Relative abundance analysis of the platform elements of *Streptognathodus*, *Idiognathodus*, and *Cavusgnathus* in the Oread, Lecompton, Deer Creek and Topeka Limestones has shown that there is a regular variation in the relative abundance of these elements which can be correlated with changes in lithology. The platform element of *Cavusgnathus* is dominant in marginal marine shales and siltstones. The platform elements of *Streptognathodus* and *Idiognathodus* predominate in the offshore marine limestones. The fissile black shales and the gray shales which overlie them are believed to have been deposited under restricted nearshore (possibly lagoonal) conditions. They are dominated by the platform elements of *Streptognathodus* and *Idiognathodus* to the virtual exclusion of the platform element of *Cavusgnathus*.

R-mode cluster analysis using the Jaccard coefficient and the WPGMA and UPGMA clustering techniques defined six conodont biofacies. Five of these had previously been recognized by Merrill (1968 and in press) by intuitive means. The six biofacies were related to five biotopes defined by Q-mode cluster analysis using the Simple Matching and the Jaccard coefficients together with the WPGMA and UPGMA clustering

techniques. The *Streptognathodus* and *Cavusgnathus* biofacies, the existence of which was already suspected from relative abundance analysis, were well defined by cluster analysis, and they lived in the offshore limestone and nearshore shale biotopes respectively. These two biofacies, and the biotopes they occur in, recur many times in the Shawnee Group. The *Streptognathodus gracilis*, the *Ligonodina subacoda*, and the *Gondolella* biofacies are more restricted in their occurrence and are present in the Larsh-Burroak, the Heebner-Plattsmouth and the Queen Hill biotopes respectively. The *Trichonodella* biofacies is also somewhat restricted in its occurrence and is dominant in the Heebner-Plattsmouth biotope.

Multielement taxonomy based on similarities of distribution, morphology, and internal characteristics of elements as well as agreement with previously defined conodont element "blue-prints" was utilized where possible. Two new species of *Anchignathodus* and one of *Cavusgnathus* are recognized. R-mode cluster analysis was not only useful in defining conodont biofacies, but also in delineating original element associations.

Some elements including two new species of *Trichonodella* and one of *Lonchodina* could not be classified in terms of a multielement species taxonomy.

INTRODUCTION

Purpose and Scope of the Study

In recent years conodonts have been studied extensively because of their abundance in parts of the geologic column and their usefulness in stratigraphic correlation. Several paleontologists (Ziegler, 1960; Müller, 1962; Collinson, 1963; Mound, 1968) concluded that conodont taxa are generally not confined to a particular sedimentary facies and that the conodont animal was pelagic. A corollary of this model is that the conodont animal was not affected appreciably by environmental factors in its distribution.

Merrill (1962, et seq.) questioned the applicability of this conclusion to the Pennsylvanian faunas, and he postulated a greater degree of environmental control of conodont distributions. On the basis of the observed distributions of conodont form taxa as well as on different abundance ratios of certain platform elements, he recognized a number of biofacies in the Conemaugh and Allegheny of the Appalachians.

The purpose of this study is to conduct an independent evaluation using quantitative methods, of the validity of Merrill's biofacies and his hypothesis that the distribution of Pennsylvanian conodont faunas was controlled, to a considerable degree, by environmental factors. A secondary purpose, one which was partially an outcome of the evaluation of biofacies, was to determine what conodont elements belonged together as component parts of multielement species.

The results of studies in environmental control of conodont distributions have important implications in chrono-stratigraphic correlation and will encourage conodont workers to re-examine critically the concept of facies independence of conodonts.

Three analytical techniques of different discriminatory power were selected. The first, a somewhat intuitive approach that has previously been effectively used by paleoecologists, consisted of recognizing groups of constantly associated conodont elements on the basis of their distribution in samples representing different paleoenvironments. This approach is analogous to "eyeballing" in taxonomy. Relative abundance analysis of selected conodont elements, a method that makes use of abundance counts, was the second technique used.

The two preceeding, essentially nonquantitative methods were both utilized with varying degrees of success by Merrill (1968 and in press). In addition to using methods similar or identical to those employed by Merrill, it was considered desirable to use an independent quantitative technique to evaluate the existence of Pennsylvanian conodont biofacies. Cluster analysis, which has been used very successfully in distributional studies of recent marine microorganisms, was the third method selected.

The Shawnee Group (Virgilian, Pennsylvanian) was selected for study not only for reasons of excellent exposures and accessibility, but also because its stratigraphy and structure are well known. In northeastern Kansas (Fig. 1) the Shawnee Group is extremely well exposed in continuous section and consists of a series of alternating beds (Fig. 2) representing a wide variety of lithologies and paleoenvironments. Further, in each of the four megacyclothems (Moore, 1936) lithologies,

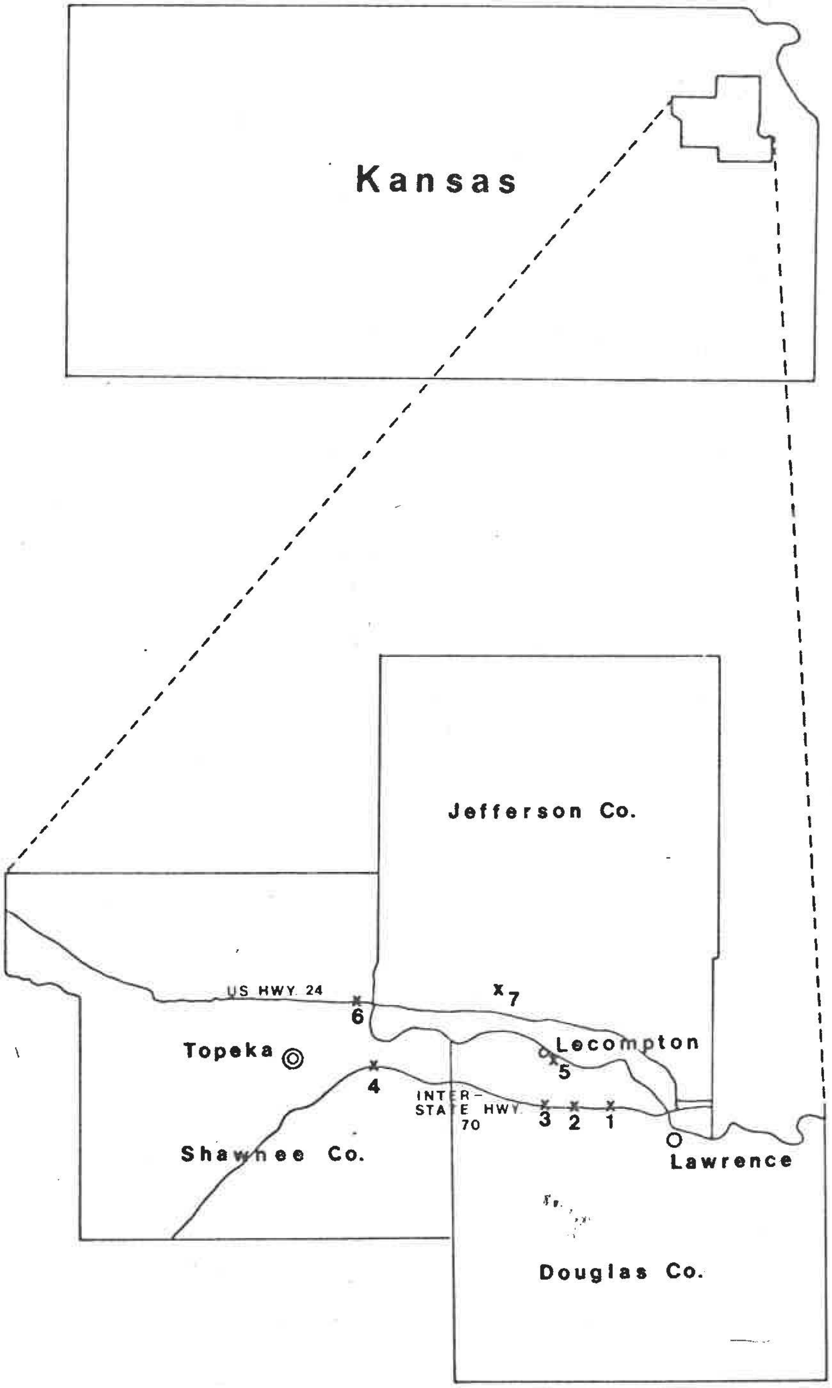

Fig.1. Study area in northeastern Kansas showing localities sampled.
Scale 1:500,000 X Locality

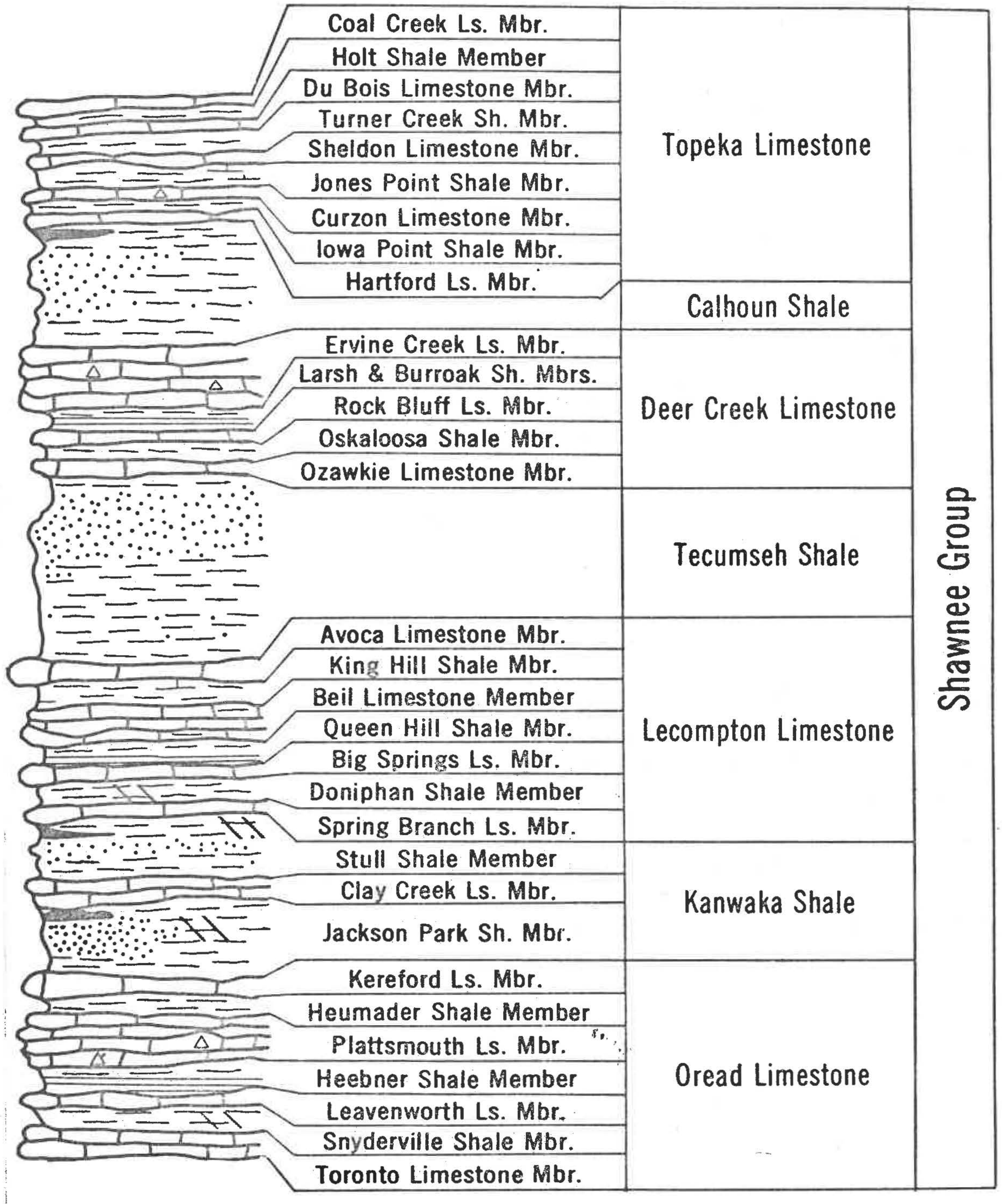

Fig.2. Stratigraphic sequence of the Shawnee Group in eastern Kansas. Figure from plate 1 of Jewett et al. (1968).

representing different environments of deposition, repeat - a factor important for testing the degree to which distribution of conodont taxa is dependent on environment. The continuous exposures available in eastern Kansas as well as the relatively short stratigraphic interval involved permitted continuous detailed channel sampling. These sediments were deposited during a time of slow evolutionary change in the conodont-bearing animal (Ellison, 1941) and this, as well as the lithologic cyclicity, made these rocks ideal for testing the degree of recurrence or alternation of faunas.

The sampling, laboratory, and scanning electron microscope procedures are described in Appendix A. The stratigraphic intervals sampled, together with sample codes and sequence, are shown on Figs. 3 to 6 and are described in Appendix B.

Each conodont was initially identified and described in terms of a form classification. Synonymies were established and the abundance of each conodont type per sample was tabulated (Appendix D). The results of R-mode cluster analysis and evaluation of the collections by methods outlined by Walliser (1964) and Jeppsson (1971) made it possible to recognize some multielement species, that is, groups of conodont elements which are believed to have been component parts of the apparatuses of natural conodont bearing species.

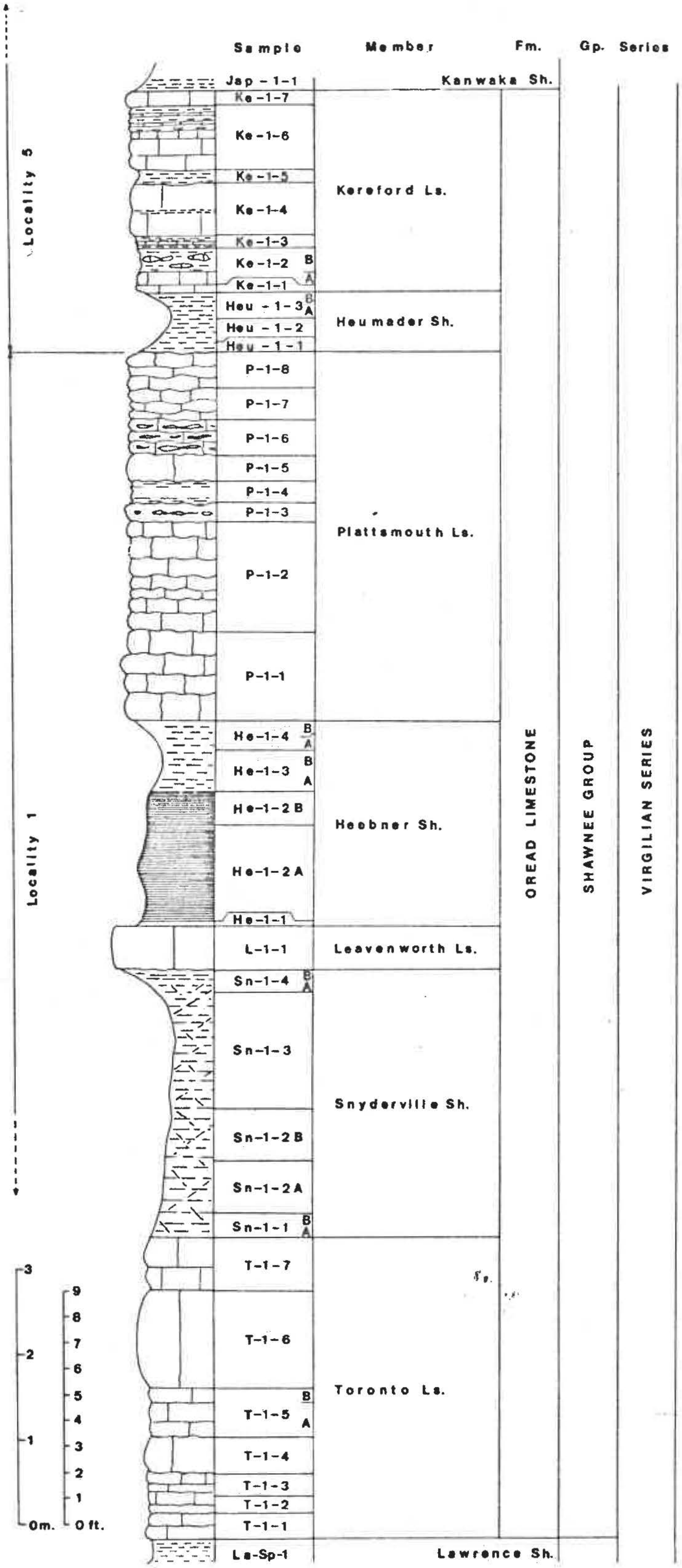

Fig.3. Composite section of the Oread Limestone at localities 1 (NW sec. 21, T. 12 S., R. 19 E., Douglas Co.) and 5 (NW SW sec. 35, T. 11 S., R. 18 E., Douglas Co.) showing units sampled.

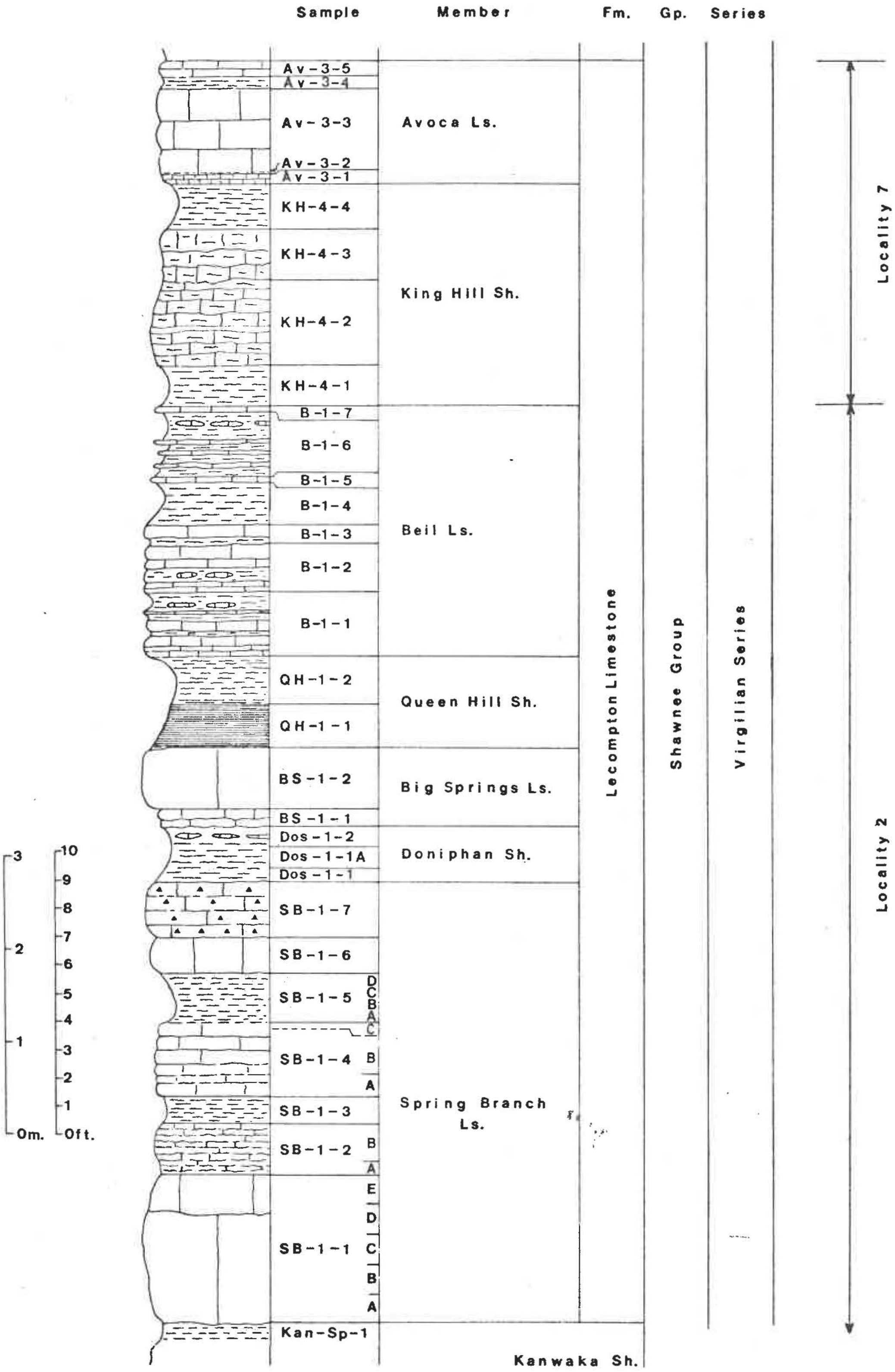

Fig.4. Composite section of the Lecompton Limestone at localities 2 (NW NW sec. 24, T. 12 S., R. 18 E., Douglas Co.) and 7 (SE NW SE sec. 8, T. 11 S., R. 18 E., Jefferson Co.) showing units sampled.

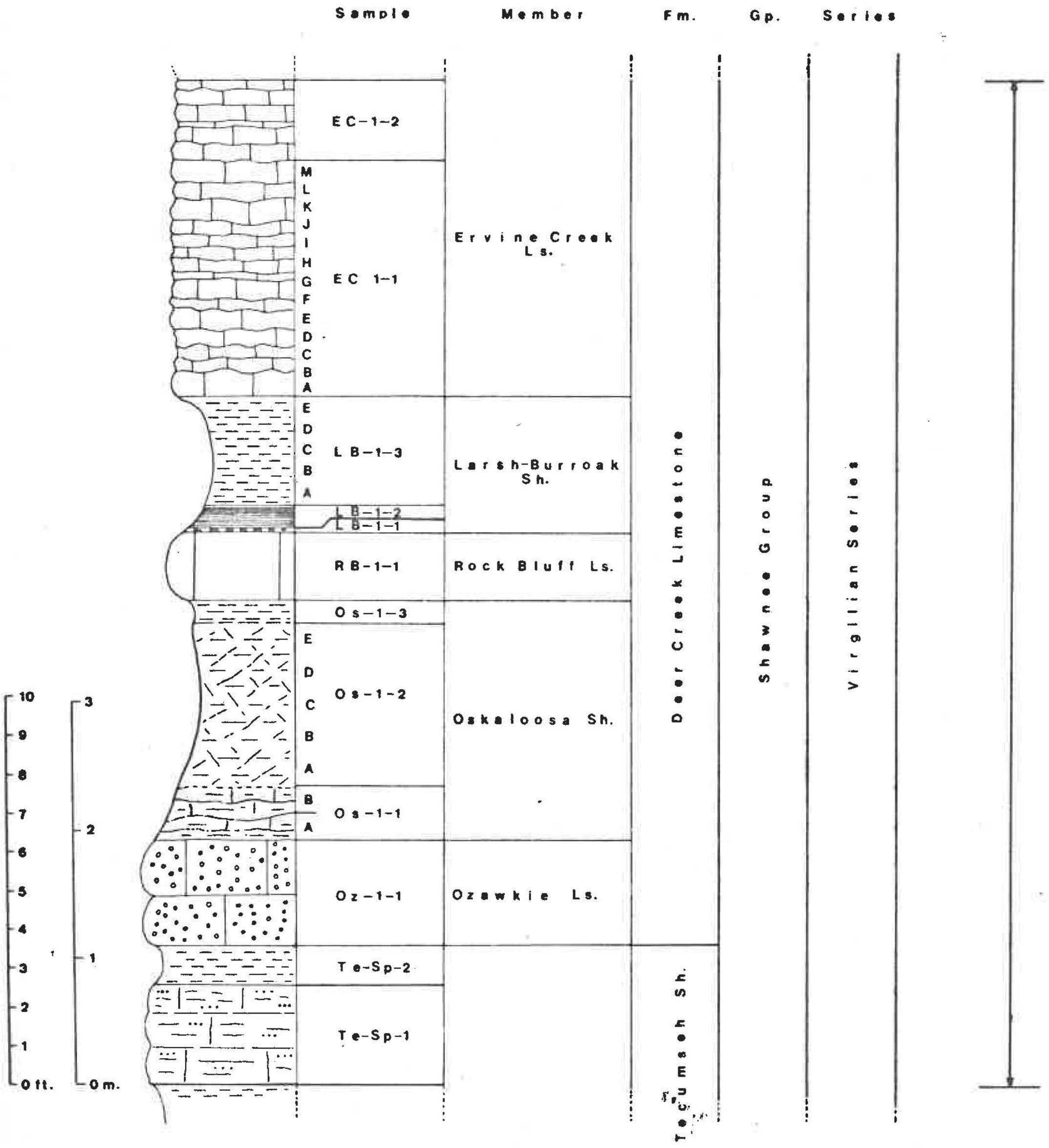

Fig. 5. Section of the Deer Creek Limestone at locality 3 (NE NW NW sec. 22, T. 12 S., R. 18 E., Douglas Co.) showing units sampled.

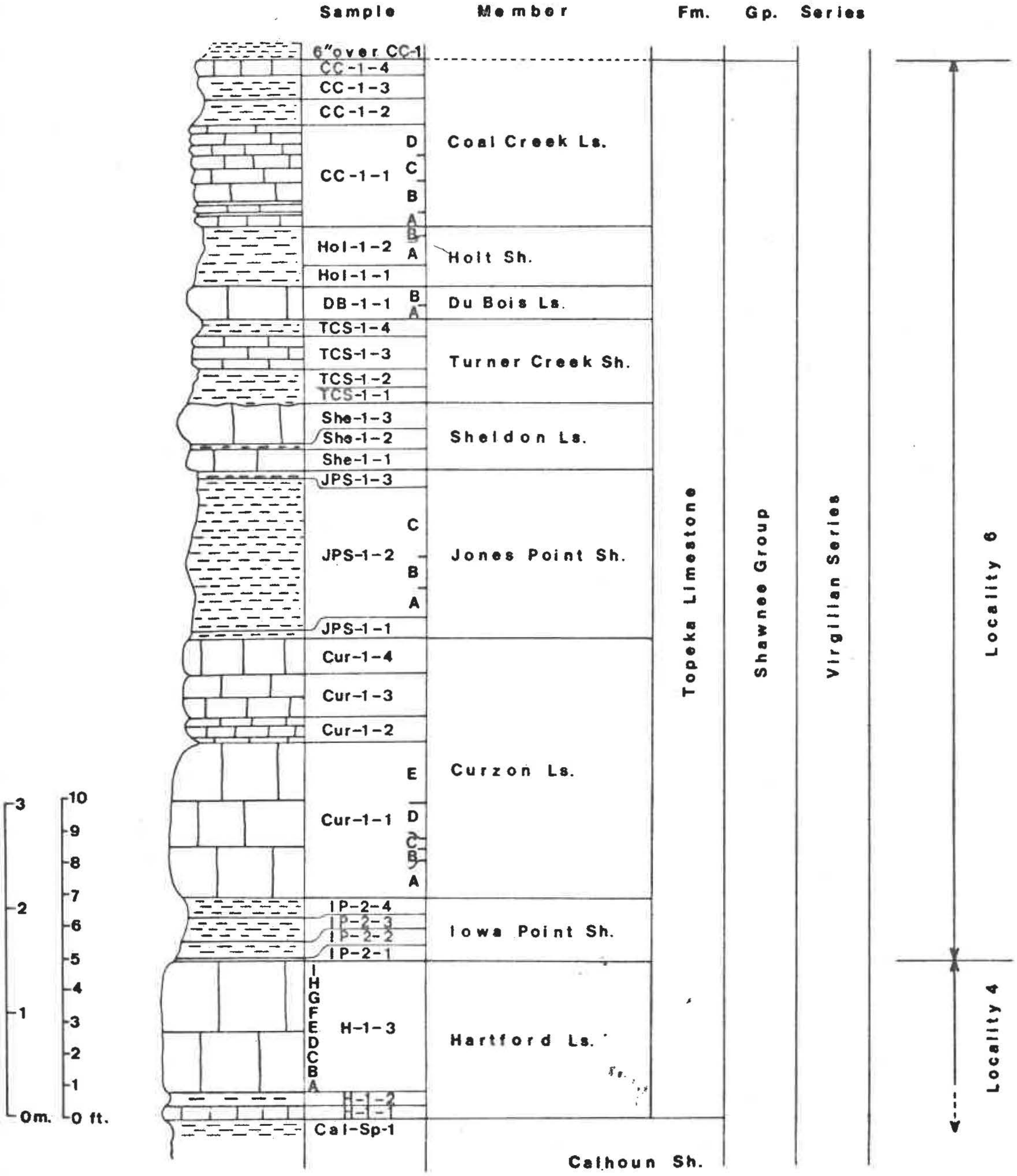

Fig.6. Composite section of the Topeka Limestone at localities 4 (SE SW sec. 2, T. 12 S., R. 16 E., Shawnee Co.) and 6 (NW SE sec. 14, T. 11 S., R. 16 E., Shawnee Co.) showing units sampled.
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PREVIOUS WORK IN THE EVALUATION OF ENVIRONMENTAL CONTROL OF CONODONT DISTRIBUTIONS

Introduction

Early conodont workers were most successful in finding conodonts in black shales. This resulted in geologists concluding that the conodont bearing animal was especially adapted to live in toxic brackish waters or that the organism died on entering such waters (Moore, 1929). Later, with the discovery of conodonts in many other lithologies these ideas were gradually changed, although even today one encounters the concept that the conodont bearing animal's environment and "the black shale environment" are one and the same.

By the late 1950's there was a great upswing in conodont research. One of the principal specifications for a good guide fossil is facies independence, and seemingly conodonts fulfilled this requirement. It was at this time that thought was first given to the paleoecology of conodonts. Müller (1956) outlined existing knowledge but concluded that practically nothing was known of the occurrence of genera in relation to facies. Müller (1962) concluded that commonly conodonts are not confined to sedimentary facies, since the same species is found in different lithologies and that many species had a world-wide distribution. Collinson (1963) stated that conodonts were so independent of facies that they are almost certainly the remains of pelagic, probably nektonic, organisms. Ziegler (1960, 1962), although noting the existence and possibility of restrictions in conodont distribution (as in reefs, sandstones, etc.) due to ecological, mechanical or stratigraphic factors, concluded that the lower Devonian conodonts of his studies transect facies.

Since the early 1960's, some of the previously accepted concepts have been re-examined. Thus, an interest has developed in what is here called environmental control of conodont distribution. By environmental control is meant simply the preference for or the ability of an organism to select a particular set of environmental conditions in which to live. Such environmental control whether on a large or small geographic scale, should result in a taxon (genus or species) being consistently more abundant in a particular lithology than in another, because different sediment types are deposited in different environments. Druce (1970) pointed out that faunal assemblages of conodonts are not mutually exclusive. This is not surprising and the writer would expect some mixing of faunal elements from different environments. This may in part represent horizontal reworking or transportation in a single time plane.

It is important to note that the concept of environmental control does not impair the usefulness of conodonts in biostratigraphy because in biostratigraphic correlation one generally deals with presence or absence of a species. Results of studies of environmental control, however, will modify applications in biostratigraphy. Thus, Druce (1970) in discussing Upper Paleozoic conodont distributions, stated that "zonations based exclusively on deep water faunas are difficult to apply to shallow water deposits."

Differences in faunas of the same age, and which are separated from one another geographically be generally large distances, have been called provincial faunas and the overall pattern is called provincialism. Faunal provincialism is apparently caused by such environmental factors as geographic barriers and climatic differences reflected in water temperature. Differences in similar aged faunas not separated by large geographic distances (as in a smaller depositional basin) have been considered to be controlled by more local environmental factors and have been called biofacies. The concept of biofacies has been used to include both the fauna and the place characterized by it. The writer prefers to separate these two aspects and will discuss this on page 25.

Provincialism

Rexroad and Jarrell (1961) considered Chesterian conodont faunas in Illinois, Texas and Oklahoma to be provincial. Provincialism in conodont faunas of Ordovician to Triassic age has been discussed more frequently in recent years by many authors including Sweet and Bergström (1962), Mosher (1968, 1970), Collinson (1970), and Aldridge, Austin, and Husri (1968).

Conodont Biofacies and Environmental Control of Conodont Distributions

A number of authors have considered the relationship between the environment of deposition and the type and relative abundance of conodont genera and species within the particular rock type deposited in that environment. Müller (1956) noted "a strong change of the relative abundance of partial-genera which obviously is not due to different age". Müller (1962), while stating that conodonts are not confined to sedimentary facies, noted that some form-genera are fairly abundant in certain facies only, for example in the near-reef (e.g. most species of Icriodus, and "Belodus" from the Silurian). Ziegler (1960, 1962) defended the view that the distribution of conodont genera and species is independent of facies but pointed out that conodonts are rare in the reef environment. Observations by Müller and Clark (1967) led them to conclude that in the near-reef facies the genus Icriodus is the prevailing and commonly the only conodont of Early to Early Late Devonian age. More recently (Seddon 1970a, 1970b) working in the Canning Basin of Australia, formalized this concept by establishing an Icriodus biofacies in the near-reef, back-reef, and reef limestones and a Palmatolepis biofacies in the inter-reef and the outer fringes of the fore-reef. Druce (1970) expressed much the same concept for the Upper Devonian; however, rather than using "biofacies", he referred to certain conodont assemblages predominating in shallow or deep water deposits. Ferrigno (1971) concluded that some Middle Devonian conodont faunas of Ontario were environmentally controlled. Barnett (1971) concluded on the basis of biometric studies that *Spathognathodus remscheidensis* "was abundant in sublittoral lagoons, biostromal reefs and crinoidal meadows but decreased in abundance further seawards."

A number of references to ecologic control in Mississippian sediments have been made. Globensky (1967) suggested that differences in conodont distributions in subzones of the Mississippian Windsor Group of eastern Canada were possibly due to environmental factors which may have been related to tectonic instability.

Varker (1967) interpreted the distribution of *Apatognathus* to have been strongly influenced by facies control and stated that "*Apatognathus* ? appears to have favored certain conditions to the exclusion of others." Meischner (1970) observed facies control in Lower Carboniferous conodonts of Germany, as did Aldridge, Austin and Husri (1968) in England and Ireland.

Druce (1970), discussing lower Carboniferous faunas, defined a deep water conodont faunal assemblage consisting of *Siphonodella* and *Pseudopolygnathus* of the *triangularis* type associated with *Dinodus*, *Doliognathus*, *Dollymae*, *Scaliognathus*, and *Staurognathus* and a shallow water conodont faunal assemblage consisting of *Spathognathodus*, *Polygnathus* and *Clydagnathus*.

Environmental control of Pennsylvanian conodont faunas from the Appalachians has been reported by Merrill (1962, et seq.) and Merrill and King (1971).

Hieke (1967) found that conodont abundance maxima in the Triassic Muschelkalk of Germany were correlatable and that the peaks were independent of the limestone lithofacies. From this he concluded that the conodont maxima represent time planes and that they were the result of climatic factors.

GEOLOGY AND STRATIGRAPHY OF THE SHAWNEE GROUP

The Shawnee Group of eastern Kansas consists of an alternating sequence of sedimentary rocks which are notable for the variety of lithologies represented and the relationship of these lithologies to one another. These beds were recognized by Moore (1931, 1936, 1949)to represent cyclothems of an unusually complete nature. It was in the Shawnee Group of eastern Kansas that Moore (1936) first recognized megacyclothems, a cycle of cyclothems.

Weller (1960) wrote that: "A still larger Pennsylvanian cycle occurs in Kansas. It consists of four successive megacyclothems. Each group of this type is separated from adjacent similar ones by comparatively thick sequences of detrital strata probably arranged in several imperfectly differentiated cyclothems that include channel sandstones and generally one or more thin coals. They are termed hypercyclothems and there are four of them." Clearly Weller was writing of the Shawnee Group.

Moore (1936) stated that: "The outstanding elements in the Shawnee cyclic sedimentary rhythm are the three or four different types of limestone that appear in the same order in each of the four limestone formations of the group. ... The thin shale members that separate the limestones differ from one another in various characters and the order of succession of these is constant in each formation."

The orderly repetition of lithologies within the megacyclothems of the Shawnee Group record the repetition of various environments of deposition.

The origin of cyclic sedimentation has been debated for some years; however, no universally acceptable explanation has yet been given (Weller, 1964). The interested reader is referred to Weller (1960, 1964) for an extensive discussion of this problem.

Moore (1964) wrote that "in regional perspective, eastern Kansas could be depicted reliably as a stable platform area which repeatedly was submerged shallowly by invading seas".

Troell (1969) interpreted the Shawnee Group limestone beds as having been deposited in a shelf environment, and stated that the Shawnee Group beds were deposited in a non-oceanic, epicontinental sea which spread inland for many hundreds of miles. Similarly Toomey (1966) in discussing the depositional environment of the Leavenworth Limestone stated that "most of Kansas and Nebraska comprised a slowly subsiding open-sea carbonate platform where limestones were prominent but where shales and sandstones were also deposited". The reader is referred to Toomey (1966) and Rascoe (1962) for a consideration of the paleogeographic setting of Kansas and the surrounding area during the deposition of the Shawnee Group.

Johnson and Adkison (1967) summarized diverging opinions on the depth of the late Pennsylvanian seas. They wrote that: "The late Pennsylvanian sea advanced from the southwest (Wanless, 1950, p.20). The depth of water was estimated by E. L. Yochelson (written commun.,

1960) to have been not more than 50-75 feet, and by Moore (Wanless, 1950, p.26) to have been less than 100 feet. Elias (1937, p.421) estimated that the maximum depth of the late Paleozoic sea in Kansas was about 180 feet. The sediment supplied to the sea was derived mainly from an upland to the east and south (Moore, 1929, p.483)."

The isochroneity of the members of cyclothems has been advocated by Weller (1960), Moore and Merriam (1965) and Reed and Burchett (1964). The diachroneity of cyclic sediments, particularly those of Pennsylvanian age was discussed by Shaw (1964).

A significant feature is that although sediments representing a multitude of depositional environments were deposited, none of these apparently represent deep water, non-platform deposition. The depositional environments of individual members of the Shawnee Group have been considered by various authors and the reader is referred to Appendix B for a summary of these interpretations.

The stratigraphic classification used in this study is adopted from Moore (1964), Moore and Merriam (1965) and Jewett,et al. (1968). The term "Larsh-Burroak" is used in the sense of Moore (1964) and Moore and Merriam (1965).

GENERAL PATTERNS OF CONODONT DISTRIBUTION IN THE SHAWNEE GROUP

Many members of the Shawnee Group, particularly those of the Oread Limestone are known to have a wide areal distribution, often maintaining generally uniform lithologies throughout this wide areal extent. This suggests that the depositional environment of each of these members was often fairly uniform throughout its time of deposition. The faunas of the Shawnee Group of northeastern Kansas are, to a noticeable degree, environmentally controlled, and the writer believes that the faunas present in northeastern Kansas can, for example, be expected to be present in the same members in the subsurface of western Kansas or in southern Kansas. If this is the case, then conodont faunas can be used for correlating members of the Shawnee Group of northeastern Kansas with the same units in the subsurface. Such correlations would represent lithostratigraphic rather than biostratigraphic correlations. For the most part faunas recurr in similar or identical lithologies at a variety of stratigraphic levels throughout the Shawnee Group. It has not been possible, for example, to differentiate the faunas of the Snyderville, the Oskaloosa, and the Turner Creek shales nor those of the Toronto and the Hartford limestones, despite the considerable stratigraphic intervals that separate these members.

Stratigraphic units having characteristic lithologies and faunas are most desirable for correlation purposes. In the Shawnee Group of northeastern Kansas several members fit this description and their characteristics will be described briefly. These members contain faunas which are dominant in that particular member and have generally not been found in other members of the Shawnee Group.

The Heebner Shale contains a diagnostic fauna consisting of conodont elements belonging to *Streptognathodus simulator*, *Streptognathodus eccentricus*, *Idiognathodus magnificus* and *Ligonodina subacoda*. The same fauna has been reported from the Heebner Shale of Chautauqua County in southern Kansas (Ellison, 1941).

The Plattsmouth Limestone contains a few of the faunal elements that have been found in the Heebner Shale; however, the Plattsmouth also contains a characteristic well preserved fauna of elements of *Ozarkodina* ? *kansasensis* n. sp., *Trichonodella* spp., *Lonchodina douglasi* n. sp., *Hindeodella* sp. B, *Ozarkodina* [?] *curvata*, *Anchignathodus adenticulatus* n. sp., *Ellisonia teicherti*, and *Hindeodus* sp. A. This fauna is possibly repeated in the lower Spring Branch Limestone; however, this requires further evaluation.

The Queen Hill Shale is the only member of the Shawnee Group in northeastern Kansas that was found to contain elements of species of *Gondollella* (Ellison, 1941; this study). Elements belonging to species of *Gondolella* were also found by the writer in this member in southern Kansas. Mendenhall (1951) reported the platform (Sp) element of a species of *Gondolella*, *G.elegantula* from the Queen Hill Shale of the Shawnee Group of Nebraska.

In addition to these three members which are faunally distinct, a number of other restrictions of some species were noted. The most significant of these is the fact that species of *Idiognathodus*, as here recognized, has not been found above the Queen Hill Shale by Ellison

(1941), by Perlmutter (1971), or by the writer. Related to this is an interesting distribution of *Idiognathodus tersus*, *Idiognathodus antiquus*, *Streptognathodus wabaunsensis* and *Streptognathodus oppletus*. These four species are found in a variety of lithologies representing a wide range of depositional environments from the base of the Plattsmouth Limestone (Oread Limestone) to the top of the Queen Hill Shale (Lecompton Limestone). Two specimens of *Streptognathodus oppletus* were found above the Queen Hill Shale.

It should be noted that *Streptognathodus* sp. A has only been recovered from the Spring Branch Member of the Lecompton Limestone. *Anchignathodus adenticulatus* n. sp. has not been recovered from below the middle part of the Plattsmouth Limestone nor from above the middle part of the Spring Branch Limestone. The stratigraphically highest sample (SB-1-3) containing this species contained an unusually high number of specimens of this species.

For a more detailed tabulation of the distribution of conodonts in the Shawnee Group the reader is referred to Appendix D.

BIOFACIES ANALYSIS

Introduction

Biofacies analysis was defined by Kaesler (1966) as "the study of assemblages of organisms, their areal and chronologic distribution, and the environmental factors that affect them". In biofacies analysis a distinction is often made between biotopes and biofacies. Kaesler (1966) defined a biotope as "an area of relatively uniform environmental conditions evidenced by a particular fauna found in the area and presumably adapted to environmental conditions there." In a geological context a biotope is represented by a body of sediment deposited in and characteristic of that environment. Biofacies (Kaesler, 1966) were defined as "a group of organisms found together and presumably adapted to environmental conditions in their place of occurrence, such group differing from contemporary assemblages found in different environments". This definition is valid, but the paleoecologist must remember that associations of organisms or parts of organisms can be due, entirely or in part, to factors such as transportation and reworking. Kaesler summarized this by stating that "an assumption of paleoecology is that effects of transportation and mixing of faunas is not great enough to obscure biofacies relationships completely."

Mello and Buzas (1968) felt that Kaesler's use of the term biofacies was too restrictive. They used the term biofacies as (1) an area which is defined by species and (2) the species that are contained in it. Mello and Buzas combined the concepts of biofacies and biotopes--an understandable point of view; however, in this study it is of value to separate the two. A biotope represents a place or an environment in which groups of organisms, a biofacies, live.

A variety of approaches of differing levels of complexity, objectivity, and sophistication are available to the paleoecologist for biotope and biofacies analysis. Buzas (1970) discussed biofacies extensively and considered various approaches to their quantification. He stated that "in some instances quantitative measures have been employed while in others, study of data tables constituted the basis for recognition of biofacies."

Conodont biofacies, based on the mutual occurrence of discrete elements, have generally been defined in the latter manner, i.e. by the study of distribution charts. The process of establishing what particular elements commonly occur together (biofacies) in a particular lithology (biotope) requires large collections from a diversity of rock types representing differing depositional environments. Such large collections from different environments of deposition plus extensive experience can make this method of biofacies analysis a surprisingly sound one. However, it has the limitation that the defined groups of associated elements, while generally being valid, are difficult to demonstrate and the groups may not be reproducible by other workers. This nonquantitative method of defining conodont biofacies has been used by Merrill (1968 and in press), Seddon (1970 a, 1970 b), and Druce (1970). Merrill defined a number of conodont biofacies in the Allegheny Group (Middle Pennsylvanian) of Ohio, adjacent Pennsylvania and West Virginia. (See Table 1.)

TABLE 1. Conodont Biofacies Recognized by Merrill (1968 and in press) in the Allegheny Group (Middle Pennsylvanian) of Ohio, and Adjacent Pennsylvania and West Virginia.

Cavusgnathus Biofacies (Merrill, in press)	Appalachian Fauna (Merrill, 1968)
Cavusgnathus spp.	Hibbardella n.sp. 2
Hibbardella 2 new species	Hindeodus spp.
Ligonodina 1 new species	Ligonodina n.sp. 4
Neoprioniodus 2 new species	Neoprioniodus n.sp. 7
Ozarkodina 1 new species	New genus A, n.sp. 3
	New genus B, n.sp. 1

TABLE 1. (continued)

Midcontinent Fauna[1] (Merrill, in press)	Ubiquitous Forms[2] (Merrill, 1968)
Hibbardella subacoda	*Gnathodus* spp.
Ligonodina lexingtonensis	*Idiognathodus* spp.
Ligonodina typa	*Streptognathodus* spp.
Lonchodina clarki	*Ozarkodina* spp.
Lonchodina ponderosa	*Spathognathodus* spp.
Metalonchodina bidentata	Others
Neoprioniodus conjunctus	
Neoprioniodus bulbosus	

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[1] *Gondolella* spp. was not found in Appalachians by Merrill (1964 and 1968). Although considered to be part of the Midcontinent fauna by Merrill (1968) it was not listed under this heading by him. Merrill (in press) has suggested the existence of a separate *Gondolella* biofacies.

[2] Some of the members of this group were also grouped in an off-shore *Idiognathodus* biofacies by Merrill (1968). Merrill (in press) called this the *Streptognathodus* biofacies and it will be so designated in this paper.

Merrill (1968) considered the Appalachian and Midcontinent associations as examples of provincialism. Later Merrill (in press), although retaining the names "Midcontinent" and "Appalachian", considered them to be biofacies; however, he continued to refer to them as faunas. Merrill (1968 and in press) concluded that the Cavusgnathus biofacies is generally restricted to shales which, on the basis of their lithology and macrofauna, were deposited in a nearshore environment. The faunal elements of the Streptognathodus biofacies were interpreted by Merrill to have predominated in limestones which were deposited in offshore rather than nearshore conditions. Merrill (in press) postulated, at least for the Midcontinent (an area that includes the writer's study area) that the Midcontinent fauna was only dominant in thin, often black, fissile shale units and in the thin limestones which immediately underlie them. The lithologies in which the Appalachian fauna predominates were not defined; however, this fauna was apparently more common and better developed in the purer limestones. None of the taxa of a particular fauna or biofacies were considered mutually exclusive; that is, taxa of one could be found in another, although in lesser numbers. The elements of the ubiquitous group were also defined as part of the Streptognathodus biofacies (Merrill, in press).

Examination of the figures and descriptions of Merrill (1968) convinced the writer that the Shawnee Group conodont faunas are nearly identical to those of the Allegheny Group of Ohio and adjacent areas, at least in elements other than the Sp elements of Streptognathodus, Gnathodus, and Idiognathodus. This permitted the writer to tentatively equate (Tables 2 and 3) some of the

TABLE 2. Tentative Comparison of Some of the Taxa of Merrill (in press) with those of this Study.

Merrill (in press)		This Study
Cavusgnathus biofacies		
Hibbardella 2 new species	=	*Ligonodina conflexus*, Tr element *Cavusgnathus* Tr element
Ligonodina 1 new species	=	*Ligonodina conflexus*, Hi element
Neoprioniodus 2 new species	=	*Cavusgnathus*, Ne element + possibly *Neoprioniodus* sp. A
Ozarkodina 1 new species	=	*Cavusgnathus*, Oz element

TABLE 3. Tentative Comparison of Some of the Taxa of Merrill (1968) with those of this Study.

Merrill (1968)		This Study
Hibbardella n.sp. 2	=	*Streptognathodus* and *Idiognathodus*, Tr element
Hindeodus spp.	=	*Hindeodus* sp. A
		Ellisonia teicherti, Tr element
		Trichonodella obtusa
		Trichonodella plattsmouthi n.sp.
		Trichonodella asymmetrica n.sp.
		Trichonodella sp.
New genus A, n.sp. 3	=	*Ozarkodina* [?] *curvata*
Ligonodina n.sp. 4	= ?	*Streptognathodus* and *Idiognathodus*, Hi element
New genus B, n.sp. 1	=	*Lonchodina douglasi* n.sp.
Neoprioniodus n.sp. 7	=	*Ellisonia teicherti*, Ne element

taxa of this study with those of Merrill (1968 and in press).

On the basis of the following criteria the writer was able to recognize the presence of the Cavusgnathus and Gondolella biofacies, as well as the Midcontinent fauna of Merrill (in press):

A. consistent mutual association of two or more taxa in a particular lithology;

B. consistent abundance of an element type in a particular lithology;

C. similar distribution, i.e. range of two or more elements;

D. similar morphology in associated elements, i.e. similar color, transparency, denticle arrangement, and white matter distribution;

E. comparison with the element composition of Mississippian and Pennsylvanian natural assemblages which have been described by a number of authors including Scott (1942), Rhodes (1952), and Schmidt and Müller (1964).

The Appalachian fauna, the Streptognathodus biofacies, and the ubiquitous group, all associations defined by Merrill, could not be recognized by the above criteria. This, as well as the fact that even the recognizable biofacies continued to be difficult to demonstrate made it desirable to select quantitative methods, which would test in a comprehensive manner the existence of conodont biofacies in these Pennsylvanian rocks. Relative abundance analysis was the first method used and this was followed by Q- and R-mode analysis.

Relative Abundance Analysis

A method of conodont biofacies analysis, one which provides repeatable results, makes use of abundance counts, and is easily represented visually, consists of a comparison of the percentage of one element to another in any sample or group of samples. In this type of comparison it is important to select and compare only abundantly occurring elements having similar morphology, size distribution and suspected similar function since otherwise sedimentological and laboratory influences tend to alter original relationships. For example, although the Sp and Ne elements of most if not all species of *Streptognathodus* and *Idiognathodus* should be present in a ratio of 1:1 (Rhodes, 1952), this is far from being the case in the writer's collections. There are 18,153 Sp elements of *Streptognathodus* spp. and *Idiognathodus* spp. and only 379 of the Ne element present. Clearly, any percentage comparisons between, for example, arched or elongated blades and platform elements would lead to unreliable results. Ellison (1968) explained the discrepencies between theoretical and actual ratios as being the result of sorting during and after deposition. An additional factor, which in the writer's opinion plays a significant role, is selective laboratory recovery of certain element types; such factors as specific gravity differences in heavy liquids and differential recovery during magnetic separation.

In processing a great variety of rock types from the Upper Pennsylvanian the most common problem encountered, particularly in processing shales, is that very large amounts of fines are left after breakdown and washing of a sample. These fine when put through heavy liquid often form a thick mat at the top of the separation funnel and the particles do not remain free floating for any appreciable length of time, despite agitation. The writer believes that in such situations smaller lighter elements such as hindeodelliform or neoprioniodiform elements would have less of an opportunity to settle out than the larger platform elements and would be incorporated in the light fraction.

The Sp or platform elements of Cavusgnathus, Streptognathodus and Idiognathodus fulfill the requirements as outlined and have been found as part of two natural assemblages, Lewistonella Scott and Scottognathus Rhodes.

The percentage that was calculated for each conodont bearing sample was:

$$\frac{C}{C + I + S} \quad X \quad 100 \quad = \quad \text{percent relative abundance}$$

Where C = no. of Sp elements of Cavusgnathus spp.
I = no. of Sp elements of Idiognathodus spp.
S = no. of Sp elements of Streptognathodus spp.

The calculated percentage for each sample was plotted on stratigraphic sections. In those samples lacking C but containing I or S, the percentage of C making up the total percent was plotted as 0%. All conodont bearing samples studied contained at least one or more of these three platform element types.

Merrill (1968 and in press) using the same relationship showed that in short sections (e.g. Locality Vanport 24) there appeared to be a regular alternation of Cavusgnathus and Idiognathodus faunas corresponding to shale and limestone lithologies respectively. Further, he was able to plot the percentages of Cavusgnathus for a relatively thick continuously exposed shale as well as the over and underlying limestones at his locality (Putnam Hill 3 / Vanport 3). It was of great interest to conduct a similar analysis of the same relationship for the well exposed, lithologically diverse Shawnee Group.

The results of the relative abundance analysis strongly support Merrill (1962, et seq.) in his contention that a regular alternation of conodont faunas exists in some Pennsylvanian rocks. The percentage curves are an expression of a regular distribution of the Sp elements of Cavusgnathus and Streptognathodus-Idiognathodus. The basic patterns which emerge from examination of the percentage curves are the following:

A) In limestone, particularly those that tend toward being massive, thick-bedded, and relatively pure, the Sp elements of either Streptognathodus, Idiognathodus, or both, dominate. In thinner bedded sequences, consisting of alternating shale and shaly limestone, the predominant platform element is that of Cavusgnathus. Thin shales interbedded between thicker massive limestones contain a predominance of Streptognathodus and Idiognathodus rather than the expected predominance of Cavusgnathus.

B) In green and gray marine shales such as the upper Lawrence Shale, the upper Snyderville Shale, the Heumader Shale, the upper Oskaloosa Shale, the Iowa Point Shale, the Jones Point Shale and the Turner Creek Shale which are either above or below limestone units there is a noticeable predominance of the Sp element of Cavusgnathus. In non-marine shales or claystones, conodonts are missing altogether. Such environments and the sediment laid down in them account for the major gaps in the percentage curves. These include parts of the Snyderville, the Doniphan, the Oskaloosa and the Jones Point Shales (Moore, 1964; Johnson and Adkison, 1964).

C) The fissile black shales, the gray shales that immediately overlie them, the gray to black shale of the Topeka Limestone, the Holt Shale, which is in homologous position to the black fissile shales, are similar in their conodont content to the limestones; Streptognathodus or Idiognathodus are abundant while Cavusgnathus is rare or completely absent.

On the basis of the various opinions on the depositional environments which deposited the rocks of the Shawnee Group that have been expressed by various authors (See Appendix B) the writer agrees with Merrill (1968 and in press) that generally green conodont bearing shales in which the Sp element of Cavusgnathus predominates usually represents a nearshore depositional environment and that the limestones carrying a predominance of Streptognathodus and Idiognathodus were usually deposited in an offshore environment. Shaly limestones and carbonate rich shales are presumed to represent intermediate or transitional environments.

The other depositional environment to consider is that of the black fissile shales and their associated soft gray to black shales. Moore (1936) interpreted this paleoenvironment to have been nearshore in shallow waters, possibly in lagoons. This interpretation appears to be the most reasonable of the various existing opinions. Taken together with the interpretations of McCrone (1963) for the Permian Bennett Shale, and of Moore (1964) for the Pennsylvanian black shales causes the writer to conclude that these rock types were probably deposited under restricted lagoonal conditions transitional between those of the marginal and open marine environments.

In the following discussion of relative abundances only the distribution of the Sp elements of Cavusgnathus, Streptognathodus and Idiognathodus is considered. The Sp elements of Streptognathodus and Cavusgnathus have been found throughout the Shawnee Group; however, that of Idiognathodus is more restricted and has been found only from the base of the Heebner Shale member of the Oread Limestone to the top of the Queen Hill Shale member of the Lecompton Limestone.

Idiognathodus, as here recognized, was not found above the Shawnee Group by Ellison (1941) or by Perlmutter (1971). As indicated, the relative abundance curves which have been plotted are based only on the Sp elements of Cavusgnathus, Streptognathodus, and Idiognathodus. Theoretically, similar results should be obtainable by, for example, plotting the relative abundance of the Oz element of Cavusgnathus versus that of Streptognathodus and Idiognathodus, or the relative abundance of all the nonplatform elements of Cavusgnathus versus those of the nonplatform elements of Streptognathodus and Idiognathodus. Although a regular variation of the relative abundance of the nonplatform elements can be shown, they are generally under-represented, probably due to sorting, differential breakage and possibly laboratory factors. This under-representation makes it less desirable to use the nonplatform elements for relative abundance analysis because the resulting percentage curves would be more erratic and based on a smaller number of specimens.

Although relative abundance curves can demonstrate the existence of certain faunal patterns, the existence of other biofacies may be masked or may not be brought out.

In the discussion of relative abundances which follows, the writer will refer to Cavusgnathus, Streptognathodus, and Idiognathodus instead of the Sp elements of these genera in order to simplify the discussion.

The right-hand curve of Figure 7 was taken from Elias' (1964) drawing for the Oread Limestone which is based on independent criteria such as lithology, position in the sedimentary cycle and megafossils. The overall similarity of the two curves is remarkable with the only area of divergence in the Heebner Shale. Elias (1964) apparently interpreted the Heebner Shale to have been deposited under nearshore marginal marine conditions; however, this and other black shales are faunally unlike other members deposited in a nearshore environment and either do not contain Cavusgnathus or do so only rarely. The conodonts in the black shales and the gray calcareous shales which directly overlie them are dominated instead by Streptognathodus and Idiognathodus.

Curves similar to those of Elias (1964) have been drawn for the Oread Limestone by Troell (1969) and for Pennsylvanian and Permian cyclothems by Moore (1964).

Relative Abundance Analysis of the Oread Limestone

Cavusgnathus predominates in the upper part of the Lawrence Shale, as shown on Figure 7. The shale was deposited under nearshore conditions (Troell, 1969); however, it represents a transition and was followed by a rapid transgression and an increase in water depth (Troell, 1969)

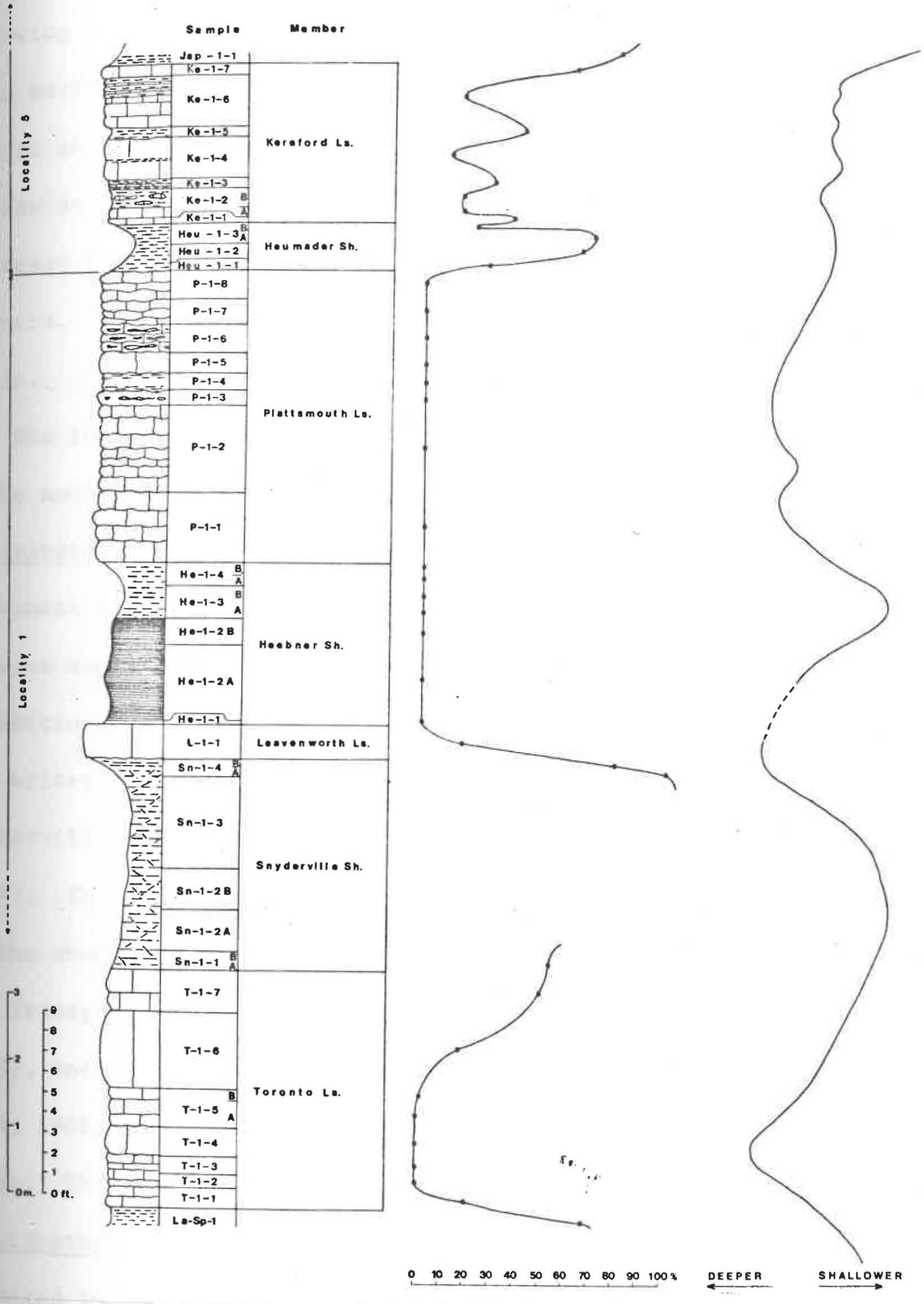


Fig.7. Stratigraphic section of the Oread Limestone at localities 1 and 5 showing relative abundance curve of the Sp elements of Streptognathodus, Idiognathodus and Cavusgnathus on the left curve. Increase in percent reflects increase in the Sp element of Cavusgnathus. Gap in the curve is due to lack of conodonts in the corresponding units. Water depth fluctuation curve on extreme right after Elias (1964).

allowing the Toronto Limestone to be laid down, for the most part under open marine conditions. A faunal change accompanied the environmental change and Streptognathodus rather than Cavusgnathus became dominant. A slow decrease in water depth (Troell, 1969) was reflected by an increase in Cavusgnathus during the deposition of the upper part of the Toronto. This regression culminated in the deposition of the Snyderville Shale.

The lowermost Snyderville Shale has been interpreted (Moore, 1964) to be nonmarine; however, a meager conodont fauna dominated by Cavusgnathus has been recovered from the lowermost few centimeters. The lowermost few centimeters consist of green shale containing calcareous nodules suggests that the environment represented by this interval is transitional and probably represents marginal nearshore marine conditions. The writer recovered only charophytes in the middle part of the Snyderville and these beds have been interpreted as nonmarine (Moore, 1964). The lack of conodonts in the middle Snyderville results in a gap in the abundance curve (Fig.7).

Transgression started near the middle of Snyderville time (Troell, 1969), and resulted in shallow nearshore conditions (Moore, 1964; Toomey, 1964, 1969) and the deposition of the upper beds of the Snyderville Shale. These uppermost few centimeters contain an abundance of Cavusgnathus rather than Streptognathodus. Continued transgression resulted in the deposition of the Leavenworth Limestone under open marine, shallow water conditions (Toomey, 1964, 1969). This was again accompanied by a change in fauna to one dominated by Streptognathodus rather than Cavusgnathus.

The Heebner Shale was probably deposited as a result of a slight regression under nearshore, shallow water, restricted (possibly lagoonal) conditions (Moore, 1936, 1964). *Cavusgnathus* was evidently unable to tolerate these environmental conditions because *Streptognathodus* and *Idiognathodus* are abundant to the complete exclusion of *Cavusgnathus*.

A return to open marine deposition in clear shallow water (Moore, 1964) allowed the deposition of the Plattsmouth Limestone. Faunally, the Plattsmouth Limestone is most similar to the underlying Heebner Shale and *Cavusgnathus* has not been found in this member. The overlying Heumader Shale was deposited under nearshore conditions in a retreating sea (Johnson and Adkison, 1967), and a sharp increase in *Cavusgnathus* can be correlated with the appearance of these conditions.

This regression is believed to have been followed by fluctuations in the water depths and resulted in the shale-limestone alternation of the Kereford Limestone. The fluctuation is reflected in the regular variation of the lithology along with the relative abundances of the platform elements. Moore (1964) interpreted the environment to have been similar to that of the Beil Limestone in the Lecompton megacycle except that it was deposited nearer shore and had a muddy bottom.

The overlying Kanwaka Shale is largely nonmarine (Johnson and Adkison, 1967); however, the lowermost 15 centimeters of the Jackson Point Shale Member of the Kanwaka Shale contain what is interpreted as a nearshore marginal marine conodont fauna in which *Cavusgnathus* predominates.

Relative Abundance Analysis of the Lecompton Limestone

The upper part of the Kanwaka Shale, the Stull Shale Member, was deposited under marine conditions (Johnson and Adkison, 1967) and contains a predominance of Cavusgnathus. (Fig.8).

The Spring Branch Limestone at the base of the Lecompton megacycle was laid down under marine conditions of intermediate to greatest distance from the invading sea margins (Moore, 1964). It is the cyclothemic equivalent of the Toronto Limestone of the Oread megacycle. In the massive lower portion of the Spring Branch Limestone Streptognathodus and Idiognathodus predominate. This part of the Spring Branch was deposited in quiet marine waters which were perhaps deeper than normal marine (Yochelson in Johnson and Adkison, 1967). The upper Spring Branch Limestone becomes increasingly shaly and was, according to Johnson and Adkison (1967) deposited in shallower water. The shallowing as well as possible fluctuations in sea level, is reflected in the increase of Cavusgnathus in this part of the Spring Branch Limestone. Several Spring Branch Limestone samples, one of them a limestone breccia, were found to be barren of conodonts and as a result there are some discontinuities in the relative abundance curve.

The Doniphan Shale was considered to represent nonmarine, estuarine deposition by Johnson and Adkison (1967). Moore and Merriam (1965) interpreted it as having had a similar environment to that of the Snyderville Shale. Cavusgnathus rather than Streptognathodus or Idiognathodus predominates and on the basis of comparison with the Snyderville Shale of the Oread Limestone this would suggest that the member was deposited in a nearshore marginal marine environment.

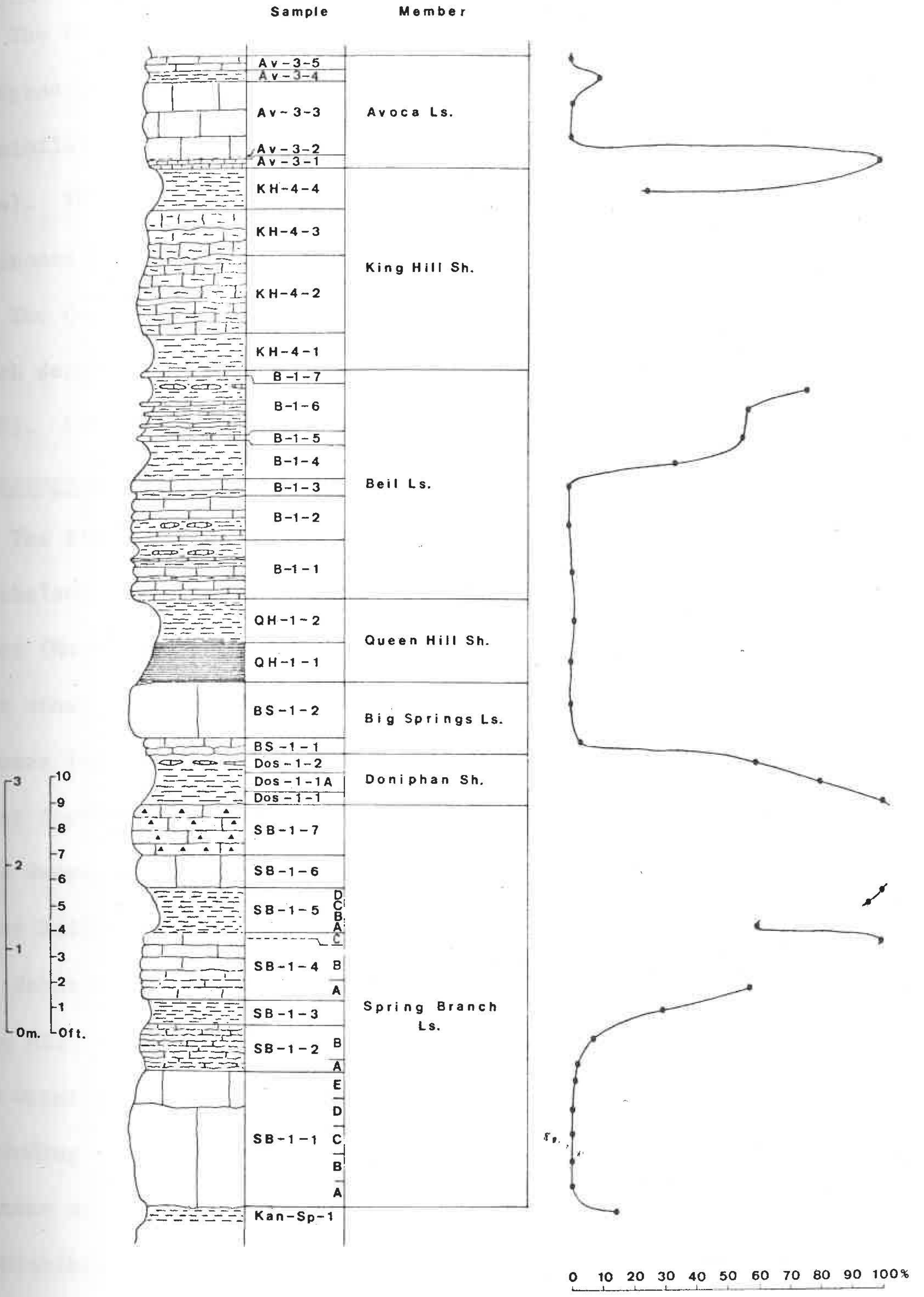


Fig.8. Stratigraphic section of the Lecompton Limestone at localities 2 and 7 showing relative abundance curve of the Sp elements of Streptognathodus, Idiognathodus, and Cavusgnathus. Increase in percent reflects increase in the Sp element of Cavusgnathus. Gaps in curve are due to lack of conodonts in corresponding units.

The Big Springs Limestone was deposited in a deeper sea than the Doniphan Shale (Johnson and Adkison, 1967) in an environment identical or similar to that which deposited the Spring Branch Limestone (Moore, 1964). This more offshore deposition was accompanied by a return to dominance by Streptognathodus and Idiognathodus.

The Queen Hill Shale was deposited under conditions similar to those which deposited the Heebner Shale (Moore, 1964; Johnson and Adkison, 1967). Like the Heebner Shale, the Queen Hill is dominated by Streptognathodus, to the virtual exclusion of Cavusgnathus (Fig.8).

The Beil Limestone records deposition in quiet normal marine waters (Yochelson, 1960 in Johnson and Adkison, 1967) far from the nearest shore (Moore, 1964). The Beil is dominated by Streptognathodus, like most other offshore limestones, however, the upper Beil Limestone becomes increasingly shaly and this possibly reflects a decrease in water depth and deposition closer to shore. This environment is reflected in a decrease in Streptognathodus and an increase in Cavusgnathus in the upper Beil Limestone (Fig.8).

Johnson and Adkison (1967) considered that the lower part of the King Hill Shale may have been deposited under continental conditions and the upper part under shallow marine conditions. The lack of fossils, including conodonts, in the lower three-quarters of the member supports Johnson and Adkison's interpretation. The lack of conodonts is responsible for the break in the abundance curve (Fig.8). A small conodont fauna was recovered from the uppermost King Hill Shale and this supports the interpretation of Johnson and Adkison and Lokke and Van Sant (1966) that the upper part was deposited under marine conditions.

The shale lithology, a fauna and flora of ostracodes, gastropods and charophytes reported by Lokke and Van Sant, as well as its position directly under a limestone which was deposited under deeper marine conditions (Johnson and Adkison, 1967) indicate that the uppermost shale unit of the King Hill Shale was deposited under the marginal marine conditions described by Moore (1964). The number of conodonts recovered in this upper shale unit is too small to be considered significant. Of four specimens (all platform elements) recovered, three are assignable to a species of Streptognathodus and one to a species of Cavusgnathus.

The lowermost Avoca Limestone, like the upper King Hill Shale, contains few conodonts and only a single conodont, a specimen of Cavusgnathus, was recovered. It is probable that the shaly lowermost bed was deposited under nearshore marine conditions although Johnson and Adkison (1967) interpreted the lower Avoca to have been deposited under deeper marine conditions. The upper Avoca Limestone consists of more massive limestones with a single interbedded shale near the top of the member. This part of the member contains a predominance of Streptognathodus rather than Cavusgnathus. Environmentally the upper part of the member apparently represents deposition under normal offshore marine conditions.

Relative Abundance Analysis of the Deer Creek Limestone

The Tecumseh Shale which underlies the Deer Creek Limestone (Fig.9) was for the most part deposited under continental conditions; however, the upper part of the Tecumseh represents deposition in a transgressing sea (Johnson and Adkison, 1967). Only two conodonts, both Cavusgnathus, were found in samples from the Tecumseh Shale. Environmentally the

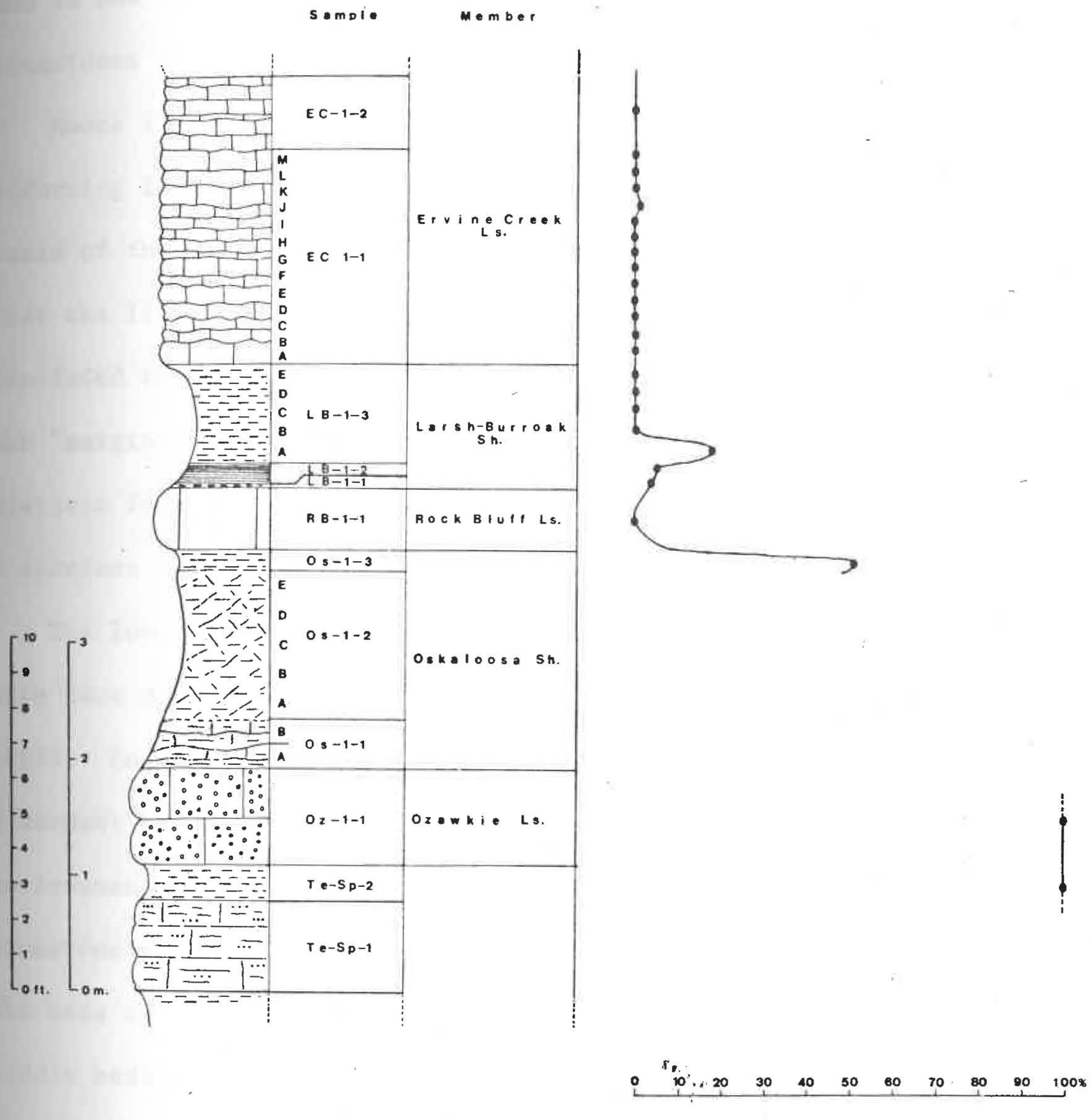


Fig.9. Stratigraphic section of the Deer Creek Limestone at locality 3 showing relative abundance of the Sp elements of Streptognathodus and Cavusgnathus. Increase in percent reflects increase in the Sp element of Cavusgnathus. Gap in curve is due to lack of conodonts in corresponding units.

upper shale unit of the Tecumseh Shale was probably deposited under nearshore marginal marine conditions.

The Ozawkie Limestone is the basal member of the Deer Creek Limestone and is the cyclothemic equivalent of the Spring Branch and the Toronto limestones of the Lecompton and Oread megacycles respectively.

Moore (1964) defined the Ozawkie-type (Knightites) Assemblage as occurring in the upper part of the Ozawkie Limestone. Presumably on the basis of the abundant Osagia, characteristic gastropods, plus the fact that the lithology consists of an oolitic limestone, Moore (1964) concluded that at least the upper part of the Ozawkie was deposited in the "marginal parts of the retreating sea, though at an undeterminable distance from the nearest strand line." Only a single conodont element, a specimen of Cavusgnathus, was recovered from the Ozawkie Limestone.

The lower and middle part of the Oskaloosa Shale was interpreted to have been deposited under continental conditions (Johnson and Adkison, 1967). Only a single unidentifiable conodont fragment was found in the lowermost beds, and these beds apparently represent a transitional environment between the marginal marine deposition of the Ozawkie Limestone (Moore, 1964) and the continental deposition represented by the beds of the middle Oskaloosa Shale (Johnson and Adkison, 1967). The middle beds of the Oskaloosa Shale were barren of conodonts and this supports a continental environment of deposition for these beds. The uppermost unit of the Oskaloosa Shale was deposited in shallow marine water as mud bordering the shore (Moore, 1964). These nearshore shales contain a megafauna of Chonetes, Juresania, Derbyia and Aviculopecten (Moore, 1964). A rich conodont fauna in which Cavusgnathus was the dominant platform element, was recovered from this unit (Fig.9).

The Rock Bluff Limestone was deposited under marine conditions (Johnson and Adkison, 1967). There is a sharp decrease in Cavusgnathus in the Rock Bluff Limestone and Streptognathodus is abundant (Fig.9).

The shales of the Larsh-Burroak were probably, like the Heebner and Queen Hill shales, laid down under nearshore, shallow water, restricted (possibly lagoonal) marine conditions (Moore, 1936, 1964). Although Cavusgnathus is more abundant in this member than in other lithologically similar units, Streptognathodus is by far the more abundant of the two. Cavusgnathus merrilli n.sp. is more common in the Larsh-Burroak and Queen Hill shales than is Cavusgnathus lautus, a species more common in the non-restricted nearshore marine shales such as those of the upper Snyderville or Oskaloosa. Black shales and the shales which directly overlie them are faunally more similar to limestones than to other shales and there is a suggestion that is supported by cluster analysis that Cavusgnathus merrilli n.sp. may have been dominant in a biofacies other than the one in which other species of Cavusgnathus were most common.

The Ervine Creek Limestone was deposited under normal marine conditions (Johnson and Adkison, 1967) in shallow waters far from the nearest shore (Moore, 1964). These offshore marine conditions were accompanied by a dominance of Streptognathodus and a near absence of Cavusgnathus (Fig.9).

Relative Abundance Analysis of the Topeka Limestone

Moore (1949) somewhat tentatively considered the Hartford Limestone and the associated shaly deposits at the top of the Calhoun and at the base of the Iowa Point Shale as constituting the terminal part (cyclothem E) of the Deer Creek megacyclothem. In this interpretation the Hartford Limestone is the cyclothemic equivalent of the Clay Creek Limestone of the Kanwaka Shale and the upper part of the Iowa Point Shale is the cyclothemic equivalent of the upper Lawrence Shale, the upper Kanwaka Shale and the upper Tecumseh Shale of the three lower megacyclothems.

Locally, the upper Calhoun Shale was deposited under marine conditions (Johnson and Adkison, 1967). The uppermost beds of the Calhoun Shale contain a thin coal seam and the shale beds above this were apparently laid down under nearshore conditions. These shales contain moderately high concentrations of Cavusgnathus (Fig. 10).

The Hartford Limestone records normal but shallow marine deposition (Johnson and Adkison, 1967) and there is a noticeable increase in Streptognathodus over Cavusgnathus in this unit.

Johnson and Adkison (1967) interpreted the Iowa Point Shale to represent deposition under mostly marine with some local estuarine, conditions. The Iowa Point Shale at locality 6 is interpreted to have been deposited under nearshore marine conditions. The change in environmental conditions was accompanied by a sharp increase in Cavusgnathus (Fig. 10).

Moore (1949) interpreted the Curzon Limestone to be the cyclothemic equivalent of the Toronto, the Spring Branch, and the Ozawkie Limestones of the three lower megacyclothems of the Shawnee Group respectively.

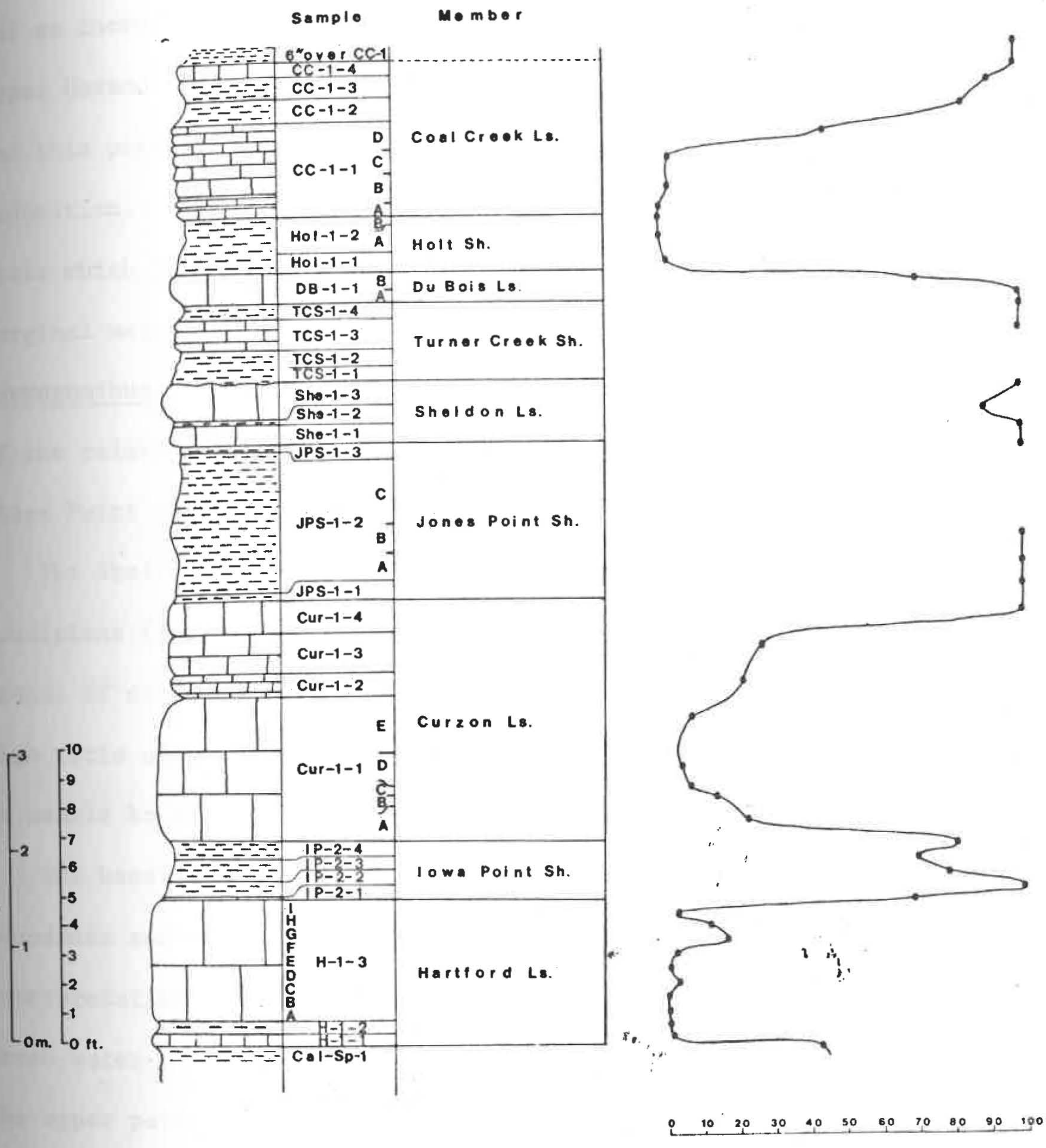


Fig.10. Stratigraphic section of the Topeka Limestone at localities 4 and 6 showing relative abundance of the Sp elements of Streptognathodus and Cavusgnathus. Increase in percent reflects increase in the Sp element of Cavusgnathus. Gap in curve is due to lack of conodonts in corresponding units.

Johnson and Adkison (1967) considered the Curzon to have been deposited under conditions similar to those under which the Hartford Limestone was laid down. Again there is a well-defined decrease in the Cavusgnathus and an increase in Streptognathodus (Fig. 10). In the thinner bedded upper Curzon there is a gradual increase in the abundance of Cavusgnathus and this presumably reflects a shallowing of the sea and more shoreward deposition. The more nearshore deposition culminated in the Jones Point Shale which for the most part was probably deposited under nearshore marginal marine conditions and contains high concentrations of Cavusgnathus relative to Streptognathodus (1318 : 1). The discontinuity of the relative abundance curve (Fig. 10) in the middle beds of the Jones Point Shale probably results from nonmarine deposition.

The Sheldon Limestone was deposited under relatively shallow marine conditions (Johnson and Adkison, 1967). When compared with the conodont faunas of normal marine limestones the Sheldon contains an unusually high ratio of Cavusgnathus to Streptognathodus (393 : 1). The writer is unable to offer a satisfactory explanation for this ratio.

The basal beds of the Turner Creek Shale were found to be barren of conodonts and this supports Johnson and Adkison (1967) in their interpretation that the basal beds of this member was deposited in a fresh water or swamp environment, at least locally. They interpreted the upper part to have been deposited under marine conditions. This is supported by the presence of abundant conodonts in the upper half of the Turner Creek Shale. Cavusgnathus is the dominant platform element present (Fig. 10).

The Du Bois Limestone was deposited under marine conditions (Johnson and Adkison, 1967). Moore (1949) considered this to be the cyclothemic equivalent of the Leavenworth, the Big Springs and the Rock Bluff limestones of the three lower megacyclothems respectively. Unlike these three members the Du Bois Limestone contains high concentrations of Cavusgnathus relative to Streptognathodus (141 : 58). The writer is unable to offer an explanation for this, especially since little is known of the environment of deposition of this unit.

The Holt Shale was probably deposited under conditions similar to that envisioned by Moore (1936, 1964) for the Heebner Shale. The Holt Shale is closely comparable to the Heebner, the Queen Hill and the Larsh-Burroak Shales, even though the black fissile portion is absent, at least at locality 6. Like these shales, the Holt Shale contains an abundance of Streptognathodus with the virtual exclusion of Cavusgnathus (1812 : 7).

The Coal Creek Limestone which contains such an abundance of marine fossils is lithologically and probably faunally most similar to the Beil Limestone of the Lecompton megacycle. It, like the Beil, was apparently deposited under normal marine conditions far from the nearest shore. Streptognathodus predominates in the lower more massive beds; however, the upper beds become increasingly shaly and in these beds Cavusgnathus increases in abundance (Fig. 10).

The relative abundance relationship between the Sp elements of Cavusgnathus, Streptognathodus and Idiognathodus provides a measure of nearness to shore that can be used in addition to lithological and macrofossil criteria. This has been pointed out by Merrill (1968 and in press) and by Merrill and King (1971).

Attempts at evaluating other relative abundance relationships such as

$$\frac{An}{An + C} \times 100, \quad \frac{An}{An + S + I} \times 100 \quad \text{and} \quad \frac{I}{I + S} \times 100$$

where

An = no. of Sp elements of Anchignathodus

C = no. of Sp elements of Cavusgnathus

S = no. of Sp elements of Streptognathodus

I = no. of Sp elements of Idiognathodus

proved to be unsuccessful; that is, no regular variation corresponding to lithological changes could be detected.

Relative abundance analysis provides a visual representation of the orderly relative variation in abundance of one group of organisms, or their parts, versus another, provided an orderly interpretable pattern is present. In the analysis of the preceeding section the relative abundance of a major component of three genera, the Sp element, was shown to vary in a regular manner. Species of Cavusgnathus, with the possible exception of Cavusgnathus merrilli n.sp., are consistently more abundant in rocks representing nearshore marginal marine deposition. Species of Streptognathodus and Idiognathodus predominate in limestones deposited under normal open marine conditions and in black fissile shales and the soft, gray shales which directly overlie them, both of which were probably the result of deposition under restricted, probably lagoonal, nearshore marine conditions.

Cluster Analysis

Introduction

While the groups of associated conodont taxa defined by Merrill (1968 and in press) and at least partially supported by the writer appear to be reasonable, a number of other methods exist that permit the paleoecologist to examine the validity of these groups. These methods include cluster analysis (Sokal and Sneath, 1963), factor analysis (Imbrie, 1964), recurrent group analysis (Kohut, 1969; Sweet, 1970 b) and association analysis (Vilks, Anthony and Williams, 1970). In addition, the chi square statistic was used very effectively for defining species association by Johnson (1962) and Valentine and Mallory (1965). The work of Johnson (1962) is of particular interest to the writer in that Johnson investigated faunal associations in Pennsylvanian cyclothems. For this study cluster analysis was selected, although it is planned to test the application of some of the other methods in later studies.

Cluster analysis groups variables such as species and samples according to the magnitudes and interrelationships among their similarity coefficients (Sokal and Rohlf, 1969). The analysis involves two major steps; First, similarity coefficients are calculated between all pairs of categories; second, similar categories are clustered to form groups (Valentine and Peddicord, 1967). In cluster analysis, data matrices can be studied in two ways. In the first, the Q-mode technique, "objects (samples) are related to each other on the basis of their attributes (species)"; whereas in the second, the R-mode technique, "attributes are related to each other on the basis of the objects in which they are found" (Hazel, 1970).

Although cluster analysis has been used extensively in ecologic studies, particularly those involving modern marine organisms, the technique has only rarely been used with distributional data of fossil organisms. Hazel (1970) used both the Q- and R-mode in demonstrating the potential value of cluster analysis in biostratigraphy. Stehli (1971) and Rowell and McBride (in press) used cluster analysis to test the existence of faunal provinces in the Cambrian and Permian respectively. Valentine and Peddicord (1967), Scott (1970), Gould (1970), and Kaesler and Taylor (in press) are the only authors, however, who have used cluster analysis in an attempt to define fossil assemblages.

Choice of Similarity Coefficients

The choice of similarity coefficient to be used in cluster analysis is limited somewhat by the fact that for most ecologic and probably all paleoecologic purposes, total abundance counts of each species in a sample cannot be used. Imbrie (1955) and Kaesler (1966) discussed the reasons for this extensively, the most important of which are probably sorting and differential breakage.

Binary coefficients have come to be used almost exclusively in cluster analysis of ecologic data (Hazel, 1970) and will be used in this study. Cheetham and Hazel (1969) discussed and compared various binary coefficients. In this study two similarity coefficients, the simple matching and the Jaccard coefficients, were used. These two coefficients were used because they were used successfully in ecologic studies of modern faunas (Maddocks, 1966; Kaesler, 1966; etc.) and because they are able to utilize presence-absence data. It was of interest to determine the usefulness of these coefficients in dealing with the distribution of fossils.

The simple matching coefficient was given by Kaesler (1966) as:

$$S_{sm} = \frac{a + d}{n}$$

where a is the number of samples containing the two items being compared.

d is the number of times both items are absent.

n is the total number of comparisons.

The Jaccard coefficient was given by Kaesler (1966) and Scott (1970) as:

$$S_j = \frac{a}{a + b + c}$$

where a is the number of samples containing the two items being compared.

b is the number in which one item is present alone.

c is the number in which only the second item is present.

The two coefficients differ among other things in the manner in which they treat negative matches or mutual absences in the numerator and denominator (Cheetham and Hazel, 1969). The simple matching coefficient gives equal weight to both positive and negative matches, whereas the Jaccard coefficient ignores negative matches. This difference makes the simple matching coefficient unusable in R-mode (species by species) analysis. Kaesler (1966) stated that, "Whereas the absence of both species A and B at station 1 is of ecologic interest, it provides no useful information for clustering species into biofacies. Perfect similarity caused by negative matches alone would not justify grouping the species in the same biofacies, so negative matches must be ignored." Mello and Buzas (1968) concurred with this reasoning, as does the writer.

As already suggested, negative matches may be significant in Q-mode (sample by sample) biotope analysis. The writer agrees with Kaesler (1966) who wrote that, "If the study area is relatively small (e.g., Todos Santos Bay), or if it comprises an ecologic unit which many environments and faunas recur, negative matches give important information, as do positive matches on similarity of two stations, although the information is of a different kind. If species A occurs at both stations 1 and 2, a straightforward reason exists for considering the stations similar to the extent 1/n, where n is the total number of species in the study. By similar reasoning, if sampling is adequate, the absence of species B from the two stations is also meaningful. The stations are similar in being ecologically intolerable to species B." The above reasons support the use of the simple matching coefficient in the writer's Q-mode (biotope) analysis.

The writer also used the Jaccard coefficient in Q-mode analysis so that he could compare the results of using both types of coefficient on paleontological data. Such a comparison is desirable, particularly since Mello and Buzas (1968) selected the Jaccard coefficient for use in Q-mode analysis. These authors did not disagree with Kaesler (1966) in his use of negative matches in sample to sample comparisons but instead preferred to use the Jaccard coefficient on the basis of its properties.

It may be of interest to list some of the published opinions of these two coefficients (Table 4).

TABLE 4. Views on the Use and Characteristics of the Simple Matching and Jaccard Coefficients.

Simple Matching Coefficient	Jaccard Coefficient
Can be too insensitive to inadequate sampling (Mello and Buzas, 1968).	Places more emphasis, as one does intuitively, on those samples which contain many individuals and of course, at the same time, many species (Mello and Buzas, 1968).
This coefficient can indicate "high similarity between stations at which only a few species are found, even if no species occurs at both stations" (Kaesler, 1966).	Relative to other coefficients the Jaccard coefficient tends to emphasize difference (Hazel, 1970).
Yields erratic results (Hazel, 1970).	Mismatches (present in one unit being compared but not the other) in the denominator are given equal weight with the matches (Hall, 1969). Hall suggested a system of weighting.

A great number of binary coefficients have been proposed (Cheetham and Hazel, 1969), and a number of them could possibly have been used in place of the simple matching and Jaccards coefficient. Among them is the Fager coefficient which was effectively used by Valentine and Peddicord (1967) on paleontologic data to define groups of associated mollusks by means of cluster analysis. Valentine and Peddicord's claim that use of the Fager coefficient led to "more natural clusters" than did the same analysis using Jaccards coefficient makes it of interest, at a later date, to analyze the writer's data using that coefficient.

Clustering Technique

Clustering of similarity coefficients results in a dendrogram, a two dimensional representation of a multidimensional relationship (Kaesler, 1966); however, before similarity coefficients can be clustered the investigator must decide on the clustering technique to be used. The various clustering methods were discussed by Sokal and Sneath (1963). Hazel (1970) stated that the weighted and unweighted pair-group methods (abbreviated WPGM and UPGM respectively) are the most commonly used. He pointed out that "for many, perhaps most, purposes, the amount of distortion is the most important consideration in choosing which clustering method to use."

Kaesler (1971, personal communication) stated that empirical evidence has shown time and again that the unweighted pair group method with simple arithmetic averages gives clusters with small amounts of distortion. Farris (1969) has demonstrated on theoretical, rather than empirical grounds, that the UPGMA should give less distortion.

The writer used the UPGMA and WPGMA methods in his Q- and R-mode analyses. These methods were used because of the factors discussed above as well as the fact that Kaesler (1966), Maddocks (1966), and Mello and Buzas (1968) among others, successfully used one or the other, or both, clustering methods. These methods are apparently reliable in giving clusters with small amounts of distortion.

Phenon Line Selection

In analyzing dendrograms resulting from Q- and R-mode analyses the question of where to draw phenon lines arises. In a number of the writer's analyses there exist natural discontinuities which more or less objectively define groups of samples or elements as belonging together (Mello and Buzas, 1968); however, these discontinuities are positioned so that no single phenon line serves to effectively separate the clusters. Although Sokal and Sneath (1963) in a numerical taxonomic context stated that a phenon line must not bend up and down, this at times has seemed the most appropriate solution. Another possibility and one recognized by Mello and Buzas (1968) is to select several levels of demarcation. These authors wrote:

> "We are not sure that there is any compelling reason to use a single level of demarcation in nontaxonomic analysis. It might well happen that clusters chosen at several levels within a single dendrogram might more closely approach reasonable sample or species arrangements."

Kaesler (1966) wrote that:

> "the best procedure in biofacies analysis is probably to avoid drawing lines and to let the dendrograms stand alone as representation of similarity".

Support of the use of several phenon levels comes from examination of the writer's dendrograms. In each of the four dendrograms of Q- and R-mode analysis the same clusters or groups can be recognized, although often at differing similarity levels. In many cases although the same sample to sample or species to species relationship is maintained, a cluster that was easily recognized previously, is "lost" in a larger group because a single phenon line fails to define it.

The writer will use several levels of demarcation and will refrain from drawing phenon lines.

Organization of Data

The abundance and distribution of 79 element types in 171 samples was tabulated (Appendix D). Of 171 samples, 18 were barren of conodonts. The organization of the data is shown in Table 5.

Initially, both Q- and R-mode analyses using the UPGMA and WPGMA methods of clustering were done on the overall distribution of the 79 element types in 153 samples, i.e. on a 79 X 153 data matrix (Table 5).

Secondly, both Q- and R-mode analyses were done on the same data as above; however, 9 element categories which could not be identified to species were omitted. These categories were Streptognathodus sp., Idiognathodus sp., Cavusgnathus sp., Anchignathodus sp., Ozarkodina ? sp., unidentifiable Oz elements, unidentifiable Hi elements, unidentifiable Ne elements, and genus and species indeterminate. These elements had been broken and damaged by geological and laboratory factors, and their

TABLE 5. Summary of Organization of Data, showing Coefficients and Clustering Methods used.

	Data Matrix 1			Data Matrix 2			Data Matrix 3		
	79 X 153			70 X 148			70 X 50		
	Distribution data of 79 element types in 153 ungrouped samples. (Appendix D).			Distribution data of 70 element types in 148 ungrouped samples; nine element categories and five samples were omitted.			Distribution data of 70 element types in 50 grouped or composite samples.		
Q-mode Cluster Analysis	Jaccard Coefficient	UPGMA	1A	Jaccard Coefficient	UPGMA	2A	Jaccard Coefficient	UPGMA	3A
		WPGMA	1B		WPGMA	2B		WPGMA	3B
	Simple Matching Coefficient	UPGMA	1C	Simple Matching Coefficient	UPGMA	2C	Simple Matching Coefficient	UPGMA	3C
		WPGMA	1D		WPGMA	2D		WPGMA	3D
R-mode Cluster Analysis	Jaccard Coefficient	UPGMA	1E	Jaccard Coefficient	UPGMA	2E	Jaccard Coefficient	UPGMA	3E
		WPGMA	1F		WPGMA	2F		WPGMA	3F

distribution was judged to have little or no paleoecological significance. The elimination of 9 element categories resulted in 5 samples, those containing only one or more of these element types, having to be omitted. The elimination of 9 taxa and 5 samples resulted in a 70 X 148 data matrix (Table 5).

Thirdly, the 148 samples of the second data matrix were condensed and grouped into 50 composite samples. If all samples from a member were of similar lithology, then these were grouped together as one composite sample (Appendix C). The composite samples were separated either at stratigraphic (i.e. member) or at lithologic boundaries (Appendix B). The grouping of the 148 samples resulted in a 70 X 50 data matrix. Table 5 summarizes the ways in which the data was organized and shows the coefficients and clustering methods used. Each of the 18 cluster analyses computed were assigned an analysis number, 1 A, 1 B, ..., 3 F to facilitate easier reference.

In the Q-mode analyses, as discussed previously, both the simple matching and Jaccard coefficients were utilized, whereas in the R-mode only the Jaccard coefficient was used.

Cophenetic Correlation Coefficient

The cophenetic correlation coefficient was developed by Sokal and Rohlf (1962) to measure distortion due to cluster analysis. The coefficient is "a product-moment correlation coefficient computed between corresponding elements of two matrices" (Kaesler, 1970). Kaesler pointed out that:

> The danger of indiscriminant use of cluster analysis is particularly great in ecological and paleoecological studies, as has been recognized by botanical ecologists (Greig-Smith, 1964). Limiting environmental parameters may be correlated with time, latitude, depth or other continuous variables.
>
> Cluster analysis is not always the most appropriate method of analyzing data from distributional paleoecology. Ordination techniques based on factor analysis provide a better estimate of similarities among groups of stations where cophenetic correlation coefficients are low. The cophenetic correlation coefficient should be employed to measure the amount of distortion introduced by cluster analysis and to aid in choosing which clustering method to use if cluster analysis is indicated at all.

The cophenetic correlation coefficients of the writer's cluster analyses are shown on Table 6.

Generally high cophenetic correlation values obtained for most of the analyses support the use of this method of analysis as opposed to other methods such as ordination techniques (Kaesler, 1970). It is of interest, and possible significance, to note that Farris (1969) observed that if attempts are made to maximize the cophenetic correlation coefficient by

TABLE 6. Cophenetic Correlation Coefficients of Q- and R-mode Cluster Analyses.

	Data Matrix 1		Data Matrix 2		Data Matrix 3	
Q-mode Cluster Analysis	Analysis 1A	0.778	Analysis 2A	0.775	Analysis 3A	0.848
	Analysis 1B	0.680	Analysis 2B	0.694	Analysis 3B	0.771
	Analysis 1C	0.832	Analysis 2C	0.841	Analysis 3C	0.860
	Analysis 1D	0.738	Analysis 2D	0.832	Analysis 3D	0.808
R-mode Cluster Analysis	Analysis 1E	0.884	Analysis 2E	0.894	Analysis 3E	0.863
	Analysis 1F	0.865	Analysis 2F	0.894	Analysis 3F	0.816

re-arranging clusters then dissimilar rather than similar species or samples may be grouped together. Kaesler (1970) stated that the practise of maximizing cophenetic correlation coefficients by trial-and-error is generally not followed in paleoecologic work and that the coefficient is still a useful measure of distortion.

Analyses 1 B and 2 B have low cophenetic correlation coefficients. Both these Q-mode analyses were computed on data in which the samples had not been grouped, using the Jaccard coefficient and the WPGMA clustering method. This suggests that distortion due to clustering (Kaesler, 1970) is strongest in analyses 1 B and 2 B, although some of the other analyses such as 1 D have nearly as low cophenetic correlation coefficients. With the exception of analysis 2 F those analyses using the UPGMA clustering method consistently gave higher cophenetic correlation coefficients than did those using the WPGMA method, regardless of the similarity coefficient used.

The lower cophenetic correlation coefficient found in analyses 1 B, 1 D, 2 A, and 2 B give support to the writer's decision not use the Q-mode analyses of data sets 1 and 2 for further paleoecologic analysis.

It should be noted, however, that analyses 3 D and 3 F, both using the WPGMA clustering method, appear to give the most satisfactory results in the Q- and R-mode analyses, respectively, although only a small difference could be noted between analyses 3 C and 3 D and between 3 E and 3 F. The decision of which results were satisfactory was based on the level at which clusters were defined, on the clarity of breaks in the overall cluster network, on the position of the items being clustered relative to one another and whether or not the clusters made sense. In the writer's analyses, at least in the Q-mode analyses, neither choice of similarity coefficient nor the clustering method seemed to be as significant as whether or not the samples were grouped.

Results of Q-mode Cluster Analyses

This type of analysis groups samples that are similar to one another on the basis of their contained attributes, in this case, conodonts. In the context of Shawnee Group conodonts, the method permits one, using explicit methods, to evaluate what samples and members are faunally most similar. Such an evaluation can be used in paleontologic correlation, or as is the case in this study, it may be used to determine if recurring lithologically similar units are similar faunally, i.e., if similar faunas recur.

Q-mode cluster analysis produced satisfactory results for data set three where grouped data was used. The dendrograms resulting from Q-mode cluster analysis of the ungrouped data matrices 1 and 2 were so large, the clusters so poorly defined, and the samples arranged in such an erratic manner that interpretation and presentation was not possible. As a consequence, all discussion of Q-mode analysis will be concerned with results obtained from analysis of data matrix 3. In each of the four Q-mode analyses (analyses 3 A, 3 B, 3 C, and 3 D) there is a recurrence of groups. These groups or clusters are generally composed of the same samples and were consistently identified on different dendrograms (Figs. 11 to 14).

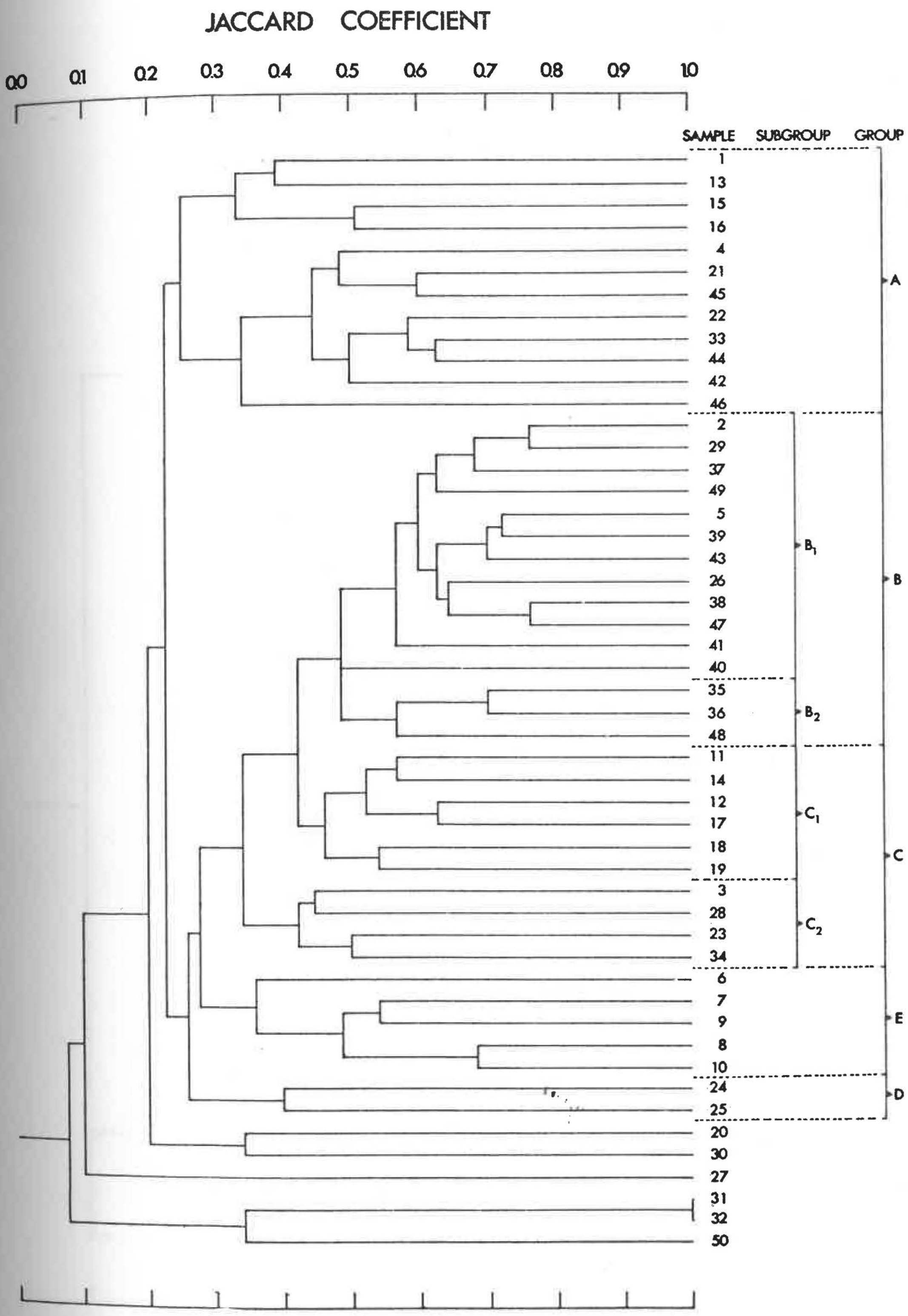


Fig.11. Dendrogram of Q-mode cluster analysis 3A of grouped samples using the Jaccard coefficient and the UPGMA clustering method. For sample codes see Appendix C.

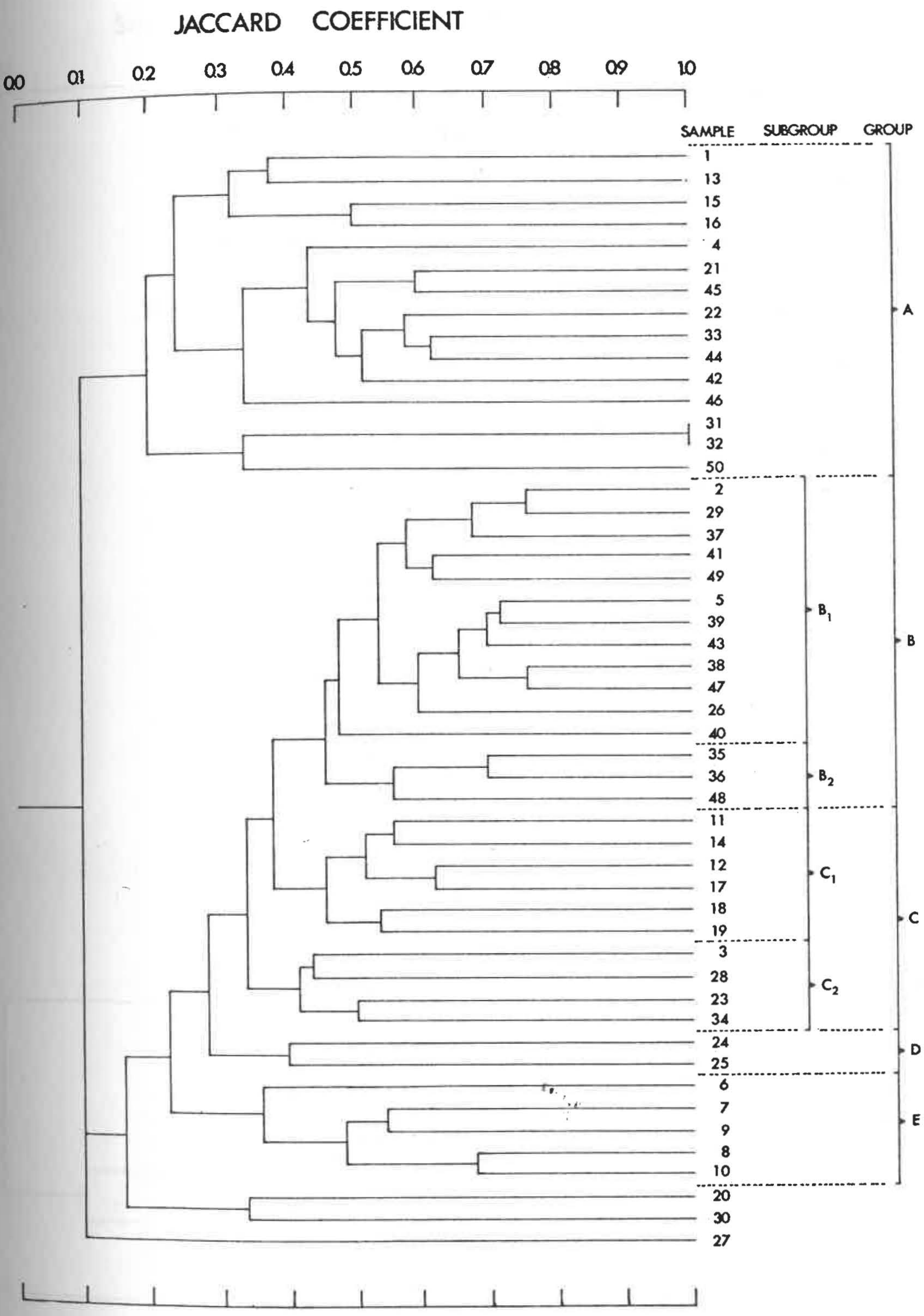


Fig.12. Dendrogram of Q-mode cluster analysis 3B of grouped samples using the Jaccard coefficient and the WPGMA clustering method. For sample codes see Appendix C.

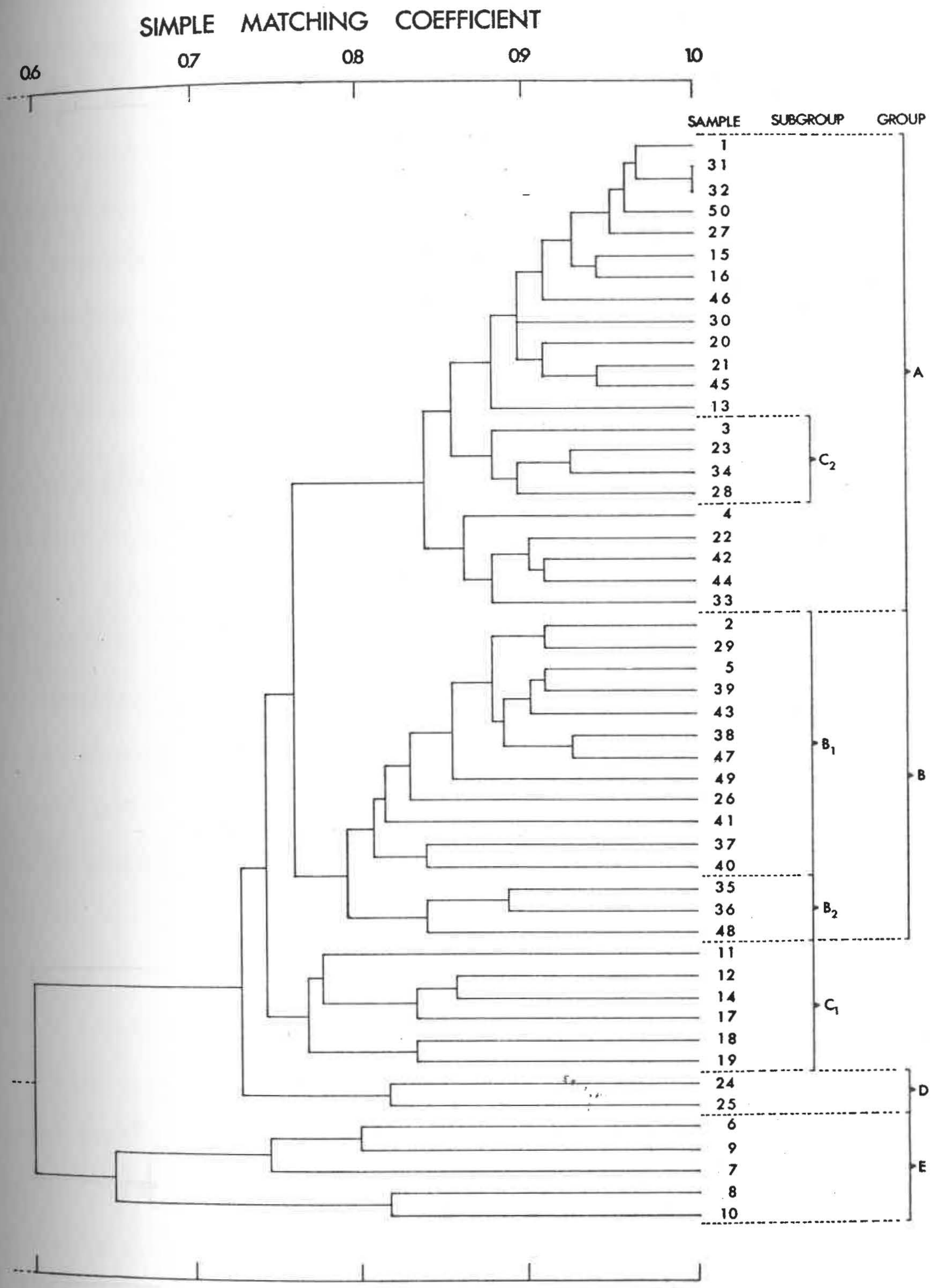


Fig.13. Dendrogram of Q-mode cluster analysis 3C of grouped samples using the simple matching coefficient and the UPGMA clustering method. For sample codes see Appendix C.

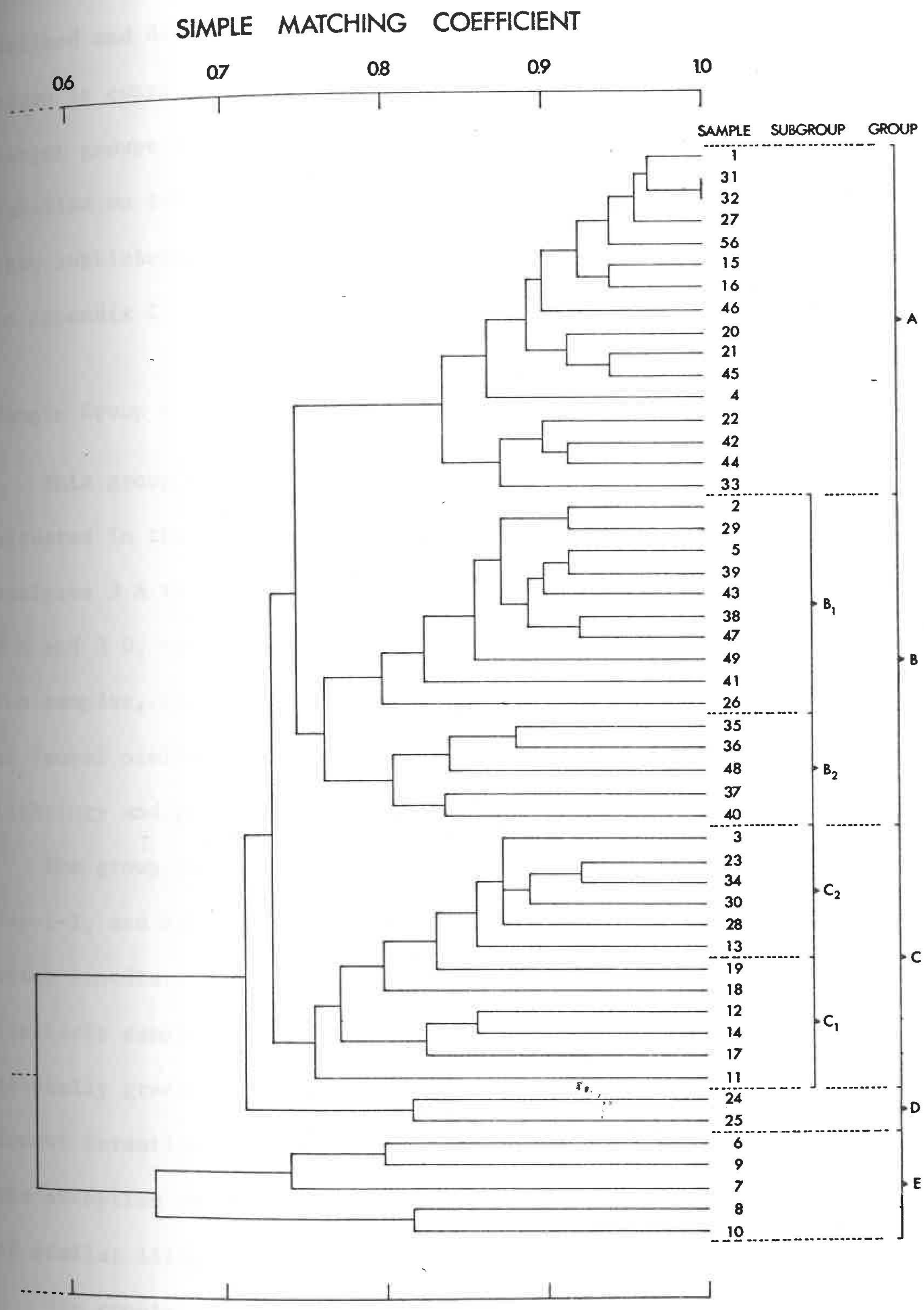


Fig.14. Dendrogram of Q-mode cluster analysis 3D of grouped samples using the simple matching coefficient and the WPGMA clustering method. For sample codes see Appendix C.

The sample groups together with their sample codes and numbers are defined and discussed below. Unless noted differently each well defined group is considered a biotope and is given a descriptive biotope name. Larger groups are often divisible into smaller subclusters which are labelled on the dendrograms (Figs. 11 to 14) as sample subgroups rather than subbiotopes. The sample codes and their numbers have been tabulated in Appendix C.

Sample Group A Nearshore Shale Biotope

This group (Table 7) which forms one of the major clusters, is situated in the uppermost portion of the dendrograms resulting from analyses 3 A to 3 D (Figs. 11 to 14). Of the four analyses, analyses 3 B and 3 D, both using the WPGMA clustering method, show this group best. The samples, which have been clustered into sample group A on the basis of faunal similarity, generally have several things in common, namely, lithology and position in the stratigraphic sequence.

The group (Table 7) contains samples, La-Sp-1, Te-Sp-2, 6" over CC-1, Jap-1-1, and Kan-Sp-1, all of which are soft, generally green shales which immediately over or underlie the four formations studied. Similarly samples Sn-1-4 A to C, Os-1-3, and Dos-1-1 to 2 represent soft, generally green shales in identical position within each of the three lowest formations studied. The remaining samples of group A are, with the exception of samples Oz-1-1, Sb-1-4 A to C, and She-1-1 to 3, all of similar lithological type, namely green shale.

The consistent grouping of green shale samples from regular stratigraphic positions within or just above or below the four formations

TABLE 7. Comparison of Samples Included in Sample Group A (Nearshore Shale Biotope) on Dendrograms (Figs. 11 to 14) Produced by Q-mode Cluster Analyses 3A to 3D.

Sample	Member	Analysis 3 A	3 B	3 C	3 D
La-Sp-1	(Lawrence Sh.)	1	1	1	1
Te-Sp-2	(Tecumseh Sh.)		31	31	31
Oz-1-1	(Ozawkie Ls.)		32	32	32
KH-4-4	(Upper King Hill Sh.)			27	27
6" over CC-1	(Lr.Severy Sh.)		50	50	50
Jap-1-1	(Lr. Jackson Point Sh.)	15	15	15	15
Kan-Sp-1	(U. Stull Sh.)	16	16	16	16
TCS-1-3 + 4	(U. Turner Creek Sh.)	46	46	46	46
SB-1-4 A to C	(M. Spring Branch Ls.)			20	20
SB-1-5 A to D	(M. Spring Branch Ls.)	21	21	21	21
She-1-1 to 3	(Sheldon Ls.)	45	45	45	45
Sn-1-4 A + B	(Lr. Snyderville Sh.)	4	4	4	4
Dos-1-1 to 2	(Doniphan Sh.)	22	22	22	22
IP-2-1 to 4	(Iowa Point Sh.)	42	42	42	42
JPS-1-1 to 3	(U. Oskaloosa Sh.)	33	33	33	33
Ke-1-5	(U. Kereford Ls.)	13	13	13	
AV-3-5	(U. Avoca Ls.)			30	

studied indicates a certain faunal similarity and a recurrence of fauna. As indicated previously these shales are believed to represent nearshore marginal marine deposition in a transgressive or regressive cycle.

The environmental aspects of the Ozawkie Limestones (sample Oz-1-1) was discussed on p. 47. Sample Oz-1-1 contained only a single conodont, a specimen of Cavusgnathus. The clustering of this sample in this group reflects a faunal similarity to such samples as Te-Sp-2 and KH-4-4. This faunal similarity is based on the presence of an impoverished fauna of only a few conodont types of which Cavusgnathus is generally one. As indicated on p. 47 the Ozawkie was probably deposited under nearshore marine conditions.

The consistent clustering of sample She-1-1 to 3 (Sheldon Ls.) in this biotope reflects the general faunal similarity of this member to marginal marine shales.

Sample SB-1-4A to C from the Spring Branch Limestone came from a stratigraphic sequence consisting of thin-bedded shaly limestones, and it is not unreasonable for such rocks to be faunally similar to the nearshore shales, as indicated by the cluster analysis.

The placement of sample Av-3-5 in this group in analysis 3C suggests a faunal similarity of this sample to some of the shale samples grouped in the nearshore shale biotope. This suggestion is supported by the lithology of the sample, a shaly, gray limestone, and by its position directly underlying the Tecumseh Shale.

Sample Group B

This well defined sample group (Table 8) which is divisible into two closely related subgroups, forms another major cluster (Table 8, Figs. 11-14). The group is compositionally stable although there is a slight amount of interchanging or shifting of samples between the subgroups from one dendrogram to another. The samples of this group consist for the most part of limestones, black shales and the grey shales associated with them.

Subgroup B_1 Offshore Limestone Biotope

This subgroup (Table 8) contains most of the significant thick and nodular bedded limestone units sampled and reflects the faunal similarity of these units. A number of these units are of similar lithology and occupy similar position within the formations sampled. The Toronto and the Curzon limestones are similar lithologically and occur in similar positions in their respective megacyclothems. The Hartford Limestone (Samples H-1-1 and H-1-3A to I) is lithologically and faunally similar to the Toronto and Curzon limestones, although not in equivalent position to these (Moore, 1949). The Beil, the Ervine Creek, and the Coal Creek represent nodular, pure to somewhat shaly limestones which occur in similar positions in three formations. The Plattsmouth Limestone, which is the cyclothemic equivalent of these three members, is faunally distinct and does not cluster with these units. Similar comparisons may be made between the Leavenworth and the Du Bois limestones.

Of the three shale samples (Av-3-4, H-1-2, and Cal-Sp-1) which are included in the subgroup B_1, the first two are from thin partings between

TABLE 8. Comparison of Samples Included in Sample Group B which Includes Sample Subgroup B_1 (Offshore Limestone Biotope) and B_2 (Larsh-Burroak Biotope) on Dendrograms (Figs. 11 to 14) Produced by Q-mode Analyses 3A to 3D.

Subgroup B_1 Offshore Limestone Biotope

Sample	Member	Analysis 3 A	3 B	3 C	3 D
T-1-1 to 7	(Toronto Ls.)	2	2	2	2
Av-3-4	(U. Avoca Ls.)	29	29	29	29
L-1-1	(Leavenworth Ls.)	5	5	5	5
H-1-1	(Lr. Hartford Ls.)	39	39	39	39
Cur-1-1 to 4	(Curzon Ls.)	43	43	43	43
Cal-Sp-1	(U.Calhoun Sh.)	38	38	38	38
DB-1-1 A + B	(Du Bois Ls.)	47	47	47	47
CC-1-1 to 4	(Coal Creek Ls.)	49	49	49	49
H-1-3 A to I	(M. and U. Hartford Ls.)	41	41	41	41
B-1-1 to 7	(Beil Ls.)	26	26	26	26
EC-1-1 to 2	(Ervine Creek Ls.)	37	37	37	
H-1-2	(Lr. Hartford Ls.)	40*	40	40	

* In analysis 3A (Fig. 11) this sample can also be considered to be a part of Subgroup B_2.

TABLE 8. (continued)

Subgroup B_2 Larsh-Burroak Biotope

Sample	Member	Analysis	3 A	3 B	3 C	3 D
LB-1-1 to 2	(Lr. Larsh-Burroak Sh.)		35	35	35	35
LB-1-3 A to E	(U. Larsh-Burroak Sh.)		36	36	36	36
Hol-1 to 2	(Holt Sh.)		48	48	48	48
EC-1-1 to 2	(Ervine Creek Ls.)					37
H-1-2	(Lr. Hartford Ls.)					40

thick bedded limestones. This, plus their faunal similarity to thicker limestones, suggests that the conditions causing the deposition of the thin shale partings were of such brief duration that a faunal change did not have time to take place, and the fauna continued to be the same as that of the associated limestones. Sample Cal-Sp-1 from the Upper Calhoun Shale is similar in overall fauna to the overlying Hartford Limestone despite the difference in lithology and depositional environment; however, despite the fact that the overall faunal characteristics of limestones are present, relative abundance analysis (Fig. 10) shows that the Sp element of Cavusgnathus predominates over that of Streptognathodus. This suggests that the uppermost unit of the Calhoun Shale was transitional both in terms of fauna and environment between nearshore and offshore conditions.

Subgroup B_2 Larsh-Burroak Biotope

This subgroup (Table 8) consistently contains the Larsh-Burroak and Holt shales which are not only similar in position in their respective formations, but are also similar lithologically. The cluster indicates that the soft grey shales overlying the fissile black shales of the Larsh-Burroak are faunally more similar to each other and to the Holt Shale than, for example, to the green shales and siltstones of Group A.

The faunal similarity of black fissile shales to the softer calcareous shales which directly overlie them is also indicated in clustering of the Heebner and Queen Hill Shales of Groups E and D respectively.

The subgroup is a part of a larger well defined cluster (Group B) in all analyses (Figs. 11-14). This, plus the fact that there is some interchanging of samples 37 and 40 between the two subgroups (Table 8) indicates that the black shales, the softer shales that directly overlie them, and the limestones of subgroup B_1, are faunally similar. Relative abundance analysis based only on the Sp elements of Cavusgnathus, Streptognathodus, and Idiognathodus led to similar conclusions.

Sample Group C

The group (Table 9) is stable in its sample content, although being variable in the position of its two subgroups C_1 and C_2. There is a gradation between the two subgroups in analysis 3D (Fig. 14), and in analysis 3C (Fig. 13) subgroup C_2 is, for unknown reasons, placed in sample Group A.

Subgroup C_1

With the exception of several gaps the members represented by samples of this subgroup (Table 9, and Figs. 11 to 14) cover the sampled interval from the base of the Heumader Shale of the Oread Limestone to the middle of the Spring Branch Limestone of the Lecompton Limestone. The samples clustered in the subgroup are of variable lithology although the cluster analysis indicates that they are similar faunally.

As discussed previously, Q-mode comparisons can cluster samples for differing reasons. If a part of the stratigraphic section sampled is dominated by a particular fauna which occurs in various lithologies then the groups obtained through cluster analysis will reflect this; i.e.

TABLE 9. Comparison of Samples Included in Sample Group C which Includes Sample Subgroups C_1 and C_2 on Dendrograms (Figs. 11 to 14) Produced by Q-mode Analyses 3A to 3D.

Subgroup C_1

Sample	Member	Analysis	3 A	3 B	3 C	3 D
SB-1-3	(M. Spring Branch Ls.)		19	19	19	19
SB-1-2 A + B	(M. Spring Branch Ls.)		18	18	18	18
Ke-1-1 to 4	(Lr. Kereford Ls.)		12	12	12	12
Ke-1-6 to 7	(U. Kereford Ls.)		14	14	14	14
SB-1-1 A to E	(Lr. Spring Branch Ls.)		17	17	17	17
Heu-1-1 to 3	(Heumader Sh.)		11	11	11	11

Subgroup C_2

Sample	Member	Analysis	3 A	3 B	3 C	3 D
SN-1-1 A +B	(Lr. Snyderville Sh.)		3	3	3	3
BS-1-1 to 2	(Big Springs Ls.)		23	23	23	23
RB-1-1	(Rock Bluff Ls.)		34	34	34	34
Av-3-5	(U.Avoca Ls.)					30
Av-3-1 to 3	(Lr. Avoca Ls.)		28	28	28	28
Ke-1-5	(U. Kereford Ls.)					13

different rock types representing various depositional environments will be grouped together.

Examination of the distribution charts (Appendix D) shows that this part of the section is dominated and characterized by the Sp elements of *Streptognathodus oppletus*, *Streptognathodus wabaunsensis*, *Idiognathodus tersus*, and *Idiognathodus antiquus*. This sort of faunal dominance and disregard for changes in lithology can and does mask other patterns such as those that have been shown to exist by relative abundance analysis (Figs. 7 and 8).

This cluster could in a peculiar sense, be considered to represent a biotope, one which rather than being defined by only one set of environmental conditions is characterized instead by several depositional environments of quite different character. However, the writer prefers to use biotope for an area of relatively uniform environmental conditions (Kaesler, 1966) and consequently does not consider the beds represented by the samples of this cluster to constitute a biotope. Rocks representing a variety of environments are grouped together and represent a temporary dominance of what may be the only ubiquitous faunal elements that the writer has been able to recognize. This apparently reflects a temporary evolutionary (?) burst and disregard for environmental constrictions by a segment of the overall fauna, a feature of significance for biostratigraphy.

Subgroup C_2

This cluster (Table 9) is erratic and difficult to interpret. The cluster, like cluster C_1, cannot be considered to represent a biotope. Two of the samples (Av-3-5 and Ke-1-5) are included in this subgroup only in analysis 3D. Three of the remaining four samples represent limestone lithologies indicating some faunal similarity in these limestones. The consistent clustering together of the Big Springs and Rock Bluff Limestones is of interest since they are apparently not only similar lithologically and faunally but also in their position in their respective formations. The grouping of the samples from the lower Snyderville Shale (Sn-1-1A and B) in this group could be considered anomalous; however, the lower portion of this unit is gradational with the underlying Toronto Limestone and is largely composed of limestone nodules. The fauna of the lower Snyderville Shale may be a reflection of this transitional environment.

Sample Group D Queen Hill Biotope

This small cluster (Table 10, Figs. 11-14) is constant in sample content and consistently groups together the faunally similar samples from the lower and upper Queen Hill Shale. Although such a grouping may seem natural the fact that the two parts of the Queen Hill Shale are quite different lithologically makes this noteworthy.

TABLE 10. Comparison of Samples Included in Sample Group D (Queen Hill Biotope) on Dendrograms (Figs. 11 to 14) Produced by Q-mode Analyses 3A to 3D.

Sample	Member	Analysis 3 A	3 B	3 C	3 D
QH-1-1	(Lr. Queen Hill Sh.)	24	24	24	24
QH-1-2	(U. Queen Hill Sh.)	25	25	25	25

Sample Group E Heebner-Plattsmouth Biotope

Group E (Table 11, and Figs. 11-14) is very stable in terms of sample content. The group contains the samples taken from the base of the Heebner Shale to the top of the overlying Plattsmouth Limestone. Even without cluster analysis it was apparent that the two members were faunally similar despite radically different lithologies, and analysis by cluster analysis supported this. Sample P-1-4, a shale sample from the Plattsmouth Limestone, is faunally most similar to the Heebner and was probably deposited under temporary conditions similar to those under which the upper Heebner Shale was laid down.

Results of R-mode Cluster Analyses

In R-mode cluster analysis of paleoecological data, species (or their parts) are related to each other on the basis of the samples in which they are found. Stated slightly differently "the relationships among species are quantified" (Kaesler, 1966).

The success of R-mode cluster analysis is judged on similar criteria as in Q-mode analysis. The presence of distinct breaks in the cluster network, the clear definition of individual clusters, the similarity level at which a cluster is defined, and examination of the taxa included in each cluster are criteria employed. Of these, the examination of the taxa contained in a cluster is the most significant since the grouping of taxonomic categories in a cluster should have some paleoecological or biological basis.

TABLE 11. Comparison of Samples Included in Sample Group E (Heebner-Plattsmouth Biotope) on Dendrograms (Figs. 11 to 14) Produced by Q-mode Analyses 3A to 3D.

Sample	Member	Analysis 3 A	3 B	3 C	3 D
He-1-1 to 2	(Lr. Heebner Sh.)	6	6	6	6
P-1-4	(M. Plattsmouth Ls.)	9	9	9	9
He-1-3 to 4	(U. Heebner Sh.)	7	7	7	7
P-1-1 to 3	(Lr. Plattsmouth Ls.)	8	8	8	8
P-1-5 to 8	(U. Plattsmouth Ls.)	10	10	10	10

R-mode cluster analysis produced satisfactory results in the six analyses which were done. Of the six, the four corresponding to data matrices 2 and 3 are considered the best and are shown on Figs. 15 to 18.

In each of analyses 2E, 2F, 3E, and 3F the same clusters generally containing the same taxa could be identified on each of the dendrograms (Figs. 15-18). The taxa generally clustered in the same biofacies despite the fact that different data formats and clustering methods were used. The splitting and shifting of groups and subgroups on the dendrograms resulting from R-mode analysis (Figs. 15-18) is presumed to be the result of using different clustering methods and different data matrices. Analysis 3F (Fig. 18) was considered to have yielded the best results on the criteria outlined above.

The species groups together with the names of the taxa they contain are defined and discussed in the following pages. For the analyses the different conodont element types were given code numbers (Appendix C) and both the species groups and numbers are indicated on the dendrograms. Unless noted differently each well defined species group is considered a biofacies. Larger species groups (i.e. clusters) are often divisible into smaller clusters and on the dendrograms these are labelled species subgroups rather than subbiofacies.

Significance of Conodont Biofacies and their Relation to Biotopes

R-mode analysis groups those species together that are most often associated. A group or cluster may include A) the component parts of a single natural conodont species or B) elements belonging to several

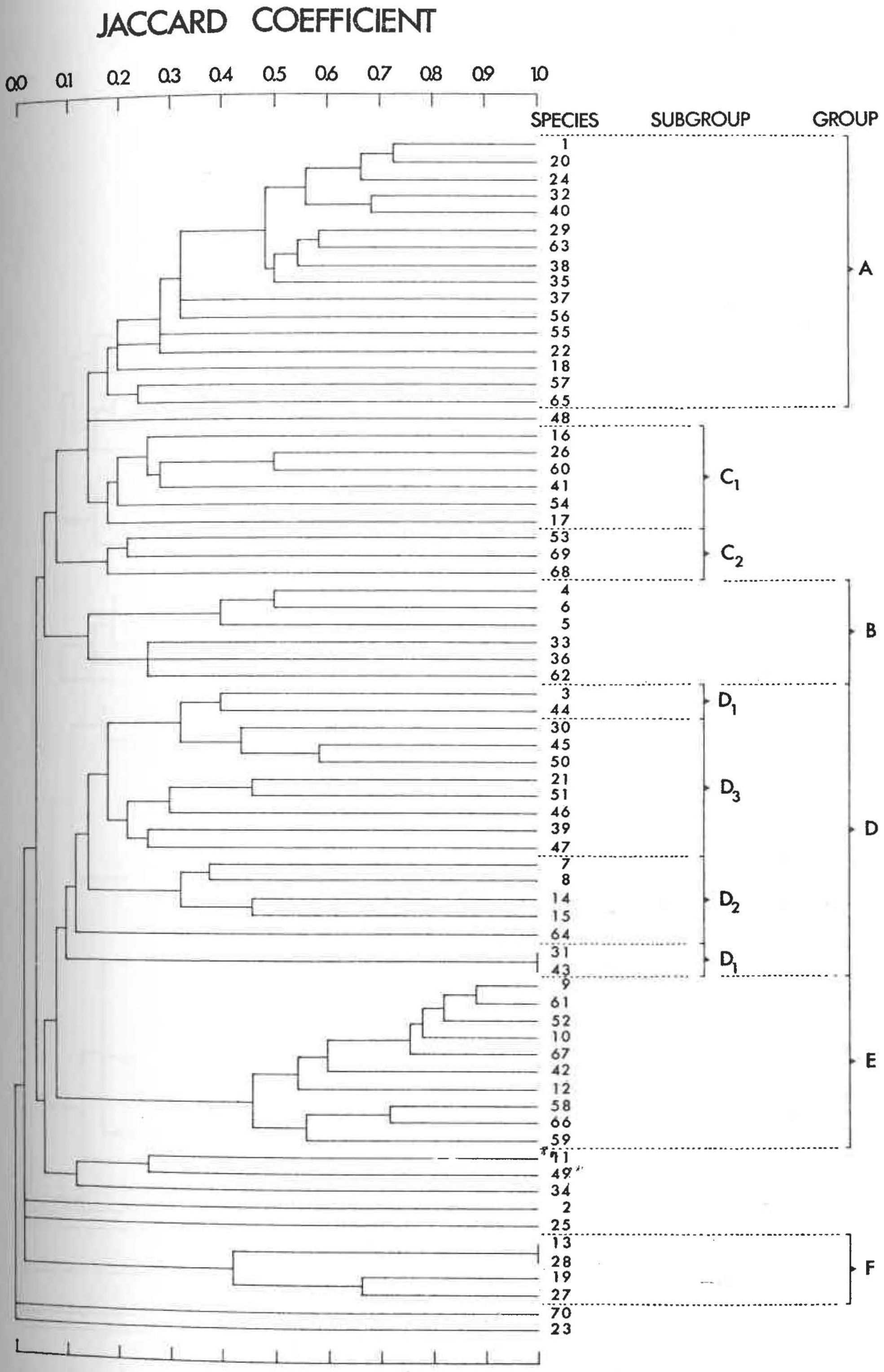


Fig.15. Dendrogram of R-mode cluster analysis 2E of ungrouped samples using the Jaccard coefficient and the UPGMA clustering method. For species names see Appendix C.

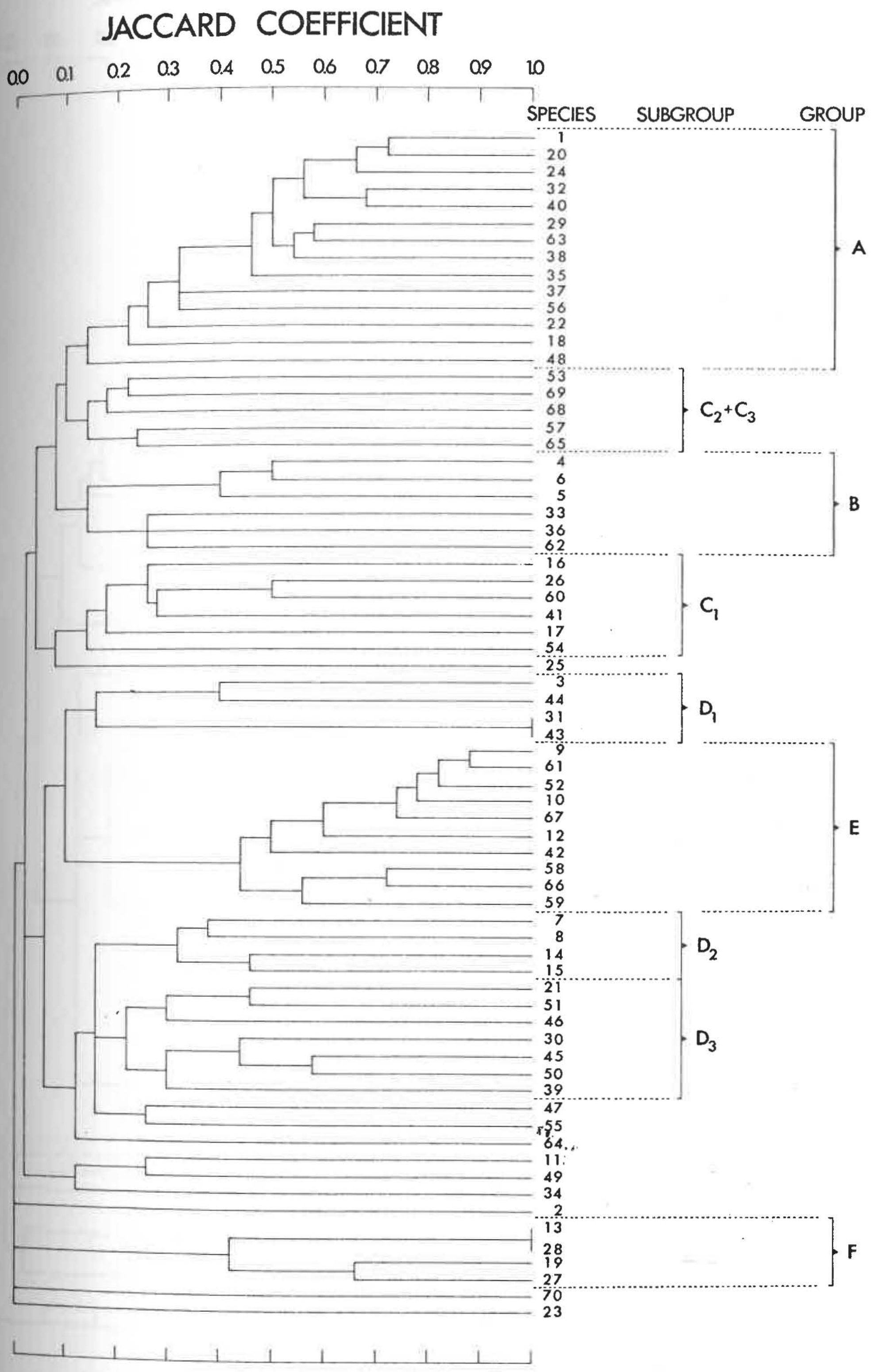


Fig.16. Dendrogram of R-mode cluster analysis 2F of ungrouped samples using the Jaccard coefficient and the WPGMA clustering method. For species names see Appendix C.

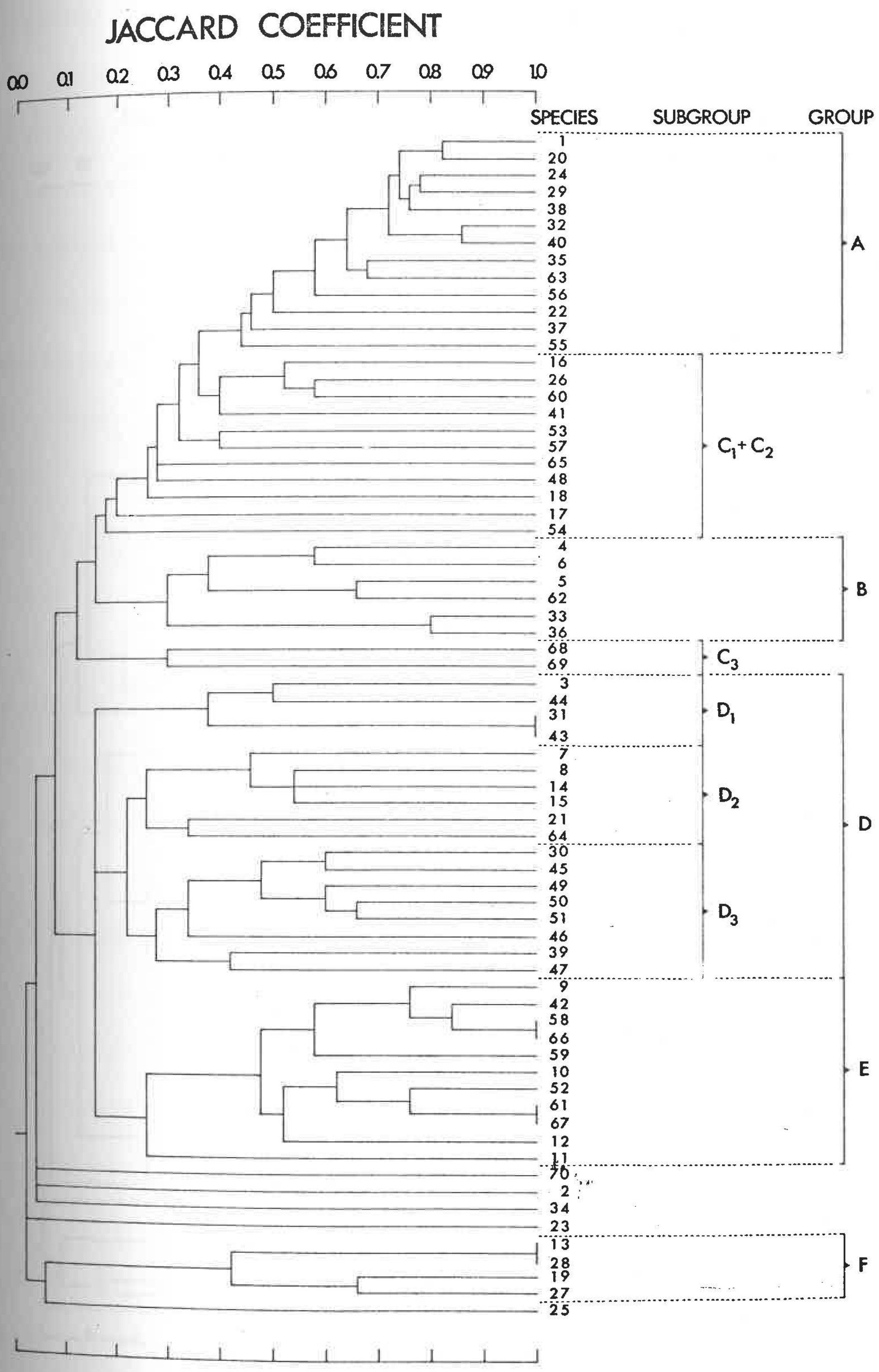


Fig.17. Dendrogram of R-mode cluster analysis 3E of grouped samples using the Jaccard coefficient and the UPGMA clustering method. For species names see Appendix C.

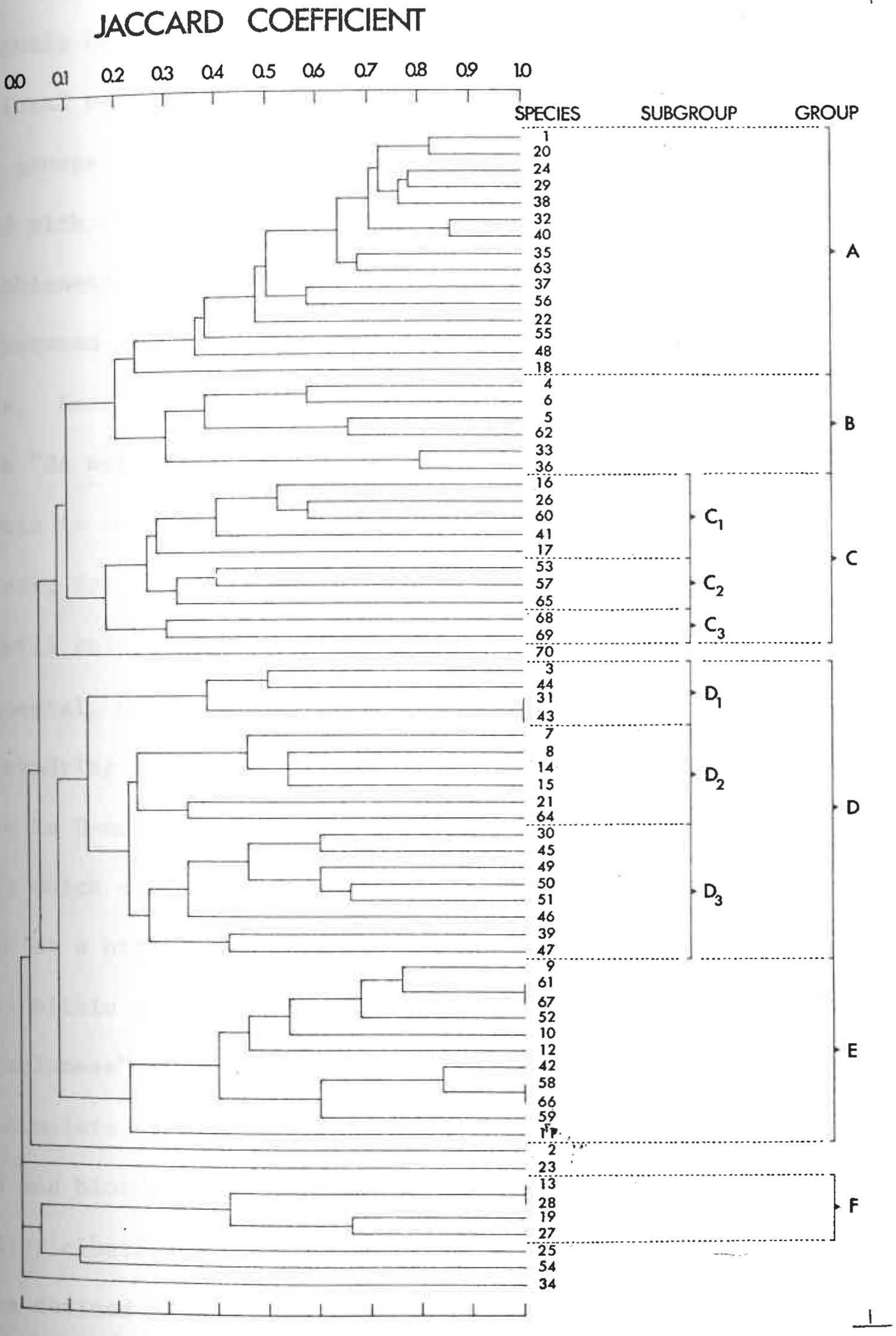


Fig.18. Dendrogram of R-mode cluster analysis 3F of grouped samples using the Jaccard coefficient and the WPGMA clustering method. For species names see Appendix C.

environmentally associated natural conodont species. In A and B this association may be found, on examination of distribution data, to consistently occur in rocks representing a restricted number of depositional environments.

The groups of associated taxa defined by cluster analysis must be compared with the distribution of the individual taxa to determine the "reasonableness" of the group as well as to see what congruency, if any, exists between biotopes and biofacies established by Q- and R-mode analyses. Kaesler (1966) concluded that biofacies determined by cluster analysis "do not necessarily occupy biotopes defined quantitatively." While this is correct, it is desirable to evaluate the degree of congruence, for as Mello and Buzas (1968) have written "hopefully, the R-mode will tell us which species are responsible for the areal [i.e. environmental, writer's comment] units recognized through the Q-mode."

In studying the distribution of recent or subfossil material it is possible in Q-mode analysis to construct a biotope map by joining those stations which are part of well defined clusters and which are joined together at a high level of affinity. Examination of faunal lists from stations within a particular biotope permits assessment of the "reasonableness" of a particular biotope. In biofacies analysis of a single complete stratigraphic section, a great number of timeplanes are sampled and biotope maps cannot be drawn. Fortunately, conodont biofacies defined by cluster analysis show a high degree of congruency with the biotopes defined by the same technique. In matching biofacies and biotopes the researcher is generally only able to show the dominant faunal association, or biofacies, in a biotope. However, biotopes may, and generally do, contain less dominant faunal elements from other biofacies. Rowell (in press) demonstrated the usefulness of the two way table of Williams and Lambert (1961) in showing the predominance of the species of one biofacies over those of another in a biotope and such a table may be of value in relating paleobiofacies and paleobiotopes to one another.

The primary and secondary links between biofacies and biotopes defined in this study are shown in Table 12.

Species Group A Streptognathodus Biofacies

This biofacies (Table 13) was described by Merrill(1968 and in press) under two designations, the Idiognathodus and Streptognathodus biofacies respectively.

As here recognized, the biofacies contains different associated conodonts than those placed in it by Merrill (1968 and in press). The elements Ozarkodina [?] curvata; Ellisonia teicherti, Pl element; and Ellisonia teicherti, Ne element were placed in the Appalachian fauna by Merrill (1968). These conodonts are apparently not as restricted in their occurrence as previously thought and have been found in a variety of lithologies, being most common in massive, somewhat impure limestones.

Merrill (1968) defined the ubiquitous group as containing conodont elements which are "present in every Pennsylvanian sample coinciding with ranges of individual genera and species." The writer is unable to recognize a "ubiquitous" group, and many of the taxa included by Merrill in this group are here placed in the Streptognathodus biofacies. Some of the major components of Merrill's ubiquitous group, such as Streptognathodus and Idiognathodus, although found in most samples have

TABLE 12. Primary Links (Solid Lines) Between Biofacies and Biotopes Established by Cluster Analysis. Secondary Links (Broken Lines) Established by Comparison with Abundance Counts (Appendix D).

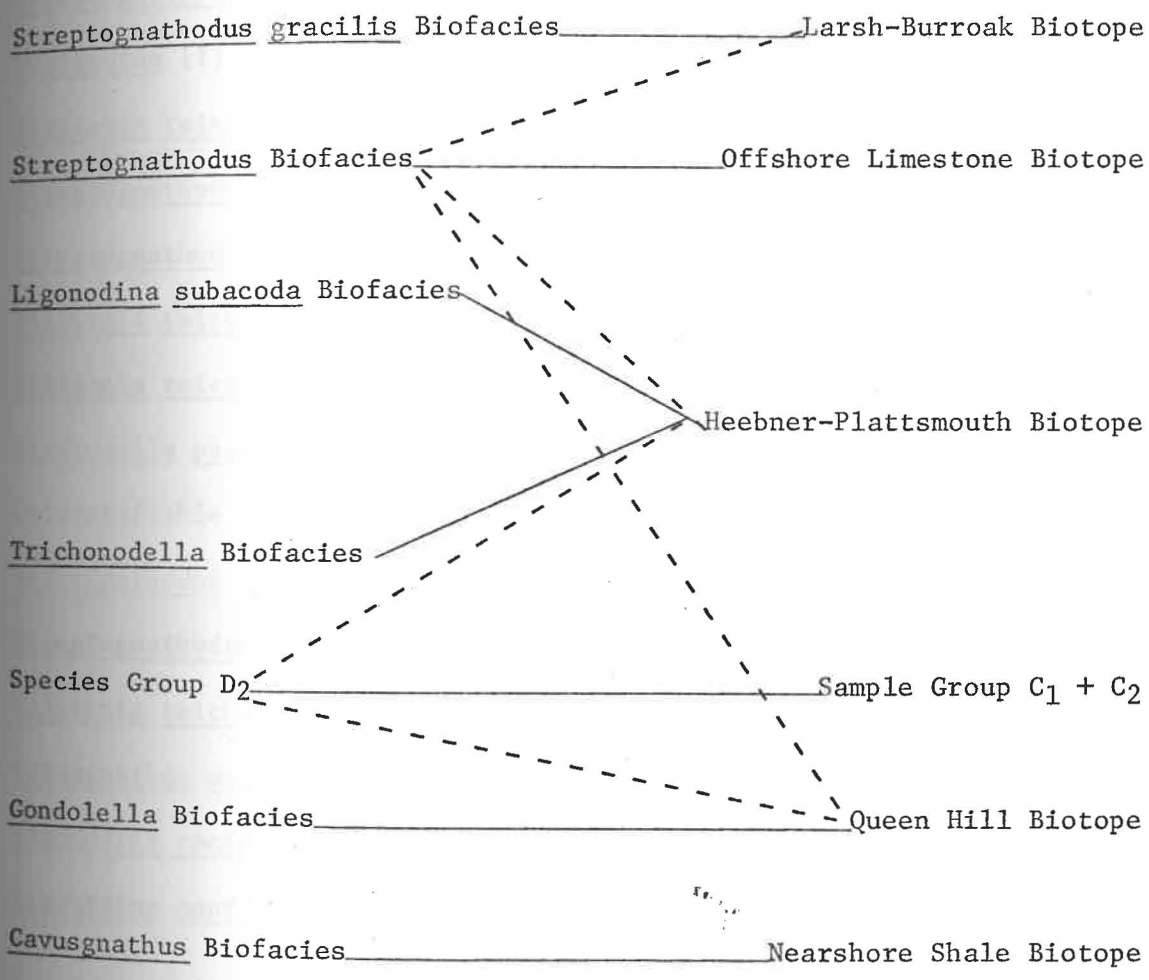


TABLE 13. Comparison of Elements Included in Species Group A *Streptognathodus* Biofacies) Shown on Dendrograms (Figs. 15 to 18) Produced by R-mode Analyses 2E and 2F and 3E and 3F.

Analysis Taxon	2 E	2 F	3 E	3 F
Streptognathodus elegantulus, Sp element	1	1	1	1
Anchignathodus minutus	20	20	20	20
Streptognathodus and *Idiognathodus* Oz element	24	24	24	24
Ozarkodina [?] *curvata*	29	29	29	29
Ellisonia teicherti, Hi element	38	38	38	38
Streptognathodus and *Idiognathodus* Ne element	32	32	32	32
Streptognathodus and *Idiognathodus* Hi element	40	40	40	40
Ellisonia teicherti, Pl element	35	35	35	35
Ellisonia teicherti, Ne element	63	63	63	63
Hindeodella parva	37	37	37	37
Unidentifiable Tr elements	56	56	56	56
Anchignathodus moorei n.sp.	22	22	22	22
Streptognathodus and *Idiognathodus* Tr element	55		55	55
Ellisonia teicherti, Tr element	48*	48		48
Cavusgnathus merrilli n.sp.	18	18		18
Ligonodina conflexus, Hi element	57			
Ligonodina conflexus, Pl (?) element	65			

* Questionably in this cluster in analysis 2E (Fig. 15).

been shown by relative abundance analysis to vary directly in response to changes in environment. Merrill apparently recognized this by placing these taxa in both the ubiquitous group and his *Streptognathodus-Idiognathodus* biofacies.

The distribution and clustering of the rare *Cavusgnathus merrilli* n.sp. suggests that this species did not belong in the *Cavusgnathus* biofacies but instead was part of the *Streptognathodus* biofacies.

Taxonomic Interpretation of *Streptognathodus* Biofacies

This biofacies (Figs. 15-18) is stable from analysis to analysis (Table 13). It includes the elements of at least three multielement species.

Elements 1, 24, 32, 40 and 55 (Table 13) are, on the basis of cluster analysis, similar ranges and comparison with the natural assemblages reported by Rhodes (1952), considered to constitute a multielement species, *Streptognathodus elegantulus* Stauffer and Plummer. The only element unique to the species is the platform or Sp element. The remaining elements are also component parts of most, but possibly not all, other multielement species of *Streptognathodus* and *Idiognathodus*. As a result, although the platform element of *Streptognathodus elegantulus* can be designated as *Streptognathodus elegantulus* Sp element, the remaining elements of the species are referred to as *Streptognathodus* and *Idiognathodus* Oz, Ne, Hi, and Tr elements. (Table 13).

Elements 38, 35, 63, and 48 are considered to be the Hi, Pl, Ne, and Tr elements of *Ellisonia teicherti* Sweet. The fact that these elements are consistently grouped together (Table 13) is of interest since Sweet

(1970a; 1970b) used recurrent group analysis to define this multielement species. The writer has been unable to recognize the LB element of the species (Sweet, 1970b, pl.4, fig. 23).

Elements 20 and 22 are interpreted as representing two species of Anchignathodus. The writer has been unable to find any evidence that there was more than a single element type in the apparatus of species of Anchignathodus. This is in agreement with Sweet (1970a; 1970b).

Elements 29 and 37, Ozarkodina [?] curvata and Hindeodella parva respectively, are consistently grouped in this cluster. Ziegler (1970, personal communication) pointed out the similarity of O.[?] curvata to Falcodus, in particular to the falcodiform element of the multielement species Elsonella rhenana of Lindström and Ziegler (1965). He suggested that Ozarkodina [?] curvata may have served structurally and functionally in a similar manner to the falcodiform element of Elsonella rhenana and that the elements associated with Ozarkodina [?] curvata in a multielement apparatus may have been similar in number and general morphology. It is considered possible, but as yet unproven, that Hindeodella parva may have been the Hi element in such a multielement apparatus.

Element 18, Cavusgnathus merrilli n.sp., is a new species based on characteristic Sp elements.

Element 56, unidentifiable Tr elements, are broken specimens of the Tr element of Cavusgnathus, Streptognathodus, and Idiognathodus. For the most part these specimens probably belonged to species of the latter two genera and it is probably for this reason that this taxonomic category is clustered with element 55, the Tr element of Streptognathodus and Idiognathodus.

Elements 57 and 65 are included in this cluster in analysis 2E (Fig. 15). The writer is unable to attach any significance to this, particularly since these two elements are included in the *Cavusgnathus* biofacies in the remaining three analyses (Figs. 16-18).

Results of Q-mode and relative abundance analysis lead to the conclusion that the *Streptognathodus* biofacies was the dominant fauna of the offshore limestone biotope.

Species Group B *Streptognathodus gracilis* Biofacies

The *Streptognathodus gracilis* biofacies (Table 14) is well defined and is apparently congruent with the Larsh-Burroak biotope. Environmentally this biotope must certainly be similar to the lower Heebner-Plattsmouth or the Queen Hill biotopes; however, all three are quite distinct faunally, containing quite different lineages, and the writer concludes that subtle environmental differences existed in each of these.

Taxonomic Interpretations of the *Streptognathodus gracilis* Biofacies

Cluster analysis suggests that the six element types that are consistently grouped together (Table 14) may have been the component elements of two or more multielement species. All the elements are rare and because of this it is not presently possible to define these multielement species. Although Rhodes (1952) considered that the platform elements *Streptognathodus gracilis* and *Streptognathodus excelsus* had the same nonplatform elements associated with them as did other platform species of *Streptognathodus*, the consistent clustering of

TABLE 14. Comparison of Elements Included in Species Group B (*Streptognathodus gracilis* biofacies) Shown on Dendrograms (Figs. 15 to 18) Produced by R-mode Analyses 2E and 2F and 3E and 3F.

Taxon	Analysis	2 E	2 F	3 E	3 F
Streptognathodus gracilis		4	4	4	4
Streptognathodus excelsus		6	6	6	6
Streptognathodus gracilis[?]		5	5	5	5
Neoprioniodus sp. A		62	62	62	62
Synprioniodina sp. A		33	33	33	33
Plectospathodus sp.		36	36	36	36

Neoprioniodus sp. A, *Synprioniodina* sp. A, and *Plectospathodus* sp. with these two platform elements suggests the possibility that some or all of these may have been parts of the apparatuses of *Streptognathodus gracilis* and *Streptognathodus excelsus*. The writer cannot discount this possibility for *Synprioniodina* sp. A and *Plectospathodus* sp.; however, he does consider this unlikely for *Neoprioniodus* sp. A. The possible taxonomic placement of the latter element is discussed in the systematics under *Cavusgnathus merrilli* n.sp.

Species Group C *Cavusgnathus* Biofacies

The *Cavusgnathus* biofacies of Merrill (1968 and in press) was well defined by cluster analysis (Figs. 15-18) and contains faunal elements almost identical to that listed by him. Q-mode analysis consistently defined a cluster of shale samples termed the shale biotope. It is reasonable, after examination of the distribution of the taxa of the *Cavusgnathus* biofacies, to conclude that this biofacies was the dominant fauna of the nearshore shale biotope. The existence of this biofacies was also demonstrated by relative abundance analysis (Figs. 7-10).

Taxonomic Interpretations of the *Cavusgnathus* Biofacies

This biofacies is best defined in analysis 3F (Fig. 18) and can be subdivided into three subgroups. In analyses 2E, 2F, and 3E, there is some wandering and integration of these subgroups.

Subgroup C_1. Subgroup C_1 (Table 15) consistently contains elements 16, 26, 60, 41, 17, and, in three of four analyses, element 54. On the basis of the cluster analysis as well as other criteria discussed in the systematics section, this subgroup is considered to contain the elements of two multielement species, *Cavusgnathus lautus* and *Cavusgnathus flexus*. The element composition of these two multielement species is homologous to that of the natural assemblage genus *Lewistonella* Scott. The two species can be differentiated only on the basis of possessing different Sp elements. In all other respects they are apparently identical.

Elements 18 and 48, *Cavusgnathus merrilli* n.sp. and *Ellisonia teicherti* Tr element, respectively, are for unknown reasons part of subgroup C_1 in analysis 3E (Fig. 17). This is considered anomalous since in the remaining three analyses (Figs. 15, 16, 18) they are clustered in the *Streptognathodus* biofacies (Species Group A).

Subgroups C_2 and C_3. These two subgroups (Table 15) must be considered together since they are combined into a single cluster in two of the analyses (Figs. 15-18).

Elements 53, 57, 65, 68, and 69 are interpreted, on the basis of cluster analysis, morphological similarity, and other features considered in the systematics, to be the elements of the multielement species *Ligonodina conflexus* (Ellison).

TABLE 15. Comparison of Elements Included in Species Group C (*Cavusgnathus* Biofacies) which Includes Species Subgroups C_1, C_2, and C_3 Shown on Dendrograms (Figs. 15 to 18) Produced by R-mode Analyses 2E and 2F and 3E and 3F.

Subgroup C_1

Taxon	Analysis	2 E	2 F	3 E	3 F
Cavusgnathus lautus, Sp element		16	16	16	16
Cavusgnathus Oz element		26	26	26	26
Cavusgnathus Ne element		60	60	60	60
Cavusgnathus Hi element		41	41	41	41
Cavusgnathus flexus, Sp element		17	17	17	17
Cavusgnathus Tr element		54	54	54	
Ellisonia teicherti, Tr element				48	
Cavusgnathus merrilli n.sp.				18	

Subgroup C_2

Taxon	Analysis	2 E	2 F	3 E	3 F
Ligonodina conflexus, Tr element		53	53	53	53
Ligonodina conflexus, Hi element			57	57	57
Ligonodina conflexus, Pl (?) element			65	65	65
Ligonodina conflexus, Oz (?)element		68	68	Part of Subgroup C_1	
Ligonodina conflexus, Ne (?) element		69	69		

Subgroup C_3

Taxon	Analysis	2 E	2 F	3 E	3 F
Ligonodina conflexus, Oz (?) element		Combined with Subgroup C_2	Combined with Subgroup C_2	68	68
Ligonodina conflexus, Ne (?) element				69	69

Species Group D Trichonodella Biofacies

The Trichonodella biofacies (Table 16, and Figs. 15-18) is a somewhat complex grouping of three smaller subgroups, the faunal elements of two of which, subgroups D_1 and D_3, generally correspond to most of the elements placed in the Appalachian fauna of Merrill (1968 and in press). The writer prefers not to use the term "Appalachian fauna" since it, like the term "Midcontinent fauna" implies provincialism. Elements of species of the Trichonodella biofacies have been found in the Pennsylvanian of Colorado by Murray and Chronic (1965), in the Appalachians by Merrill (1968 and in press) and in Kansas. Species subgroups D_1 and D_3 contain a high percentage of the faunal elements grouped by Merrill (in press) in the Appalachian fauna; however, several important elements, such as some of the component parts of Ellisonia teicherti, have been found to have a wider distribution, particularly in various types of limestones, than previously thought. These are better included in the Streptognathodus rather than the Trichonodella biofacies, a decision supported by cluster analysis. The two subgroups, D_1 and D_3, of the Trichonodella biofacies are best developed in the Plattsmouth Limestone, and many of the species of this study have only been found in this member.

Q-mode analysis consistently defines the Heebner-Plattsmouth biotope, a grouping of Heebner Shale and Plattsmouth Limestone samples. Distribution of the elements of subgroup D_1 and D_3 of the Trichonodella biofacies suggests that this biofacies is congruent with a part of the Heebner-Plattsmouth biotope. This biotope comprises samples from two separate paleoenvironments, the nodular limestone and the black shale depositional environments, represented by the Plattsmouth Limestone and

TABLE 16. Comparison of Elements Included in Species Group D (*Trichonodella* Biofacies) which Includes Species Subgroups D_1, D_2, and D_3 Shown on Dendrograms (Figs. 15 to 18) Produced by R-mode analyses 2E and 2F and 3E and 3F.

Subgroup D_1

Taxon	Analysis 2 E	2 F	3 E	3 F
Streptognathodus sp. aff. *S.elegantulus*	3	3	3	3
Trichonodella plattsmouthi n.sp.	44	44	44	44
Ozarkodina ? sp. aff. *O.* ? *kansasensis*	31	31	31	31
Trichonodella obtusa	43	43	43	43

Subgroup D_2

Taxon	Analysis 2 E	2 F	3 E	3 F
Streptognathodus oppletus, Sp element	7	7	7	7
Streptognathodus wabaunsensis, Sp element	8	8	8	8
Idiognathodus antiquus, Sp element	14	14	14	14
Idiognathodus tersus, Sp element	15	15	15	15
Anchignathodus adenticulatus n.sp.			21	21
Lonchodus ? sp.	64		64	64

TABLE 16. (continued)

Subgroup D_3

Taxon	Analysis	2 E	2 F	3 E	3 F
Ozarkodina ? *kansasensis*		30	30	30	30
Trichonodella asymmetrica n.sp.		45	45	45	45
Lonchodina sp. A				49	49
Lonchodina sp. B.		51	51	51	51
Lonchodina douglasi n.sp.		50	50	50	50
Trichonodella sp.		46	46	46	46
Hindeodella sp. B		39	39	39	39
Hindeodus sp. A		47		47	47
Anchignathodus adenticulatus n.sp.		21	21		

Heebner Shale respectively. The Ligonodina subacoda biofacies was dominant during deposition of the Heebner Shale whereas the Trichonodella biofacies was more strongly represented during Plattsmouth Limestone sedimentation. The Larsh-Burroak and the overlying Ervine Creek are lithologically similar to the Heebner-Plattsmouth section; however, although the Larsh-Burroak and the Ervine Creek are, like the Heebner and the Plattsmouth faunally similar to one another, there is apparently little faunal similarity between the Larsh-Burroak - Ervine Creek and the Heebner-Plattsmouth sequences.

Subgroup D_2 is not, strictly speaking, considered to belong to the Trichonodella biofacies. The subgroup is apparently grouped with subgroups D_1 and D_3 because the Sp elements of the multielement species Streptognathodus oppletus, Streptognathodus wabaunsensis, Idiognathodus tersus and Idiognathodus antiquus occur as associates of the Trichonodella biofacies in the Plattsmouth Limestone. However, these elements are also found in a variety of different lithologies from the Plattsmouth Limestone to slightly above the Queen Hill Shale. The four species represented by the Sp elements above, apparently tolerated a variety of environments.

Taxonomic Interpretations of the *Trichonodella* Biofacies

Subgroups D_1 and D_3. *Streptognathodus* sp.aff. *S.elegantulus* represents the Sp element of what may be a new species of *Streptognathodus*. Similar distribution, morphology (basal cavity and denticulation) and cluster analysis suggest that elements 39, 43, 44, 45, 46, 50, 51, *Hindeodella* sp. B, *Trichonodella obtusa*, *Trichonodella plattsmouthi* n.sp., *Trichonodella asymmetrica* n.sp., *Trichonodella* sp., *Lonchodina* sp. A, *Lonchodina douglasi* n.sp. and *Lonchodina* sp. B respectively may have been part of the same multielement species. Unfortunately, these elements are of infrequent occurrence and as a result the writer is unable to prove this association.

In a similar manner, *Ozarkodina* ? *kansasensis* n.sp. and *Ozarkodina* ? sp.aff. *O.* ? *kansasensis*, elements 30 and 31 respectively, may have been associated as part of the same apparatus. *Ozarkodina* ? *kansasensis* n.sp. is similar and probably related to *Ozarkodina* [?] *curvata*. It seems likely that the apparatuses of which these two elements were part were similar in terms of number and type of elements.

Element 21, *Anchignathodus adenticulatus* n.sp., is rare and has a limited distribution. This species, like other species of *Anchignathodus* is believed to have occurred without other element associations in the conodont bearing animal (Sweet, 1970a; 1970b).

Subgroup D_2. Elements 7, 8, 14, 15 or the Sp elements of Streptognathodus oppletus, Streptognathodus wabaunsensis, Idiognathodus antiquus and Idiognathodus tersus respectively are constantly associated, a feature reflected in the cluster analysis. The elements are interpreted as Sp elements of four multielement conodont species.

The inclusion of Lonchodus ? sp., based on a single specimen from the Plattsmouth Limestone, in subgroup D_2 is not considered significant.

Species Group E, Ligonodina subacoda Biofacies

This biofacies (Table 17) is well defined and is consistent in its taxa content (Figs. 15-18). The consistency of the clustering is a reflection of the fact that the elements of Group E generally occur together and are somewhat restricted in occurrence. They most commonly occur in the Heebner Shale and in parts of the overlying Plattsmouth Limestone.

The Ligonodina subacoda biofacies was recognized by Merrill (1968) and termed the Midcontinent fauna (Merrill, in press). The fauna is widely distributed and has been found in the midcontinent area, in Illinois (Rhodes, 1952) and in the Appalachians (Merrill, 1968 and in press).

Q-mode analysis consistently defines a cluster of Heebner Shale and Plattsmouth Limestone samples which are representative of the Heebner-Plattsmouth biotope. It is in these two units that the Ligonodina subacoda biofacies is most strongly represented, and the writer concludes that there is a strong congruence between the Ligonodina subacoda biofacies and the Heebner-Plattsmouth biotope.

TABLE 17. Comparison of Elements Included in Species Group E (*Ligonodina subacoda* Biofacies) Shown on Dendrograms (Figs. 15 to 18) Produced by R-mode Analyses 2E and 2F and 3E and 3F.

Taxon / Analysis	2 E	2 F	3 E	3 F
Streptognathodus simulator, Sp element	9	9	9	9
Ligonodina subacoda, Ne element	61	61	61	61
Lonchodina ? *ponderosa*	67	67	67	67
Ligonodina subacoda, Tr element	52	52	52	52
Streptognathodus eccentricus, Sp element	10	10	10	10
Idiognathodus magnificus, Sp element	12	12	12	12
Lonchodus simplex	42	42	42	42
Ligonodina lexingtonensis	58	58	58	58
Ligonodina subacoda, Pl element	66	66	66	66
Ligonodina subacoda, Hi element	59	59	59	59
Streptognathodus ? sp.			11	11

Merrill (in press) postulated, at least for the Midcontinent area, that his Midcontinent fauna is only dominant in thin, often black shale units and the thin limestones that underlie them. In the Shawnee Group the Heebner, the Queen Hill, the Larsh-Burroak and the Holt shales, all thin and generally of black color are underlain by thin dense limestones, the Leavenworth, the Big Springs, the Rock Bluff and the Du Bois members respectively. None of these limestones have been found to contain any conodonts included by Merrill in his Midcontinent fauna. Merrill (in press) also suggested the possibility that his Midcontinent fauna could be composed of two biofacies in which the one here termed the Ligonodina subacoda biofacies lived farther offshore than did that which contained Gondolella, the Gondolella biofacies. In the Shawnee Group, the Ligonodina subacoda and Gondolella biofacies occur independent of one another in the Heebner Shale and Plattsmouth Limestone members of the Oread Limestone and the Queen Hill Shale member of the Lecompton Limestone respectively. Little support can be found in the Shawnee Group for Merrill's hypothesis. It is possible, but seemingly unlikely, that the exact environmental conditions necessary for both biofacies to be present simultaneously in parallel biotope belts were never reached during the deposition of the Shawnee Group. Such a situation could conceivably result in the development of only one of a biofacies pair as proposed by Merrill (in press).

Taxonomic Interpretation of the Ligonodina subacoda Biofacies

Elements 52, 59, 66 and 61 (Table 17) are interpreted as the elements of a multielement species, Ligonodina subacoda (Gunnell). The reader is referred to page 199 of the systematic paleontology for a discussion of this multielement species.

Ligonodina lexingtonensis and Lonchodina ? ponderosa, although constantly associated and as a result clustered with the elements of Ligonodina subacoda (Gunnell), are not interpreted to be part of the same apparatus.

Lonchodus simplex (Pander), a category used for comb-like broken conodonts, is consistently grouped in this biofacies. This is a reflection of its limited distribution and the fact that it is probably derived through fragmentation of the various non-platform elements of this biofacies.

On the basis of Rhodes' (1952) studies, elements 9, 10, and 12 are considered to be the Sp elements of the multielement species Streptognathodus simulator, Streptognathodus eccentricus and Idiognathodus magnificus.

Element 11, Streptognathodus ? sp., is based on a single specimen from the Heebner Shale. This single element has no taxonomic or paleoecologic significance.

Species Group F Gondolella Biofacies

The concept of a Gondolella biofacies was first discussed by Merrill (in press) who wrote that Gondolella "is strongly linked to the Midcontinent fauna, but is so restricted therein as to represent a distinct biofacies."

The Gondolella biofacies (Table 18, and Figs. 15-18) which is restricted in its occurrence was well defined by cluster analysis, as was the Queen Hill biotope with which it is congruent. The defining faunal elements of the biofacies have been found only in the Queen Hill Shale and rarely in the basal few centimeters of the overlying Beil Limestone. The Queen Hill Shale was probably, like the lithologically similar Heebner and Larsh-Burroak shales, deposited under shallow nearshore, possibly lagoonal conditions. (Moore, 1936, 1964).

Merrill (in press) suggested that this biofacies might represent the nearshore portion of the Midcontinent fauna (the Ligonodina subacoda biofacies of the writer) and that it represented "some sort of environmental extreme associated with the conditions favoring the Midcontinent fauna."

It is unknown what environmental factors affected the distribution of the Gondolella biofacies. It would seem reasonable to find this biofacies in the Heebner and Larsh-Burroak Shales since they are identical lithologically to the Queen Hill Shale; however, this is not the case, and it appears likely that subtle ecological differences existed in the depositional environments of these members. A possibility, one difficult to evaluate, is that the ecological difference may have existed in the water conditions rather than in the substrate.

The taxa content of this biofacies is stable and reflects the restricted occurrence of the contained elements. The four elements of the Gondolella biofacies have been found only in the Queen Hill Shale and the directly overlying lower Beil Limestone.

TABLE 18. Comparison of Elements Included in Species Group F (*Gondolella* Biofacies) Shown on Dendrograms (Figs. 15 to 18) and Produced by R-mode Analyses 2E and 2F and 3E and 3F.

Taxon	Analysis	2 E	2 F	3 E	3 F
Idiognathodus delicatus, Sp element		13	13	13	13
Gondolella denuda, Hi (?) element		28	28	28	28
Gondolella denuda, Sp element		19	19	19	19
Gondolella denuda, Oz element		27	27	27	27

Taxonomic Interpretation of the Gondolella Biofacies

Cluster analysis confirms the writer's previous interpretation based on similarity of distribution and morphology that elements 28, 19, and 27 (Table 18) represent part or all of the elements belonging to a multielement species, Gondolella denuda Ellison. Rhodes (1952) described Illinella as a natural assemblage composed of the form genera Gondolella, Lonchodus, and Lonchodina. The Hi (?) element of Gondolella denuda Ellison bears similarities to, and may be homologous with the Lonchodina component of Rhodes (1952). No elements comparable with or identical to the Lonchodus component of Rhodes (1952) have been found associated with the elements of Gondolella denuda Ellison; however, the single element Lonchodus ? sp. from the Plattsmouth Limestone is similar. The Oz element of Gondolella denuda Ellison which has generally been identified as Prioniodina ? camerata (Gunnell) has been found by the writer associated with the Sp element of species of Gondolella in samples from the Shawnee Group from northern and southern Kansas, and from Madison Co., Iowa. The latter sample was generously supplied by G. K. Merrill. Further, Stauffer and Plummer (1932) found Euprioniodina sp. B (= Oz element of Gondolella denuda Ellison) associated with three species of Gondolella. The similarities in distribution of the Sp element of species of Gondolella and the Oz element which has been referred to as Prioniodina ? camerata makes the writer suspect that the latter element, or one very similar to it, is the Oz element of a number of different species of Gondolella. For example, Lonchodina transitans, a new species reported by Merrill and King (1971) from the Seville Member of Illinois is very similar to the Oz element of Gondolella denuda

Ellison and is considered to be a component part of what is here interpreted as a multielement species, *Gondolella gymna* Merrill and King.

The recognition of Oz elements, similar to the Oz elements of *Cavusgnathus*, *Streptognathodus*, and *Idiognathodus*, in the apparatus of species of *Gondolella* makes it easier to analogize the element plan of *Gondolella* with those of the other three genera.

Ellison (1937) derived *Gondolella* from *Prioniodina* ? *camerata* by gradual reduction of the weak posterior bar. If, as the writer believes, they are both parts of the same apparatus then any evolutionary derivation of one from the other would be improbable and the more likely relationship between the two would be a simple symmetry transition.

The clustering of the Sp element of the rare species, *Idiognathodus delicatus*, in this biofacies is a reflection of the fact that the only specimen found came from the Queen Hill Shale. It is possible that there is a restriction of this species to this biofacies. Ellison (1941) found that the Sp element of this species, was at least in the Virgilian Series, confined to the Queen Hill Shale.

Taxa not Placed in Species Groups

In addition to the taxa that were consistently placed in a particular biofacies, a number of taxa exist (Table 19) whose position in the various cluster analyses is variable. These are invariably rare taxa which are known only from few specimens and from a restricted number of horizons. Little or nothing can be said of their taxonomic or ecologic significance, at least as a result of this study.

TABLE 19. Elements not Placed into Definite Species Groups on Dendrograms (Figs. 15 to 18) Produced by R-mode Analyses 2E and 2F and 3E and 3F.

Taxon Analysis	2 E	2 F	3 E	3 F
Metalonchodina ? sp.	70	70	70	70
Streptognathodus sp. A, Sp element	2	2	2	2
Anchignathodus sp. aff. *A. campbelli*	23	23	23	23
Ozarkodina sp. A	25	25	25	25
Synprioniodina sp. B	34	34	34	34

SUMMARY

(1) Biofacies analysis of Shawnee Group conodonts by study of distribution data, relative abundance analysis, and cluster analysis support Merrill (1962 et seq.) in his conclusion that Pennsylvanian conodont biofacies exist. The six conodont biofacies defined are interpretable taxonomically and paleoecologically and are found in five biotopes. Well developed biofacies are a direct reflection of strong environmental control on conodont bearing animals living on the craton in shallow Pennsylvanian seas.

(2) The Shawnee Group sediments of eastern Kansas are excellent for the examination of paleoecologic relationships because of continuous exposure, a unique cyclic repetition of sediments representing a number of distinct depositional environments, and a stratigraphic succession that is well known. In addition, the conodonts are present in a variety of lithologies representing different depositional environments, they evolved slowly compared to earlier forms, and they are easily recovered.

The shales of the Shawnee Group have, unlike the Upper Pennsylvanian and Lower Permian beds studied by Perlmutter (1971), yielded rich conodont faunas. Perlmutter, although reporting generally barren shales, concluded that shale and limestone faunas are similar, a conclusion not in accord with the results of this study.

(3) The significance of biotopes in a paleontological context is not always clear because of our lack of understanding of the processes in paleoenvironments. Not only are we uncertain as to precise conditions

necessary for the formation of different lithologies, but we are equally uncertain about parameters like water depth and distance to shore.

In considering the habitat of Pennsylvanian conodonts it must be remembered that the zoological affinities, life history and habitat of the conodont bearing animal are completely unknown. Although the ecologic model based on a planktonic mode of life, suggested by Seddon and Sweet (1971) for Ordovician and Devonian conodont faunas may apply to Pennsylvanian conodont faunas, an alternate model may also explain Pennsylvanian conodont distributions. In this alternate model conodonts were benthonic during their adult life and pelagic during a larval stage. Such a life cycle would result in wide dispersal. In such a model the biotope boundaries would be vertical rather than horizontal, as envisioned by Seddon and Sweet (1971). No filter effect such as that described by Seddon and Sweet (1971) has been recognized; however, both models would produce identical conodont distributions.

(4) Some biotopes and their contained biofacies are restricted in their occurrence in the section studied. It is necessary to examine similar rocks for their conodont faunas in both a geographic and vertical sense.

(5) The grouping of conodonts into biofacies causes special problems, and both ecological and zoological meanings of biofacies must be examined. The biofacies defined by Merrill (1968 and in press) were treated as lists of discrete conodont elements; however, the elements contained in a particular biofacies are the component parts of conodont bearing animals. It is desirable to establish,where possible, what

elements belonged together and to define multielement species, a procedure that has been followed in this study. Conodont biofacies are better thought of as associated conodont bearing species which are dominant in a particular biotope than as merely lists of associated elements.

(6) The applicability of cluster analysis to biofacies analysis of fossil organisms is clearly demonstrated. Stehli (1971) pointed out the problems of noise in paleontologic data due to time related problems and the fact that collection and study methods are less perfect than for recent material. If the noise is taken into account then cluster analyses of conodont distributions can, as in this study, define biofacies and biotopes satisfactorily. Further, cluster analysis substantiates or refutes intuitively conceived biofacies and biotope relationships and suggests new ones that require examination. As a method it is more explicit and allows results to be compared easier than with more traditional methods.

(7) Q-mode analysis effectively groups samples into clusters on the basis of their faunal similarity. Such groupings are an explicit, repeatable method of evaluating the degree of faunal similarity, although it says nothing of its meaning. The clusters may be composed of lithologically similar samples, representing a single possibly repeating environment or may group lithologically unlike samples representing a variety of depositional environments. If a single or two closely related depositional environments are represented by the samples of a cluster then the cluster or sample group may represent a biotope.

Q-mode cluster analysis of data matrices one and two (Table 5), consisting of 79 element types in 153 samples and 70 element types in 148 samples, respectively, were uninterpretable; however, when these 153 and 148 samples were grouped into fifty composite samples as they were in data matrix three (Table 5) the interpretability of the analysis improved considerably. This is apparently because each individual sample is variable in faunal content and a much better approximation of the fauna of a particular lithology is derived from a larger composite sample. For Q-mode cluster analysis a large composite sample would apparently be better than a series of closer spaced samples. Those analyses using the simple matching coefficient (analyses 3C and 3D) produced dendrograms the clusters of which (Figs. 13 and 14) seem slightly better defined.

(8) R-mode analysis of conodont distribution data groups taxonomic units into groups or clusters which may be (A) the component parts of a single conodont bearing animal or (B) the component parts of more than one environmentally associated conodont bearing animal. Study of distributional data may show that situations A and B can be linked to certain lithologies representing particular depositional environments. If a particular species group cannot be related to a particular biotope then the species group may not represent a biofacies but may be a ubiquitous group.

R-mode analyses 3E and 3F (Table 5) using data in which the samples had been grouped resulted in dendrograms (Figs. 17 and 18) which although seeming to be slightly better defined than those using ungrouped data (analyses 2E and 2F), are in other respects very similar to the latter (Figs. 15 and 16).

Large composite samples and a series of closer spaced samples from a lithologically distinct sampling unit are apparently equally effective in being used to obtain distributional data for R-mode cluster analysis.

(9) It is desirable to continue using binary coefficients in biofacies analysis even though the use of absolute abundances would seem to be a more rigorous method in paleoecological studies. Unfortunately, it is generally unknown what geological and/or laboratory factors have affected absolute abundances. Relative abundance curves represent one method of making use of quantitative counts and it may be possible to develop statistical or empirical methods for biofacies analysis which make use of relative abundance data.

(10) In dendrograms resulting from cluster analysis of conodont distributions a single level of significance, above which relationships are considered significant, cannot be selected. The writer agrees with Mello and Buzas (1968) that, in a non-taxonomic context, there can be several levels at which clusters would reasonably reflect sample or species arrangement. As a consequence the writer has followed the suggestion of Kaesler (1966) and avoided drawing phenon lines, thus letting the dendrograms stand alone as representations of similarity.

(11) Weighting of one group of taxa over another for purposes of deliminating biotopes is undesirable because of the many uncertainties involved (Kaesler, 1966). The distribution of specimens of the nine taxonomic categories (p.61) which were omitted in data matrices two and three (Table 5) was considered to have been influenced by post depositional and laboratory rather than paleoecological factors. This was not considered to represent weighting.

(12) Cluster analysis defines mutually exclusive biotopes and biofacies (Kaesler, 1966); however, experience has shown that such mutual exclusivity rarely if ever exists. A biotope may contain representatives of more than one biofacies, although one will generally be dominant. Similarly, a biofacies may be linked with several biotopes although it too will generally be dominant in one of these. Transitional species will be forced into one cluster or another (Kaesler, 1966) as will uniformly distributed species (Hazel, 1970). In cluster analysis of conodont distributions, an element type can only be clustered at one point on the dendrograms, despite the fact that it is known to have been associated with a number of multielement species. For example, the element here termed the Streptognathodus and Idiognathodus Ne element is known to have been the Ne element associated with the Sp element of various species of Streptognathodus and Idiognathodus; but, the cluster analysis can only place it with one and consequently places it with the most abundant Sp element, that of Streptognathodus elegantulus.

Mutual exclusivity of biotopes and biofacies, although a negative feature of cluster analysis, is not serious as long as the investigator re-examines his data matrix and has a knowledge of his fauna so he can detect secondarly links between biotopes and biofacies as well as any anomalous groupings. Cluster analysis is a useful method of picking out the strongest signals from an uninterpretable mass of data. The weaker signals are obscured and must be identified from the data.

(13) Different methods and criteria of biofacies analysis measure or evaluate different aspects and may yield different results. For example, Q-mode cluster analysis, based on analysis of the distribution

of all elements, suggested (Table 8) that the Du Bois Limestone is faunally most similar to limestone samples grouped in the Offshore Limestone Biotope; however, relative abundance analysis, based only on the relative abundance of the Sp elements of *Cavusgnathus* and *Streptognathodus* indicated that the Du Bois Limestone was, because of its very high concentrations of the Sp element of *Cavusgnathus*, most similar faunally to some of the green shales considered to have been deposited in a near shore environment. Cluster analysis has the advantage of being able to evaluate the entire fauna whereas relative abundance analysis can concern itself with only a few elements at a time.

In cluster analysis of paleoecologic data it is generally necessary to reduce absolute abundance counts to presence-absence. In such a case the fact that a sample contains several thousand Sp elements of *Cavusgnathus* and a single one of *Streptognathodus* cannot be weighed despite the fact that this may be considered significant. This may be judged a negative feature; however, on the other side of the coin presence-absence data are available from a variety of published sources and may generally be more reliable than absolute abundance data. This has the effect of making data from other studies available for paleoecologic analysis. Further, in evaluating impoverished faunas, in which some conodont element types are clearly under-represented, the use of presence-absence in cluster analysis allows such samples to be used along with those containing a larger number of each element type. It is, of course, necessary for collections to be adequate; however, under-representation of element types in some samples does not necessarily preclude their use in cluster analysis.

SYSTEMATIC PALEONTOLOGY

Introduction

The writer has used the results of cluster analysis as well as criteria discussed by Walliser (1964) and Jeppsson (1971) such as similarity of occurrence, frequency variation, microstructure and apparatus composition to establish a multielement taxonomy for Upper Pennsylvanian conodonts. Along with many other workers (e.g. Lindström, 1970; Jeppsson, 1969, 1971; Sweet and Bergström, 1970; Sweet, 1970a, 1970b), the writer feels that it is desirable to reconstruct the apparatuses of conodont bearing animals, whenever feasible.

The techniques and criteria for grouping have been developed at a somewhat faster pace than the resulting nomenclatural problems have been solved. Although the International Zoological Code demands the strict application of the Law of Priority, the practicing conodont worker has found it difficult or impossible to comply with it. The reader is referred to Sinclair (1953), Rhodes (1953, 1962), Hass (1962a), Moore (1962), Müller (1956), and Schmidt and Müller (1964) for a discussion of different points of view. More recently the strict application of the Rules by Jeppsson (1969) has led to taxonomic situations which have seriously alarmed some specialists (see Ziegler, 1970).

Elements of multielement species have been given the element symbols of Jeppsson (1971) so that analogous element composition may be recognized in different multielement species. These symbols are designated as the Sp, the Oz, the Ne, the Hi, the Pl and the Tr elements and they are the abbreviations for the spathognathodid, the ozarkodinid, the neoprioniodid, the hindeodellid, the plectospathodid and the trichonodellid components respectively of the apparatuses of conodont bearing animals. In some cases the symbols could only be questionably assigned. The suprageneric classification of Lindström (1970) is used where applicable. Many species, particularly those of most species of Streptognathodus and Idiognathodus, as well as those of two species of Cavusgnathus, are known to have shared identical nonplatform components. In such situations the writer had little recourse but to place the descriptions of the nonplatform elements after the descriptions of platform elements to which they are common.

Order Conodontophorida Eichenberg 1930

Superfamily Polygnathacea Bassler 1925

Family Idiognathodontidae Harris and Hollingsworth 1933

Genus Streptognathodus Stauffer and Plummer

Type species.- Streptognathodus excelsus, Stauffer and Plummer, 1932, original designation.

Scottella Rhodes, 1952, p. 890 (partim)

Scottognathus Rhodes, 1953, p. 612 (pro Scottella)

The genera Streptognathodus and Idiognathodus form a continuous intergrading morphologic series and their species can generally be differentiated only on the basis of differences in their platform elements since their nonplatform elements are apparently identical (Rhodes, 1952).

The platform element of species included in Streptognathodus have a large, flaring gnathodid basal cavity, and on the oral surface, an oral trough which in mature (i.e. large) elements contains on the anterior portion a carina which is an extension of the blade. In immature (i.e. small) Sp elements of some species, the carina extends to the posterior end. The oral surface is ornamented with transverse ridges which are separated by the oral trough and are thus discontinuous. In some borderline species there is little evidence in the Sp element of an oral trough, and the transverse ridges are nearly continuous across the platform, being separated only in the central portion of the platform by an oral groove, i.e. a hairline discontinuity in the ridges.

During growth of the Sp element of some species there is an ontogenetic recapitulation of their phylogeny, a factor not unimportant for taxonomy.

Rhodes (1952) indicated that idiognathodiform and streptognathodiform platform elements substituted for one another in the same natural assemblage species. This, plus the fact that the Sp elements of both Streptognathodus and Idiognathodus grade into one another morphologically, might support a decision to suppress one of these generic names; however, the fact that idiognathodid Sp elements have not been found above the Queen Hill Shale whereas streptognathodid Sp elements are found in abundance throughout the Shawnee Group suggests that the distribution of these element types is at times mutually exclusive, a factory which is of enough significance to warrant recognition at the generic rather than the specific level.

Streptognathodus elegantulus Stauffer and Plummer, Sp element

Pl. 1, figs. 1 a - e

Streptognathodus elegantulus Stauffer and Plummer, 1932, p. 47, pl. 4, figs. 6-7, 22, 27.

Polygnathus pawhuskaensis Harris and Hollingsworth, 1933, p. 199, pl. 1, figs. 12, a, b.

Streptognathodus sulcatus Gunnell, 1933, p. 280, pl. 32, fig. 10.

Streptognathodus elegantulus Stauffer and Plummer; Ellison, 1941, p. 127, pl. 22, figs. 1-6, 10.

Streptognathodus sulcatus Gunnell; Ellison, 1941, pl. 22, fig. 8 [non fig. 12]

Streptognathodus elegantulus Stauffer and Plummer; Branson, 1944, p. 327, pl. 46, figs. 1-6, 10.

Streptognathodus sulcatus Gunnell; Branson, 1944, p. 327, pl. 46, fig. 8 [non fig. 12]

Streptognathodus elegantulus Stauffer and Plummer; Rhodes, 1952, p. 893, pl. 127, figs. 11-12.

Streptognathodus cf. *S. elongatus* Gunnell; Rhodes, 1952, p. 894, pl. 127, figs. 3-4, 8.

Streptognathodus elegantulus Stauffer and Plummer; Stone, 1959, p. 158, text-fig. 14.

Streptognathodus elegantulus Stauffer and Plummer; Jennings, 1959, p. 995, pl. 124, fig. 6.

Streptognathodus elegantulus Stauffer and Plummer; Koike, 1967, p. 311, pl. 3, figs. 13-15.

Streptognathodus elegantulus Stauffer and Plummer; Higgins and Bouckaert,
1968, p. 46, pl. 5, figs. 8, 10.

[non] Streptognathodus elegantulus Stauffer and Plummer; Hass, 1962b,
(in Mamay and Yochelson), p. 209, pl. 34, fig. 44.

[non] Streptognathodus elegantulus Stauffer and Plummer; Stibane, 1967,
p. 336, pl. 36, figs. 19-22.

Discussion.- Ellison (1941) described this element as lacking accessory lobes and having a deep median trough. These characteristics are among the defining features of this element; however, study of conodonts from the Shawnee Group has shown that greater ontogenetic and morphologic variation exists than has previously been reported.

Ontogenetic Variation.- Small individuals have a prominent sub-central to central carina extending from the anterior to the posterior portion of the platform (Pl. 1, fig. 1 a). In addition, they have a sharply pointed posterior terminus, the blade denticles are high in relation to the plane of the platform, and although the position of the transverse ridges is already defined, these ridges are weakly developed.

As individuals mature there is an increase in size, the carina decreases in length, the transverse ridges increase in strength and the blade becomes more like the platform in size. In addition, there is also a tendency for the posterior tip to become more rounded (Pl. 1, figs. 1 d - e).

Among immature specimens of the Sp element of S.elegantulus there are some that are similar to Streptognathodus elongatus Gunnell. The fact that they fit into ontogenetic series of the Sp element of S.elegantulus plus the fact that Ellison (1941) only reported S.elongatus from higher in the section makes it unlikely that these small forms represent S.elongatus; however, the criteria by which S.elongatus are distinguished from the Sp element of S.elegantulus, being more slender and having a V-shaped trough in cross-section, is somewhat subjective. Examination of platform elements labelled S.elongatus and donated by G. K. Merrill to Philipps University proved that the writer could not objectively distinguish this material from other platform elements in the same collection labelled S.elegantulus. S.elongatus may at a later date have to be placed in synonymy with S.elegantulus.

Morphologic Variation.- Mature Sp elements of S.elegantulus generally fit the concepts for this element as established by Stauffer and Plummer (1932) and Ellison (1941). Some variations have been noted.

The oral trough, although generally U-shaped and deep, is much shallower in some specimens. Stauffer and Plummer (1932) illustrated specimens which showed the rounded and flattened lateral margins, called parapets by Merrill (1964), together with a corresponding rounding of the transverse ridges. These features are shown by some specimens (Pl. 1, fig. 1 e) from the Shawnee Group. As a rule specimens of the Sp element of S.elegantulus from the Shawnee Group shows relatively abrupt and non-flattened parapets with strong, straight transverse ridges.

Another variation present in both mature and immature specimens and one previously recognized by Merrill (1964), is the presence of one or two complete transverse ridges at the posterior end of the platform (Pl. 1, figs. 1 d - e). These forms are similar to, and transitional with the Sp element of S.oppletus (Merrill, 1964).

Symmetry Variation.- The writer here means that variation, if any, occurring between sinistral and dextral forms of a conodont element.

Both sinistral and dextral specimens of the Sp element of S.elegantulus have been recovered in approximately equal numbers. Sinistral or dextral is determined by orienting the specimen in oral view with the posterior end downward (Lane, 1967). Sinistral and dextral forms have the same morphological features, and the species thus falls into the class II symmetry of Lane (1968). In some specimens right or left handedness is difficult to determine particuarly if the blade is broken. The writer has found that the platform is commonly curved more on the outer side than the inner side so as to produce a slight asymmetry (Pl. 1, fig. 1 c). Further, the outer parapet is shorter and does not extend as far anteriorly as does the inner parapet. It has been observed that the outer apron flares more than the inner apron.

Material:	14,873 specimens; figured specimens UKMIP 1,900,901 to 1,900,905.
Distribution:	Lawrence Shale to Coal Creek Limestone Member, Topeka Limestone.

Streptognathodus sp. A, Sp element

Pl. 1, figs. 2 a - e

Some platform elements differ from the Sp elements of S.elegantulus in that the posterior end of the carina curves gently outward and terminates against an outer transverse ridge. This morphological feature could be judged to be within the variation of *S.elegantulus* were it not for the fact that it has been used to define several other species considered indicative of the Lower Pennsylvanian. *Streptognathodus lateralis*, a platform species, was diagnosed as having a short carina which terminates against the transverse ridges of the outer side of the platform and has having an oral trough on the inner side of the platform (Higgins and Bouckaert, 1968). *Streptognathodus japonicus* also shows a carina which in its posterior portion merges "into longitudinal ridge of outer side" (Igo and Koike, 1964) as does *Streptognathodus parallelus* of Clarke (1960).

In the writer's view *S.lateralis* is probably a synonym of *S.japonicus* and *S.parallelus*; however, Dunn (1970a) placed them in separate specific categories, *Declinognathus lateralis* (Higgins and Bouckaert) and *Declinognathus noduliferus* (Ellison and Graves) respectively.

Since this is the first record of this morphotype in the Upper Pennsylvanian it is considered best to use open nomenclature at present. It would be desirable to determine if similar forms occur in the Middle Pennsylvanian, and it may be found that an outward curvature of the posterior part of the carina in the Sp element of *Streptognathodus* is a recurring phenomenon, one that is possibly a recapitulation of earlier evolutionary history. Dunn (1970a) has given extensive synonymies for *Declinognathus* and included most or all forms which show outward curvature and termination of the posterior portion of the carina. The position of *Streptognathodus lanceolatus* Webster (1969) relative to the species considered by Dunn (1966, 1970a, 1971) and the writer's form is uncertain.

Material: 14 specimens, figured specimens UKMIP 1,900,906 to 1,900,908.

Distribution: Spring Branch Limestone Member, Lecompton Limestone.

Streptognathodus sp. aff. *Streptognathodus elegantulus* Stauffer and Plummer, Sp element

Pl. 1, figs. 3 a - b

Small specimens of this element type have not been recovered. Medium to large sized specimens are characterized by a very shallow to nonexistent trough. Transverse ridges are present on both sides of this trough, although they are stronger and longer on one side than the other, producing an asymmetrical platform. The platform is elongated with a rounded posterior and in most specimens only low poorly developed parapets are present. The carina in mature specimens extends approximately one-third the length of the anterior platform, although isolated nodes sometimes extend farther posteriorly. In smaller specimens a very prominent carina, which is higher than the platform surface, and which extends almost to the posterior end, has been observed. There are no accessory lobes present. The blade of the specimens available are all partially broken; however, the preserved portions are judged to be identical to other species of *Streptognathodus*.

Aborally, a typically gnathodid basal cavity which cannot be distinguished from that of Sp elements of other species of *Streptognathodus* is present.

Comparison.- This platform type is most closely compared with that of S.elegantulus of which it may be a variant. It differs from typical specimens of the latter in that it has a shallow trough, a generally rounded posterior, and unequally developed, irregular transverse ridges.

Material: 14 specimens; figured specimen UKMIP 1,900,909.

Distribution: Plattsmouth Limestone Member, Oread Limestone to Holt Shale Member, Topeka Limestone; most common in the Plattsmouth Limestone.

Streptognathodus gracilis Stauffer and Plummer, Sp element

Pl. 2, figs. 1 a - b

Streptognathodus gracilis Stauffer and Plummer, 1932, p. 48, pl. 4, figs. 12, 23.

Streptognathodus holmesi Gunnell, 1933, p. 280, pl. 32, figs. 1, 2.

Streptognathodus sulciferus Gunnell, 1933, p. 281, pl. 32, fig. 12.

Streptognathodus corrugatus Gunnell, 1933, p. 281, pl. 32, fig. 13.

Streptognathodus rugosus Gunnell, 1933, p. 282, pl. 32, fig. 18.

Streptognathodus curvatus Gunnell, 1933, p. 283, pl. 33, fig. 1.

Streptognathodus ruidus Gunnell, 1933, p. 282, pl. 32, fig. 17.

Streptognathodus spatulatus Gunnell, 1933, p. 281, pl. 32, fig. 14.

Streptognathodus gracilis Stauffer and Plummer; Ellison, 1941, p. 128, pl. 22, figs. 7, 11.

Streptognathodus gracilis Stauffer and Plummer; Branson and Mehl, 1944, p. 246, pl. 94, fig. 72.

Streptognathodus gracilis Stauffer and Plummer; Branson, 1944, p. 327, pl. 46, figs. 7, 11.

Streptognathodus gracilis Stauffer and Plummer; Rhodes, 1952, p. 94, pl. 127, figs. 1, 16.

Streptognathodus gracilis Stauffer and Plummer; Stone, 1959, p. 158, text-fig. 9.

Streptognathodus elegantulus Stauffer and Plummer; Hass, 1962b (*in* Mamay and Yochelson), p. 209, pl. 34, fig. 44.

The Sp element of *S.gracilis* is characterized by having an accessory lobe on the inner side of the platform. The trough is deeply concave, and the element is in all respects other than lobation identical to the Sp element of *S.elegantulus* of Ellison (1941). In the Sp element of *S.gracilis* as in that of the closely related *S.elegantulus* there is a tendency for the median trough to become shallower, thus becoming transitional with the Sp element of *S.wabaunsensis* Gunnell. If the trough is not median then the specimen is assignable to *S.simulator* Ellison.

No immatures were recognized. In almost all specimens the inner accessory lobe is poorly developed and is present as a single node. The trough in most cases is relatively shallow; however, the specimens are still assignable to *S.gracilis*.

Both sinistral and dextral forms were recovered in approximately equal numbers.

Material: 59 specimens; figured specimens UKMIP 1,900,910 to 1,900,911.

Distribution: Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone; most common in the Larsh-Burroak Shale Member, Deer Creek Limestone.

Streptognathodus excelsus Stauffer and Plummer, Sp element

Pl. 2, figs. 2 a - c

Streptognathodus excelsus Stauffer and Plummer, 1932, p. 48, pl. 4, figs. 2, 5.

Streptognathodus increbescens Stauffer and Plummer, 1932, p. 49, pl. 4, figs. 9, 15-16.

Streptognathodus clavatulus Gunnell, 1933, p. 280, pl. 31, fig. 9.

Streptognathodus multinodosus Gunnell, 1933, p. 280, pl. 32, fig. 11.

Streptognathodus subdivisis Gunnell, 1933, p. 281, pl. 32, fig. 16.

Streptognathodus minutus Gunnell, 1933, p. 282, pl. 32, fig. 65.

Streptognathodus chanutensis Gunnell, 1933, p. 282, pl. 32, figs. 66-68.

Streptognathodus clarki Gunnell, 1933, p. 283, pl. 33, fig. 3.

Streptognathodus excelsus Stauffer and Plummer; Ellison, 1941, p. 130, pl. 22, figs. 15, 17, 20.

Streptognathodus excelsus Stauffer and Plummer; Branson and Mehl, 1944, p. 256, pl. 94, figs. 73-74.

Streptognathodus excelsus Stauffer and Plummer; Branson, 1944, p. 327, pl. 46, figs. 15, 17, 20.

Streptognathodus excelsus Stauffer and Plummer; Rhodes, 1952, p. 893,
pl. 127, figs. 5-6, 14.

Streptognathodus cf. *S.excelsus* Stauffer and Plummer; Rhodes, 1952,
p. 893, pl. 127, figs. 17, 25.

Streptognathodus excelsus Stauffer and Plummer; Stone, 1959, p. 158,
text-fig. 3.

Streptognathodus excellsus (sic) Stauffer and Plummer; Hass, 1962a,
p. W62, figs. 38-7a, b.

The Sp element of *Streptognathodus excelsus* is almost identical to that of *S.elegantulus* and *S.gracilis* except for the presence of two accessory lobes. An accessory lobe is developed at each side near the anterior portion of the platform. The Sp element of *S.excelsus* differs from that of the similar *S.cancellosus* (Gunnell) in lacking posterior transverse ridges and possessing a true median trough rather than a shallow, narrow oral groove (Ellison, 1941).

The species is rare in the Shawnee Group, and it was not possible to reconstruct an ontogenetic series of the platform element. Ellison (1941) pointed out that there is a tendency for the oral trough to become shallow, a feature that has been noted not only in mature and very large specimens but also in younger forms. As in the Sp elements of *S.elegantulus* and *S.gracilis* both sinistral and dextral specimens have been found.

Material: 21 specimens; figured specimens UKMIP 1,900,912 to 1,900,913.

Distribution: Toronto Limestone Member, Oread Limestone, to the Coal Creek Limestone Member, Topeka Limestone; most common in the Larsh-Burroak Shale Member, Deer Creek Limestone.

Streptognathodus gracilis Stauffer and Plummer [?], Sp element

Pl. 2, figs. 4 a - d

Several specimens were recovered which differ from the Sp element of S.gracilis chiefly in possessing an accessory lobe which rather than being on the inside of the platform is located on the outside. Both sinistral and dextral forms were recovered.

No immatures were identified. Mature specimens are much like the Sp elements of S.gracilis, and vary chiefly in the configuration of the trough. In some cases, the trough is deep and well defined, in others it becomes much shallower. There is also some variation in the position of the trough--in some specimens the trough is median, while in others it is slightly eccentric approaching that of the Sp element of S.simulator. Laterally and aborally, the specimens are similar to the Sp element of S.gracilis.

Material: 12 specimens; figured specimens UKMIP 1,900,915 to 1,900,916.

Distribution: Toronto Limestone Member, Oread Limestone to Coal Creek Limestone Member, Topeka

Limestone; most common in the Larsh-Burroak Shale Member, Deer Creek Limestone.

Streptognathodus oppletus Ellison, Sp element

Pl. 2, figs. 5 a - c

Idiognathodus multinodosus Gunnell, 1933, p. 279, pl. 33, fig. 5.

[?] Streptognathodus cariniferus Gunnell, 1933, p. 276, pl. 31, fig. 52.

Streptognathodus oppletus Ellison, 1941, p. 132, pl. 22, figs. 13-14, 16.

Streptognathodus oppletus Ellison; Branson, 1944, p. 309, pl. 45, figs. 13-14, 16.

[?] Streptognathodus mucronatus Youngquist and Downs, 1949, p. 170, figs. 6-7.

Streptognathodus cf. S.oppletus Ellison; Rhodes, 1952, p. 894, pl. 127, fig. 18.

Streptognathodus oppletus Ellison; Stone, 1959, p. 15, text-fig. 12.

[?] Streptognathodus oppletus Ellison; Omara and Kenawy, 1966, p. 77, pl. 11, figs. 8, 9.

Streptognathodus angustus Dunn, 1966, p. 1302, pl. 158, figs. 11-13.

Streptognathodus parvus Dunn, 1966, p. 1302, pl. 158, figs. 9-10.

Idiognathodus parvus (Dunn); Koike, 1967, p. 305, pl. 2, figs. 13 [non figs. 11-12, 14-17].

Streptognathodus parvus Dunn, 1970a, p. 340, pl. 64, figs. 8-11, 16-17, text-fig. 9I.

Streptognathodus parvus Dunn, 1970b, p. 2970, text-fig. 4.

Ellison (1941) described this element as having a prominent carina, a filled posterior platform on which the transverse ridges may be complete from one margin to the other, and a poorly developed accessory lobe which commonly consists of only a single node. Merrill (1964) noted that the trough was narrow, shallow and rudimentary and that the poorly developed accessory lobe may or may not be present.

In the Shawnee Group, this element does not have an accessory lobe and the carina is not particularly prominent. Furthermore, the posterior transverse ridges are only rarely complete. The specimens examined represent one end of the morphological spectrum and one that is at times difficult to distinguish from the Sp element of Idiognathodus tersus, with which it is associated.

Partial ontogenetic series show little change during growth. In immature specimens the carina extends approximately half the length of the platform. As the element gets larger the carina occupies only about the anterior one-third of the platform. Younger individuals tend to be straighter whereas in older ones the posterior curbs inward, producing a slightly more asymmetrical element.

Merrill (1964) coined the term "frill" for orally flaring parapets in the anterior part of the platform. He indicated this to be a well developed feature of the Sp element of this species, and the writer has observed this in a number of specimens (Pl. 2, fig. 5 c). Well developed, rapidly descending sulci are present in the anterior portion bearing the nearly complete transverse ridges. There is a moderately deep trough having on each side sharply defined parapets bearing weak remnants of transverse ridges. Both sinistral and dextral specimens were found.

Material: 106 specimens; figured specimens UKMIP 1,900,917 to 1,900,919.

Distribution: Plattsmouth Limestone Member, Oread Limestone, to Larsh-Burroak Shale Member, Deer Creek Limestone. Very rare above Queen Hill Shale Member, Lecompton Limestone.

Streptognathodus wabaunsensis Gunnell, Sp element

Pl. 2, figs. 6 a - c

Streptognathodus wabaunsensis Gunnell, 1933, p. 285, pl. 33, fig. 32.

Streptognathodus walteri Gunnell, 1933, p. 284, pl. 33, fig. 31.

Streptognathodus accuminatus Gunnell, 1933, p. 285, pl. 33, fig. 33.

Streptognathodus farmeri Gunnell, 1933, p. 285, pl. 33, fig. 34.

Streptognathodus flangulatus Gunnell, 1933, p. 285, pl. 33, fig. 35.

Streptognathodus wabaunsensis Gunnell; Ellison, 1941, p. 131, pl. 22, figs. 18, 19.

Streptognathodus wabaunsensis Gunnell; Branson, 1944, p. 327, pl. 46, figs. 18, 19, 21, 22.

[?] *Streptognathodus* cf. *S.wabaunsensis* Gunnell; Rhodes, 1952, p. 804, pl. 127, fig. 2.

Streptognathodus wabaunsensis Gunnell; Jones, 1956, p. 132, figs. 5, 7, 18 a - b.

Streptognathodus wabaunsensis Gunnell; Stone, 1959, p. 158, text-fig. 11.

This element was described by Ellison (1941) as having a flat to slightly concave oral surface bearing a shallow median trough and an inner accessory lobe situated far anteriorly. This Sp element is morphologically intermediate between that of Streptognathodus gracilis and that of Idiognathodus antiquus. All three have a single accessory lobe but vary in the presence, absence, or near absence of an oral trough or groove.

The specimens encountered in this study invariably occur with the Sp element of Idiognathodus antiquus and can only be differentiated from this element by the fact that most or all of the transverse ridges are bisected by a narrow oral groove. All transitions toward the Sp element of Idiognathodus antiquus are present.

Only incomplete ontogenetic series of S.wabaunsensis could be assembled. The smaller specimens recovered show fewer transverse ridges than the larger; however, no decrease in length of the carina with increase of size could be noted. The transverse ridges vary in the degree to which they are bisected by the narrow oral groove. Some specimens have all the transverse ridges severed, while in others only those of the posterior two-thirds are severed and those that are farthest anteriorly are complete. Commonly, only the anterior two to three transverse ridges are complete. The oral surface of Shawnee Group specimens varies from completely flat to slightly concave; however, the oral surface of most specimens appear to be flatter than those illustrated by Ellison (1941).

Immature specimens have a relatively straight platform, whereas older individuals have a tendency for the posterior end to twist inward, similar to that feature of the Sp element of Idiognathodus antiquus. Merrill (1964) included in this element specimens with a second accessory lobe. The writer has only two specimens of this type and will follow Merrill's suggestion. Other specimens bear only one accessory lobe, generally consisting of one to three nodes. The position of the lobe varies, being sometimes situated farther posteriorly than forms described by Ellison (1941).

Both sinistral and dextral specimens were recovered in approximately equal numbers.

Material: 42 specimens; figured specimens UKMIP 1,900,920 to 1,900,922.

Distribution: Plattsmouth Limestone Member, Oread Limestone to the Queen Hill Shale Member, Lecompton Limestone.

Streptognathodus simulator Ellison, Sp element

Pl. 3, figs. 1 a - d

Streptognathodus simulator Ellison; 1941, p. 133, pl. 22, figs. 25, 27-30.

Streptognathodus simulator Ellison; Branson, 1944, p. 327, pl. 46, figs. 25, 27-30.

[?] Streptognathodus cf. S. simulator Ellison; Rhodes, 1952, p. 894, pl. 127, fig. 13.

Streptognathodus simulator Ellison; Stone, 1959, p. 158, text-fig. 7.

Streptognathodus simulator Ellison; Jennings, 1959, p. 994, pl. 124, fig. 7.

The Sp element of Streptognathodus simulator is differentiated from that of other species of Streptognathodus in possessing an eccentric trough and less than two accessory lobes (Ellison, 1941; Merrill, 1964). Small individuals, although displaying the asymmetry of the adult forms, do not show accessory lobes. Unlike the Sp element of S.elegantulus at a similar stage, the carina is not strongly developed and usually extends only one-third to one-half the length of the platform before ending at a transverse ridge or veering over toward the inner or outer border of the platform. Immature specimens, because they do not show the accessory lobes, cannot be distinguished from immature Sp elements of the similar and related S.eccentricus.

Mendenhall (1951) and Merrill (1964) described what is essentially the Sp element of S.simulator but without accessory lobes. It is not known if these were mature specimens. Mendenhall considered these to be a new species. Merrill included the non-lobate forms with the Sp elements of S.simulator.

Both sinistral and dextral forms have been recovered in approximately equal numbers. The accessory lobe, when developed, is limited to the inner side.

As Ellison (1941) indicated, some of the transverse ridges may coalesce from one side of the eccentric trough to the other. This feature, plus the fact that in many specimens the trough is only weakly developed and the transverse ridges are prevented from joining only by a hairline groove, makes this element difficult to separate from the Sp element of species of Idiognathodus with which S.simulator is associated.

The Sp elements of both S.simulator and S.eccentricus often break cleanly parallel to the oral groove. This apparently reflects some structural weakness in the layers between the groove and the upper limit of the basal cavity.

Material: 598 specimens (numerous specimens split parallel to oral groove not included in counts); figured specimens UKMIP 1,900,927 to 1,900,931.

Distribution: Heebner Shale Member to Plattsmouth Limestone Member, Oread Limestone.

Streptognathodus eccentricus Ellison, Sp element

Pl. 3, figs. 2 a - e

Streptognathodus eccentricus Ellison, 1941, p. 132, pl. 22, fig. 24.

Streptognathodus eccentricus Ellison; Branson, 1944, p. 327, pl. 46, fig. 24.

Streptognathodus cf. S.eccentricus Ellison; Rhodes, 1952, p. 894, pl. 127, figs. 7, 19.

Streptognathodus eccentricus Ellison; Stone, 1959, p. 158, text-fig. 1.

Streptognathodus eccentricus Ellison; Jennings, 1959, p. 995, pl. 124, fig. 9.

The Sp element of Streptognathodus eccentricus possesses an eccentric trough and is differentiated from that of S.simulator by possessing two accessory lobes.

Very small, immature specimens of this element have not been found. Accessory lobes are absent in small specimens of S.eccentricus and they cannot be distinguished from similar sized Sp elements of S.simulator. Merrill (1964) noted that there is a tendency for the transverse ridges to fuse across the trough. Some of the writer's specimens exhibit this, and particularly in mature specimens the trough is only weakly developed and the transverse ridges are only separated by a hairline oral groove, if separated at all. The inner lobe is larger than the outside lobe, sometimes pronouncedly so.

Sinistral and dextral specimens were recovered in approximately equal numbers.

The writer attempted to determine whether or not S.simulator and S.eccentricus should be considered synonymous, however, it could not be shown that the Sp element of one represented a growth stage of the other.

Material: 38 specimens; figured specimens UKMIP 1,900,923 to 1,900,925.

Distribution: Heebner Shale Member, Oread Limestone.

Streptognathodus sp.

Sp elements of Streptognathodus that were poorly preserved or broken and which could not be identified to species were placed in this taxonomic category.

Material: 1703 specimens.

Streptognathodus ? sp.

Pl. 2, fig. 3

A single dextral specimen was recovered which appears to represent the Sp element of a species of Streptognathodus except that the blade has partially migrated to the outer side of the platform. This has resulted in a fusion of the blade and the outer parapet. On the inner side of the platform there is a wide sulci which is nearly absent on the outer side of the platform. Slightly posterior to the sulci where the carina would be in Sp elements of Streptognathodus is a smooth, elongated, bowl-shaped depression occupying the anterior one-third of the platform. This depression grades posteriorly into a deeper oral trough.

The raised transverse ridges are poorly developed and are present as nodes on the inner side and as short strong ridges on the outer side. A typical gnathodid basal cavity, which flares more on the outer than on the inner side, is present.

Material: 1 specimen; figured specimen UKMIP 1,900,914.

Distribution: Heebner Shale Member, Oread Limestone.

Genus Idiognathodus Gunnell, 1931

Type Species.- Idiognathodus claviformis Gunnell, 1931 original designation.

Scottella Rhodes, 1952, p. 890 (partim)

Scottognathus Rhodes, 1953, p. 612 (pro Scottella)

The Sp elements of species of *Idiognathodus* from the lower Shawnee Group have a large gnathodid basal cavity, a carina which is located in median position and an oral surface which bears transverse ridges complete across the platform. There is no oral trough or groove; however, the oral surface may be slightly concave. The completeness of the transverse ridges is stressed and forms with more than a few interrupted ridges should be assigned to *Streptognathodus*. Although this may seem arbitrary, in practice this is the only method of dealing with such borderline species as *S.simulator*, *S.eccentricus*, *S.oppletus* and *I.tersus*.

The nonplatform elements of species of *Idiognathodus* are seemingly identical, a probability strongly supported by studies of natural assemblages (Rhodes, 1952). As a result, the taxonomy of species of *Idiognathodus*, is like that of species of *Streptognathodus*, based largely on variation in the morphology of platform elements. These platform elements can change appearance radically during growth and in addition to using normal taxonomic criteria it is necessary to study growth stages in order to distinguish different types.

Idiognathodus magnificus Stauffer and Plummer, Sp element

Pl. 3, figs. 3 a - e

[?] *Idiognathodus arcuatus* Gunnell, 1931, p. 250, pl. 29, fig. 26.

Idiognathodus magnificus Stauffer and Plummer, 1932, p. 46, pl. 4, figs. 8, 18, 20 [non fig. 19].

[?] *Idiognathodus expansus* Stauffer and Plummer, 1932, p. 46, pl. 4, figs. 1, 3.

Idiognathodus pustulata Harris and Hollingsworth, 1933, p. 204, pl. 1, fig. 11.

Idiognathodus cuneiformis Gunnell, 1933, p. 270, pl. 31, fig. 8.

Idiognathodus harkeyi Gunnell, 1933, p. 270, pl. 31, fig. 11.

Idiognathodus siculus Gunnell, 1933, p. 271, pl. 31, fig. 14.

Idiognathodus sulciferus Gunnell, 1933, p. 271, pl. 31, fig. 16.

Idiognathodus clavatus Gunnell, 1933, p. 271, pl. 31, fig. 19.

Idiognathodus ruidus Gunnell, 1933, p. 272, pl. 31, fig. 25.

Idiognathodus megistus Gunnell, 1933, p. 273, pl. 31, fig. 30.

Idiognathodus cicatricosus Gunnell, 1933, p. 274, pl. 31, fig. 34.

Idiognathodus wintersetensis Gunnell, 1933, p. 274, pl. 31, figs. 36, 51.

Idiognathodus strigillatus Gunnell, 1933, p. 274, pl. 31, fig. 37; pl. 32, fig. 8.

Idiognathodus vadosus Gunnell, 1933, p. 275, pl. 31, fig. 45.

Idiognathodus erodus Gunnell, 1933, p. 275, pl. 31, fig. 48.

Idiognathodus fusiformis Gunnell, 1933, p. 276, pl. 31, fig. 49.

Idiognathodus walteri Gunnell, 1933, p. 277, pl. 32, fig. 9.

Idiognathodus magnificus Stauffer and Plummer; Ellison, 1941, p. 135, pl. 23, figs. 2, 3, 6, 9 [misprinted as figs. 2, 4, 7, 10].

Idiognathodus magnificus Stauffer and Plummer; Ellison and Graves, 1941, p. 2, pl. 3, figs. 25-27.

Idiognathodus sp. Branson, 1944, p. 305, pl. 44, fig. 28 [non figs. 26-27]

Idiognathodus sp. Youngquist and Heezen, 1948, p. 770, pl. 118, fig. 14.

[?] *Idiognathodus gomphus* Youngquist and Downs, 1949, p. 167, pl. 31, figs. 14-15.

Idiognathodus magnificus Stauffer and Plummer; McLaughlin, 1952, p. 619, pl. 83, figs. 12-14.

Idiognathodus cf. *I.magnificus* Stauffer and Plummer; Rhodes, 1952, p. 894, pl. 127, fig. 23.

Idiognathodus magnificus Stauffer and Plummer; Jennings, 1959, p. 995, pl. 124, figs. 1-2.

Idiognathodus cf. *magnificus* Stauffer and Plummer; Clarke, 1960, p. 28, pl. 5, figs. 3-5 [fig. 2?].

Idiognathodus magnificus Stauffer and Plummer; Hass, 1962b (*in* Mamay and Yochelson), p. 209, pl. 34, fig. 43.

[?] *Idiognathodus* cf. *I.magnificus* Stauffer and Plummer; Murray and Chronic, 1965, p. 601, pl. 71, figs. 7-12.

Idiognathodus incurvus Dunn, 1966, p. 1301, pl. 158, figs. 2-3.

[?] *Idiognathodus* sp. Lane, 1967, p. 936, pl. 119, figs. 10-11.

Idiognathodus cf. *I.magnificus* Dunn, 1970a, p. 334, pl. 63, fig. 19.

Webster (1969) considered this species to be the gerontic form of *Idiognathodus delicatus* Gunnell. The possibility of this was first considered by Ellison (1941) and re-examined by Merrill (1964). Webster (1969) had sufficient material to give his view validity; however, the writer's collections necessitate a different observation.

Juvenile specimens do not show accessory lobes on either side of the platform, although having five to six clearly defined transverse ridges. As the element grows larger the number of transverse ridges increases and on the inner side of the platform of some specimens an indentation in the parapet appears. It is on or near thisindentation that a single inner accessory node appears when the conodont is approximately one-third to one-half of its maximum size. This accessory node may either get larger and thus by itself constitute the inner accessory lobe or else additional nodes may be added later to this lobe. The outer accessory lobe does not appear until the individuals are in the mature to gerontic stage. The outer accessory lobe consists in most cases of a number of poorly defined nodes, but in several cases it consists of a circular ridge and node arrangement.

Two accessory lobes are thus only present in large mature forms. It would not be possible to consider any of the immature forms to be Idiognathodus delicatus, a form characterized as having two accessory lobes which are well set-off.

Both sinistral and dextral forms have been recovered, although for unknown reasons the dextral forms predominate. The specimens described here have only weakly developed accessory lobes and this weakening of the lobes to the point where they consist of only one or two nodes seems to be a characteristic feature of Shawnee Group idiognathodid and streptognathodid Sp elements.

The Sp elements of Idiognathodus magnificus from the Shawnee Group occur as robust types primarily from the Heebner Shale and more rarely, the Plattsmouth Limestone. Slighter more slender individuals obviously closely related to the Sp elements of Idiognathodus antiquus, with which they are associated, have been found in the Kereford Limestone. The more robust types are associated with the Sp elements of Streptognathodus simulator and Streptognathodus eccentricus and are transitional with these elements, being distinguished primarily by the complete transverse ridges.

Material: 39 specimens; figured specimens UKMIP 1,900,932 to 1,900,936.

Distribution: Heebner Shale Member to Kereford Limestone Member, Oread Limestone.

Idiognathodus delicatus Gunnell, Sp element

Pl. 3, fig. 4

Idiognathodus delicatus Gunnell, 1931, p. 250, pl. 29, figs. 23-25.

Idiognathodus delicatus Gunnell; Stauffer and Plummer, 1932, p. 45, pl. 4, figs. 4, 21, 24-26.

Idiognathodus magnificus Stauffer and Plummer, 1932, p. 46, pl. 4, fig. 19 [non figs. 8, 18, 20].

Idiognathodus modulatus Gunnell, 1933, p. 271, pl. 31, fig. 15.

Idiognathodus spathodus Gunnell, 1933, p. 273, pl. 31, fig. 28.

Idiognathodus semipapulatus Gunnell, 1933, p. 273, pl. 31, figs. 29, 50.

Idiognathodus lanceolatus Gunnell, 1933, p. 273, pl. 31, figs. 31-32.

Idiognathodus folium Gunnell, 1933, p. 274, pl. 31, fig. 33.

Idiognathodus gemmiformis Gunnell, 1933, p. 275, pl. 31, fig. 44.

Idiognathodus warei Gunnell, 1933, p. 279, pl. 32, figs. 59-61.

Idiognathodus kansensis Gunnell, 1933, p. 279, pl. 32, figs. 62-64.

Idiognathodus corrugatus Gunnell, 1933, p. 277, pl. 32, figs. 6-7.

Idiognathodus delicatus Gunnell; Ellison, 1941, p. 134, pl. 22, figs. 31-36.

Idiognathodus delicatus Gunnell; Ellison and Graves, 1941, p. 2, pl. 3, figs. 20, 23.

Idiognathodus delicatus Gunnell; Branson and Mehl, 1944 (*in* Shimer and Shrock), p. 246, pl. 94, figs. 56-58.

Idiognathodus delicatus Gunnell; Branson, 1944, p. 309, pl. 46, figs. 31-36.

Idiognathodus kansensis Gunnell; Glaessner, 1945, p. 64, pl. 4, figs. 9 a - c.

Idiognathodus delicatus Gunnell; McLaughlin, 1952, p. 619, pl. 83, figs. 8-11.

Idiognathodus cf. I.delicatus Gunnell; Rhodes, 1952, p. 895, pl. 127, fig. 15.

Idiognathodus magnificus Stauffer and Plummer; Hass, 1962b (in Mamay and Yochelson), p. 209, pl. 34, fig. 43.

[?] Idiognathodus meekerensis Murray and Chronic, 1965, p. 601, pl. 71, figs. 13-29.

Idiognathodus delicatus Gunnell; Stibane, 1967, p. 334, pl. 37, figs. 9-11.

[?] Idiognathodus meekerensis Murray and Chronic; Stibane, 1967, p. 334, pl. 37, figs. 12-22.

Idiognathodus delicatus Gunnell; Koike, 1967, p. 304, pl. 2, figs. 18-23.

A single specimen fits this specific category as described by Ellison (1941) and Merrill (1964). The reader is referred to the section dealing with the Sp element of Idiognathodus magnificus Stauffer and Plummer for a discussion of the status of these two species.

Material: 1 specimen; figured specimen UKMIP 1,900,937.

Distribution: Queen Hill Shale Member, Lecompton Limestone.

Idiognathodus tersus Ellison, Sp element

Pl. 4, figs. 1 a - d

Idiognathodus tersus Ellison, 1941, p. 134, pl. 23, figs. 4-5
[misprinted as figs. 5-6].

This element was defined by Ellison (1941) as an idiognathodid platform lacking accessory lobes and having six to fifteen complete transverse ridges.

Partial ontogenetic series of this element have been recovered. Immature individuals are characterized by having a longer carina and few transverse ridges. As the element becomes larger, the carina becomes shorter and ends farther anteriorly. The difference in the length of the carina between immature and mature specimens is not as pronounced as in the Sp element of S.elegantulus. The transverse ridges increase in number until in mature individuals they number about nine. In some specimens, particularly those from the Queen Hill Shale frills on either side of the sulci flare outwards.

As pointed out by Merrill (1964), the Sp element of I.tersus is completely intergradational morphologically with that of S.oppletus. Immature Sp elements of I.tersus can be differentiated from those of S.oppletus only with great difficulty and it is necessary to have sufficient material to assemble ontogenetic series.

The Sp element of Idiognathodus tersus is commonly associated with that of Idiognathodus antiquus. Considerable time was spent arranging growth stages of these Sp elements to determine if these were synonmous;

however, it was concluded that this was unlikely because mature individuals of equal size of both species have been found often within the same sample. Distributional and ontogenetic information about these species are needed from other parts of the Pennsylvanian.

Merrill (1964) included Sp elements which bore a rudimentary inner accessory node in I.tersus. Such specimens were included by the writer in I.antiquus.

Material:	365 specimens; figured specimens UKMIP 1,900,938 to 1,900,941.
Distribution:	Plattsmouth Limestone Member, Oread Limestone to the Queen Hill Shale Member, Lecompton Limestone.

Idiognathodus antiquus Stauffer and Plummer, Sp element

Pl. 4, figs. 2 a - e

Idiognathodus antiquus Stauffer and Plummer, 1932, p. 44, pl. 4, fig. 17.

Idiognathodus porcatus Gunnell, 1933, p. 272, pl. 31, fig. 21.

Idiognathodus chiriformis Gunnell, 1933, p. 272, pl. 31, fig. 23.

Idiognathodus liratus Gunnell, 1933, p. 273, pl. 31, fig. 27.

Idiognathodus corrugatus Gunnell, 1933, p. 277, pl. 32, fig. 7 [non fig. 6].

Idiognathodus antiquus Stauffer and Plummer; Ellison, 1941, p. 136, pl. 23, figs. 1, 7, 18 [misprinted as figs. 1, 8, 19].

Idiognathodus sinuosis Ellison and Graves, 1941, p. 6, pl. 3, fig. 22.

Idiognathodus cf. I.antiquus Stauffer and Plummer; Rhodes, 1952, p. 895, pl. 127, fig. 21.

Idiognathodus antiquus Stauffer and Plummer; Jones, 1956, p. 132, text-fig. 7.5 (16 a - b).

Idiognathodus humerus Dunn, 1966, p. 1300, pl. 158, figs. 6-7.

Idiognathodus humerus Dunn, 1970a, p. 333, pl. 63, figs. 1-2, text-fig. 9K.

Idiognathodus sinuosis Ellison and Graves; Dunn, 1970a, p. 333, pl. 63, figs. 3-4, text-fig. 9L.

Idiognathodus humerus Dunn, 1970b, p. 2970, text-fig. 4 [misprinted as *I.humerosus* in text-fig. 4].

Idiognathodus sinuosis Dunn, 1970b, p. 2970, text-fig. 4.

Idiognathodus antiquus is distinguished from other species of *Idiognathodus* by having an accessory lobe on the inner side of the platform (Ellison, 1941; Merrill, 1964).

Excellent ontogenetic series of this element have been recovered particularly from the Spring Branch Limestone. Very small specimens are characterized by having two to four complete transverse ridges at the posterior end and a carina which extends approximately two-thirds of the length of the platform. The carina terminates against a complete ridge. In smaller specimens, the inner accessory lobe is present only as a single, sometimes poorly defined, node.

As the element grows there is an increase in overall size and in the number of complete transverse ridges. As the number of transverse ridges increase and they are present farther anteriorly, the carina becomes shorter until in mature specimens the carina extends only about one-quarter of the length of the platform, still terminating against a transverse ridge. In medium sized specimens the node grows larger, gradually forming an accessory lobe. This accessory lobe becomes progressively larger until in large specimens the lobe usually consists of several nodes or a single prominent node.

Immature specimens have relatively straight platforms; however, as the element increases in size, a noticeable twist inwards of the posterior end develops, producing an asymmetrical platform. Platform elements of this form have been called *I.sinuosis* by Ellison and Graves (1941).

Although there is neither an oral trough or groove, a slight concavity of the oral surface is generally present. The carina in many medium sized and larger specimens is set off from the platform on either side by deep, descending sulci, resulting in the anterior portion of the parapets extending as free edges.

Both sinistral and dextral forms of the Sp element of *I.antiquus* have been recovered, in approximately equal numbers. Dunn (1966) named what he defined as an exclusively sinistral form, *I.humerus* and believed (Dunn, 1970a) that this together with *I.sinuosis* represented a conodont pair. He considered *I.humerus* to be distinct from *I.antiquus* because the type of the former, a platform element, was a dextral specimen. This does not seem to be a valid criteria for the definition of a new species, for had Stauffer and Plummer (1932) been concerned with conodont element pairs then they could just as well have selected a sinistral, or both a sinistral and a dextral element for their type.

Immature specimens have either a very poorly defined lobe or lack it altogether. When the accessory lobe is missing then the specimens are difficult to distinguish from the Sp elements of *I.tersus*. When such specimens occur in association with more mature forms clearly assignable to *I.antiquus*, the writer has placed them with this latter category. The difficulty arises, however, when only immature specimens are present in a sample, a condition possibly influenced by sorting. In cases like this there is little alternative but to place the specimens in *I.tersus*.

Material: 230 specimens; figured specimens UKMIP 1,900,942 to 1,900,945.

Distribution: Plattsmouth Limestone Member, Oread Limestone to Queen Hill Shale Member, Lecompton Limestone.

Idiognathodus sp.

Sp elements of *Idiognathodus* that were poorly preserved or broken and which could not be identified to species were placed in this taxonomic category.

Material: 37 specimens.

Streptognathodus and *Idiognathodus* Oz, Ne, Hi and Tr elements

The conodont elements described on the following pages under the above heading are considered to be the nonplatform components of the species of *Streptognathodus* and *Idiognathodus* of this study, except possibly those of *Streptognathodus gracilis*, *Streptognathodus gracilis* [?], and *Streptognathodus excelsus*. The recognition of these elements as the nonplatform elements of species of *Streptognathodus* and

Idiognathodus was based on comparisons with the element composition of natural assemblages (Rhodes, 1952), theoretical considerations discussed by Jeppsson (1971), and the constant association of these elements with each other and with the platform elements of species of *Streptognathodus* and *Idiognathodus*. R-mode cluster analysis grouped the elements here called *Streptognathodus elegantulus* Sp element, *Streptognathodus* and *Idiognathodus* Oz element, *Streptognathodus* and *Idiognathodus* Ne element, *Streptognathodus* and *Idiognathodus* Hi element, and *Streptognathodus* and *Idiognathodus* Tr element together in the *Streptognathodus* biofacies. These elements are interpreted to be components of the apparatus of the multielement species *Streptognathodus elegantulus*; however, the last five of these elements are also interpreted to be component parts of other species of *Streptognathodus* and *Idiognathodus*. As pointed out in the summary of biofacies analysis, in R-mode analysis a conodont element can only be clustered at one point on the dendrogram despite the fact that it may have been a component part of the apparatuses of different species. Cluster analysis places them with the most regularly occurring component, in this case the Sp element of *Streptognathodus elegantulus*.

On the basis of Rhodes' (1952) work, it is likely that *Streptognathodus gracilis*, *Streptognathodus gracilis* [?], and *Streptognathodus excelsus* bore the same nonplatform elements as did other species of *Streptognathodus*; however, R-mode cluster analysis grouped these three species together with the rare elements, *Synprioniodina* sp. A, *Neoprioniodus* sp. A, and *Plectospathodus* sp. (figs. 15 to 18 and Table 14). Although unlikely, the possibility exists that the apparatuses of *Streptognathodus gracilis*, *Streptognathodus gracilis* [?], and Streptognathodus excelsus may have contained one or more of these nonplatform elements. This cannot be confirmed in this study.

Streptognathodus and Idiognathodus Oz element

Pl. 7, figs. 4 a - h

For comprehensive synonymies the reader is referred to Rhodes, Austin and Druce (1969) and Webster (1969), under Ozarkodina delicatula (Stauffer and Plummer).

Small specimens are characterized by being slightly arched, having two to three discrete denticles on the anterior bar, a large major denticle oriented toward the posterior, and a posterior bar bearing five to six discrete denticles. There is a tendency in very small individuals to have a longer posterior than anterior bar.

Intermediate sized specimens are more common than smaller sized individuals and show a slightly greater amount of arching than the latter. The denticles are still discrete but may be irregular in size due to denticle insertion between larger denticles. The anterior bar has approximately the same length as the posterior bar and these bars carry three to four and five to six denticles respectively.

The largest individuals show nearly complete fusion of denticles, considerable arching, and an anterior bar longer than a posterior bar. In large individuals there is often a development of a downward "hooking" of the posterior bar at the extreme posterior end. (Pl. 7, fig. 4 c).

Both sinistral and dextral specimens have been collected. The anterior end of the blade usually curves inward whereas the posterior end is flexed outwards.

Material: 1326 specimens; figured specimens UKMIP 1,900,986 to 1,900,991.

Distribution: Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

Streptognathodus and *Idiognathodus* Ne element

Pl. 9, figs. 2 a - b

For a partial pre-1969 synonymy the reader is referred to Webster (1969) under *Synprioniodina microdenta* Ellison.

Synprioniodina forsenta Stauffer; Higgins, 1961, p. 220, pl. 12, fig. 8.

[?] *Synprioniodina laxilabrum* Rexroad and Collinson, 1965, p. 23, pl. 1, figs. 3-5.

Synprioniodina microdenta Ellison; Higgins and Bouckaert, 1968, p. 47, pl. 1, fig. 6.

[?] *Synprioniodina laxilabrum* Rexroad and Collinson; Thompson and Goebel, 1968, p. 44, pl. 3, fig. 10.

Synprioniodina microdenta Ellison; Webster, 1969, p. 50, pl. 8, fig. 15.

Euprioniodina microdenta (Ellison); Rhodes, Austin and Druce, 1969, pl. 22, figs. 16 a - b.

The Ne element shows little change during ontogenetic growth, other than an increase in size, and small immature individuals have essentially the same morphologic characteristics as larger mature ones.

The writer recovered both sinistral and dextral Ne elements. The existence of "pairs" of this species was evident from the literature.

For example, Higgins and Bouckaert (1968, pl. 1, fig. 6) illustrated a sinistral (?) individual while Igo and Koike (1964, pl. 27, figs. 11-17) figured dextral (?) specimens.

The detailed morphology of this element has been adequately described by Ellison (1941), Rhodes (1952), Igo and Koike (1964) and Rhodes, Austin and Druce (1969). The fine "needle-like denticles" which are located between the larger denticles on the posterior bar (Rhodes, et al., 1969) are sometimes missing. It is not known if this is of taxonomic or stratigraphic importance.

Examination of the figured paratypes plus the illustration of the holotype of Synprioniodina microdenta (Ellison, 1941, pl. 20, figs. 45, 46) shows that the figured material is considerably stouter and more symmetrical than that which later workers have placed in this species. This factor may necessitate taxonomic revision.

Material:	379 specimens; figured specimens UKMIP 1,901,008 to 1,901,009.
Distribution:	Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

Streptognathodus and Idiognathodus Hi element

Pl. 10, figs. 4 a - d
Pl. 11, figs. 3 a - d

This element has recently been described in detail by Higgins and Bouckaert (1968) and Rhodes, et al. (1969), and the reader is referred to these authors for synonymies under Hindeodella ibergensis Bischoff.

The element shows considerable variation in the degree of incurvature of the anterior bar. It was impossible to objectively subdivide this element taxonomically, on the basis of the variation in the anterior bar, since all morphologic intergradations occur, often within the same sample or member.

In a number of specimens a swelling of the posterior bar has been observed approximately one-third to one-half the total posterior bar distance from the main cusp (Pl. 10, figs. 4 a - d). Both sinistral and dextral specimens showing such swelling were found in the Shawnee Group; however, the material recovered was too fragmentary to evaluate possible taxonomic significance of this feature, and this may represent a pathologic phenomena.

Higgins and Bouckaert (1968) regarded this element type to have been the hindeodellid component of such natural assemblage genera as *Scottognathus* Rhodes.

Material: 330 specimens; figured specimens UKMIP 1,901,029 and UKMIP 1,901,037 to 1,901,039.

Distribution: Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

Streptognathodus and *Idiognathodus* Tr element

Pl. 16, figs. 4 a - d

[?] *Hindeodella pulchra* Ellison, 1941, p. 117, pl. 20, fig. 20.

Hibbardella fragilis Higgins, 1961, p. 213, pl. 12, fig. 4, text-fig. 2.

Hibbardella acuta Murray and Chronic, 1965, p. 598, pl. 73, figs. 3-5.

Hibbardella acuta Murray and Chronic; Higgins and Bouckaert, 1968,
p. 36, pl. 1, fig. 9.

Hibbardella (Hibbardella) acuta Rhodes, Austin and Druce, 1969, p. 112,
pl. 25, figs. 19 a - 20.

A number of the Kansas specimens show one, rarely two secondary denticles between the primary denticles of the anterior arch.

Mature and immature specimens are the same, with the exception of size, difference and the depth of the arch. The depth of the anterior arch varies slightly and does not seem to be as deep in immature specimens.

The element is extremely fragile and commonly broken. It is probable, but inconfirmable despite examination of the type, that Hindeodella pulchra Ellison represents the posterior bar of this element.

Although Rhodes (1952) did not find Tr elements in the apparatus of Scottognathus, Jeppsson (1971) stated that:

> "in lateral view, hindeodellized tr elements are so similar to hi elements that they are distinguished from pl and hi elements only by an investigation of both sides of the element which is possible in material preserved on shale surfaces only after extensive preparation. It seems probable that the fourth pair (?) of 'hindeodella' elements in this apparatus is the tr element."

On the basis of theoretical considerations, outlined by Jeppsson (1971), similarity of distribution (as expressed by cluster analysis and examination of the abundance data) and the hindeodellid denticulation of the posterior bar the writer considers this element to have been the Tr element of the species of Streptognathodus and Idiognathodus of this study, except possibly those of Streptognathodus gracilis, Streptognathodus gracilis [?] and Streptognathodus excelsus.

Material: 56 specimens; figured specimens UKMIP 1,901,093 to 1,901,096.

Distribution: Toronto Limestone Member, Oread Limestone, to the Holt Shale Member, Topeka Limestone.

Genus Cavusgnathus Harris and Hollingsworth, 1933

Type species.- Cavusgnathus altus Harris and Hollingsworth, 1933, original designation.

Lewistonella Scott, 1942, p. 299.

Adetognathus Lane, 1967, p. 930.

Lane (1967) proposed the genus Adetognathus for those Sp elements formerly assigned to Cavusgnathus, which if having a fixed blade at all, have one which is shorter than the long free blade. This proposal would, according to Lane, result in Pennsylvanian Sp elements previously placed in Cavusgnathus having to be included in Adetognathus. Lane included both sinistral and dextral Sp elements in Adetognathus, whereas Cavusgnathus was believed to contain only dextral forms.

As suggested by Webster (1969) the development of a longer free blade in the Sp element of Cavusgnathus represents an evolutionary trend which probably should not be recognized at the generic level.

The writer concurs in this opinion and believes that these differences should be recognized at the specific rather than the generic level.

The multielement species of this genus were recognized on the basis of similarity of distribution of the elements (using cluster analysis and examination of the conodont distributions), similar abundances of the sinistral and dextral Sp elements, color and white matter distribution, as well as analogous element composition to that reported by Scott (1942) in the natural assemblage genus *Lewistonella*. Although it is probable that the apparatus of *Cavusgnathus merrilli* n.sp. contained similar nonplatform elements to those borne by the other two species of this study, this cannot be confirmed.

Cavusgnathus lautus Gunnell Sp element

Pl. 4, figs. 3 a - h
Pl. 5, figs. 1 a - i

Cavusgnathus lautus Gunnell, 1933, p. 286, pl. 31, figs. 67-68.

Cavusgnathus gigantus Gunnell, 1933, p. 286, pl. 33, figs. 7-8.

Cavusgnathus missouriensis Gunnell, 1933, p. 286, pl. 33, figs. 10-11.

Cavusgnathus lautus Gunnell, 1933, p. 286, pl. 33, fig. 9.

Cavusgnathus lauta Gunnell; Ellison, 1941, p. 126, pl. 21, figs. 47-48.

Cavusgnathus giganta Gunnell; Ellison, 1941, p. 126, pl. 21, figs. 44-45, 49.

Cavusgnathus giganta Gunnell; Ellison and Graves, 1941, p. 2, pl. 3, fig. 3.

Cavusgnathus lauta Gunnell; Ellison and Graves, 1941, p. 2, pl. 3, fig. 2.

Cavusgnathus giganta Gunnell; Branson, 1944, p. 325, pl. 45, figs. 44-45, 49.

Cavusgnathus lauta Gunnell; Branson, 1944, p. 325, pl. 45, figs. 47-48.

Cavusgnathus giganta Gunnell; Youngquist and Downs, 1949, p. 162, pl. 30, figs. 18-20.

Cavusgnathus arca Sturgeon and Youngquist, 1949, p. 383, pl. 75, figs. 11-12.

Cavusgnathus giganta Gunnell; McLaughlin, 1952, p. 620, pl. 83, figs. 3-4, 6-7.

Cavusgnathus unicornis Youngquist and Miller; Stibane, 1967, p. 333, pl. 35, figs. 1-5.

Cavusgnathus cf. *regularis* Youngquist and Miller; Stibane, 1967, p. 333, pl. 35, figs. 6-7.

Cavusgnathus regularis Youngquist and Miller; Stibane, 1967, p. 333, pl. 35, figs. 8-19.

Adetognathus giganta (Gunnell); Lane, 1967, p. 931, pl. 120, figs. 16, 18-19; pl. 121, figs. 8, 12-13, 16.

Adetognathus lauta (Gunnell); Lane, 1967, p. 933, pl. 121, figs. 1-5, 10-11, 14-15, 17, 18.

Adetognathus sp. Lane, 1967, p. 934, pl. 122, figs. 3, 8.

Cavusgnathus gigantus Gunnell; Webster, 1969, p. 26, pl. 4, fig. 6.

Cavusgnathus lautus Gunnell; Webster, 1969, p. 28, pl. 4, fig. 9.

Adetognathus gigantus (Gunnell); Dunn, 1970a, p. 325, pl. 61, figs. 2-3, text-fig. 10E.

Adetognathus lautus (Gunnell); Dunn, 1970a, p. 327, pl. 61, figs. 1, 4, text-fig. 10C.

Adetognathus inflexus Dunn, 1970a, p. 327, pl. 61, figs. 8-10, 15-16, text-fig. 10D.

Adetognathus lautus (Gunnell); Dunn, 1970b, text-fig. 4.

Adetognathus gigantus (Gunnell); Dunn, 1970b, text-fig. 4.

Adetognathus inflexus Dunn, 1970b, text-fig. 4.

Adetognathus gigantus (Gunnell); Thompson, 1970, p. 1044, pl. 139, figs. 9-10, 14, 26.

Adetognathus lautus (Gunnell); Thompson, 1970, p. 1044, pl. 139, figs. 21-23.

Adetognathus sp. A Thompson, 1970, p. 1045, pl. 139, figs. 11, 15, 17-19.

The sinistral Sp component of this species has previously usually been described under the trivial name lautus, whereas the dextral Sp element has been referred to under the trivial name gigantus. Webster (1969) pointed out that if C.gigantus was not known to have a slightly earlier geologic occurrence than C.lautus, then abundance counts of the number of right (dextral) and left handed (sinistral) specimens would suggest that they represent the right and left handed forms of a conodont pair. The apparent disparity in stratigraphic range is quite small and may be due to sampling factors.

The writer counted 1263 sinistral specimens of the lautus type and 1242 dextral specimens of the gigantus type in his Shawnee Group collections. The orientation of the remaining 14 specimens could not be determined. On the basis of these similar abundances the writer concludes that these two forms represent an asymmetrical conodont pair. Their slight asymmetry has seemingly prevented previous workers from synonymizing them; however, the writer sees no reason for regarding only perfectly symmetrical conodonts as pairs in a conodont bearing animal.

Detailed descriptions were given by Lane (1967) for these two forms under separate species names. It should be noted, however, that Lane considered the specimens which Ellison (1941) figured as C.lauta to be a distinct, possibly new species.

Immature specimens of both sinistral and dextral Sp elements have a short fixed blade (Pl. 4, figs. 3 d - e; Pl. 5, figs. 1 f - g). As the elements mature (i.e. get larger) the inner parapet develops anteriorly and any sign of a fixed blade is lost. (Pl. 4, fig. 3 a; Pl. 5, figs. 1 a - b).

Sinistral Sp element: (Pl. 4, figs. 3 a - h). In oral view both mature and immature specimens have an inner parapet which is noticeably higher than the outside parapet. This results in a certain asymmetry of the element. The parapets bear transverse ridges which are shorter on the outer than on the inner parapet. The transverse ridges die out toward the moderately deep trough. The trough is deepest near the centre of the element and is V shaped in cross-section; however, because the parapets decrease in height toward the posterior, the trough is usually open at that end. The posterior end is sharply pointed and sometimes a short blade is developed. Immature elements are quite slim, but in mature specimens the parapets bulge outwards.

Aborally, a moderately deep, elongated basal cavity is present. The basal cavity is bordered on either side by a flaring apron and anteriorly the basal cavity continues into the blade as a narrow groove.

As seen laterally, the inner parapet overhangs the basal cavity considerably and there is a sharp indentation at the junction of the flaring apron and the lower portion of the inner parapet. The overall element is elongated and shows only slight arching.

The posterior tip of the element, when seen laterally, varies from being nearly vertical to overhanging slightly. The outer parapet decreases in height anteriorly; however, at or near the point at which the inner parapet disappears, the outer parapet gives rise to a denticulated blade having a length of one-third to slightly less than one-half the overall element length.

A fixed blade, if present, consists of only one or two denticles. The free blade begins gradually in the form of a small denticle. Anteriorly the denticles increase in size reaching a maximum height about half-way along the free blade and again decreasing regularly in height anteriorly. There is some variation in the number and development of denticles. Generally, four denticles are present in the blade; however, there is a tendency for fusion of denticles making denticle counts unreliable.

Dextral element: (Pl. 5, figs. 1 a - i). As seen in oral view both parapets are of equal height and without noticeable asymmetry. Both parapets bear transverse ridges of nearly equal length on either side of the trough. The ridges do not extend into the oral trough. Small specimens have nearly parallel sides. Mature forms have sinuous parapets and have a tendency to become wedge-shaped. The posterior end of the element is sharply pointed and because the parapets decrease in height posteriorly the posterior end is often open.

Aborally, a slender, moderately deep basal cavity is present. The basal cavity extends into the blade as a groove. In well preserved specimens, flaring aprons are present on either side of the basal cavity.

In inner lateral view the inner parapet of most specimens is slightly sinuous and concave. The sharp indentation at the junction of the inner side and the flaring apron observed in the sinistral element is not as strongly developed.

In outer lateral view the element is convex and at a point slightly more than halfway from the posterior tip the outer parapet suddenly rises to form a rather prominent denticle. This sudden appearance of a major denticle is not found in the sinistral element of the species. Anterior to the main denticle there may be a series of denticles of nearly similar size or there may only be several much smaller inconspicuous denticles.

As in the sinistral form there is a tendency toward fusion of denticles. Many of the smaller specimens bear four to six denticles on the blade; however, in larger mature specimens these have apparently been resorbed and often there is only a single large denticle or else a fused row of denticles the number of which cannot be determined.

In many specimens there is a tendency for the main cusp and the blade to be slightly offset towards the oral trough away from the outer parapet from which it originates. This offsetting occurs at the junction of the outer parapet and the first large denticle.

Material: 2519 specimens; figured specimens UKMIP
1,900,946, to 1,900,960.
Distribution: Lawrence Shale to the Severy Shale.

Cavusgnathus flexus Ellison, Sp element

Pl. 5, figs. 2 a - b

Cavusgnathus flexa Ellison, 1941, p. 126, pl. 21, figs. 42-43, 46.

Cavusgnathus flexa Ellison; Branson, 1944, p. 325, pl. 45, figs. 42-43, 46.

Cavusgnathus flexa Ellison; McLaughlin, 1952, p. 620, pl. 83, fig. 2.

The element occurs as both sinistral and dextral forms and possesses a conspiciously rounded posterior. According to Ellison (1941) it lacks a large denticle at the junction of the blade and the parapet, and has a widely flared apron.

Lane (1967) considered C.flexus to be a junior synonym of C.lautus Gunnell. Although Ellison (1941, pl. 21, figs. 42, 43, 46) figured a sinistral specimen, the finding of dextral Sp elements of C.flexus makes it impossible to place this form in C.lautus Gunnell in the sense of Lane (1967). It is possible that C.flexus as here recognized represents a variant of C.lautus Gunnell as here redefined; however, until its distribution is better known it seems best to continue to recognize this as a separate species.

Material: 54 specimens; figured specimens UKMIP 1,900,961 to 1,900,962.

Distribution: Heumader Shale Member, Oread Limestone, to the Turner Creek Shale Member, Topeka Limestone.

Cavusgnathus merrilli n.sp.

Pl. 5, figs. 3 a - f

Diagnosis.- Elongate Sp elements which occur as symmetrical sinistral and dextral forms and which are characterized by an oversized nearly central free blade, symmetrical parapets which are parallel in immature and bulging slightly outwards in mature specimens. Although the species may bear similar or identical Oz, Ne, Hi and Tr elements to those of C.lautus and C.flexus, this cannot be established at the present time.

Description.- In oral view, small sinistral and dextral forms exhibit an elongated slender platform with parallel parapets of equal height. Larger specimens have parapets which bulge outwards symmetrically, so that the outline formed by the parapets is biconvex. The parapets are not sinuous or irregular in outline as C.lautus Gunnell. The height of the parapets above the V-shaped trough is the same in both parapets except that at the anterior limit of the outer parapet, at the junction with the blade, it rises very slightly in height and continues as the blade. Both parapets decrease in height at the posterior end causing the posterior end to be open. Transverse ridges are present and these extend from the parapets into the trough, although stopping before reaching the deepest portion of the trough. The posterior end is rounded, although not as sharply as some Sp elements of C.flexus. One of the characteristic features, a blade which is nearly central is best observed in oral view. This feature is particularly striking in immature specimens and the orientation (i.e. sinistral or dextral) cannot be differentiated with certainty in these.

Aborally, a long moderately deep wedge shaped basal cavity is present. The basal cavity starts from a narrow point at the posterior end and gradually widens uniformly anteriorly, reaching a maximum width under the posterior end of the blade. Flaring aprons are present on either side of the basal cavity; however, they are only poorly preserved in most specimens.

In inner lateral view the free blade is seen to be as long as or longer than the platform. Although the platform is unarched, the blade, particularly in small specimens, arches sharply downward and gives the whole element an arched appearance. The size of the blade is somewhat out of proportion to the size of the platform. The inner parapet is slightly overhanging; however, the sharp indentation found at the junction of the lower inner parapet and the flaring apron of the sinistral Sp element of C.lautus Gunnell appears to be missing or only slightly developed.

The free blade starts as a small denticle and anterior to this there is a gradual increase in the size of denticles. However, rather than one denticle being dominant, four or five equally large, sometimes delicate, denticles are present. Toward the anterior limit of the blade a smaller denticle or two is present and the anterior terminus of the blade is vertical.

In some specimens, particularly the larger ones from the Larsh-Burroak Shale, the white matter of the platform is restricted to the transverse ridges and below this the conodont is a translucent amber color.

Remarks.- Species of Cavusgnathus with median or near median blade are not common. This feature has been found, for example, in

Streptognathodus [?] unicornis of Rexroad and Burton (1961). For a discussion of the latter species and its taxonomic history, the reader is referred to Lane (1967) and Webster (1969). The possibility exists that Cavusgnathus merrilli is recapitulating in part of its growth an ancestral species like Streptognathodus [?] unicornis Rexroad and Burton. The species differs from species of Taphrognathus in not having a central blade and lacking a carina. It is similar to some species of Idiognathoides as figured by Lane (1967, pl. 123, figs. 10, 16-17).

Etymology.- Named after Dr. G. K. Merrill formerly of Monmouth College, Illinois, and presently at the University of Texas at Arlington, who generously aided the writer in many ways.

Material:	155 specimens; figured specimens, holotype UKMIP 1,900,963, paratypes UKMIP 1,900,964 to 1,900,965; unfigured paratypes UKMIP 1,901,097 to 1,901,106.
Distribution:	Kereford Limestone Member, Oread Limestone, to the Coal Creek Limestone Member, Topeka Limestone. The most abundant specimens of this species were recovered in the Larsh-Burroak Shale Member, Deer Creek Limestone.

Cavusgnathus sp.

Many Sp elements could be identified only as Cavusgnathus sp. on the basis of the preserved posterior tip. Most of these fragments probably represent fragments of the platform element of Cavusgnathus lautus Gunnell.

Material: 1433 specimens.

Cavusgnathus Oz, Ne, Hi and Tr elements

The conodont elements described on the following pages under the above heading are considered to be the nonplatform components of Cavusgnathus lautus and Cavusgnathus flexus.

Cavusgnathus Oz element

Pl. 8, figs. 1 a - e

The element shows little arching or lateral bowing, has a nearly straight aboral margin, possesses a very short anterior blade bearing two to six compressed denticles and a very long thin posterior blade bearing numerous compressed discrete denticles. Near the posterior tip of the posterior bar one or two larger posteriorly inclined spike-like denticles may be present.

The entire blade-like element is laterally compressed to a noticeable degree and lacks any sign of a swelling or thickening parallel to its length above its aboral edge. Anterior to the main cusp there are two to six compressed slightly posteriorly inclined denticles which increase in size toward the main cusp. Small immature specimens bear two to three anterior bar denticles, whereas larger mature specimens have up to six. In larger specimens there is a tendency toward fusion of these denticles.

The main cusp is considerably higher and wider than any of the other denticles. It is, like all the denticles, laterally compressed and has very sharp anterior and posterior edges. In small specimens it is straight with a very sharp tip. In larger specimens the main cusp is often slightly recurved.

The posterior blade is thin and, anterior to the posterior tip region, there are three to five short weak denticles. The number of posterior bar denticles depends on size and smaller denticles are inserted between the slightly larger ones. The denticles of the posterior blade appear to be more irregular, less dominant, and farther apart than those of the anterior bar.

Aborally, an elongate, shallow basal cavity is present, mainly under the main cusp. The basal cavity tip is inclined anteriorly and the basal cavity is continued anteriorly and posteriorly as a narrow groove.

Both sinistral and dextral forms have been found. In inner lateral view the element is concave and the posterior bar twists inward further than does the lower part.

The color and distribution of white matter is of interest. Unaltered specimens, particularly from green shales, are a transparent to translucent amber brown color in their lower one-third. White matter appears in the denticles in the form of white feathery structures.

Comparison.- This element is most similar to Ozarkodina recta Rexroad; however, it differs in having a much shorter anterior than posterior blade. It differs from the Oz element of Streptognathodus and Idiognathodus in not being strongly arched, having denticles which are compressed to a greater degree, having a much shorter anterior than posterior bar and having a different white matter distribution.

Material:	179 specimens; figured specimens UKMIP 1,900,992 to 1,900,995.
Distribution:	Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

Cavusgnathus Ne element

Pl. 9, figs. 5 a - b

Neoprioniodus epemoebus Rexroad, 1957, p. 34, pl. 2, figs. 15, 21.

The posterior bar, which is long, slender and delicate in small immature specimens, is stouter in mature specimens. It is slightly arched but shows little lateral bowing and bears six or more laterally compressed, slightly inward-curving, anteriorly inclined denticles. The main cusp is biconvex in cross-section, is curved inward, and is noticeably inclined anteriorly.

The aboral groove extending along the posterior bar is shallow but relatively wide. It expands slightly on the inner side at the base of the main cusp. There is no anticusp present. Instead, the aboral edge curves gently around and continues as the anterior edge of the main cusp. Both mature and immature specimens have been recovered. Other than the greater size and robustness in mature specimens, there is apparently little difference between them.

Both sinistral and dextral specimens were recovered.

Material:	91 specimens; figured specimens UKMIP 1,901,013 to 1,901,014.
Distribution:	Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

Cavusgnathus Hi element

Pl. 11, figs. 2 a - b

This element, of which both sinistral and dextral specimens have been recovered, is shorter than, but most similar to, the element which has been called Hindeodella montanaensis (Scott) by Rhodes, Austin, and Druce (1969).

Material:	42 specimens; figured specimen UKMIP 1,901,035.
Distribution:	Snyderville Shale Member, Oread Limestone, to the Coal Creek Limestone Member, Topeka Limestone.

Cavusgnathus Tr element

Pl. 16, figs. 3 a - c

Diplododella alternata Branson and Mehl; Murray and Chronic, 1965,
p. 597, pl. 73, figs. 1-2.

This element has been found only as small specimens. The anterior lateral bars are symmetric to slightly asymmetric and form a shallow arch. They curve anteriorly, so that each arm is convex when seen in anterior view. The denticulation of the anterior bars, although poorly preserved, apparently consists of alternating large and small denticles (Pl. 16, fig. 3 b). The main cusp is laterally compressed and inclined posteriorly. It is flat on the lower one-half to three-quarters of the anterior edge and sharp above this. The posterior edge is sharp-edged. A cross-section of the cusp near the base is triangular in outline; near the top, it is biconvex. Aborally, a narrow aboral groove is present under the posterior bar. It expands slightly under the main cusp to form a sub-triangular basal cavity. No continuation of the aboral groove into the anterior lateral bars was observed.

Comparison.- This element is distinct from, but similar to, Hibbardella ortha Rexroad. The reader is referred to Thompson and Goebel (1968), Webster (1969), and Rhodes, Austin and Druce (1969) for discussions of H.ortha. It differs from H.ortha in having anteriorly bowed anterior bars. It differs from H.milleri Rexroad in lacking a central denticle anterior to the main cusp, possessing an anteriorly bevelled main cusp, in being more delicate, and in not being as irregular in anterior bar symmetry. It is smaller than the Tr element of

Ligonodina conflexus (Ellison), and bears distinct denticulation on the anterior lateral and posterior bars.

The denticulation of Diplododella alternata Branson and Mehl is distinct from that of this element.

The specimen illustrated on Pl. 16, fig. 3 a, is the only specimen of its type recovered and it may not belong to a species of Cavusgnathus.

Remarks.- The consistent association of this element with the elements of the Cavusgnathus biofacies, the results of cluster analysis (Table 15) as well as theoretical considerations presented by Jeppsson (1971) suggest that this represents the Tr element of Cavusgnathus lautus and Cavusgnathus flexus. In this regard it is of possible significance to note that Scott (1942) figured a specimen (Pl. 40, fig. 16) which could well have been the posterior bar of the Tr element of the natural assemblage Lewistonella.

Material:	12 specimens; figured specimens UKMIP 1,901,091 to 1,901,092.
Distribution:	Heumader Shale Member, Oread Limestone, to the Du Bois Limestone Member, Topeka Limestone.

Genus Anchignathodus Sweet, 1970a

Type Species.- Anchignathodus typicalis Sweet, 1970a, original designation.

The genus Anchignathodus was established by Sweet (1970a; 1970b) for apparatuses containing "only paired individually asymmetric elements that are more or less conspiciously arched, straight or slightly bowed blades."

In establishing this genus Sweet recognized the fact that Lower Carboniferous and younger Sp elements which had previously been placed in the genus Spathognathodus were distinct from older conodonts of the same general morphology, by having a large cup-like basal cavity rather than a small navel and a narrow aboral groove, and in being morphologically closest to several form genera included by Hass (1959, 1962a) in the Idiognathodontinae.

The writer's analysis supports Sweet (1970a; 1970b) in the concept that the only elements contained in the apparatus of Anchignathodus were paired Sp elements. Although the inability to find associated elements was initially believed to be in conflict with the element composition of the natural assemblage, Lochriea Scott, it appears that the elements previously assigned to Spathognathodus were component parts of a number of multielement apparatuses having different element compositions and belonging to different families. Lochriea Scott represents one such apparatus. A second apparatus of this type was figured by Jeppsson (1969, fig. 2) and by Lindström (1970, fig. 8). Anchignathodus is a third such apparatus.

Perlmutter (1971) probably incorrectly applied the element blueprint of Jeppsson (1969) and Lindström (1970), which was based on Silurian collections, to Upper Pennsylvanian and Lower Permian collections. The writer believes that Perlmutter was dealing with a new species of Anchignathodus and that the elements which Perlmutter considered to be part of the same apparatus were in fact part of the apparatus of Cavusgnathus lautus. This is strongly supported by the writer's R-mode cluster analyses, as well as by morphological evidence.

Anchignathodus minutus (Ellison)

Pl. 6, figs. 2 a - i

Spathodus minutus Ellison, 1941, p. 120, pl. 20, figs. 50-52.

[?] *Spathognathodus minutus* (Ellison); Ellison and Graves, 1941, p. 3, pl. 2, figs. 1, 3, 5 [mispelled *S.minutis* on p. 3].

Spathognathodus minutus (Ellison); Youngquist and Downs, 1949, p. 169, pl. 30, fig. 4.

Spathognathodus minutus (Ellison); Sturgeon and Youngquist, 1949, p. 385, pl. 74, figs. 9-11; pl. 75, fig. 19.

[?] *Spathognathodus* cf. *minutus* (Ellison); Huckriede, 1958, p. 162, pl. 10, fig. 8.

[?] *Spathognathodus minutus* ? (Ellison); Clarke, 1960, p. 20, pl. 3, figs. 9, 14-15.

Spathognathodus minutus ? (Ellison); Hass, 1962b (*in* Mamay and Yochelson), p. 209, pl. 34, fig. 36.

Spathognathodus minutus (Ellison); Rexroad and Burton, 1961, p. 1156, pl. 141, figs. 10-11.

Spathognathodus cf. *minutus* (Ellison); Rhodes, 1963, p. 404, pl. 47, fig. 3.

Spathognathodus echigoensis Igo and Koike, 1964, p. 187, pl. 28, fig. 24 [non fig. 25].

Spathognathus minutus (Ellison); Dunn, 1965, p. 1149, pl. 140, figs. 15, 21, 24.

Spathognathodus minutus (Ellison); Murray and Chronic, 1965, p. 606, pl. 72, figs. 29-30.

Spathognathodus minutus (Ellison); Igo and Koike, 1965, p. 88, pl. 9, figs. 16-18.

Spathognathodus minutus (Ellison); Koike, 1967, p. 311, pl. 3, figs. 39-42.

Spathognathodus coloradoensis Murray and Chronic; Koike, 1967, p. 310, pl. 3, fig. 23 [non fig. 24].

Spathognathodus cristula Youngquist and Miller; Stibane, 1967, p. 335, pl. 35, figs. 21-25.

Spathognathodus minutus (Ellison); Webster, 1969, p. 44, pl. 7, fig. 4.

[?] Spathognathodus rexroadi Webster, 1969, p. 45, pl. 7, figs. 1-3.

Spathognathodus minutus (Ellison); Dunn, 1970a, p. 339, pl. 61, figs. 27, 30.

[?] Anchignathodus typicalis Sweet, 1970a, p. 7, pl. 1, figs. 13, 22.

[?] Anchignathodus typicalis Sweet, 1970b, p. 222, pl. 1, figs. 13, 20.

Among the anchignathodids recovered there are many individuals of varying size which lack denticles anterior to the main cusp and thus fit the definition of Spathognathodus cristula of Youngquist and Miller (1949). No relatively complete ontogenetic series of individuals lacking denticles anterior to the main cusp could be assembled, nor could any stratigraphic restriction in distribution be detected. In any sample containing very abundant individuals of A.minutus only a few both matures and immature specimens of the cristula type were present. Ellison and Graves (1941) identified a group of Pennsylvanian anchignathodids lacking anterior denticles as Spathognathodus minutus (Ellison). These forms were called Spathognathodus cristula by later authors (Rexroad and Burton, 1961) but are still considered synonymous with Spathognathodus minutus by Ellison (1970, personal communication).

The writer considers the individuals lacking denticles anterior to the main cusp to be variants of Anchignathodus minutus (Ellison).

Immature individuals of Anchignathodus minutus are characterized by having only a minimum of four to five posterior denticles, a short stubby subtriangular outline in lateral view, a main cusp which is not conspicuously larger than the posterior denticles, and a large subtriangular basal cavity. The anterior margin is relatively straight from the top to the base of the main cusp. At the base of the main cusp, the anterior margin projects slightly at the point at which the first anterior denticle will grow. As specimens mature they increase in size, in length, in the number of posterior denticles, and a strengthening of the main cusp. Fourteen to fifteen laterally compressed posterior denticles which are fused for most of their length are already present in medium sized specimens. Anterior to the main cusp one to two medium sized small denticles may appear. Mature and gerontic specimens are characterized by large size plus coalescing of denticles.

The symmetrical basal cavity is restricted to the posterior two-thirds of the element and this position does not vary during ontogeny. The elongated posterior terminus of the basal cavity extends only as far as to the posterior limit of the element, sometimes in the form of a short aboral groove. The anterior terminus is more rounded and continues anteriorly as a narrow aboral groove. A basal cavity tip, the oral extension of the basal cavity into the main cusp, is present. Striations parallel to the length of the denticles are observed at high magnification (Pl. 6, fig. 2 g). Both sinistral and dextral forms have been recovered (Pl. 6, figs. 2 h - i).

Material: 1323 specimens; figured specimens UKMIP 1,900,970 to 1,900,977.

Distribution: Lawrence Shale to the Coal Creek Limestone Member, Topeka Limestone.

Anchignathodus adenticulatus n.sp.

Pl. 7, figs. 1 a - b

Diagnosis.- This is a species of Anchignathodus which lacks denticles on the posterior half to one-third of the blade. Instead of denticles the blade is continued as a knife-edge-like posterior extension which is continuous in height with the anterior denticles of the blade. A large basal cavity which extends beyond the posterior limit of the blade is present. The anterior and posterior margins of the species are vertical, or nearly so and do not overhang. A basal cavity tip has not been observed even at high magnification.

Description.- The species has only been found as medium sized to small specimens. The laterally compressed main cusp is only moderately large and is in some specimens replaced by two thinner, spike-like denticles of equal height. The anterior margin of the main cusp is nearly vertical. In none of the specimens examined were denticles anterior to the main cusp(s); however, some specimens have a slight anterior projection or anterior curvature at the base of the main cusp(s). Posterior to the main cusp(s) are two to six laterally compressed denticles. In some specimens these denticles decrease evenly in height posteriorly, whereas in others they are irregular in height. The oral side of the posterior one-half to one-third of the blade is occupied by a knife-edge-like extension which is usually continuous in height with the denticles of the blade. The extension is generally clear and shows no white matter; however, in one specimen occur what are apparently remnants of the white matter of denticles. These remnants plus the projections on the knife-like extension suggest that the posterior denticles of the bar have been resorbed. The posterior margin of the species is nearly vertical in relation to the long axis of the element.

In the specimens available there is little lateral bowing and it has not been possible to determine if both sinistral and dextral elements are present.

Aborally, the basal cavity is large, thin-walled, oval in outline, and the posterior portion extends appreciably beyond the posterior limit of the blade. The basal cavity continues anteriorly as a very short, thin, aboral groove and even at high magnification there is little evidence of a basal cavity tip. The blade itself is slightly arched but the underlying basal cavity fits into this arch so that the overall element shows little or no arching.

Comparison.- The species is most similar to *Anchignathodus coloradoensis* (Murray and Chronic). *Anchignathodus coloradoensis* was characterized by Murray and Chronic (1965) as having a denticle depression, a vertical anterior edge, long fourth and fifth denticles and a subelliptical basal cavity confined to the posterior half and extending slightly beyond the posterior end of the blade. Illustrations of *A. coloradoensis* (Murray and Chronic, 1965, pl. 72, figs. 11-12) show no evidence of lack of denticles on the posterior portion of the posterior bar and the authors stated that the "denticles on the posterior portion of the figured specimens of A.coloradoensis are broken, but if present, the longest denticle would apparently be nearly equivalent to the longest denticle on the anterior half of the blade." Examination of the types clearly shows that posterior denticles are indeed lacking; however, the posterior portion is not damaged and consists of a nondenticulated ridge. Clearly the types require refiguring and redescribing. In addition to the type material, the writer examined specimens of A.coloradoensis from Nevada, kindly made available by Dr. G. D. Webster. The material from Nevada is similar to the type material. A.adenticulatus differs from A.coloradoensis in lacking a denticle depression and having a posterior ridge which is continuous in height with the blade denticles, rather than being considerably lower.

Spathognathodus ohioensis of Merrill (in manuscript) is closely related to A.adenticulatus n.sp. but differs in having an overhanging posterior margin. A.adenticulatus n.sp. and A.moorei n.sp. are often associated and intergradations of the two exist.

Etymology.- In allusion to the lack of denticles on the posterior portion of the blade.

Material:	20 specimens; figured specimens, holotype UKMIP 1,900,979; paratype UKMIP 1,900,978; unfigured paratypes UKMIP 1,901,107 to 1,901,111.
Distribution:	Plattsmouth Limestone Member, Oread Limestone, to the Spring Branch Limestone Member, Lecompton Limestone.

Anchignathodus sp. cf. A.campbelli (Rexroad)

Pl. 7, fig. 2

Spathognathodus campbelli Rexroad, 1957, p. 37, pl. 3, figs. 13-15.

A single poorly preserved specimen differs from other anchignathodids found in the Shawnee Group by its elongated, low form, its lack of a subtriangular outline, its subequally sized denticles and its apparent lack of a main cusp.

The specimen seems most similar to A.campbelli (Rexroad); however, much more and better material is needed before a definite relationship can be established.

Material: 1 specimen; figured specimen UKMIP 1,900,980.

Distribution: Ervine Creek Limestone Member, Deer Creek Limestone.

Anchignathodus moorei n.sp.

Pl. 7, figs. 3 a - f

Diagnosis.- A small species of Anchignathodus having a number of slender delicate denticles near the anterior end of the blade, a distinctive subelliptical basal cavity which extends beyond the posterior limit of the blade, and near vertical anterior and posterior margins.

Description.- The blade is thin, laterally unbowed and unarched. At the anterior end of the blade a varying number of fine, approximately equal sized laterally compressed denticles are present. In some specimens the most anterior denticle is the largest with a gradual reduction in height of denticles posteriorly. In other specimens the two most anterior denticles are the longest (Pl. 7, fig. 3 a). More rarely the third to the fifth denticles are the longest (Pl. 7, fig. 3 c). Anterior to the larger anterior denticles there may be one to several small denticles, usually near or at the base of a larger denticle. Posterior to the anterior denticle(s) there is a rapid decrease in height and prominence of the denticles until near the posterior end of the bar only very short compressed denticles are present. A denticle gap or a sudden drecrease in height of denticles may be present immediately posterior to the larger anterior denticle(s) (Pl. 7, fig. 3 c).

Aborally, a large, thin-walled, subelliptical basal cavity is present. The basal cavity occupies approximately the posterior three-quarters of the aboral side of the element and extends farther posteriorly than does the blade. Anteriorly, the basal cavity widens slightly before narrowing and continuing as a thin short aboral groove. In lateral side view the basal cavity is seen to be relatively shallow being the deepest at a point slightly posterior and aboral to the larger anterior denticles. No basal cavity tip has been observed.

The apparent lack of lateral bowing and the relatively symmetrical basal cavity has made it difficult to distinguish sinistral and dextral forms.

A microstructure of fine striations on the denticles has been observed under high magnification (Pl. 7, fig. 3 d).

Comparison.- *Anchignathodus moorei* is closely related to *Anchignathodus adenticulatus* n.sp. and *Anchignathodus spiculus* (Youngquist and Miller, 1949). Unlike *Anchignathodus adenticulatus* n.sp. it has denticles extending to the posterior limit of the blade. *Anchignathodus minutus* (Ellison) has a large broad main cusp, denticles which gradually decrease in height posteriorly, non-vertical anterior and posterior edges, and a deeper more anterior basal cavity clearly showing a basal cavity tip. *A.spiculus* (Youngquist and Miller) and *A.moorei* n.sp. are similar; however, *A.moorei* n.sp. is smaller and more delicate in its gross morphology, has very fine more irregular denticles, and a flaring apron which extends posteriorly beyond the blade.

Etymology.- Named after Dr. R. C. Moore, University of Kansas, who has for many years encouraged paleoecologic research on the cyclic sediments of Kansas.

Material: 356 specimens; figured specimens, holotype UKMIP 1,900,981; paratypes UKMIP 1,900,982 to 1,900,985; unfigured paratypes UKMIP 1,901,112 to 1,901,121.

Distribution: Toronto Limestone Member, Oread Limestone, to the Coal Creek Limestone Member, Topeka Limestone.

Anchignathodus sp.

Broken or poorly preserved anchignathodids which could not be identified to species were placed in this taxonomic category.

Material: 36 specimens.

Superfamily Gondolellidae Lindström 1970

Family Gondolellidae Lindström 1970

Genus Gondolella Stauffer and Plummer, 1932

Type species.- Gondolella elegantula Stauffer and Plummer, 1932, original designation.

Illinella Rhodes, 1952, p. 898.

Ellison (1941) reported three species of Gondolella from the Queen Hill Shale of the Lecompton Formation, although only two of these, G.denuda and G.elegantula were indicated on his distribution charts.

Gondolella denuda Ellison

Pl. 6, figs. 1 a - f
Pl. 8, figs. 3 a - b, 4 a - b

The elements belonging to this multielement species are constantly associated with one another in a restricted stratigraphic interval. The similarity of distribution was well shown by cluster analysis (figs. 15 to 18), and some of the implications of grouping these elements into a single multielement species have been discussed in the section dealing with the taxonomic interpretation of the Gondolella biofacies. The Oz and Hi (?) elements both bear an unusually deep and large basal cavity, one which penetrates about halfway up the cusp. The axis of the basal cavity is not parallel to that of the cusp but is vertical in relation to the posteriorly inclined main cusp. All three of the elements are a transparent dark brown color except for their denticles, the upper half of which is a characteristic translucent white.

Sp element

Pl. 6, figs. 1 a - f

The reader is referred to Clark and Mosher (1966) under *Gondolella denuda* for a complete synonymy of this element.

The elements recovered agree in most respects with previous descriptions (Ellison, 1941; Clark and Mosher, 1966) of the Sp element of *Gondolella denuda* Ellison. The distinguishing feature of the Sp element is a platform which is rudimentary or absent. In the specimens examined by the writer, the number of blade denticles ranged from eight to fifteen and seem to vary with size. The blade denticles were found to be shorter than those illustrated by Ellison (1941) and Clark and Mosher (1966). Both sinistral and dextral forms of this element were found.

Material:	23 specimens; figured specimens UKMIP 1,900,967 to 1,900,969.
Distribution:	Queen Hill Shale Member, Lecompton Limestone. In the Shawnee Group of Nebraska the element is also restricted to the Queen Hill Shale (Mendenhall, 1951).

Oz element

Pl. 8, figs. 3 a - b

Euprioniodina sp. B, Stauffer and Plummer, 1932, p. 32, pl. 2, fig. 34.

Bryantodus cameratus Gunnell, 1933, p. 268, pl. 32, fig. 47.

Prioniodina ? camerata (Gunnell); Ellison, 1941, p. 118, pl. 20, figs. 48-49, 53. [On plate 20 cited as Prioniodina ? camerata (Stauffer and Plummer)].

Ozarkodina camerata (Ellison); Lindström, p. 107, fig. 40 A.

The reader is referred to Prioniodina ? camerata (Gunnell) in Ellison (1941) for a description of this element. Both sinistral and dextral specimens were recovered.

Material: 12 specimens; figured specimen UKMIP 1,900,997.

Distribution: Queen Hill Shale Member to lowermost Beil Limestone Member, Lecompton Limestone.

Hi (?) element

Pl. 8, figs. 4 a - b

Hindeodella sp., Ellison, 1941, p. 118, pl. 20, fig. 19.

The element has been recovered only as individuals bearing incomplete anterior and posterior bars. The anterior bar is apparently the stouter but bears an unknown number of denticles which are flat on the inside and slightly convex on the outside of the element. The posterior bar bears at least three small denticles having similar characteristics to those of the anterior bar. The main cusp is long and slender, and about halfway up from its base bends slightly posteriorly and inwards. It is characterized by having a concave inner side and a convex outer side. The basal cavity is subelliptical, flares on the outer side and has a straight margin on the inner side. (Pl. 8, fig. 4 a).

Material: 6 specimens; figured specimen UKMIP 1,900,998.

Distribution: Queen Hill Shale Member, Lecompton Limestone.

Superfamily Prioniodinacea (Bassler 1925)

Family Prioniodinidae Bassler 1925

Genus *Ligonodina* Bassler, 1925

Type species.- *Ligonodina pectinata* Bassler, 1925, original designation.

Ligonodina conflexus (Ellison)

Pl. 12, figs. 1 a - c

Pl. 14, figs. 1 a - c, 2 a - b, 4 a - b

Pl. 16, figs. 1 a - d

The elements of this multielement species have characteristic sparse denticulation, and broad aboral grooves and basal cavities. The elements have a similar distribution and are most often found in the green shales of the *Cavusgnathus* biofacies. The fact that they are consistently associated is reflected in the results of R-mode analysis (Table 15).

Most of the Pl (?), Ne (?), and Oz (?) elements are, in unaltered specimens,transparent and of a golden brown color. The middle part of the denticles is translucent and of a solid white color. The denticle tips are clear, nearly colorless, and often contain trains of triangular interlamellar spaces similar to those shown by Lindström (1964, p. 18, fig. 4 B). The Hi and Tr elements are generally larger and are, at least in lower portion of the bars, also transparent and also of a golden brown color. The denticles and the upper part of the bars of some specimens are a translucent white color. This color is caused by rays of white matter similar to those shown by Lindström (1964, p. 16, fig. 3 E). As in Lindström's illustration a train of triangular interlamellar spaces is seen in most denticles. Some Hi and Tr elements are perfectly clear throughout and rays of white matter could not be seen.

The Hi and Tr elements form part of a symmetry transition similar to that illustrated by Lindström (1964, p. 81, fig. 27 E-I). It is probable that the Oz (?), Ne (?), and Pl (?) elements are part of the same series.

The species as here recognized has an analogous element composition to Ligonodina elegans of Jeppsson (1969).

Hi element

Pl. 12, figs. 1 a - c

This element consists of a short anterior and long posterior bar on the aboral side of which a distinctive long, wide aboral groove extends the full length of both bars. Unlike the Hi element of Ligonodina subacoda (Gunnell) in which the groove expands sharply into a pronounced basal cavity, the widening of the basal cavity in this element is gradual (Pl. 12, fig. 1 c). There are one to two discrete denticles on the anterior bar and two on the posterior bar. There is a characteristic spike-like denticle at the posterior tip of the posterior bar. The denticulation is noticeably sparse and the bar denticles are smaller than the recurved main cusp. The main denticle is sharply compressed in mature specimens and has a sharp anterior edge. In immature specimens the main cusp is more gently rounded in cross-section. Both sinistral and dextral specimens have been recovered (Pl. 12, figs. 1 a - b).

Comparison.- The element is most similar to the Hi element of Ligonodina subacoda and to Ligonodina lexingtonensis. It differs from both in having a characteristic basal cavity and aboral groove, having longer anterior and posterior bars, lacking shovel-like aprons and having characteristic denticulation.

Material: 53 specimens; figured specimens UKMIP 1,901,046 to 1,901,047.

Distribution: Snyderville Shale Member, Oread Limestone to the Sheldon Limestone Member, Topeka Limestone.

Pl (?) element

Pl. 14, figs. 1 a - c

Euprioniodina ? sp. Gunnell, 1933, p. 269, pl. 33, fig. 24.

Prioniodus ? conflexus Ellison, 1941, p. 114, pl. 20, fig. 25.

A number of perfect specimens of this element have been recovered. Immature specimens have a large main cusp and a large basal cavity but lack anterior or posterior bars (Pl. 14, fig. 1 a). As the element increases in size the posterior bar develops followed by the anterior bar. With maturity the bars increase in strength and denticles develop (Pl. 14, fig. 1 b). Both sinistral and dextral specimens were recovered.

Comparison.- Lonchodina festiva of Bender and Stoppel (1965) is very similar to this element.

Material:	18 specimens; figured specimens UKMIP 1,901,068 to 1,901,070.
Distribution:	Leavenworth Limestone Member, Oread Limestone, to the Curzon Limestone Member, Topeka Limestone.

Ne (?) element

Pl. 14, figs. 2 a - b

This is a simple laterally compressed horn-like element which aborally bears a large, flaring subcircular basal cavity. Anterior to the main cusp there are one or two erect small denticles. The main cusp, which dominates the element, is inclined posteriorly and is slightly curved. The basal cavity is unusually large and has a subcircular outline. The anterior side of the basal cavity is, unlike the posterior side, elongated rather than subcircular. This elongation is the result of the two sides of the flaring apron coming together causing a depression. The basal cavity is shallow and a small basal cavity tip is present under the main cusp. Anterior to the main cusp one or two small nearly vertical denticles are present.

Material: 5 specimens; figured specimens UKMIP
1,901,071 to 1,901,072.

Distribution: Snyderville Shale Member, Oread Limestone,
to Jones Point Shale Member, Topeka
Limestone.

Oz (?) element

Pl. 14, figs. 4 a - b

This element has an unusually broad, elongated basal cavity and on the specimens available bears four discrete, very slightly laterally compressed denticles. Anterior to the main cusp, which is the second denticle from the anterior, there is a single straight denticle of approximately half the length of the main cusp. The main cusp is recurved and the basal cavity deepens into a basal cavity tip under it (Pl. 14, fig. 4 b). Posterior to the main cusp there are two straight posteriorly inclined denticles. These may be of equal length or the more posterior denticle may be the shorter. A short posterior projection may be present at the base of the last posterior denticle.

The element is only slightly arched; however, it is sharply bowed laterally. Between the main cusp and the first posterior denticle there is a sharp flexure, so that the two posterior denticles lie in a different plane to the main cusp and the anterior denticle. The basal cavity underlies all of the element, is broadest slightly posterior to the main cusp, and narrows towards either extremity. Due to the flexure there is a flaring of the inner apron between the main cusp and the first posterior denticle. Both sinistral and dextral specimens have been recovered.

Material: 9 specimens; figured specimens UKMIP 1,901,074 to 1,901,075.

Distribution: Snyderville Shale Member, Oread Limestone, to the Hartford Limestone Member, Topeka Limestone.

Tr element

Pl. 16, figs. 1 a - d

This element has a long, slightly curved posterior bar bearing as many as six well developed, discrete denticles and two lateral anterior bars which, although usually broken off, are very short, stout, and apparently carry only one denticle each (Pl. 16, fig. 1 c). The large recurved main cusp is laterally compressed and, in most but not all specimens, the anterior and posterior edges are sharp. The lateral bars project anteriorly making an obtuse angle with the plane of the posterior bar. At the junction of the two lateral bars and the main cusp, a characteristic anterior bevel (Pl. 16, fig. 1 d), which may be large or small, is present. Aborally, a wide, moderately deep groove extending the full length of the posterior bar is present (Pl. 16, fig. 1 a). This groove bifurcates under the main cusp and continues somewhat shallower in the lateral arms. A well developed basal cavity was not observed under the main cusp.

Material: 20 specimens; figured specimens UKMIP 1,901,085 to 1,901,088.

Distribution: Toronto Limestone Member, Oread Limestone, to the Sheldon Limestone Member, Topeka Limestone.

Ligonodina subacoda (Gunnell)

Pl. 9, figs. 6 a - b

Pl. 12, figs. 3, 4 a - c

Pl. 16, figs. 2 a - b

This multielement species was defined on the basis of the constant association of its elements in a restricted stratigraphic interval. The element association was initially recognized by inspection of the distribution charts and was supported by R-mode cluster analysis (Table 17).

The element composition of this species is similar to that of the natural assemblage species which Rhodes (1952) described under the name Duboisella typica as well as to Ligonodina elegans and Plectodina furcata of Jeppsson (1969). The writer has not yet had the opportunity of examining the type species of Duboisella. Although Rhodes (1952) reported a metalonchodinid element as part of his assemblage such an element was not recovered by the writer.

As pointed out by Lindström (1970) the denticles of species of the family Prioniodinidae "are usually long and discrete, the cusps particularly prominent and the basal cavity not very deep." This description agrees with those of the elements of this species except that some elements such as the Hi and Pl elements have a deeper basal cavity. The elements of this species all have rather short stubby posterior, and in some elements anterior bars. Unaltered elements are transparent and a golden brown color except for the denticles which may be partially or wholly composed of translucent white matter, generally in the upper half.

Ne element

Pl. 9, figs. 6 a - b

Prioniodus conjunctus Gunnell, 1931, p. 247, pl. 29, fig. 7.

Higgins (1962) and Rhodes, et al. (1969) have provided comprehensive synonymies and descriptions of this element under Neoprioniodus conjunctus (Gunnell).

Immature specimens are similar to mature ones except that apparently there is less fusion of denticles, and they are smaller.

Both sinistral and dextral forms have been recovered.

Material: 45 specimens; figured specimen UKMIP 1,901,015.

Distribution: Heebner Shale Member to the Plattsmouth Limestone Member, Oread Limestone.

Hi element

Pl. 12, fig. 3

Idioprioniodus typus Gunnell, 1933, p. 265, pl. 31, fig. 47.

Prioniodus ? galesburgensis Gunnell, 1933, p. 267, pl. 31, fig. 12.

Ligonodina typa (Gunnell); Ellison, 1941, p. 114, pl. 20, figs. 8-11.

Ligonodina typa (Gunnell); Rhodes, 1952, p. 897, pl. 128, figs. 1, 4-6.

Ligonodina typa (Gunnell); Bischoff and Ziegler, 1956, p. 149, pl. 13, fig. 25.

Ligonodina typa (Gunnell); Bischoff, 1957, p. 31, pl. 5, fig. 3-4, 12.

Ligonodina typa (Gunnell); Higgins, 1961, p. 220, pl. 11, fig. 6.

Ligonodina typa (Gunnell); Higgins, 1962, pl. 16, fig. 7.

Ligonodina hanaii, Igo and Koike, 1964, p. 186, pl. 28, figs. 21-22.

Ligonodina typa (Gunnell); Murray and Chronic, 1965, p. 602, pl. 72, figs. 35-36.

Ligonodina hanaii Igo and Koike, 1965, p. 86, pl. 8, fig. 8.

Ligonodina typa (Gunnell); Higgins and Bouckaert, 1968, p. 42, pl. 2, fig. 11.

Specimens of this element recovered from the Shawnee Group agree in most respects with descriptions by Ellison (1941) for this element; however, some variations were noted.

The element was described by Ellison (1941) as having a "lateral limb projected aborad-inward in a plane at approximately right-angles to the posterior bar". In the specimens examined this is not true in that this angle between the planes formed by the two limbs was more often greater than 90 degrees. The writer believes that this is also the case in the specimens illustrated by Ellison (1941, pl. 20, figs. 8-10) and Murray and Chronic (1965, pl. 72, figs. 35 and 36). The basal cavity is subelliptical and consists of a slight widening beneath the main cusp and continues anteriorly and posteriorly as a basal groove.

A feature that has been found useful in the identification of the element is best developed in mature individuals and consists of a characteristic aboral downward curvature of the inner, and sometimes the outer, margins of the basal cavity under the main cusp.

Both sinistral and dextral individuals were recovered.

Material: 56 specimens; figured specimen UKMIP 1,901,050.

Distribution: Heebner Shale Member, Oread Limestone, to the Hartford Limestone Member, Topeka Limestone.

Pl element

Pl. 12, figs. 4 a - c

Prioniodus clarki Gunnell, 1931, p. 247, pl. 29, fig. 8.

Prioniodus cornutus Stauffer and Plummer, 1932, p. 27, pl. 3, fig. 23.

[?] *Prioniodus clarki* Gunnell; Stauffer and Plummer, 1932, p. 27, pl. 3, figs. 27-28.

Lonchodina clarki (Gunnell); Ellison, 1941, p. 116, pl. 20, figs. 21, 27, 30-31.

Lonchodina clarki (Gunnell); Rhodes, 1952, p. 898, pl. 128, figs. 1, 3-6.

Lonchodina clarki (Gunnell); Murray and Chronic, 1965, p. 603, pl. 73, figs. 22, 28.

[non] *Lonchodina clarki* (Gunnell); Higgins and Bouckaert, 1968, p. 43, pl. 2, fig. 1.

The posterior sharp edge of the main cusp continues downward toward the base of the cusp, swerves slightly toward the inside of the cusp and is continuous and in line with the posterior bar. Viewed from the outer side, the basal part of the cusp is expanded posteriorly in such a manner as to produce a sharp "crease" (Pl. 12, fig. 4 c). Between the crease and the posterior sharp edge of the cusp, there is, near the base of the cusp, a concave groove. In most specimens the bars are broken off and missing and the crease has been found very useful in the identification of the element. However, the anterior bar is the more massive and the anterior bar denticles, when present, curve posteriorly similar to the main cusp. The posterior bar denticles could not be observed. The planes of the two bars diverge from each other at approximately 90 degrees when seen laterally. At the same time the two bars are directed downwards at approximately the same angle relative to the main cusp.

Aborally, a deep basal cavity is present under the main cusp and the basal cavity tip penetrates approximately one-third the way up the main cusp. The basal cavity is subelliptical and rounded at the posterior end. An aboral groove is present in both bars.

Both sinistral and dextral specimens have been recovered.

Comparison.- *Lonchodina paraclarki* Hass is probably synonymous with this element; however, it is necessary to examine the types of the former. *L.paraclarki* Hass has been illustrated by Hass (1953), Rexroad (1958), Stanley (1958), Thompson and Goebel (1968), and Rhodes,et al. (1969).

Material: 33 specimens; figured specimens UKMIP 1,901,051 to 1,901,053.

Distribution: Heebner Shale Member to Plattsmouth Limestone Member, Oread Limestone.

Tr element

Pl. 16, figs. 2 a - b

Prioniodus subacodus Gunnell, 1931, p. 246, pl. 29, fig. 5.

Prioniodus missouriensis Gunnell, 1931, p. 246, pl. 29, fig. 9.

Idioprioniodus striatus Gunnell, 1933, p. 265, pl. 32, figs. 36-37.

Hibbardella subacoda (Gunnell); Ellison, 1941, p. 118, pl. 20, figs. 22-26.

[?] Trichognathus subacoda (Gunnell); Ellison and Graves, 1941, p. 3, pl. 1, fig. 19.

Hibbardella subacoda (Gunnell); Youngquist and Heezen, 1948, p. 768, pl. 118, fig. 13.

Hibbardella cf. H. subacoda (Gunnell); Rhodes, 1952, p. 897, pl. 128, figs. 1, 3-4.

Roundya subacoda (Gunnell); Higgins, 1961, p. 220, pl. 11, fig. 13.

Roundya subacoda (Gunnell); Higgins, 1962, p. 11, pl. 1, fig. 1.

[?] Roundya sp. Webster, 1969, p. 43, pl. 8, figs. 7-8.

[?] Hibbardella sp. Dunn, 1970a, p. 332, pl. 64, fig. 29.

The reader is referred to Ellison (1941) for a description of this element under Hibbardella subacoda (Gunnell).

Material: 33 specimens; figured specimens UKMIP 1,901,089 to 1,901,090.

Distribution: Heebner Shale Member to Heumader Shale Member, Oread Limestone.

Ligonodina lexingtonensis (Gunnell)

Pl. 12, figs. 2 a - b

Prioniodus lexingtonensis Gunnell, 1931, p. 246, pl. 29, fig. 4.

Prioniodus tridentatus Gunnell, 1931, p. 246, pl. 29, fig. 3.

[?] *Prioniodus tridentatus* Gunnell; Stauffer and Plummer, 1932, p. 28, pl. 3, figs. 24-26.

Idioprioniodus camurus Gunnell, 1933, p. 265, pl. 32, fig. 30.

[?] *Euprioniodina* ? sp. Gunnell, 1933, p. 269, pl. 33, fig. 6.

Ligonodina lexingtonensis (Gunnell); Ellison, 1941, p. 115, pl. 20, figs. 13-15.

[?] *Ligonodina* aff. *L.lexingtonensis* (Gunnell); Sturgeon and Youngquist, 1949, p. 384, pl. 14, figs. 14-15.

The reader is referred to Ellison (1941) for a description of this species. The species as recognized by Gunnell (1931) and subsequent authors is based on Hi elements only.

Material: 28 specimens; figured specimens UKMIP 1,901,048 to 1,901,049.

Distribution: Heebner Shale Member to the Kereford Limestone Member, Oread Limestone.

Superfamily Uncertain

Family Uncertain

Genus Ellisonia Müller

Type species.- Ellisonia triassica Müller, 1956a, original designation.

Ellisonia teicherti Sweet

Pl. 10, figs. 1 a - d, 2 a - f

Pl. 11, figs. 1 a - c

Pl. 15, fig. 5

Ellisonia teicherti Sweet, 1970a, p. 8, pl. 1, figs. 3-4, 7-8, 12.

Ellisonia teicherti Sweet, 1970b, p. 232, pl. 4, figs. 20-28.

This multielement species was recognized on the basis of similarity of element distribution (as expressed by cluster analysis), of morphology and color, as well as by comparison with descriptions of the species by Sweet (1970a; 1970b).

Three of the four elements (the Pl, Hi, and Tr element) bear a characteristic callus, a groove parallel to the aboral margin. The Pl and Tr elements bear very similar small triangular basal cavities and are also most similar in their denticulation. The Hi, Pl and Ne elements have characteristic spatulate aboral projections. Unaltered elements of this species are transparent and are a light yellowish-brown color, except for most or all of their denticles which are a translucent white.

The elements placed in Ellisonia teicherti exhibit some variation from those placed in this species by Sweet (1970a; 1970b). The Ne element unlike the three other elements, cannot be shown to possess a callus, a characteristic groove parallel to the aboral margin. The callus is presumed to be the same structure that Sweet (1970a) termed "an escutcheonlike attachment surface on the inner side of the element". The LA element of *Ellisonia teicherti* (Sweet 1970a; 1970b) could not be identified in the writer's collections either on the basis of Sweet's figures or by comparison with hypotypes in the collections of the University of Kansas Museum of Invertebrate Paleontology.

Sweet (1970a; 1970b) considered the fact that all elements of *Ellisonia teicherti* were opaque and almost uniformly white in even earliest stages of growth to be of considerable significance. Unaltered elements of this species from the Shawnee Group are a transparent light yellowish-brown color except for most or all of the denticles, which are a translucent white.

Examination of the primary types of *Ellisonia teicherti* may show that the material from the Shawnee Group can, on the basis of morphological and color differences, be considered a new species. At the present time, however, the writer considers the Pennsylvanian material to fall within the range of variation of *Ellisonia teicherti*.

Ne element

Pl. 10, figs. 1 a - d

Ellisonia teicherti Sweet, 1970a, p. 8, pl. 1, fig. 4.

Ellisonia teicherti Sweet, 1970b, p. 232, LD elements pl. 4, figs. 27-28.

The long slender posterior bar which is slightly arched and bowed decreases in width posteriorly (Pl. 10, fig. 1 a). It bears numerous discrete or slightly compressed sharp denticles which are inclined anteriorly very gently and which alternate in size (Pl. 10, fig. 1 c). The laterally compressed main cusp is biconvex in cross section, is recurved, and is directed anteriorly. There are no denticles anterior to the main cusp; however, slightly posterior to the main cusp there may be a denticle which reaches nearly the same size as the main cusp. A well developed spatulate anticusp is present (Pl. 10, figs. 1 b - c).

The anterior end of the element curves sharply inward relative to the posterior bar (Pl. 10, fig. 1 c).

Aborally, a fine aboral groove is present under most, or all, of the posterior bar and anticusp. The aboral groove expands noticeably under the main cusp to form a basal cavity, the inner side of which flares so that there is a noticeable expansion (Pl. 10, figs. 1 a, 1 d).

Both sinistral and dextral specimens have been recovered (Pl. 10, figs. 1 a - b). Immature specimens apparently differ only in size and robustness from mature specimens.

Remarks.- The LD element of Sweet (1970b, pl. 4, figs. 27-28) bears a slightly longer main cusp than the writer's specimens. The writer has been unable to observe the escutcheonlike scar which Sweet mentions, although this is clearly present in the other elements assigned to the species.

Material: 231 specimens; figured specimens UKMIP 1,901,018 to 1,901,020.

Distribution: Toronto Limestone Member, Oread Limestone, to the Coal Creek Limestone Member, Topeka Limestone.

Pl element

Pl. 10, figs. 2 a - f

Ellisonia teicherti Sweet, 1970a, p. 8, pl. 1, fig. 7.

Ellisonia teicherti Sweet, 1970b, p. 232, LE element, pl. 4, fig. 24.

The orientation utilized by Sweet (1970a; 1970b) for this element is also used by the writer.

The sharply flexed element is characterized by having a main cusp which is only very slightly inclined and an anterior bar which is directed sharply upward and which in most of the writer's specimens is longer than the posterior bar.

The anterior bar bears numerous anteriorly inclined compressed needle-like denticles and may in some specimens (Pl. 10, fig. 2 c) have a very large anteriorly inclined spike-like terminating cusp which is biconvex in cross-section.

The main cusp is long,laterally compressed and biconvex in cross-section. It bears fine striations parallel to its length and is twisted slightly but generally lies in the plane of the posterior bar.

The overall element is rather sharply flexed and the point of flexure lies immediately anterior to the main cusp. The posterior bar also bears compressed nonalternating denticles which apparently increase in size posteriorly. The posterior termination may consist of a number of small denticles (Pl. 10, figs. 2 a - c) or a large vertical (Pl. 10, fig. 2 c) to inclined (Pl. 10, figs. 2 c - d) posterior denticle.

Aborally, a small triangular basal cavity best seen in inner lateral view, is present. In most specimens the anterior and posterior edges are sharp without a trace of an aboral groove; however, in large specimens a very fine hairline groove extends along most of the element. Well preserved specimens show a delicate structure here termed the aboral veil which extends the full length of the element. The aboral veil consists of two delicate parallel laminae through which, in some specimens, hook-like extensions can be seen at either end of the element. The relationship of the callus, the indented groove which runs parallel to the aboral margin (Pl. 10, figs. 2 c - d), to the aboral veil or to the inconspicious aboral groove is not clear. Seemingly, the aboral veil covers the aboral hooks in immature (?) specimens (Pl. 10, figs. 2 a - b). As the element increases in size the aboral veil becomes less delicate and shows itself externally as a callus. The aboral hooks get larger, appear from behind the veil and show themselves in the form of a variety of aboral hook-like structures (Pl. 10, figs. 2 c - f). Further evaluation of the development and relationship of the aboral veil, the aboral hook-like structures, the basal cavity and the callus is necessary.

Aborally, and directly under the main cusp, a very small, needle-like basal cavity is present. The axis of the basal cavity varies from being nearly parallel to the main cusp to being slightly oblique to it.

The anterior and posterior bars of unaltered specimens are clear and of a yellowish, brown color. The denticles are partially or entirely composed of white translucent matter.

Remarks.- The element shows considerable variation, and it may be possible, at a later date, to differentiate two element types. In the Heebner and Larsh-Burroak this element appears to be more massive, with shorter anterior and posterior arms, (Pl. 10, fig. 2 d). This is difficult to prove due to fragmentation of specimens.

A number of authors have reported elements of similar morphology, and it is likely that these are analogous in position and function in their respective apparatuses to the Pl element of Ellisonia teicherti. Arcugnathus tenuis, the type species of Arcugnathus Cooper 1943, is similar except that according to the original description, it lacked a main cusp and was apparently unflexed laterally. The type material of Arcugnathus tenuis could not be located and Rhodes (in Rhodes and Müller, 1966) considered the genus to be a nomen dubium and questionably placed it with Hindeodella. Hindeodella adunca of Bischoff and Ziegler (1957) and Hindeodella ? reversa of Pollock (1968) are morphologically similar to the Pl element of Ellisonia teicherti.

Material:	140 specimens; figured specimens UKMIP 1,901,022 to 1,901,024.
Distribution:	Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

Hi element

Pl. 11, figs. 1 a - e

[?] Hindeodella sp. a, Bender and Stoppel, 1965, p. 344, pl. 15, fig. 6.

Ellisonia teicherti Sweet, 1970a, p. 8, pl. 1, fig. 12.

Ellisonia teicherti Sweet, 1970b, p. 232, LB elements, pl. 4, figs. 21-22, 25-26.

This element is characterized by having a large anteriorly inclined denticle anterior to the main cusp, a spatulate anticusp and a callus which runs parallel to the aboral margin of the posterior bar and the anticusp.

The long straight posterior bar bears several compressed, erect to posteriorly inclined denticles and between each of these are numerous compressed smaller denticles. The posterior termination of the bar was not preserved in any of the writer's material. The large straight laterally compressed main cusp may be erect or inclined posteriorly (Pl. 11, fig. 1 a - b) and bears fine striations parallel to its length. Anterior to the main cusp there are one to several laterally compressed denticles of which the most anterior is the largest (Pl. 11, figs. 1 a, 1 c). The denticles anterior to the main cusp become increasingly inclined anteriorly away from the main cusp.

In small specimens there are apparently more denticles anterior to the main cusp (Pl. 11, fig. 1 c). As the element increases in size there is apparently a resorption of the smaller denticles so that in mature large specimens there is only a large anterior denticle present anterior to the main cusp with one or two smaller denticles inserted in between (Pl. 11, figs. 1 a, 1 e).

The anterior end of the platform curves sharply inward relative to the posterior bar (Pl. 11, fig. 1 b).

The anterior edge of the anteriormost denticle curves downward and gives rise to an anticusp. The shape of the anticusp varies from being broad (Pl. 11, fig. 1 c) to spatulate (Pl. 11, fig. 1 e). The shape of the anticusp may be a function of maturity and spatulate anticusps are more common in larger mature specimens.

Aborally, a small needle-like basal cavity is present under the main cusp. The basal cavity is continued posteriorly and anteriorly the full length of the element as a narrow aboral groove. A well developed callus is present parallel to the aboral margin (Pl. 11, fig. 1 b).

Both sinistral and dextral specimens have been recovered. Ontogenetic variation, other than an increase in size is mainly confined to a decrease with size in the denticle number between the main cusp and the anterior denticle.

Comparison.- This element is similar to H.megadenticulata of Murray and Chronic (1965). Examination of the figured and unfigured types shows that the latter has several well developed denticles in front of the large anterior denticle. Further, there is apparently a lack of denticulation between the main cusp and the large anterior denticle of H.megadenticulata.

Some of the unfigured paratypes of H.megadenticulata are nearly bilaterally symmetrical and need restudy.

Material:	278 specimens; figured specimens UKMIP 1,901,032 to 1,901,034.
Distribution:	Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

Tr element

Pl. 15, fig. 5

Ellisonia teicherti Sweet, 1970a, p. 8, pl. 1, fig. 3.

Ellisonia teicherti Sweet, 1970b, p. 232, U element, pl. 4, fig. 20.

The arms are of different lengths and one arm extends farther aborally than does the other. The arms are convex on the anterior side and concave on the posterior side. Seven to nine laterally compressed denticles are present on each arm. These denticles increase in length distally except for one or two small denticles right at the distal ends of the arms. The arrangement of denticles, is similar to that of Hindeodus sp. A. The main cusp is biconvex in cross-section, recurved posteriorly and is twisted slightly.

The aboral edge is sharp and seen laterally has a characteristic sinuous outline (Pl. 15, fig. 5).

A small basal cavity is present but an aboral groove was not observed. The entire aboral edge of the large specimens has a callus paralleling it on both sides of the element.

Comparison.- The element is larger and more symmetrical than those elements placed in Hindeodus sp. A.

It is possible that Hindeodus sp. A is an immature variant of the Tr element of Ellisonia teicherti. In dividing the elements into different forms the two were separated on the basis of differences in size, robustness and symmetry. The recognition and tabulation of two rather than just one form may have led to the anomalous placement of Hindeodus sp. A away from the other elements of Ellisonia teicherti in R-mode cluster analysis.

The angle at which the bars meet is less than that of Hindeodus sp. A but is greater than that of Synprioniodina ? compressa of Ellison and Graves (1941).

Material: 17 specimens; figured specimen UKMIP 1,901,084.

Distribution: Toronto Limestone Member, Oread Limestone, to the Hartford Limestone Member, Topeka Limestone.

FORM CLASSIFICATION

A number of conodont elements could not be related to a single or multielement conodont apparatus. Such elements were classified by form taxonomy. This is a valid procedure, according to the Rules of the I.C.Z.N.

Genus Ozarkodina Branson and Mehl, 1933b

Type species.- Ozarkodina typica Branson and Mehl 1933b, by original designation.

Ozarkodina sp. A

Pl. 8, figs. 2 a - b

The species is slightly arched and bowed. A large basal cavity, which is deepest under the main cusp, is present under most of the element. This basal cavity gradually narrows and tapers off towards both ends.

In the better preserved of the two specimens recovered there are four anterior and four posterior denticles. Those of the anterior are more closely spaced than those of the posterior. The denticles are compressed laterally to a slight degree. The main cusp is approximately double the length of the largest anterior or posterior denticle and bears fine ridges parallel to its length (Pl. 8, fig. 2 b).

Comparison.- The species is similar to the Oz element of Cavusgnathus lautus and Cavusgnathus flexus but differs in being arched and having an anterior bar of approximately the same length as the posterior bar. It differs from the Oz element of most species of Streptognathodus and Idiognathodus in having a much wider elongated basal cavity and in being shorter and more equidimensional. The species is also similar to O.huddlei of Druce (1969).

Material: 3 specimens; figured specimen UKMIP 1,900,996.

Distribution: Beil Limestone Member, Lecompton Limestone.

Ozarkodina [?] curvata Rexroad

Pl. 8, figs. 5 a - f

Bryantodus ? sp. Gunnell, 1933, p. 267, pl.,31, fig. 40.

Ozarkodina curvata Rexroad, 1958, p. 24, pl. 4, figs. 1-3.

Ozarkodina curvata Rexroad; Rexroad and Burton, 1961, p. 1156, pl. 141, figs. 13-14.

Ozarkodina curvata Rexroad; Rexroad and Furnish, 1964, p. 674, pl. 111, fig. 10 [non fig. 11].

Ozarkodina curvata Rexroad; Rexroad and Nicoll, 1965, p. 25, pl. 2, figs. 1-2.

Ozarkodina sp. aff. O.curvata Rexroad; Murray and Chronic, 1965, p. 605, pl. 73, fig. 29.

Ligonodina sp. Murray and Chronic, 1965, p. 603, pl. 73, fig. 16.

Ozarkodina sp. Murray and Chronic, 1965, p. 605, pl. 73, fig. 18.

Ozarkodina curvata Rexroad; Globensky, 1967, p. 446, pl. 56, fig. 20.

Ozarkodina curvata Rexroad; Thompson and Goebel, 1968, p. 40, pl. 4, fig. 19 [non pl. 3, fig. 11]

Ozarkodina curvata Rexroad; Rhodes, Austin and Druce, 1969, p. 168, pl. 27, fig. 6.

Ozarkodina curvata Rexroad; Webster, 1969, p. 42, pl. 7, fig. 10.

[?] Hindeodus sp.; Rhodes, Austin and Druce, 1969, p. 130, pl. 22, figs. 17 a - 20 b.

The abundant well-preserved specimens recovered by the writer agree in almost every detail with the original description of Rexroad (1958). The writer has recovered both sinistral and dextral forms of this species. In addition, good growth stages were studied and will be described briefly.

The smallest specimens of Ozarkodina [?] curvata (Pl. 8, fig. 5 f) have a very slender delicate posterior bar which already shows up to fourteen small denticles. At the anterior end a large, well developed posteriorly recurved cusp is present. The anterior bar is not developed and is present only as a single small denticle just anterior to the main cusp. The basal cavity is large and expands anteriorly and posteriorly as a basal groove. During ontogeny there is a corresponding increase in the number of anterior bar denticles and in the size of the anterior bar. The anterior bar denticles are apparently added at the anterior end of the anterior bar and the bar itself grows downward with an increase in size.

Medium sized individuals (Pl. 8, fig. 5 d) characteristically have two or three medium sized denticles on the anterior bar together with small projections anterior to these, at points where future denticles will grow. The posterior bar denticles are larger; however, apparently the size of the basal cavity does not change much during growth as it is approximately the same size in medium sized individuals as in smaller ones. Large, mature individuals (Pl. 8, figs. 5 a - b) are more robust and not so blade-like. The posterior limb is heavier, broader and not as thin as are smaller less mature specimens. There are from four to six laterally compressed denticles of varying sizes on the anterior bar. The maximum number of posterior bar denticles observed is fourteen. Aborally, the walls of the basal cavity are heavier and the aboral edge is relatively wide. The inner side of the basal cavity is only slightly expanded; the outer side is more so. An aboral groove which decreases in width toward the distal ends is present. The denticles, particularly the main cusp, are striated parallel to their length.

Material:	282 specimens; figured specimens UKMIP 1,900,999 to 1,901,003.
Distribution:	Toronto Limestone Member, Oread Limestone, to the Coal Creek Limestone Member, Topeka Limestone.

Ozarkodina ? _kansasensis_ n.sp.

Pl. 9, figs. 1 b - e

Diagnosis.- _Ozarkodina_ ? _kansasensis_ is characterized by a large, posteriorly recurved main cusp, compressed stout posterior bar denticles usually of a single relatively large size, up to two short compressed anterior bar denticles and an unusually large basal cavity extending anteriorly and posteriorly as an aboral groove.

Description.- The posterior bar is relatively straight along its aboral margin. Immediately behind the cusp the posterior bar is bowed inward relatively sharply so that the planes of the anterior and posterior bars are nearly at right angles to one another.

The anterior bar is downturned noticeably giving the entire element an arched aspect. The large recurved main cusp is bent very slightly at a point half-way to its tip. It is laterally compressed and biconvex in cross-section. In mature specimens the anterior bar is thin, blade-like and bears one or two short, hook-like compressed denticles. The posterior bar bears seven or more laterally compressed sharp discrete denticles, all of which, with the exception of the most posterior ones are of the similar size and height. The denticles near the posterior end of the posterior bar are slightly shorter.

Aborally, a very deep large basal cavity is present under the main cusp. Anteriorly, the basal cavity is rounded, posteriorly, it is elongated. The basal cavity is expanded only very slightly on the inner side but considerably on the outer side.

The preceding description is based on mature specimens. In addition it is of interest to describe the changes occuring during growth.

In the smallest specimens (Pl. 9, fig. 1 e), the anterior bar has not developed and only one small denticle is present at the base of the main cusp. The posterior bar bears two or more compressed, equally long denticles which are nearly the length of the main cusp. At the end of the posterior bar a single, shorter compressed denticle is present. The basal cavity is already large, even in small specimens.

During ontogeny, the anterior bar increases in size and another anterior bar denticle is added. At the same time there is an increase in the length of the posterior bar and in the number and size of the posterior bar denticles.

Both sinistral and dextral forms have been recovered.

Comparison.- The species is closely related to *Ozarkodina* [?] *curvata* Rexroad with which it is associated. Like *O.*[?] *curvata* Rexroad, it has the microstructure of fine striations (Pl. 9, fig. 1 c) on the denticles. Unlike *O.*[?] *curvata* Rexroad however, it has a main cusp which is bent and not straight, lacks the long and numerous anterior bar denticles, has more regular, heavier posterior bar denticles and a much larger basal cavity.

Etymology.- The species is named after the state of Kansas where it was first found.

Material:	35 specimens; figured specimens, holotype UKMIP 1,901,005, figured paratypes 1,901,006 to 1,901,007; unfigured paratypes UKMIP 1,901,122 to 1,901,131.
Distribution:	Heebner Shale Member, Oread Limestone, to the Beil Limestone Member, Lecompton Limestone.

Ozarkodina ? sp.aff. Ozarkodina ? kansasensis

Pl. 9, fig. 1 a

Two mature sinistral and dextral specimens were recovered. The posterior bar is long and relatively straight. The anterior bar is similar to an anticusp and is turned sharply downward relative to the posterior bar giving the overall element an arched appearance. In addition, the bar is laterally bowed.

The relatively small laterally compressed main cusp is recurved posteriorly. The three anterior bar denticles are very short, laterally compressed, and stub-like. The denticles are covered with very fine striations parallel to their length. The posterior bar is long and is covered with up to fourteen laterally compressed pointed denticles most of which are nearly of the same length.

Aborally, a large deep basal cavity, which is rounded anteriorly and elongated posteriorly, is present. The basal cavity is continued into both the anterior and posterior bar as an aboral groove. The aboral groove is wider and better developed in the posterior bar.

Remarks.- The writer is unable to determine if the specimens described are possibly very large individuals of Ozarkodina ? kansasensis n.sp. The specimens are larger than any specimens of O.? kansasensis and it has not been possible to link the two through intermediate specimens; however, the anterior bar denticulation of Ozarkodina ? sp. aff. O.? kansasensis appears to be distinct and different from that of O.? kansasensis n.sp.

Material: 2 specimens; figured specimen UKMIP 1,901,004.

Distribution: Plattsmouth Limestone Member, Oread Limestone.

Ozarkodina ? sp.

Broken or poorly preserved specimens which could not be identified to species but which were recognizable as being fragmentary remains of one of Ozarkodina [?] curvata, Ozarkodina ? kansasensis, or O.? sp.aff. O.? kansasensis were placed in this taxonomic category.

Material: 12 specimens.

Genus Synprioniodina Bassler, 1925

Type species.- Synprioniodina alternata Bassler, 1925, original designation.

The reader is referred to Huddle (1968) for a review of this genus.

Synprioniodina sp. A

Pl. 9, figs. 4 a - b

Euprioniodina caverna (Collinson and Druce); Rhodes, Austin and Druce, 1969, p. 90, pl. 22, figs. 11 a - b [nom.nud.].

[?] Euprioniodina sp. Rhodes, Austin and Druce, 1969, p. 91, pl. 22, figs. 15 a - b.

The most characteristic feature of the species is that the anterior bar reaches considerable length and stoutness. In the specimens from Kansas, the anterior bar bears eight to eleven well defined inward curving, discrete denticles. It is relatively straight and diverges from the thicker posterior bar at an angle of about 65 degrees.

The posterior bar is broken off entirely or partially in all the specimens studied; however, it, like the anterior bar, is stout and the denticles are noticeably larger than those of the anterior bar (Pl. 9, fig. 4 a). At the inner aboral junction of the anterior and posterior bars, a conspicuous rounded and flaring apical lamella (terminology of Rhodes, et al. (1969)) is present, the aboral sinuous edge of which is oriented nearly parallel to the anterior bar. At the outer aboral junction of the bars there is a depressed flat surfaced apical lamella. As used in context here, the term apical lamella (see also Fay (1952) and Hass (1962)), is considered identical to flaring apron of Ellison (1941) and flared lateral lip of Rexroad and Liebe (1962).

Aborally, a moderately large basal cavity is present under the main cusp. The basal cavity narrows towards the bars and continues in these as a narrow aboral groove.

Comparison.- The Ne element of *Streptognathodus* and *Idiognathodus* (Pl. 9, figs. 2 a - b) is most similar to this species but differs in having a weak, short, and poorly denticulated anterior bar which together with the posterior bar forms a rounded arch.

R-mode cluster analysis suggests that *Synprioniodina* sp. A may have been one of the component elements of one or all of *Streptognathodus gracilis*, *Streptognathodus gracilis* [?] and *Streptognathodus excelsus*. This cannot be demonstrated at this time conclusively.

Material:	8 specimens; figured specimens UKMIP 1,901,011 to 1,901,012.
Distribution:	Heebner Shale Member, Oread Limestone, to the Holt Shale Member, Topeka Limestone.

Synprioniodina sp. B

Pl. 9, fig. 3

The anterior bar of this species exhibits a decided anterior curvature and is longer than the anterior bar of similar elements. The element appears to be a transitional form between the Ne element of *Streptognathodus* and *Idiognathodus* (Pl. 9, figs. 2 a - b) and *Synprioniodina* sp. A (Pl. 9, figs. 4 a - b).

Material:	1 specimen; figured specimen UKMIP 1,901,010.
Distribution:	Spring Branch Limestone Member, Lecompton Limestone.

Genus Neoprioniodus Rhodes and Müller, 1956

Type species.- Prioniodus conjunctus Gunnell, 1931, original designation.

The reader is referred to Rexroad (1957) and Huddle (1968) for summaries of the taxonomic history of the genera Prioniodus and Neoprioniodus.

Neoprioniodus sp. A

Pl. 9, figs. 7 a - b

This element differs from the Ne element of Cavusgnathus lautus and Cavusgnathus flexus by possessing a well developed anticusp. It is most similar to Neoprioniodus loxus of Rexroad (1957); however, it appears to differ from the latter in having a more acute angle between the anticusp and the aboral margin of the posterior bar.

R-mode cluster analysis suggests that Neoprioniodus sp. A may have been one of the component elements of one or all of Streptognathodus gracilis, Streptognathodus gracilis [?] and Streptognathodus excelsus. This seems unlikely since the color and morphology of this element is much more like the Ne element of Cavusgnathus lautus and Cavusgnathus flexus than the Ne element of other species of Streptognathodus. It appears likely, but cannot be definitely established in this study, that Synprioniodina sp. A is the Ne element of Cavusgnathus merrilli n.sp. Of five samples containing Synprioniodina sp. A, four contain Cavusgnathus merrilli n.sp. In sample LB-1-3A from the Larsh-Burroak Shale an increase in the abundance of the Sp element of Cavusgnathus merrilli n.sp. is accompanied by a similar increase in the abundance of the Neoprioniodus sp. A. Although this might be considered fortuitous this sample contains the largest number of specimens of the two element types of all the samples in this study.

As indicated previously the nonplatform elements are, for various reasons, frequently underrepresented in conodont collections. Such underrepresentation could have the direct effect of causing a taxon to be placed incorrectly in R-mode cluster analysis.

Material: 21 specimens; figured specimens UKMIP 1,901,016 to 1,901,017.

Distribution: Larsh-Burroak Shale Member, Deer Creek Limestone, to the Coal Creek Limestone Member, Topeka Limestone.

Genus Plectospathodus Branson and Mehl, 1933b

Type species.- Plectospathodus flexuosus Branson and Mehl, 1933b, original designation.

For a discussion of this genus refer to Walliser (1957) and Ziegler (1960).

Plectospathodus sp.

Pl. 10, figs. 3 a - c

The orientation used by the writer is opposite to that employed by Rhodes, Austin and Druce (1969) in that the main cusp is considered to be posteriorly inclined and the bar anterior to the cusp is defined as the anterior bar.

This plectospathodid element has anterior and posterior bars of approximately equal length, each of which bear a series of discrete denticles. Both arching and lateral bowing are slight. On the two best preserved figured specimens the anterior and posterior bars each bear six discrete compressed denticles. The main cusp is the longest denticle on the element and is laterally compressed and inclined posteriorly.

Aborally, under the main cusp, a moderately large basal cavity is present. The basal cavity flares outward on the inner side, and is continued anteriorly and posteriorly toward the extremities as a groove which gets progressively narrower.

Remarks.- Rhodes, et al. (1969) reported the genus from Avonian (Carboniferous) rocks, although previously it had only been reported from beds of Upper Silurian and Lower Devonian age. Although rather rare, the Shawnee Group specimens apparently represent the first Pennsylvanian record of the genus.

R-mode cluster analysis suggests that *Plectospathodus* sp. may have been one of the component elements of one (or all) of *Streptognathodus gracilis*, *Streptognathodus gracilis* [?], and *Streptognathodus excelsus*. Although this seems unlikely, the rarity of this element in the rocks studied makes it impossible to say more about possible multielement relationships.

Material:	7 specimens; figured specimens UKMIP 1,901,027 to 1,901,028.
Distribution:	Heebner Shale Member, Oread Limestone, to the Ervine Creek Limestone Member, Deer Creek Limestone.

Genus Hindeodella Bassler, 1925

Type species.- Hindeodella subtilis Bassler, 1925, original designation.

The reader is referred to Huddle (1968) for a discussion and description of this genus.

Hindeodella parva Ellison

Pl. 11, figs. 4 a - d

Hindeodella parva Ellison, 1941, p. 117, pl. 20, fig. 29.

Hindeodella pulchra Ellison; Murray and Chronic, 1965, p. 559, pl. 72, fig. 28.

The species consists of a long denticulated posterior bar and a short denticulated anterior bar. Ellison (1941) based his original description on material that lacked the long denticulated posterior bar. The part designated as the posterior part by Ellison should be considered as anterior.

The anterior bar bears a large main cusp which may have one or two small denticles anterior to it. The posterior bar is two to three times the length of the anterior bar and lies in a plane approximately at a right angle to the latter. The posterior bar is slightly sinuous near its junction with the anterior bar. An aboral groove that expands slightly under the main cusp is present under both anterior and posterior bars.

Both sinistral and dextral forms of this species have been recovered. Usually, only the anterior bar is recognized due to breakage and the fact that the posterior bar by itself is difficult to distinguish.

Comparison.- A number of species recognized by other writers are similar to this species and may be identical with or closely related to it. These include the following:

Hindeodella croka Rhodes, Austin and Druce, in Rhodes, Austin and Druce (1969).

Hindeodella uncata Hass, in Hass (1959).

Hindeodella uncata (Hass), in Higgins and Bouckaert (1968) and Druce (1969).

Hindeodella brevis Branson and Mehl, in Branson and Mehl (1934), Bischoff and Ziegler (1956), Bischoff (1957), Higgins (1961, 1962), Wolska (1967), and Spassov and Filipovic (1967).

[?] Hindeodella recurvata Mosher, in Mosher (1968).

As indicated in the section dealing with the taxonomic interpretation of the Streptognathodus biofacies, this species and Ozarkodina [?] curvata may have been component elements of the same multielement apparatus.

Material:	71 specimens; figured specimens UKMIP 1,901,040 to 1,901,042.
Distribution:	Toronto Limestone Member, Oread Limestone, to the Coal Creek Limestone, Topeka Limestone.

Hindeodella sp. B

Pl. 11, fig. 5

This species possesses an anterior bar which instead of being deflected laterally to any degree is in nearly the same plane as the posterior bar. The posterior bar is straight and bears a number of larger denticles between which there are one to four secondary denticles. The anterior bar bears two or three discrete denticles and is deflected downwards fairly sharply so that an obtuse angle is formed between the two arms giving the overall element an arched appearance. The lateral deflection of the anterior arm inwards is very slight, being in the order of five to ten degrees. A moderately large, deep basal cavity, which is continued as a deep aboral groove posteriorly and anteriorly, is present under the main cusp.

Transitional forms between this species and the Hi element of Streptognathodus and Idiognathodus exist (Pl. 11, fig. 3 a); however, the species is restricted in its occurrence, and it appears likely that it is the Hi element of a multielement apparatus composed of some of the elements grouped in the Trichonodella biofacies (Table 16).

Comparison.- The species bears similarities to Hindeodella multihamata of Huckriede (1958) and subsequent authors.

Material:	7 specimens; figured specimen UKMIP 1,901,043.
Distribution:	Toronto Limestone Member, to the Plattsmouth Limestone Member, Oread Limestone.

Genus *Lonchodus* Pander, 1856

Type species.- *Centrodus simplex* Pander, 1856, by subsequent designation of Ulrich and Bassler (1926).

The reader is referred to Ulrich and Bassler (1926), Stauffer and Plummer (1932) and Sweet (1955) for a discussion of the genus. *Lonchodus* has come to be utilized for comb-shaped bars having inclined, generally straight, discrete denticles which are believed to be fragments of other better defined branch and bar type conodonts. Rhodes (*in* Rhodes and Müller, 1966) reported finding Pennsylvanian forms which fit the generic description and which he considered to be complete.

Lonchodus simplex (Pander)

Pl. 11, fig. 7

This taxonomic category is used in a strictly utilitarian manner in the sense of Hass (1953) for fragmentary comb-shaped bars having inclined, generally straight, discrete denticles.

Material: Several hundred fragments; figured specimen UKMIP 1,901,045.

Distribution: Heebner Shale Member, Oread Limestone, to the Hartford Limestone Member, Topeka Limestone. Most common in the Plattsmouth Limestone.

Lonchodus ? sp.

Pl. 11, figs. 6 a - b

This element is a slightly arched and very gently flexed element that is comb-like and bears twelve nearly erect, large, discrete denticles. The largest denticle is present at the approximate center of the bar and a smaller denticle is present between two larger denticles at three points. The base bearing the denticles is heavy and subcircular in cross-section. The denticles are not noticeably compressed.

At the anterior (?) end directly below the last denticle, an inner lateral projection is present (Pl. 11, fig. 6 b). Aborally, a narrow groove extends the entire length of the element and curves around into the anterior inner lateral projection. A basal cavity is apparently not present. The anterior inner lateral projection, which appears to be incomplete, is split where the aboral groove ends.

The described specimen is, with the exception of the possibly incomplete anterior inner lateral projection, perfectly preserved. During preparation for examination under the scanning electron microscope, the specimen was broken and a number of denticles were broken off. It is uncertain if this form bears any relation to the unfragmented specimens of Lonchodus which Rhodes (in Rhodes and Müller, 1966) reported from beds of Pennsylvanian age.

Material: 1 specimen; figured specimen UKMIP 1,901,044.

Distribution: Plattsmouth Limestone Member, Oread Limestone.

Genus Lonchodina Bassler, 1925

Type species.- Lonchodina typicalis Bassler, 1925, by original designation.

Lonchodina douglasi n.sp.

Pl. 13, figs. 1 a - g

Hibbardella ? sp. Gunnell, 1933, p. 369, pl. 31, fig. 46.

Diagnosis.- Lonchodina douglasi bears a typical lonchodinid basal cavity, a straight anterior bar which twists slightly exposing the aboral groove in inner lateral view and a posterior bar which curves posteriorly very sharply nearly at right angles to the plane of the anterior bar.

Description.- The main cusp is round to slightly elliptical in cross-section, is twisted, and is directed posteriorly. The upper part is composed of white, non-translucent material, whereas the lower part of the cusp is composed of translucent brown matter.

The anterior bar is straight but twists inwards slightly, showing when viewed laterally, a narrow aboral groove which extends the full length of the bar. Above the groove, a fairly well developed callus is present on the inner side of the conodont. Four to seven well-developed, sub-triangular, slightly compressed denticles have been observed on the anterior bar. They appear to vary in size, and there is some indication of fusion of the denticles near the main cusp.

The posterior bar is approximately the same length as the anterior bar but twists sharply inward (i.e. posteriorly) at approximately right-angles to the plane of the anterior bar. The tip or termination of the posterior bar is not preserved. Five to six discrete posterior bar denticles have been observed, all of which are round in cross-section and are apparently all of the same size. The oral groove is not visible in inner lateral view and a callus is apparently not present.

Aborally, a subcircular typically lonchodinid basal cavity is present (Pl. 13, figs. 1 a - d). Although no flaring apron is present, the rim of the basal cavity is expanded inwards so that the greater part of the basal cavity is located on the inner (posterior) side of the element. The basal cavity is continued in both anterior and posterior bars.

Both sinistral and dextral forms have been recovered.

Comparison.- The species is morphologically similar to some asymmetrical species of Apatognathus ? discussed by Varker (1967) and some species of Magnilaterella, Rexroad and Collinson (1963). It has been difficult to recognize immature elements of this species, and some specimens (Pl. 13, figs. 3 a - b) rather than being Lonchodina sp. A , may be immatures of Lonchodina douglasi n.sp.

Etymology.- The species name is derived from Douglas Co., Kansas where the species was first found.

Material:	22 specimens; figured specimens UKMIP holotype 1,901,057; paratypes UKMIP 1,901,058 to 1,901,061; unfigured paratypes UKMIP 1,901,132 to 1,901,136.
Distribution:	Heebner Shale Member, Oread Limestone, to the Spring Branch Limestone Member, Lecompton Limestone.

Lonchodina sp. A

Pl. 13, figs. 3 a - b, 4 a - b.

This species, which is sharply arched and laterally bowed, has an anterior bar which is strongly directed downward and a posterior bar that is usually twisted inwards and downwards rather sharply immediately behind the main cusp.

The anterior bar bears up to seven or more apparently discrete, laterally compressed denticles which curve inward slightly. The main cusp is also laterally compressed, is twisted near its base, and is recurved. The posterior bar is rarely complete, apparently because of its sharp inward flexure. The posterior bar is long and stout and bears numerous discrete denticles of varying length. In a single specimen the inward flexing of the posterior bar is less pronounced (Pl. 13, fig. 4 a).

Aborally, a moderately large lonchodinid basal cavity, which expands on the inner side, is present. The basal cavity is continued anteriorly and posteriorly as an aboral groove.

Comparison.- The species seems similar to Lonchodina douglasi n.sp. and Lonchodina sp. B; however, more and better preserved material is required to evaluate these relationships. The anterior bar is similar to that of Ozarkodina [?] curvata Rexroad except that it is longer and directed downwards more sharply. As indicated under Lonchodina douglasi n.sp., the specimens illustrated on Pl. 13, figs. 3 a - b, may be immatures of that species.

Material: 14 specimens; figured specimens UKMIP 1,901,064 to 1,901,067.

Distribution: Plattsmouth Limestone Member, Oread Limestone, to the Spring Branch Limestone Member, Lecompton Limestone.

Lonchodina sp. B

Pl. 13, figs. 2 a - b

This species bears two asymmetrical lateral bars, the anterior of which is short, broad and bears only a few denticles and the posterior of which is longer and bears numerous denticles. Both bars are directed downwards so that an acute angle is formed between them. The main cusp is sharp-edged, laterally compressed and is noticeably twisted. It is recurved inwards. The bar denticles are generally broken in the specimens available; however, they are apparently compressed and discrete. The bars curve inwards and a concavity is present between the bars on the outer side of the element.

Aborally, a moderately large nearly circular lonchodinid basal cavity is present. This cavity is continued into the bars as a narrow aboral groove and apparently it continues the full length of the anterior and posterior bars before dying out.

Comparison.- A gradational series exists between this species, Lonchodina douglasi n.sp. and Lonchodina sp. A. It is difficult to differentiate the three, particularly with incomplete material. More material is required to evaluate the validity of Lonchodina sp. A and Lonchodina sp. B.

Material: 13 specimens; figured specimens UKMIP 1,901,062 to 1,901,063.

Distribution: Plattsmouth Limestone Member, Oread Limestone, to the Spring Branch Limestone Member, Lecompton Limestone.

Lonchodina ? ponderosa Ellison

Pl. 12, figs. 5 a - c

Lonchodina ? ponderosa Ellison, 1941, p. 116, pl. 20, figs. 37-39.

The reader is referred to Ellison (1941) for a description of this species.

Mature specimens of this species are symmetrical or nearly so (Pl. 12, fig. 5 a). In smaller specimens the main cusp as well as being curved backward, is twisted laterally in the direction of one of the lateral bars.

Material: 25 specimens; figured specimens UKMIP 1,901,054 to 1,901,056.

Distribution: Heebner Shale Member to the Plattsmouth Limestone Member, Oread Limestone.

Genus Metalonchodina Branson and Mehl, 1941

Type species.- Prioniodus bidentatus Gunnell, 1931, original designation.

The reader is referred to Branson and Mehl (1941) for a description of the genus.

Metalonchodina ? sp.

Pl. 14, figs. 3 a - b

A single well preserved figured specimen from the Holt Shale shows little arching and has a nearly straight aboral margin. It is strongly bowed and at the anterior end bears a large main cusp which is sharply twisted inwards. Posteriorly a series of poorly preserved somewhat irregular denticles are present and a large posteriorly inclined denticle is present at the posterior. Aborally, the element bears an elongate groove which deepens under the main cusp (Pl. 14, fig. 3 a).

Two very fragmentary specimens from the Hartford Limestone although dissimilar to the figured specimen, are included in this taxonomic category. These are morphologically most similar to the Oz (?) element of Ligonodina conflexus (Ellison).

Material:	3 specimens; figured specimen UKMIP 1,901,073.
Distribution:	Figured specimen from Holt Shale Member, Topeka Limestone; unfigured specimens from the Hartford Limestone Member, Topeka Limestone.

Genus Trichonodella Branson and Mehl, 1948

Type species.- Trichognathus prima Branson and Mehl, 1933, original designation.

Hass (1953) pointed out that Trichonodella prima (Branson and Mehl) was "based on a single fragmentary conodont that differs from most of the species previously assigned to the genus by lacking a denticulated posterior bar". Hass retained in Trichonodella only those forms lacking a denticulated posterior bar and removed the rest to Roundya. This usage of Trichonodella was continued by Lindström (1964).

The other generic category which has been used by various authors for symmetrically or sub-symmetrically arched conodonts lacking a posterior bar is Diplododella Bassler. The holotype of the type species of Diplododella, Diplododella bilateris Bassler, 1925, was restudied by Huddle (1968). He reported, but did not illustrate, that a denticulated posterior bar was present. Lindström (1964) questionably considered Diplododella synonymous with Roundya, thus also implying the presence of a posterior bar or process.

The writer will utilize Trichonodella in the sense of Hass (1953) and Lindström (1964). Hass (1953) defined the genus as follows:

> "A bilaterally symmetrical unit, consisting of a denticulated arch that is surmounted by a posteriorly curved, main cusp. Pulp cavity located beneath main cusp. Basal portion of main cusp may be enlarged and extended posteriorly."

The basal cavity may be quite large and this characteristic distinguished it from Hindeodus Rexroad and Furnish, a genus having only a very small basal cavity (Rexroad and Furnish, 1964).

Trichonodella obtusa (Murray and Chronic)

Pl. 15, figs. 1 a - b

Hibbardella obtusa Murray and Chronic, 1965, p. 598, pl. 73, figs. 8-9.

This species of Trichonodella is characterized by having a perfectly symmetrical arch, the bars of which meet at an angle of approximately 80 degrees. A moderately large triangular basal cavity is present on the posterior side of the element and is continuous with a basal groove in each bar. The denticles are discrete, are longest at about the middle of each bar, and in the only specimens available are six in number. The main cusp is circular in cross-section and is recurved posteriorly. The bars are moderately thick and rounded near the main cusp but get progressively thinner and flatter toward their distal tips. The bars also increase in width distally and are bowed posteriorly very gently. The six bar denticles are compressed near the base but are round in cross-section near their tips. They are curved posteriorly. The bar denticles are situated on the oral crest of the bars, and those denticles near the main cusp are located farther anteriorly than is the main cusp. The denticles near the middle of each bar are the longest; the two denticles nearest the cusp are the shortest ones with the exception of the most distal denticles. The bar denticles closest to the main cusp are parallel to it, whereas the larger denticles flare outward.

Comparison.- Trichonodella obtusa is similar to Trichonodella excavata Branson and Mehl, 1933, but the latter differs in the characteristics of the basal cavity and the depth of the arch.

Material:	1 specimen; figured specimen UKMIP 1,901,076.
Distribution:	Plattsmouth Limestone Member, Oread Limestone.

Trichonodella plattsmouthi n.sp.

Pl. 15, figs. 2 a - c

Diagnosis.- A species of Trichonodella characterized by having a nearly symmetric arch but having one lateral bar slightly longer than the other. The bars meet at an angle of 60 to 70 degrees.

Description.- A moderately large, rounded triangular basal cavity is present under the recurved main cusp on the aboral side of the element. The basal cavity is continuous with an aboral groove in each bar. The denticles of the lateral bars vary in number between seven and nine. They are discrete and are longest at about the middle of each bar. The bars are moderately thick near the main cusp but get progressively more delicate and blade-like toward their tips. The bars are bowed posteriorly more than those of Trichonodella obtusa (Murray and Chronic) and are convex anteriorly and concave posteriorly. The discrete bar denticles are very slightly compressed but are round in cross-section near their tips. The denticles are slender, sharp and recurved. The lateral bar denticles are situated on the oral crest of the bars, and those denticles near the main cusp are located more on the outer side than is the main cusp. The bar denticles closest to the main cusp are parallel to it; however, away from it they flare increasingly.

The basal cavity expands on the posterior side so that it is best seen in posterior lateral view. It continues into the bars approximately one-third the length of the bars as an aboral groove. The edges of the aboral groove then pinch together forming a sharp edge to the distal ends of the lateral bars.

Comparison.- The species differs from Trichonodella obtusa (Murray and Chronic) in having a narrower, deeper arch, in having its lateral bars bowed posteriorly to a greater degree and in the slight asymmetry of the lateral bars.

Etymology.- Named after the Plattsmouth Limestone, the only member of the Shawnee Group in which the species has been found.

Material:	9 specimens; figured specimens, holotype UKMIP 1,901,077, paratype UKMIP 1,901,078; unfigured paratypes UKMIP 1,901,137 to 1,901,140.
Distribution:	Plattsmouth Limestone Member, Oread Limestone.

Trichonodella asymmetrica n.sp.

Pl. 15, figs. 3 a - c

Diagnosis.- A species of Trichonodella characterized by an asymmetric arch in having lateral bars of noticeably different length both of which are turned inwards towards each other so that the bars of the element lie in a different plane from that of the main cusp. The bars meet at an angle of between approximately 50 to 80 degrees and the arch is relatively deep,slightly asymmetrical and rounded in outline.

Description.- The discrete denticles are sharply pointed, compressed very slightly, and not recurved noticeably. The denticles increase in length away from the main cusp being longest near, but not at the bar tips. The main cusp is recurved and biconvex in cross-section.

Aborally, a rounded sub-triangular basal cavity is present. The basal cavity expands posteriorly and continues into the bars as an aboral groove. The aboral groove continues about half-way along the bars and then dies out.

Comparison.- The species is most similar to Trichonodella plattsmouthi n.sp. which has a similar distribution. Trichonodella asymmetrica n.sp. differs from the latter in possessing lateral bars which are turned inwards towards one another, in having distinct lateral bar denticulation and in having bars of noticeably different length.

Etymology.- In reference to the asymmetry created by possessing lateral bars of different length.

Material: 14 specimens; figured specimens, holotype UKMIP 1,901,079, paratypes UKMIP 1,901,080 to 1,901,081; unfigured paratypes UKMIP 1,901,141 to 1,901,145.

Distribution: Heebner Shale Member to the Plattsmouth Limestone Member, Oread Limestone.

Trichonodella sp.

A number of fragments, although identifiable as Trichonodella, cannot be placed in a specific category.

Material: 10 specimens.

Genus Hindeodus Rexroad and Furnish, 1964

Type species.- Trichonodella imperfecta Rexroad, 1957, original designation.

The reader is referred to Rexroad and Furnish (1964) for a description of this genus.

Hindeodus sp. A

Pl. 15, figs. 4 a - b

[?] Hindeodus imperfectus (Rexroad); Rexroad and Furnish, 1964, p. 672,
pl. 111, fig. 13 [non fig. 14]

This species of Hindeodus bears symmetrical or nearly symmetrical lateral bars which meet at an obtuse angle of approximately 140 degrees. The main cusp is gently recurved and is unequally biconvex in cross-section with the broader side being on the inner side. The side toward which the main cusp curves is the inner side.

The lateral bars are of equal length and are thin, delicate and concave on the inner side and convex on the outer side. Each bar bears five to nine laterally compressed denticles with sometimes a smaller one inserted inbetween. The bar denticles increase in length distally except for one or two which are small and are located at the ends of the bars. They are closely spaced and biconvex in cross-section. Near the main cusp the bar denticles are parallel to the main cusp but become more and more inclined away from it. The main cusp is two or three times the length of the longer bar denticles.

The aboral edge is sharp and an aboral groove has not been observed.

The small basal cavity is expanded very slightly on the inner side and forms a triangular opening. A callus-like rim extends just above the aboral edge of both bars on the inner and outer sides.

Comparison.- The species is similar to *Hindeodus imperfectus* (Rexroad) but may be distinguished from the latter by the shallow angle at which the bars meet, and the cross-section of the main cusp. The species *Hindeodus compressa* (Ellison and Graves, 1941) has bars which meet at an angle only slightly greater than 90 degrees, creating a deeper arch than is found in *Hindeodus* sp. A. Further, the basal cavity of *Hindeodus compressa* (Ellison and Graves) extends an equal distance on the inner and outer side, whereas in *Hindeodus* sp. A the basal cavity is almost entirely on the inner side.

There is a possibility that this is the Tr element of *Ellisonia teicherti*. In the section dealing with the Tr element of *Ellisonia teicherti* the writer has discussed possible reasons why this element was not grouped with other elements of *Ellisonia teicherti* in the R-mode cluster analyses.

Material:	15 specimens, figured specimens UKMIP 1,901,082 to 1,901,083.
Distribution:	Toronto Limestone Member, Oread Limestone to the Hartford Limestone Member, Topeka Limestone.

Unidentifiable Oz elements

Broken or poorly preserved Oz elements were placed in this category. They represent the Oz element of Streptognathodus and Idiognathodus, as well as more rarely that of Cavusgnathus.

Material: 413 specimens.

Unidentifiable Ne elements

Broken or poorly preserved Ne elements of the type belonging to species of Streptognathodus or Idiognathodus were placed in this category.

Material: 4 specimens.

Unidentifiable Hi elements

Fragmentary remains of Hi elements of the type belonging to species of Streptognathodus, Idiognathodus and Cavusgnathus were placed in this category if only the anterior or posterior portions of the element were preserved.

Material: 206 specimens.

Unidentifiable Tr elements

Broken or poorly preserved Tr elements of the type belonging to species of Streptognathodus, Idiognathodus and Cavusgnathus were placed in this category. For the most part these are believed to have belonged to species of the first two genera but this cannot be definitely established.

Material: 90 specimens.

Genus and Species Indeterminate

Relatively few specimens were unidentifiable to either genus or species due to fragmentation and poor preservation. Each specimen having a basal cavity was counted and tabulated. There was a noticeable increase in this category in the Heebner Shale and parts of the Plattsmouth Limestone of the Oread Formation. This increase for the most part reflects the fragmentation of elements placed in Ligonodina subacoda (Gunnell). These elements, once broken, are difficult or impossible to identify.

Material: 265 specimens.

Explanation of Plate 1

Figures 1 a - e	*Streptognathodus elegantulus* Stauffer and Plummer, Sp element. All specimens from the Larsh-Burroak Shale. Oral views of ontogenetic growth series arranged in order of increase in size; note the weakening and anterior migration of the carina with maturity.
1 a	UKMIP 1,900,901, sample LB-1-1, X254
1 b	UKMIP 1,900,902, sample LB-1-3A, X136
1 c	UKMIP 1,900,903, sample LB-1-3A, X86
1 d	UKMIP 1,900,904, sample LB-1-3A, X67
1 e	UKMIP 1,900,905, sample LB-1-1, X64
Figures 2 a - e	*Streptognathodus* sp. A, Sp element. All specimens from the Spring Branch Limestone.
2 a - b	Oral views of dextral element, UKMIP 1,900,906, sample SB-1-1C, X50 and X61 respectively.
2 c	Oral view of sinistral element, UKMIP 1,900,907, sample SB-1-1C, X43
2 d	Oral view of dextral element showing radiating transverse ridges at anterior end of platform, UKMIP 1,900,908, sample SB-1-3, X42
2 e	Inside lateral view of blade denticles showing striations, UKMIP 1,900,906, sample SB-1-1C, X290

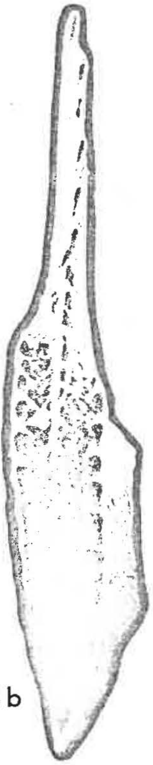
Explanation of Plate 1 (Continued)

Figures 3 a - b	Streptognathodus sp. aff. S.elegantulus Stauffer and Plummer, Sp element.
3 a	Oral view; UKMIP 1,900,909, sample P-1-4 (Plattsmouth Limestone), X82
3 b	Lateral view; UKMIP 1,900,909, X76.

von Bitter, 1971.

Plate 1


1a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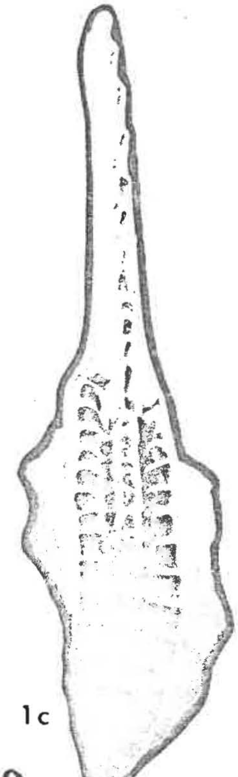
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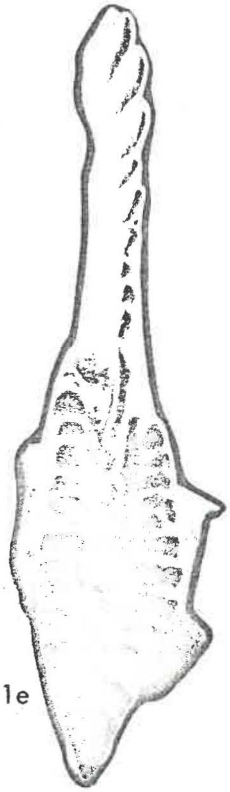
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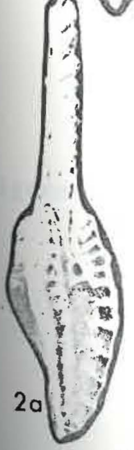
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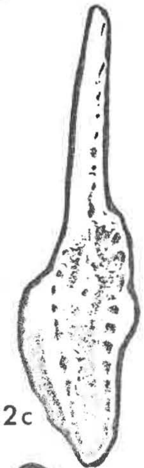
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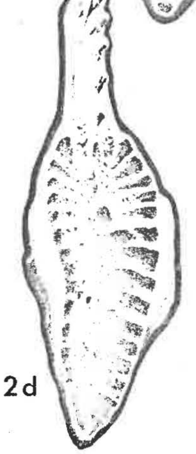
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Explanation of Plate 2

Figures 1 a - b	*Streptognathodus gracilis* Stauffer and Plummer, Sp element. All specimens from Larsh-Burroak Shale.
1 a	Oral view of sinistral element showing inner accessory lobe, UKMIP 1,900,910, sample LB-1-3B, X123
1 b	Oral view of dextral element showing inner accessory lobe, UKMIP 1,900,911, sample LB-1-1, X53
Figures 2 a - c	*Streptognathodus excelsus* Stauffer and Plummer, Sp element. All specimens from the Larsh-Burroak Shale.
2 a	Oral view of sinistral element showing two accessory lobes, UKMIP 1,900,912, sample LB-1-3B, X37
2 b	Oral view of dextral element showing two accessory lobes, UKMIP 1,900,913, sample LB-1-1, X50
2 c	Posterior portion of UKMIP 1,900,913, X984
Figure 3	*Streptognathodus* ? sp. Posterior oral view showing eccentrically located blade, UKMIP 1,900,914, sample He-1-4A (Heebner Shale), X38
Figures 4 a - d	*Streptognathodus gracilis* Stauffer and Plummer [?]
4 a	Outer accessory lobe, UKMIP 1,900,915, X1024
4 b	Oral view of anterior part of platform showing outer accessory lobe, UKMIP 1,900,915, X101

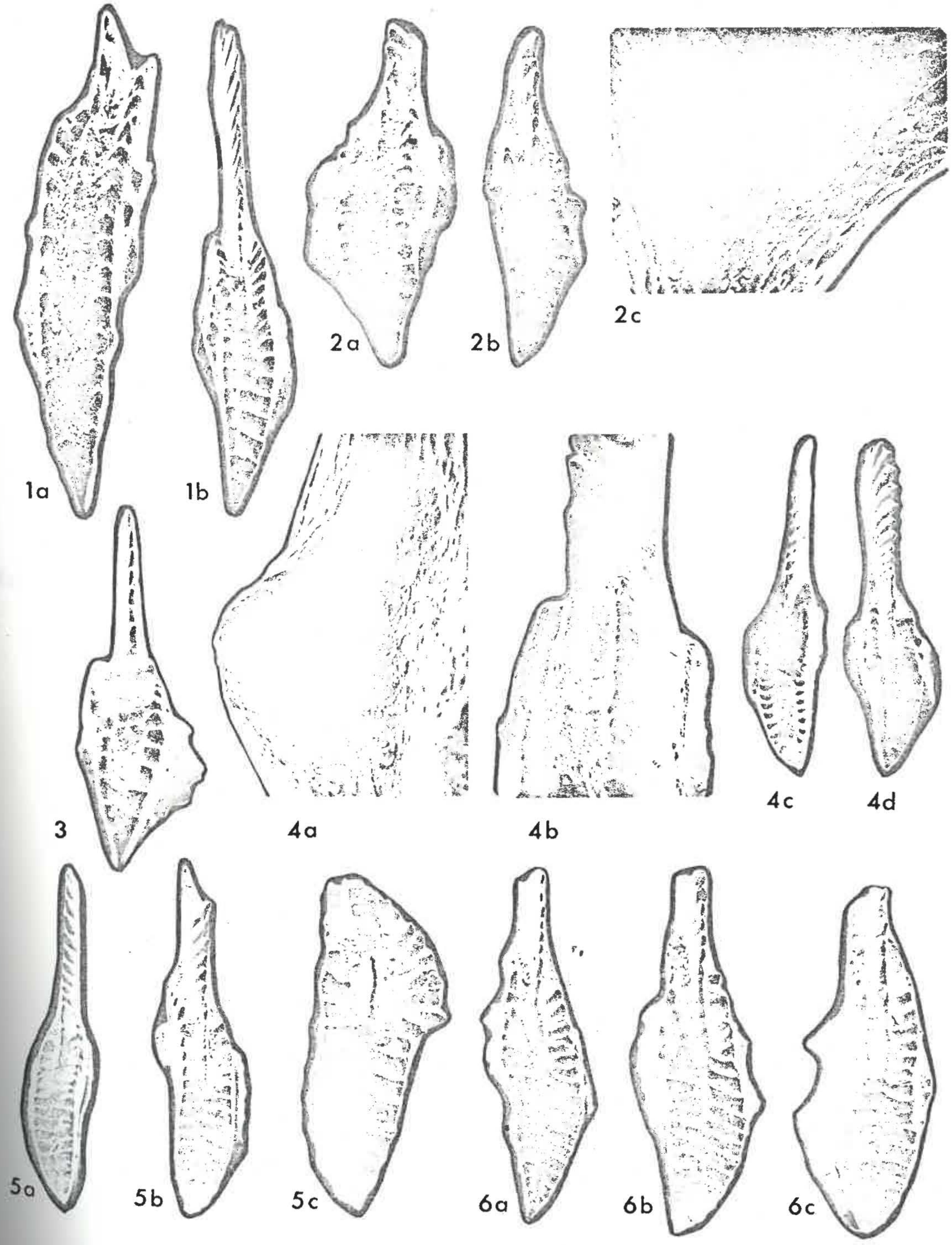
Explanation of Plate 2 (Continued)

4 c	Oral view of sinistral element, UKMIP 1,900,915, X37
4 d	Oral view of dextral element showing outer accessory lobe, UKMIP 1,900,916, sample LB-1-3D (Larsh-Burroak Shale), X40
Figures 5 a - c	*Streptognathodus oppletus* Ellison, Sp element
	Oral views of ontogenetic growth series from largest to smallest elements showing discontinuous transverse ridges, the poorly defined oral groove, and lack of accessory lobes.
5 a	Sinistral element UKMIP 1,900,917, sample P-1-6 (Plattsmouth Limestone), X67.
5 b	Dextral element UKMIP 1,900,918, sample QH-1-2 (Queen Hill Shale), X82
5 c	Element showing frill (i.e. orally flaring parapet), UKMIP 1,900,919, sample QH-1-2 (Queen Hill Shale), X153
Figures 6 a - c	*Streptognathodus wabaunsensis* Gunnell, Sp element
	Oral views of ontogenetic growth series from largest to smallest showing discontinuous transverse ridges, the poorly defined oral groove, and the inner accessory lobe.

Explanation of Plate 2 (Continued)

6 a	Dextral element, UKMIP 1,900,920, sample Ke-1-6 (Kereford Limestone), X61
6 b	Dextral element UKMIP 1,900, 921, sample SB-1-1C (Spring Branch Limestone), X86
6 c	Sinistral element UKMIP 1,900,922, sample SB-1-1B (Spring Branch Limestone), X105

Plate 2



Explanation of Plate 3

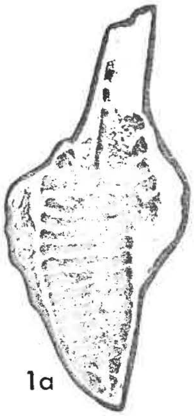
Figures 1 a - d	*Streptognathodus eccentricus* Ellison, Sp element All specimens from the Heebner Shale
1 a	Sinistral element UKMIP 1,900,923, sample He-1-4A, X40
1 b	Sinistral element UKMIP 1,900,924, sample He-1-3A, X31
1 c	Sinistral element UKMIP 1,900,925, sample He-1-4A, X40
1 d	Dextral element, UKMIP 1,900,926, sample He-1-4A, X74
Figures 2 a - e	*Streptognathodus simulator* Ellison, Sp element All specimens from Heebner Shale
2 a - c	Oral views of ontogenetic growth series from largest to smallest element showing eccentrically located oral groove and one accessory lobe on inner side (absent in smallest element).
2 a	Sinistral element UKMIP 1,900,927, sample He-1-1, X53
2 b	Sinistral element UKMIP, 1,900,928, sample He-1-3A, X69
2 c	Immature element lacking accessory lobe, UKMIP 1,900,929, sample He-1-3A, X79

Explanation of Plate 3 (Continued)

Figure 2 d	Oral view of dextral element showing some complete transverse ridges making it transitional with *Idiognathodus*, UKMIP, 1,900,930, sample He-1-3A, X79.
2 e	Element broken parallel to oral groove UKMIP, 1,900,931, sample He-1-3A, X43
Figures 3 a - e	*Idiognathodus magnificus* Stauffer and Plummer, Sp element. All specimens from Heebner Shale. Oral views of ontogenetic growth series from largest to smallest element.
3 a	Mature dextral element showing two accessory lobes, UKMIP 1,900,932, sample He-1-2B, X46
3 b	Mature dextral element with outer accessory lobe poorly developed, UKMIP 1,900,933, sample He-1-3D, X34
3 c	Immature dextral element with poor outer accessory lobe development, UKMIP 1,900,934, sample He-1-3B, X59
3 d	Immature dextral element with well developed inner accessory lobe, UKMIP 1,900,935, sample He-1-3B, X77
3 e	Immature element of (?) *Idiognathodus magnificus* showing lack of accessory lobes and breaks in some of the transverse ridges, UKMIP 1,900,936, sample He-1-3B, X60

Explanation of Plate 3 (Continued)

Figure 4	Idiognathodus delicatus Gunnell, Sp element Sinistral element oral view, showing two accessory lobes set off from the platform, UKMIP 1,900,937, sample QH-1-2 (Queen Hill Shale), X114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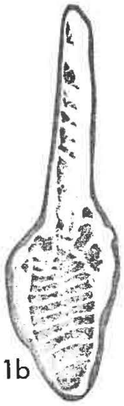
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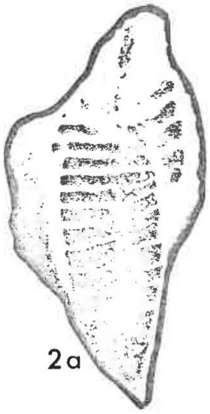
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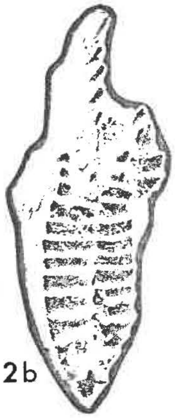
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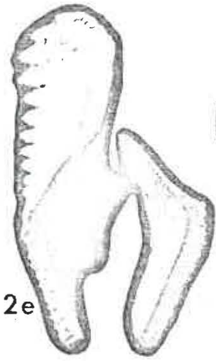
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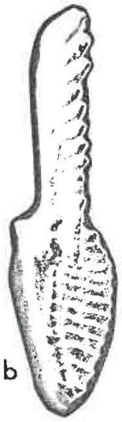
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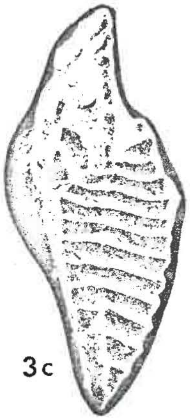
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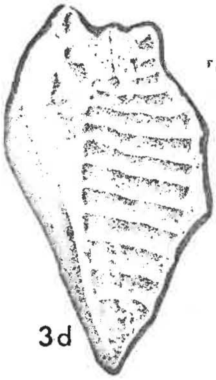
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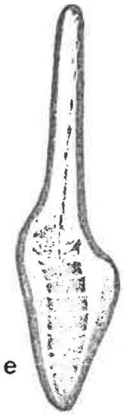
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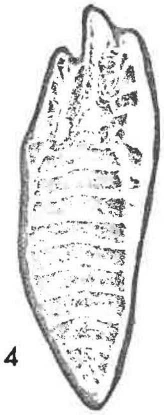
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Explanation of Plate 4

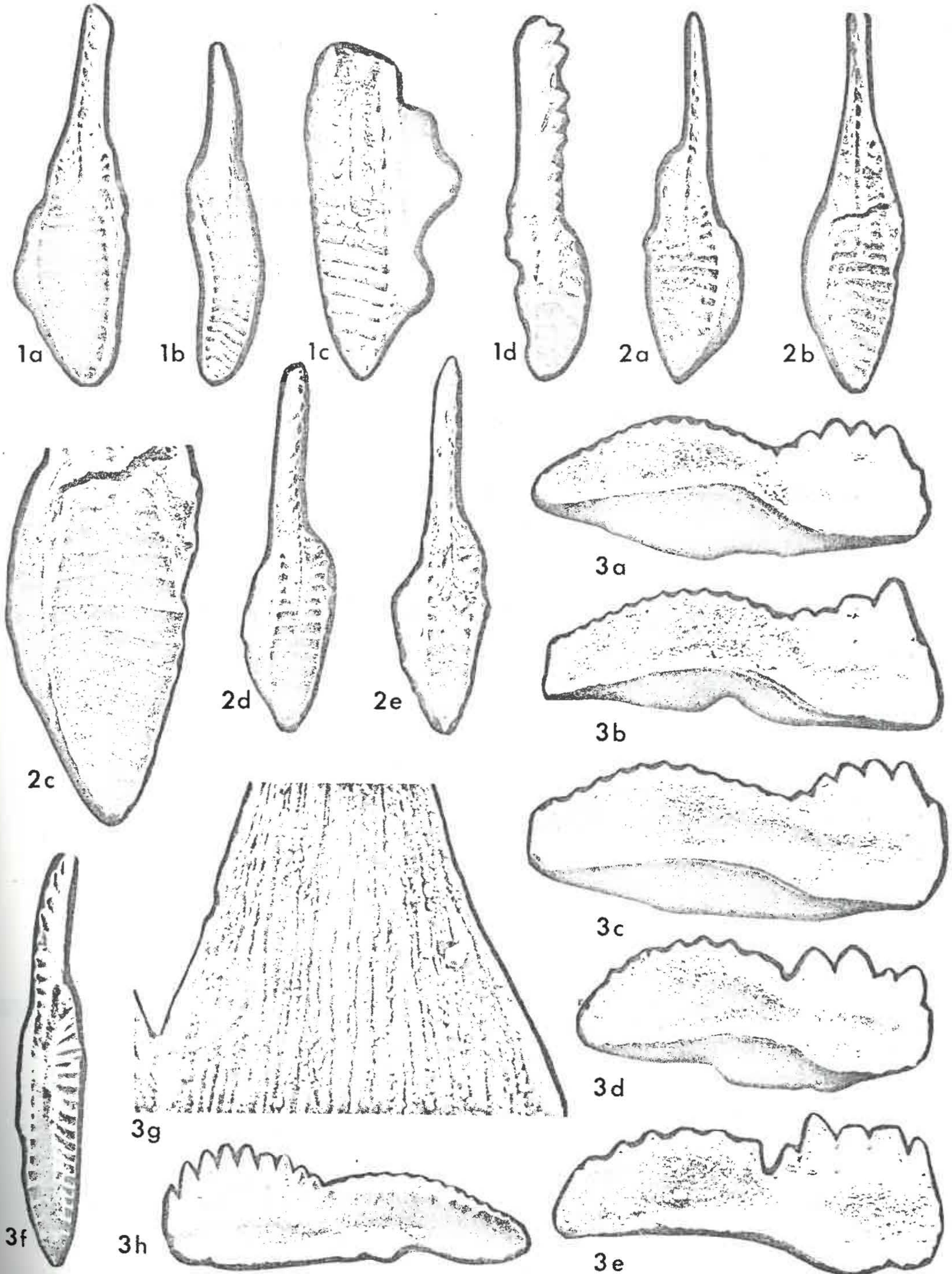
Figures 1 a - d	*Idiognathodus tersus* Ellison, Sp element All specimens from the Lecompton Limestone Oral views of ontogenetic growth series from the largest to the smallest element, showing complete transverse ridges, the carina terminating against transverse ridges, and lack of both an accessory lobe and a trough.
1 a	Mature sinistral element, UKMIP 1,900,938, sample SB-1-1C (Spring Branch Limestone), X64
1 b	Immature dextral element, UKMIP 1,900,939, sample QH-1-2 (Queen Hill Shale), X76
1 c	Immature element, UKMIP 1,900,940, sample QH-1-2 (Queen Hill Shale), X118
1 d	Immature dextral element, UKMIP 1,900,941, sample QH-1-2 (Queen Hill Shale), X103
Figures 2 a - e	*Idiognathodus antiquus* Stauffer and Plummer, Sp element. All specimens from Spring Branch Limestone Oral views of ontogenetic growth series from the largest to the smallest element showing complete transverse ridges and an inner accessory lobe.
2 a	Mature dextral element, UKMIP 1,900,942, sample SB-1-1C, X52

Explanation of Plate 4 (Continued)

2 b	Mature sinistral element, UKMIP 1,900,943, sample SB-1-1B, X86
2 c	Magnified view of platform of UKMIP 1,900,943, X174
2 d	Immature sinistral element, UKMIP 1,900,944, sample SB-1-1C, X88
2 e	Immature sinistral specimen, UKMIP 1,900,945, sample SB-1-1C, X102
Figures 3 a - h	*Cavusgnathus lautus* Gunnell, sinistral Sp element
	Specimens illustrated in 3 a - e are from the Du Bois Limestone; those shown in 3 f - h are from the Oskaloosa Shale
3 a - e	Inside lateral views of ontogenetic growth series of sinistral elements; note the variation in blade denticulation and the development of a fixed blade and a longer inner parapet with increase in size.
3 a	UKMIP 1,900,946, sample DB-1-1B, X86
3 b	UKMIP 1,900,947, sample DB-1-1B, X115
3 c	UKMIP 1,900,948, sample DB-1-1B, X123
3 d	UKMIP 1,900,949, sample DB-1-1B, X123
3 e	UKMIP 1,900,950, sample DB-1-1B, X189
3 f	Oral view of sinistral element, UKMIP 1,900,951, sample Os-1-3, X60

Explanation of Plate 4 (Continued)

3 g	Outer lateral view of blade denticle of sinistral element, UKMIP 1,900,952, sample Os-1-3, X1980
3 h	Outer lateral view of sinistral element, UKMIP 1,900,952, X89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Explanation of Plate 5

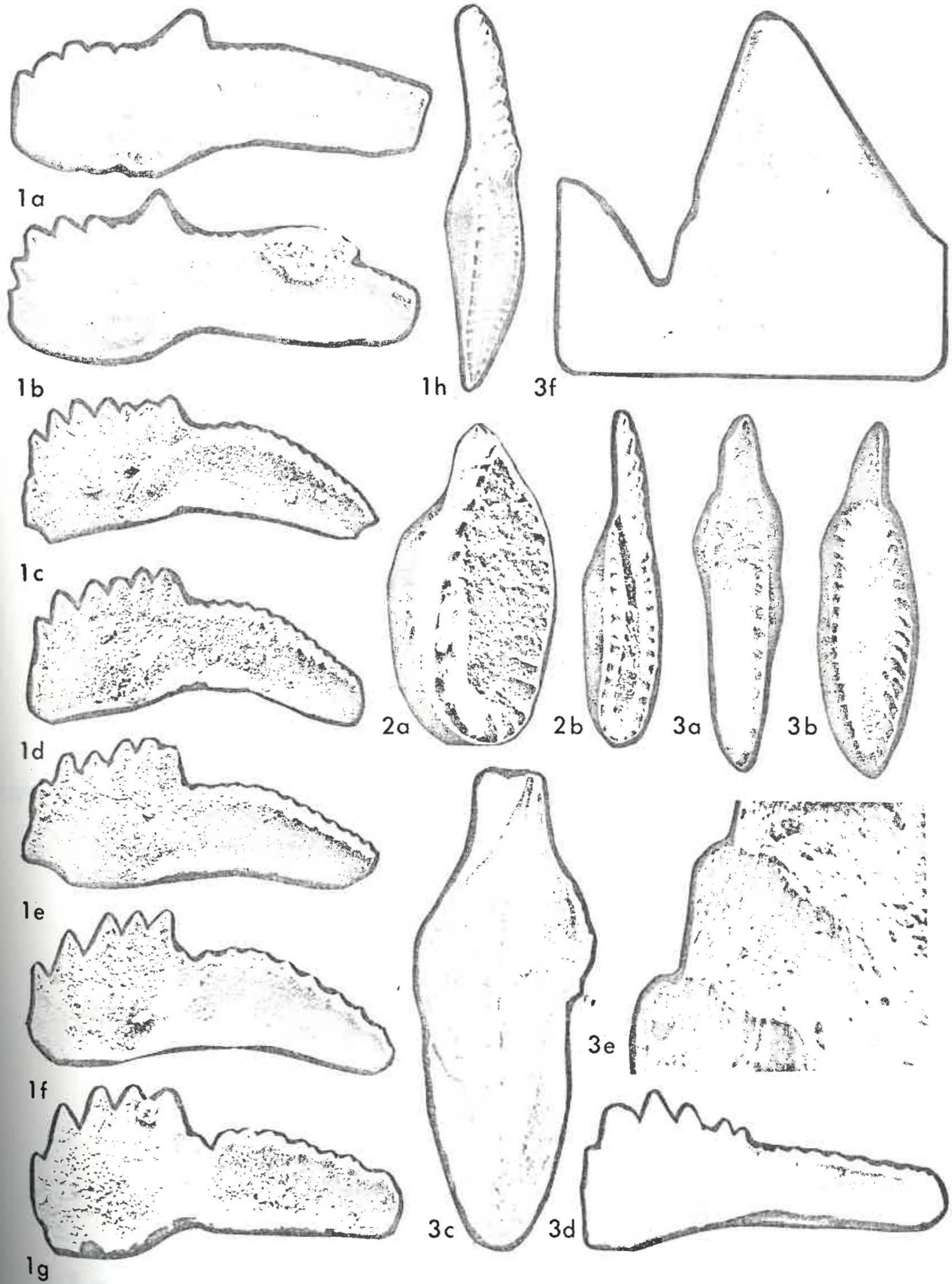
Figures 1 a - h	*Cavusgnathus lautus* Gunnell, Sp element Elements illustrated in 1 a - b are from the Jones Point Shale; those in 1 c - g are from the Du Bois Limestone; that of 1 h is from the Oskaloosa Shale.
1 a - g	Inside lateral views of ontogenetic growth series from largest to smallest of dextral elements. Note development of the main cusp, the fixed blade and the inner parapet with an increase in size.
1 a	UKMIP 1,900,953, sample JPS-1-1, X52
1 b	UKMIP 1,900,954, sample JPS-1-1, X63
1 c	UKMIP 1,900,955, sample DB-1-1B, X71
1 d	UKMIP 1,900,956, sample DB-1-1B, X81
1 e	UKMIP 1,900,957, sample DB-1-1B, X90
1 f	UKMIP 1,900,958, sample DB-1-1B, X156
1 g	UKMIP 1,900,959, sample DB-1-1B, X236
1 h	Oral view of dextral element, UKMIP 1,900,960, sample Os-1-3, X57
Figures 2 a - b	*Cavusgnathus flexus* Ellison, Sp element
2 a	Oral view of sinistral element, UKMIP 1,900,961, sample LB-1-3D (Larsh-Burroak Shale), X121
2 b	Oral view of dextral element, UKMIP 1,900,962, sample Os-1-3 (Oskaloosa Shale), X92

Explanation of Plate 5 (Continued)

Figures 3 a - f	*Cavusgnathus merrilli* n.sp. All specimens are from the Larsh-Burroak Shale
3 a	Oral view of immature dextral element showing low, nearly parallel parapets and nearly central blade, holotype UKMIP 1,900,963, sample LB-1-3A, X98
3 b	Oral view of mature, dextral (?) element, showing symmetrical parapets, moderately deep oral trough and nearly central blade, paratype UKMIP 1,900,964, sample LB-1-1, X65
3 c	Aboral view of paratype UKMIP 1,900,964, X108
3 d	Inner lateral view of dextral element, paratype UKMIP 1,900,965, sample LB-1-1, X75
3 e	Magnified view of outer transverse ridges showing microstructure, UKMIP 1,900,966, sample LB-1-1, X1045
3 f	Outer lateral view of blade denticle, paratype UKMIP 1,900,965, X741

von Bitter, 1971.

Plate 5



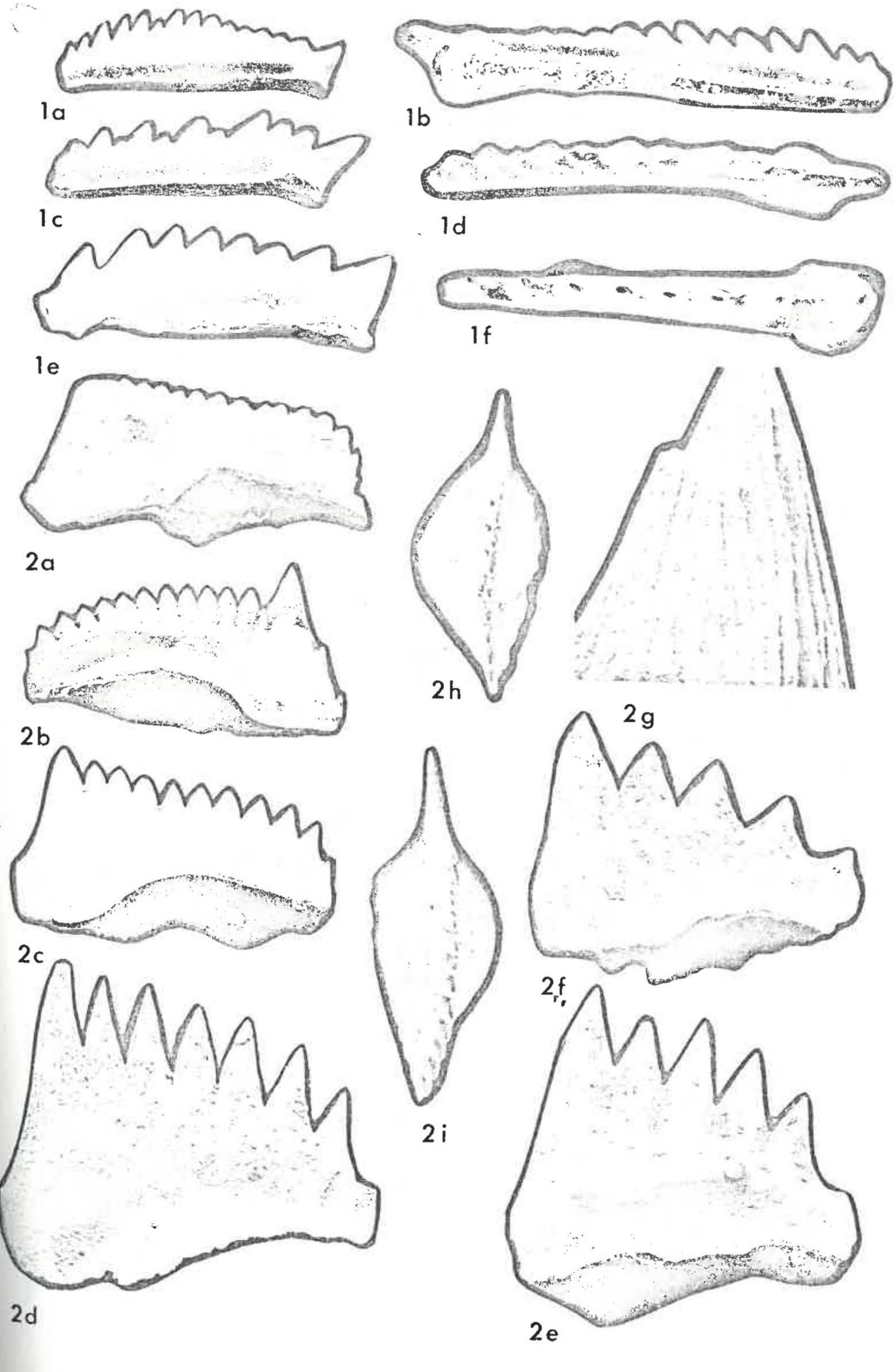
Explanation of Plate 6

Figures 1 a - f	*Gondolella denuda* Ellison, Sp element All specimens are from sample QH-1-2 from the Queen Hill Shale Figures 1 a, 1 c, 1 e show an ontogenetic growth series from largest to smallest element.
1 a	Lateral view, UKMIP 1,900,967, X48
1 b	Aboral lateral view, UKMIP 1,900,967, X75
1 c	Lateral view of dextral (?) element, UKMIP 1,900,968, X68
1 d	Oral view of dextral (?) element, UKMIP 1,900,968, X100
1 e	Lateral view, UKMIP 1,900,969, X78
1 f	Oral view, UKMIP 1,900,969, X115
Figures 2 a - i	*Anchignathodus minutus* (Ellison) Specimen figured in 2 a is from the Heebner Shale; remainder are from the Plattsmouth Limestone Figures 2 a - f shows lateral views of ontogenetic growth series from largest to smallest elements; note elongation and increase in denticle numbers with increase in size as well as rounding and coalescing of denticles in mature individuals.
2 a	Large mature element, UKMIP 1,900,970, sample He-1-4B, X41

Explanation of Plate 6 (Continued)

2 b	Mature element, UKMIP 1,900,971, sample P-1-7, X86
2 c	Mature element, UKMIP 1,900,972, sample P-1-5, X138
2 d	Immature element showing striations on denticles, UKMIP 1,900,973, sample P-1-5, X227
2 e	Immature element, UKMIP 1,900,974, sample P-1-5, X317
2 f	Immature element, UKMIP 1,900,975, sample P-1-5, X370
2 g	Detail of main cusp of UKMIP 1,900,971, X919
2 h	Sinistral element, UKMIP 1,900,976, sample P-1-7, X16
2 i	Dextral element, UKMIP 1,900,977, sample P-1-7, X114

Plate 6



Explanation of Plate 7

Figures 1 a - b	*Anchignathodus adenticulatus* n.sp.
1 a	Lateral aboral view showing large basal cavity and lack of denticulation of the posterior half of the blade, paratype UKMIP 1,900,978, sample SB-1-3 (Spring Branch Limestone), X267
1 b	Lateral view showing characteristic posterior blade, vertical anterior and posterior margins and posterior extension of the flaring apron, holotype UKMIP 1,900,979, sample P-1-7 (Plattsmouth Limestone), X97
Figure 2	*Anchignathodus* sp. cf. *A.campbelli* Rexroad
	Lateral view, UKMIP 1,900,980, sample EC-1-1 (Ervine Creek Limestone), X116
Figures 3 a - f	*Anchignathodus moorei* n.sp.
3 a	Lateral view showing characteristic irregular denticulation and large posteriorly extending basal cavity, holotype UKMIP 1,900,981, sample LB-1-1 (Larsh-Burroak Shale), X289
3 b	Lateral view showing variation in denticulation, paratype UKMIP 1,900,982, sample LB-1-1 (Larsh-Burroak Shale), X160
3 c	Lateral view showing variation in denticulation, paratype UKMIP 1,900,983, sample LB-1-1 (Larsh-Burroak Shale), X158

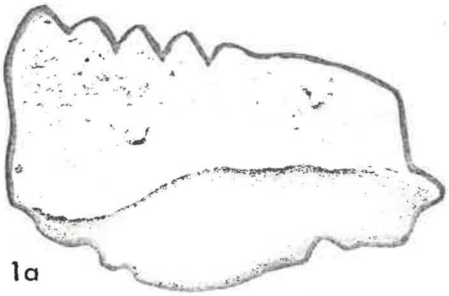
Explanation of Plate 7 (Continued)

3 d	Magnified view of the two largest denticles of paratype UKMIP 1,900,983, X1192
3 e	Aboral view, paratype UKMIP 1,900,984, sample Ke-1-6 (Kereford Limestone), X154
3 f	Oral view of sinistral (?) element, paratype UKMIP 1,900,985, sample EC-1-1J (Ervine Creek Limestone) X217
Figures 4 a - h	*Idiognathodus* and *Streptognathodus*, Oz element Figures 4 a - f show lateral views of ontogenetic growth series from largest to smallest element. Note increase in number of denticles with size.
4 a	UKMIP 1,900,986, sample P-1-3 (Plattsmouth Limestone), X40
4 b	UKMIP 1,900,987, sample LB-1-1 (Larsh-Burroak Shale), X49
4 c	UKMIP 1,900,988, sample LB-1-1 (Larsh-Burroak Shale), X62
4 d	UKMIP 1,900,989, sample P-1-3 (Plattsmouth Limestone), X69
4 e	UKMIP 1,900,990, sample LB-1-1 (Larsh-Burroak Shale), X80
4 f	UKMIP 1,900,991, sample LB-1-1 (Larsh-Burroak Shale), X100

Explanation of Plate 7 (Continued)

4 g	Aboral view of UKMIP 1,900,987, X90
4 h	Magnified view of anterior part of main cusp, UKMIP 1,900,991, X1968.

von Bitter, 1971. Plate 7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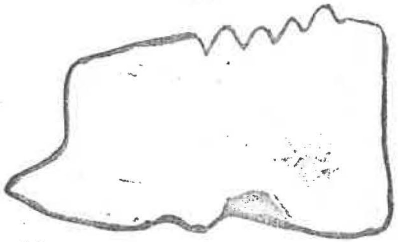
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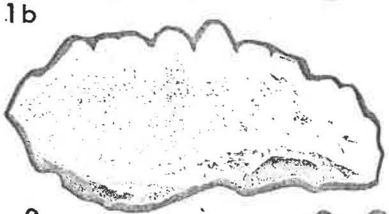
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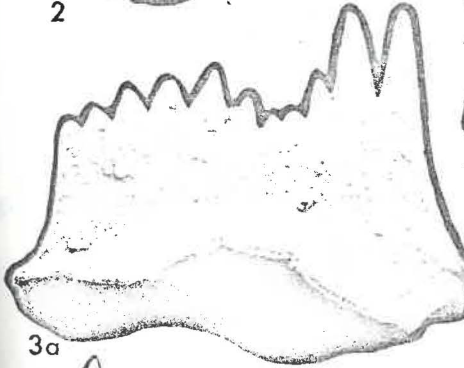
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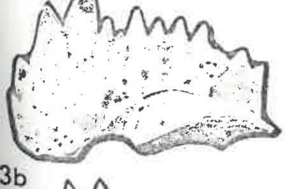
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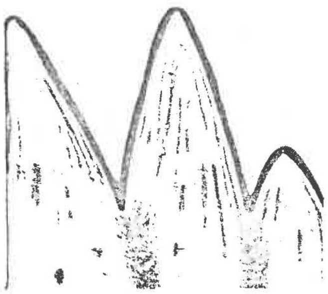
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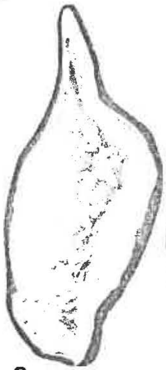
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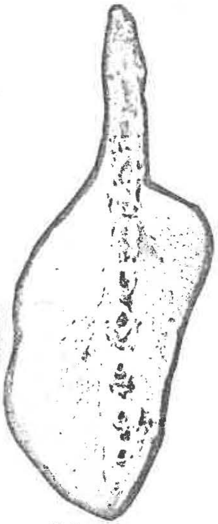
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4a


4b


4c


4d


4e


4f


4g


4h

Explanation of Plate 8

Figures 1 a - e	*Cavusgnathus lautus* Gunnell, Oz element
1 a	Lateral view of mature element in which most of the posterior blade is missing, UKMIP 1,900,992, sample Os-1-3 (Oskaloosa Shale), X91
1 b	Magnified view of first denticle posterior to main cusp of UKMIP 1,900,992, X1324
1 c	Lateral view of immature element UKMIP 1,900,993, sample JPS-1-2C (Jones Point Shale), X83
1 d	Lateral view of immature element showing relatively straight aboral margin, short anterior and long posterior blade, UKMIP 1,900,994, sample TCS-1-3 (Turner Creek Shale), X97
1 e	Aboral view, UKMIP 1,900,995, sample Os-1-3 (Oskaloosa Shale), X205
Figures 2 a - b	*Ozarkodina* sp. A
2 a	Lateral view, UKMIP 1,900,996, sample B-1-6 (Beil Limestone), X77
2 b	Magnified view of part of main cusp, UKMIP 1,900,996, X697
Figures 3 a - b	*Gondolella denuda* Ellison, Oz element
3 a	Aboral view of dextral specimen showing basal cavity expanded on outer side; short posterior blade is

Explanation of Plate 8 (Continued)

	broken off. UKMIP 1,900,997, sample QH-1-2 (Queen Hill Shale), X176
3 b	Outer lateral view of dextral specimen UKMIP 1,900,997, X84
Figures 4 a - b	*Gondolella denuda* Ellison, Hi (?) element
4 a	Aboral view, UKMIP 1,900,998, sample QH-1-2 (Queen Hill Shale), X190
4 b	Inner lateral view, UKMIP 1,900,998, X132
Figures 5 a - f	*Ozarkodina* [?] *curvata* Rexroad All specimens except that figured in 5 e are from the Plattsmouth Limestone 5 a, b, d, e, f represent inside lateral views of an ontogenetic growth series, from largest to smallest element. Note increase in size of anterior bar with increase in size.
5 a	Mature dextral element, UKMIP 1,900,999, sample P-1-4, X54
5 b	Mature sinistral element, UKMIP 1,901,000, sample P-1-1, X71
5 c	Aboral lateral view of basal cavity and aboral groove, UKMIP 1,901,000, X476

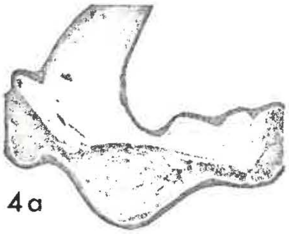
Explanation of Plate 8 (Continued)

5 d	Immature sinistral element, UKMIP 1,901,001, sample P-1-5, X84
5 e	Immature sinistral element, UKMIP 1,901,002, sample EC-1-1J (Ervine Creek Limestone), X125
5 f	Immature sinistral element, UKMIP 1,901,003, sample P-1-6, X153


1a


3a


1b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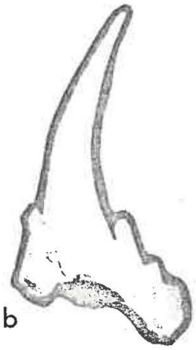
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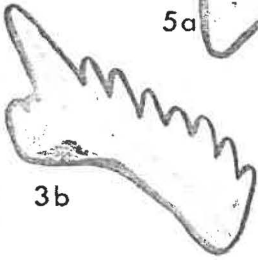
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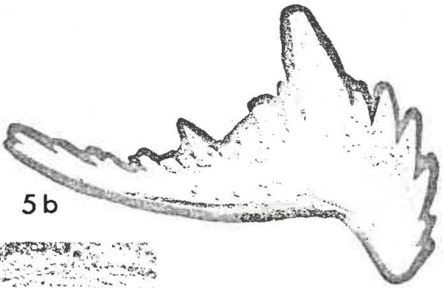
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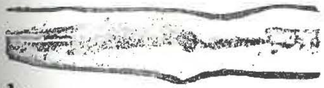
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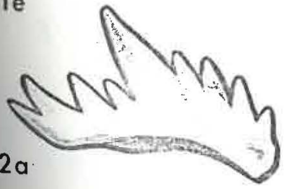
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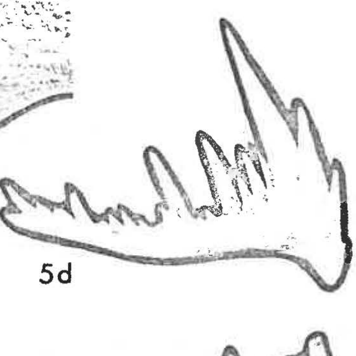
5c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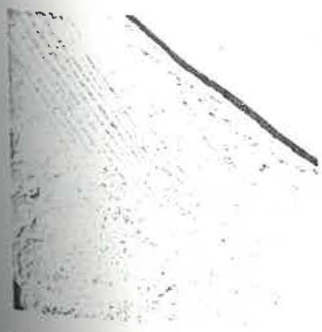
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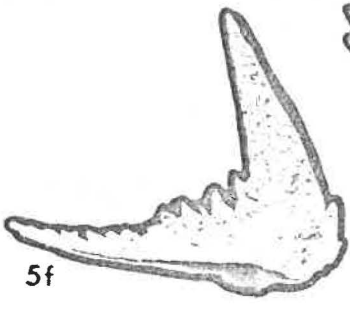
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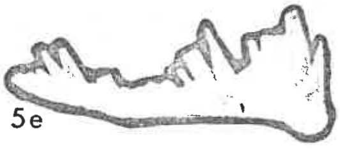
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Explanation of Plate 9

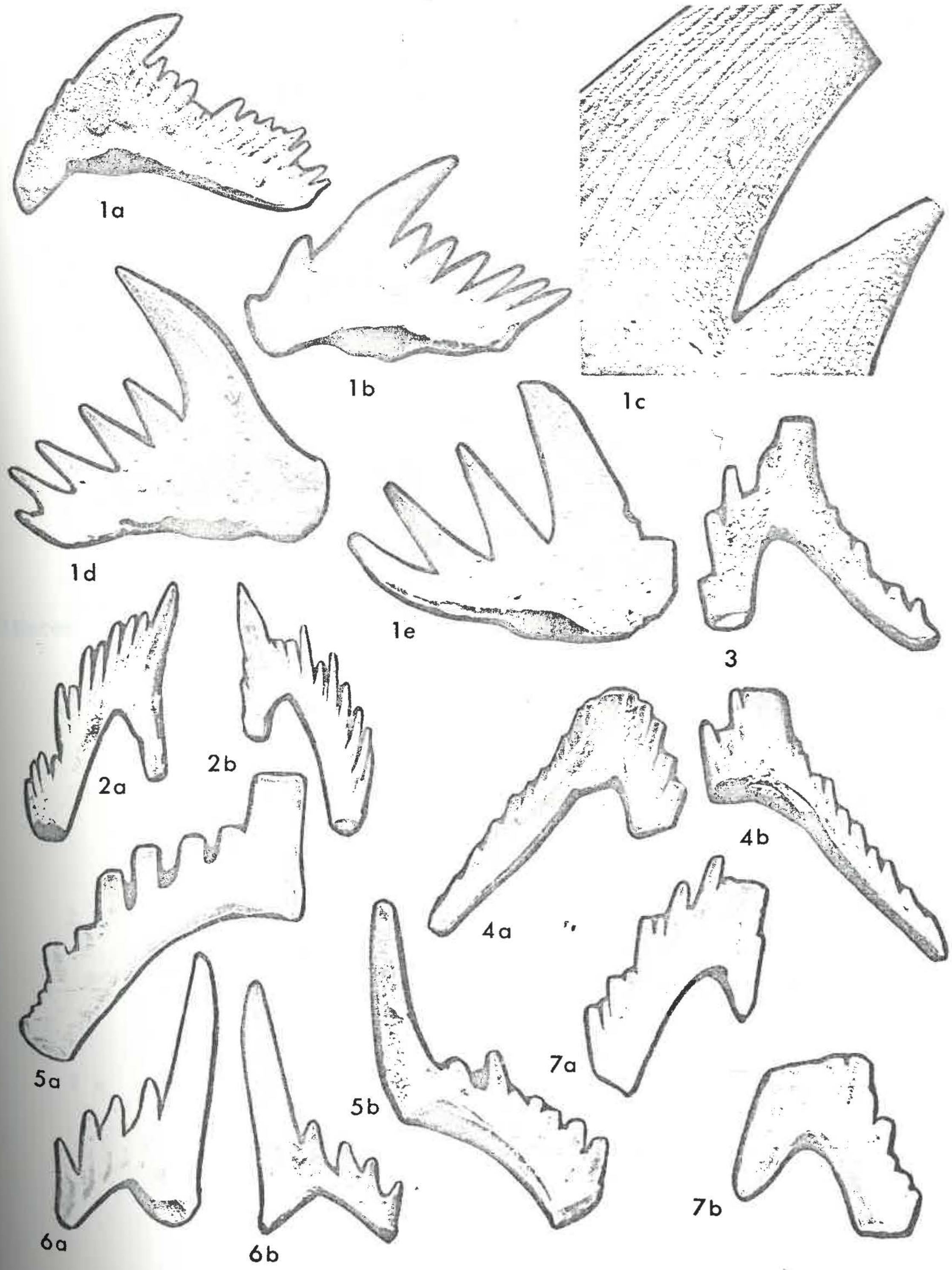
Figure 1 a	*Ozarkodina* ? sp. aff. *O*. ? *kansasensis* n.sp. Inner lateral view of mature dextral element, UKMIP 1,901,004, sample P-1-1 (Plattsmouth Limestone), X71
Figures 1 b - e	*Ozarkodina* ? *kansasensis* n.sp. All specimens from the Plattsmouth Limestone 1 b, d, e represent inside lateral views of an ontogenetic growth series from largest to smallest element. Note increase in number of denticles on both anterior and posterior bars with size increase.
1 b	Mature dextral element, holotype UKMIP 1,901,005, sample P-1-7, X98
1 c	Magnified view of main cusp and first posterior bar denticle, holotype UKMIP 1,901,005, X488
1 d	Immature sinistral element, paratype UKMIP 1,901,006, sample P-1-5, X139
1 e	Immature sinistral element, paratype UKMIP 1,901,007, sample P-1-7, X191
Figures 2 a - b	*Streptognathodus* and *Idiognathodus*, Ne element
2 a	Inner lateral view of sinistral (?) element, UKMIP 1,901,008, sample EC-1-1D (Ervine Creek Limestone), X73

Explanation of Plate 9 (Continued)

2 b	Inner lateral view of dextral (?) element, UKMIP 1,901,009, sample P-1-6 (Plattsmouth Limestone), X73
Figure 3	*Synprioniodina* sp. B Inner lateral view of sinistral (?) element showing anterior deflection of the long anterior bar, UKMIP 1,901,010, sample SB-1-2B (Spring Branch Limestone), X115
Figures 4 a - b	*Synprioniodina* sp. A
4 a	Dextral (?) element, showing strong elongated anterior bar; posterior bar partially broken, UKMIP 1,901,011, sample LB-1-1 (Larsh-Burroak Shale), X120
4 b	Sinistral (?) element, showing strong elongated anterior bar; posterior bar is missing, UKMIP 1,901,012, sample LB-1-1 (Larsh-Burroak Shale), X136
Figures 5 a - b	*Cavusgnathus*, Ne element
5 a	Inner lateral view of sinistral specimen, UKMIP 1,901,013, sample Heu-1-2 (Heumader Shale), X104
5 b	Inner lateral view of dextral specimen, UKMIP 1,901,014, sample Cur-1-4 (Curzon Limestone), X163

Explanation of Plate 9 (Continued)

Figures 6 a - b	*Ligonodina subacoda* (Gunnell), Ne element
6 a	Outer lateral view of dextral specimen, UKMIP 1,901,015, sample P-1-4 (Plattsmouth Limestone), X56
6 b	Inner lateral view of UKMIP 1,901,015, X46
Figures 7 a - b	*Neoprioniodus* sp. A
7 a	Inner lateral view of sinistral specimen, UKMIP 1,901,016, sample LB-1-3A (Larsh-Burroak Shale), X111
7 b	Outer lateral view of dextral specimen, UKMIP 1,901,017, sample LB-1-3A (Larsh-Burroak Shale), X110


1a
1b
1c
1d
1e
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2b
3
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4b
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5b
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6b
7a
7b

Explanation of Plate 10

Figures 1 a - d	*Ellisonia teicherti* Sweet, Ne element
	All specimens from the Plattsmouth Limestone, Oread Formation
1 a	Inner lateral view of a sinistral element, UKMIP 1,901,018, sample P-1-1, X106
1 b	Inner lateral view of a dextral element, UKMIP 1,901,019, sample P-1-5, X86
1 c	Inner lateral view of sinistral element showing recurving main cusp, UKMIP 1,901,018, X121
1 d	Aboral lateral view of dextral element showing basal cavity, UKMIP 1,901,020, sample P-1-5, X213
Figures 2 a - f	*Ellisonia teicherti* Sweet, Pl element
2 a	Inner lateral view of mature dextral element showing long anterior and short posterior bar, UKMIP 1,901,021, sample EC-1-1B (Ervine Creek Limestone), X90
2 b	Inner lateral view of immature dextral element, UKMIP 1,901,022, sample P-1-3 (Plattsmouth Limestone), X126
2 c	Inner lateral view of sinistral element, a variant, showing an aboral hook-like extension at end of anterior bar, UKMIP 1,901,023, sample P-1-6 (Plattsmouth Limestone), X137

Explanation of Plate 10 (Continued)

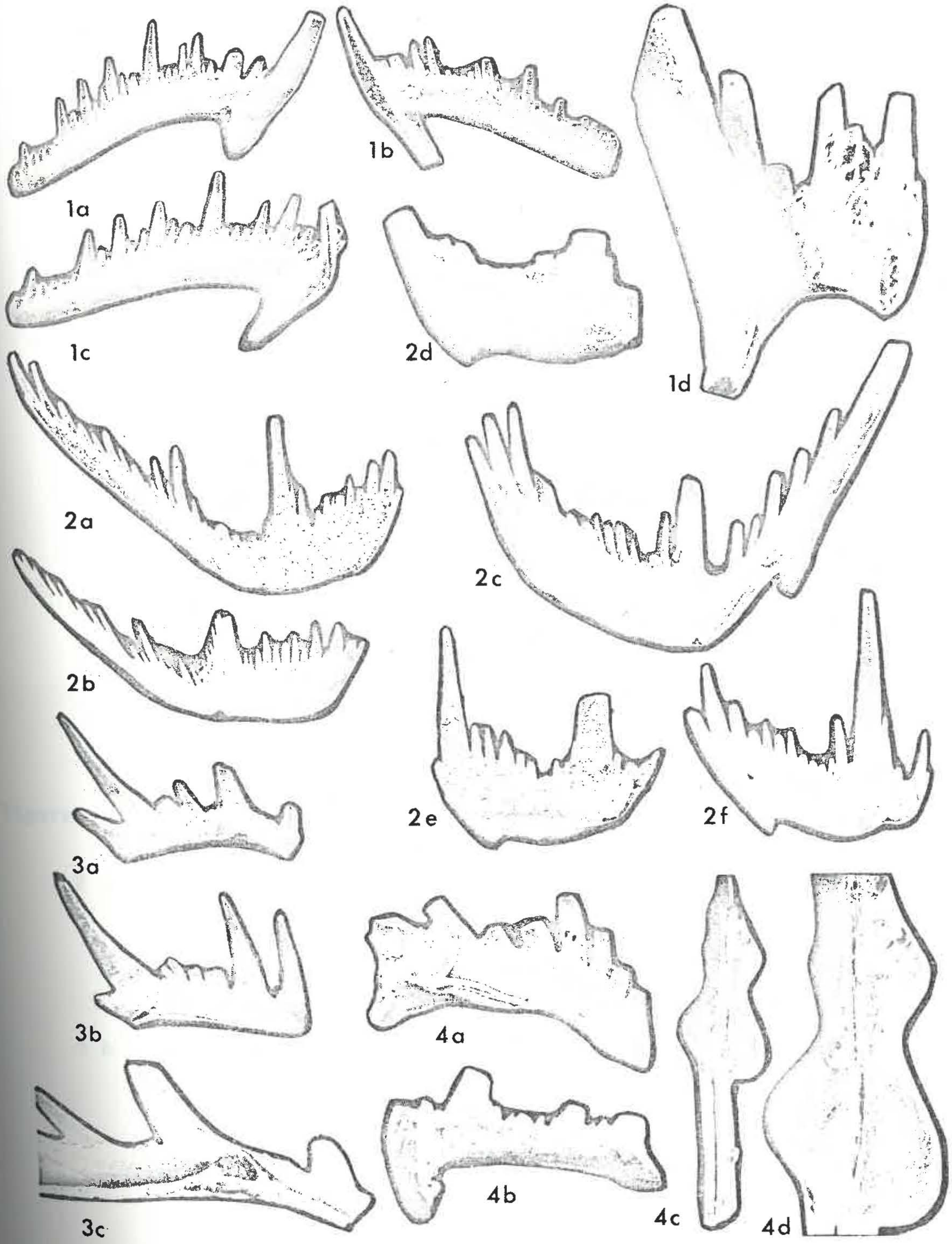
2 d	Inner lateral view of posterior bar of a stout sinistral element, UKMIP 1,901,024, sample LB-1-3E (Larsh-Burroak Shale), X84
2 e	Inner lateral view of posterior bar of a sinistral element showing nearly vertical cusp at the end of the bar, UKMIP 1,901,025, sample EC-1-1J (Ervine Creek Limestone), X112
2 f	Inner lateral view of posterior bar of a sinistral element showing variation in the orientation and number of the end denticles, UKMIP 1,901,026, sample P-1-6 (Plattsmouth Limestone), X96
Figures 3 a - c	*Plectospathodus* sp.
3 a	Lateral view of main cusp and posterior bar, UKMIP 1,901,027, sample He-1-4A (Heebner Shale), X67
3 b	Lateral view of main cusp and anterior bar, UKMIP 1,901,028, sample EC-1-1L (Ervine Creek Limestone), X90
3 c	Aboral view, UKMIP 1,901,027, X142
Figures 4 a - d	*Streptognathodus* and *Idiognathodus*, Hi element
4 a	Inside lateral view of an incomplete sinistral element showing swelling of central part of posterior bar, UKMIP 1,901,029, sample LB-1-3A (Larsh-Burroak Shale), X132

Explanation of Plate 10 (Continued)

4 b	Inside lateral view of incomplete dextral element showing swelling of central part of posterior bar, UKMIP 1,901,030, sample T-1-5B (Toronto Limestone), X109
4 c - d	Aboral views of incomplete element showing swelling of posterior bar, UKMIP 1,901,031, sample LB-1-1 (Larsh-Burroak Shale), X118 and X251 respectively.

von Bitter, 1971.

Plate 10



Explanation of Plate 11

Figures 1 a - e	*Ellisonia teicherti*, Hi element
1 a	Inner lateral view of a mature sinistral element, UKMIP 1,901,032, sample P-1-6 (Plattsmouth Limestone), X119
1 b	Inner lateral view of anterior cusp, UKMIP 1,901,032, X83
1 c	Inner lateral view of immature sinistral element, UKMIP 1,901,033, sample L-1-1 (Leavenworth Limestone), X201
1 d	Inner lateral view of mature dextral element, UKMIP 1,901,034, sample L-1-1 (Leavenworth Limestone), X79
1 e	Inner lateral view of main cusp, anterior denticles and anticusp, UKMIP 1,901,034, X148
Figures 2 a - b	*Cavusgnathus* Hi element
2 a	Inner lateral view of incomplete mature dextral element, UKMIP 1,901,035, sample B-1-4 (Beil Limestone), X92
2 b	Inner lateral view of complete immature sinistral element, UKMIP 1,901,036, sample H-1-3F (Hartford Limestone), X135

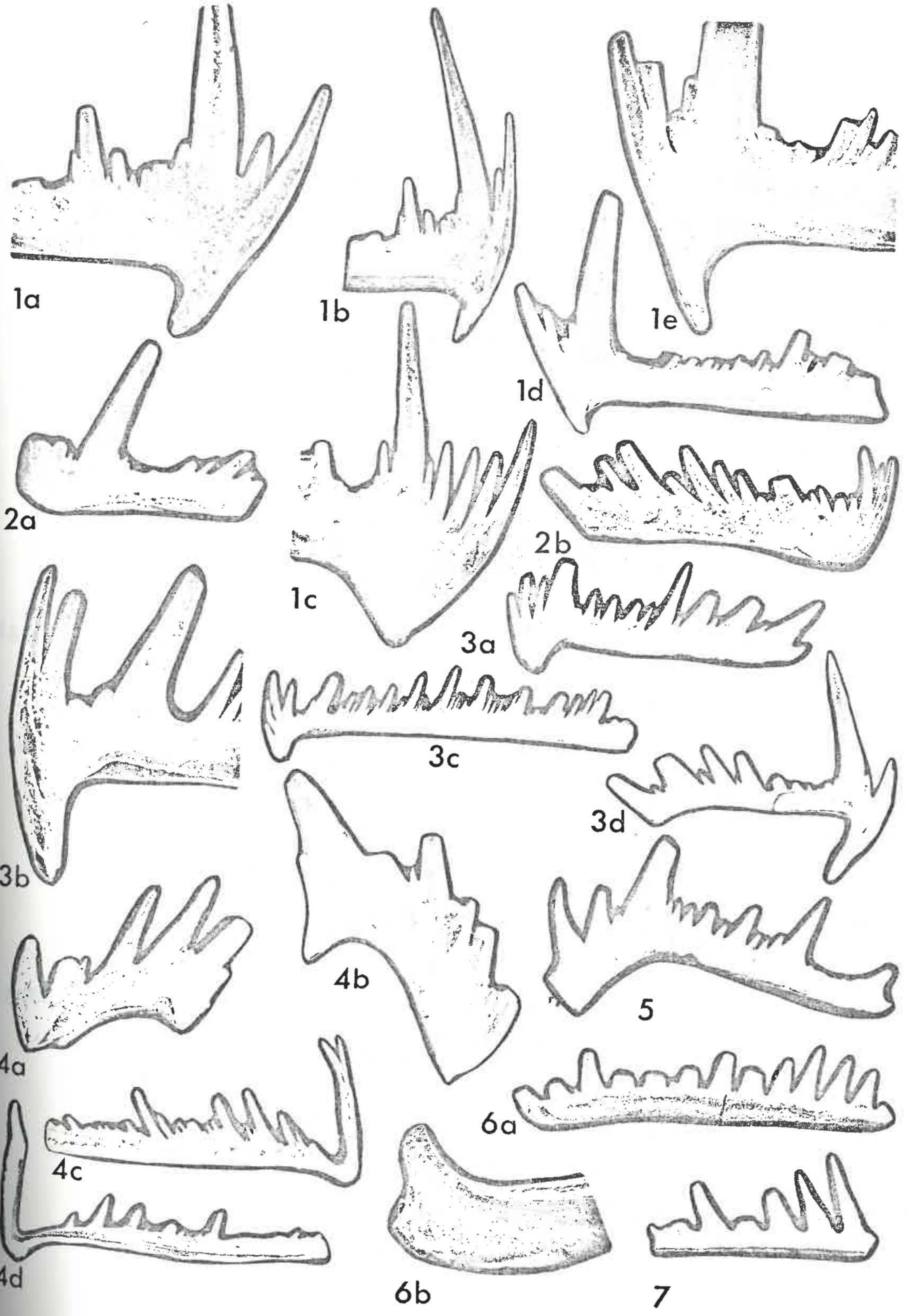
Explanation of Plate 11 (Continued)

Figures 3 a - d	*Streptognathodus* and *Idiognathodus*, Hi element
3 a	Inner lateral view of dextral element which is transitional with *Hindeodella* sp. B; UKMIP 1,901,037, sample BS-1-1 (Big Springs Limestone), X62
3 b	Inner lateral view of anterior part of dextral element, UKMIP 1,901,038, sample P-1-3 (Plattsmouth Limestone), X159
3 c	Inner lateral view of dextral element, UKMIP 1,901,038, X52
3 d	Inner lateral view of sinistral element, UKMIP 1,901,039, sample P-1-4 (Plattsmouth Limestone), X31
Figures 4 a - d	*Hindeodella parva* Ellison
4 a	Inner lateral view of anterior bar of sinistral element; small remnant of posterior bar present, UKMIP 1,901,040, sample EC-1-1J (Ervine Creek Limestone), X116
4 b	Inner lateral view of anterior bar of dextral element; anterior portion of posterior bar preserved, UKMIP 1,901,041, sample Heu-1-3A (Heumader Shale), X138
4 c	Lateral oral view of element in which both the anterior and posterior bars are preserved, UKMIP

Explanation of Plate 11 (Continued)

	1,901,042, sample EC-1-1D (Ervine Creek Limestone), X55
4 d	Aboral view of UKMIP 1,901,042, X62
Figure 5	*Hindeodella* sp. B
	Lateral inner view; note almost complete lack of inward curvature of anterior bar, UKMIP 1,901,043, sample P-1-5 (Plattsmouth Limestone), X86
Figures 6 a - b	*Lonchodus* ? sp.
6 a	Inner lateral view, UKMIP 1,901,044, sample P-1-5 (Plattsmouth Limestone), X52
6 b	Magnified view of anterior (?) end, UKMIP 1,901,044, X255
Figure 7	*Lonchodus simplex* (Pander)
	Lateral view of a fragment, UKMIP 1,901,045, sample He-1-3A (Heebner Shale), X46

von Bitter, 1971. Plate 11



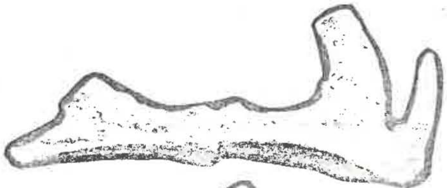
Explanation of Plate 12

Figures 1 a - c	*Ligonodina conflexus* (Ellison), Hi element
1 a	Inner lateral view of incomplete mature sinistral element; posterior bar broken, UKMIP 1,901,046, sample H-1-3D (Hartford Limestone), X51
1 b	Inner lateral view of immature dextral element, showing characteristic denticulation, UKMIP 1,901,047, sample EC-1-1B (Ervine Creek Limestone), X82
1 c	Aboral lateral view showing characteristic aboral groove and basal cavity, UKMIP 1,901,047, X82
Figures 2 a - b	*Ligonodina lexingtonensis* (Gunnell)
2 a	Inner lateral view of dextral element, UKMIP 1,901,048, sample P-1-2 (Plattsmouth Limestone), X113
2 b	Aboral view of dextral element, UKMIP 1,901,049, sample He-1-4A (Heebner Shale), X146
Figure 3	*Ligonodina subacoda* (Gunnell), Hi element
	Inner lateral view of dextral element, UKMIP 1,901,050, sample He-1-2B (Heebner Shale), X78

Explanation of Plate 12 (Continued)

Figures 4 a - c	*Ligonodina subacoda* (Gunnell), P1 element
4 a	Aboral view, UKMIP 1,901,051, sample He-1-4A, X184
4 b	Inner lateral view, UKMIP 1,901,052, sample He-1-4A, X135
4 c	Outer lateral view, UKMIP 1,901,053, sample He-1-4B, X86
Figures 5 a - c	*Lonchodina* ? *ponderosa* Ellison
	All specimens from the Heebner Shale, Oread Limestone
5 a	Inner lateral view, UKMIP 1,901,054, sample He-1-4A, X70
5 b	Outer lateral view, UKMIP 1,901,055, sample He-1-4A, X70
5 c	Aboral view, UKMIP 1,901,056, sample He-1-3B, X185

Plate 12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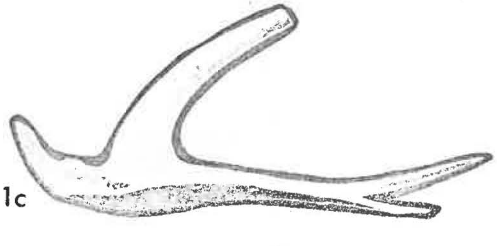
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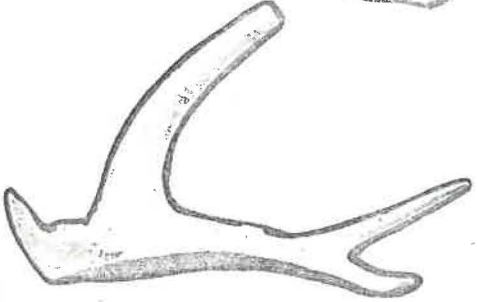
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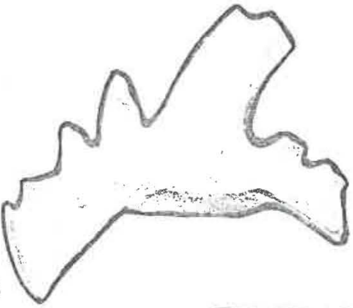
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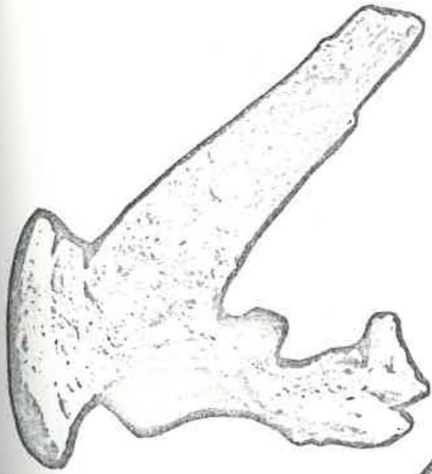
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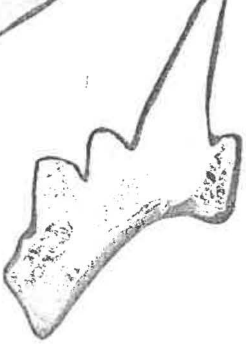
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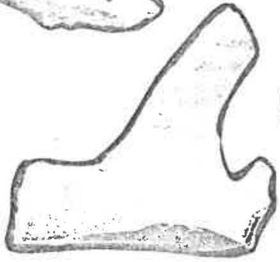
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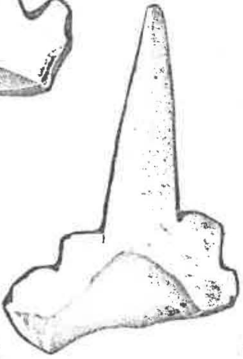
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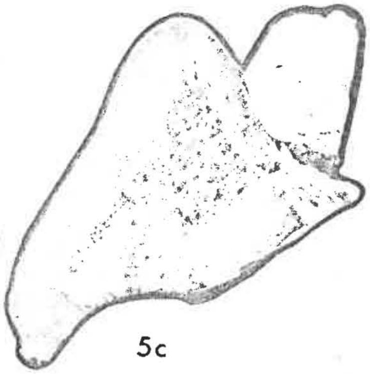
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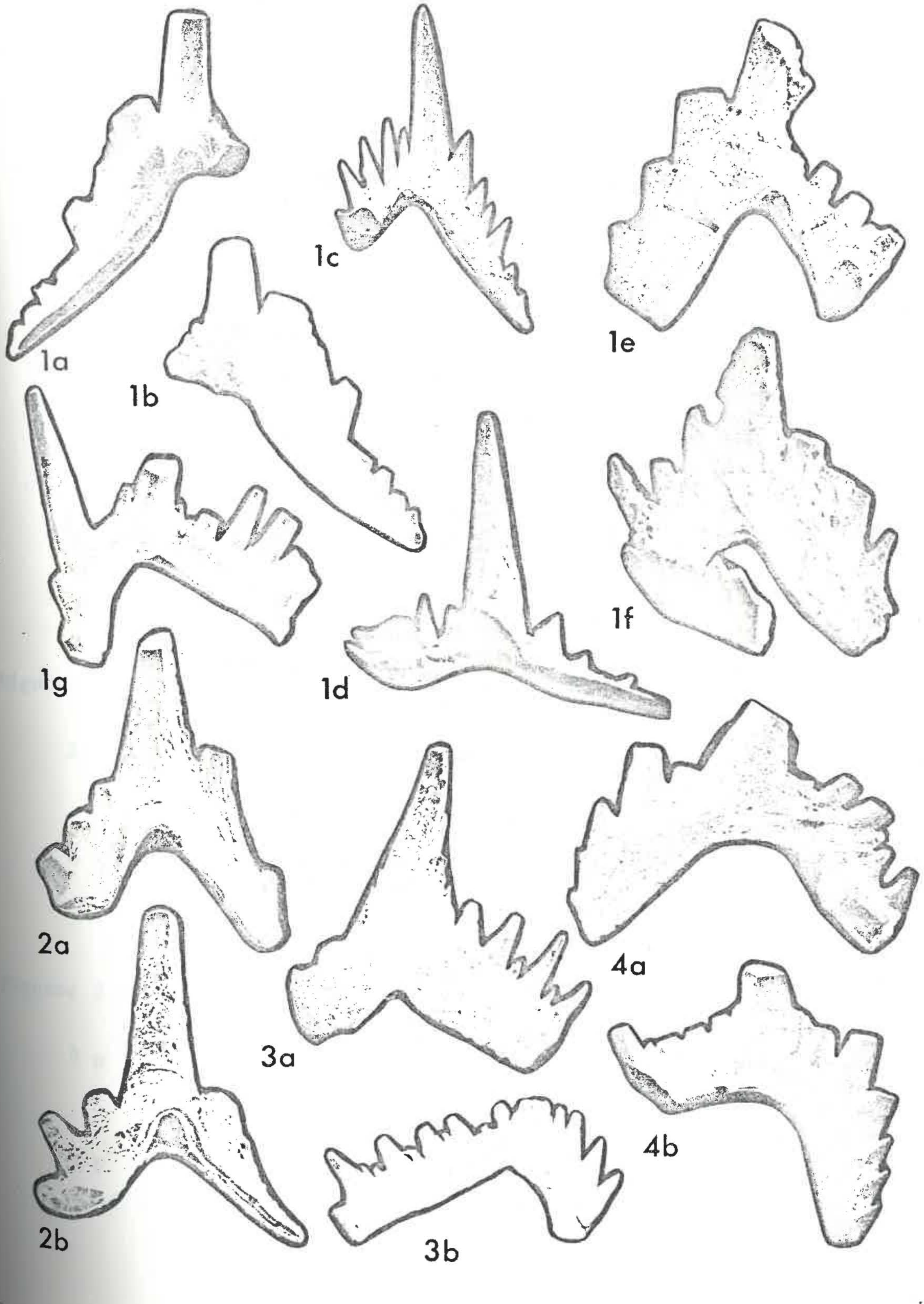
Explanation of Plate 13

Figures 1 a - g	*Lonchodina douglasi* n.sp.
	All specimens, except that figured in 1 f, from the Plattsmouth Limestone.
1 a	Inner lateral view of incomplete mature sinistral (?) element showing a well developed twisted anterior bar, holotype UKMIP 1,901,057, sample P-1-4, X63
1 b	Outer lateral view showing tendency of anterior bar denticles to fuse, holotype UKMIP 1,901,057, X61
1 c	Inner lateral view of a dextral (?) element, paratype UKMIP 1,901,058, sample P-1-1, X84
1 d	Aboral view showing lonchodinid basal cavity, paratype UKMIP 1,901,058, X134
1 e	Inner lateral view of sinistral (?) element, paratype UKMIP 1,901,059, sample P-1-1, X115
1 f	Inner lateral view of corroded, nearly complete dextral (?) element showing broad straight anterior bar and sharply curved posterior bar, paratype UKMIP 1,901,060, sample SB-1-2A(AA) (Spring Branch Limestone), X116
1 g	Inner lateral view of large mature sinistral (?) element, paratype UKMIP 1,901,061, sample P-1-4, X56

Explanation of Plate 13 (Continued)

Figures 2 a - b	Lonchodina sp. B
2 a	Inner lateral view, UKMIP 1,901,062, sample P-1-7 (Plattsmouth Limestone), X175
2 b	Aboral lateral view, UKMIP 1,901,063, sample SB-1-2B (Spring Branch Limestone), X196
Figures 3 a - b, 4 a - b	Lonchodina sp. A
3 a	Inner lateral view of (?) an immature sinistral (?) element, UKMIP 1,901,064, sample P-1-1 (Plattsmouth Limestone), X251
3 b	Inner lateral view of an (?) immature dextral (?) element, UKMIP 1,901,065, sample P-1-1 (Plattsmouth Limestone), X95
4 a	Inner lateral view of anomalous nearly complete dextral element, UKMIP 1,901,066, sample He-1-4A (Heebner Shale), X157
4 b	Inner lateral view of sinistral element, UKMIP 1,901,067, sample He-1-4A (Heebner Shale), X125


1a
1b
1c
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1e
1f
1g
2a
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3a
3b
4a
4b

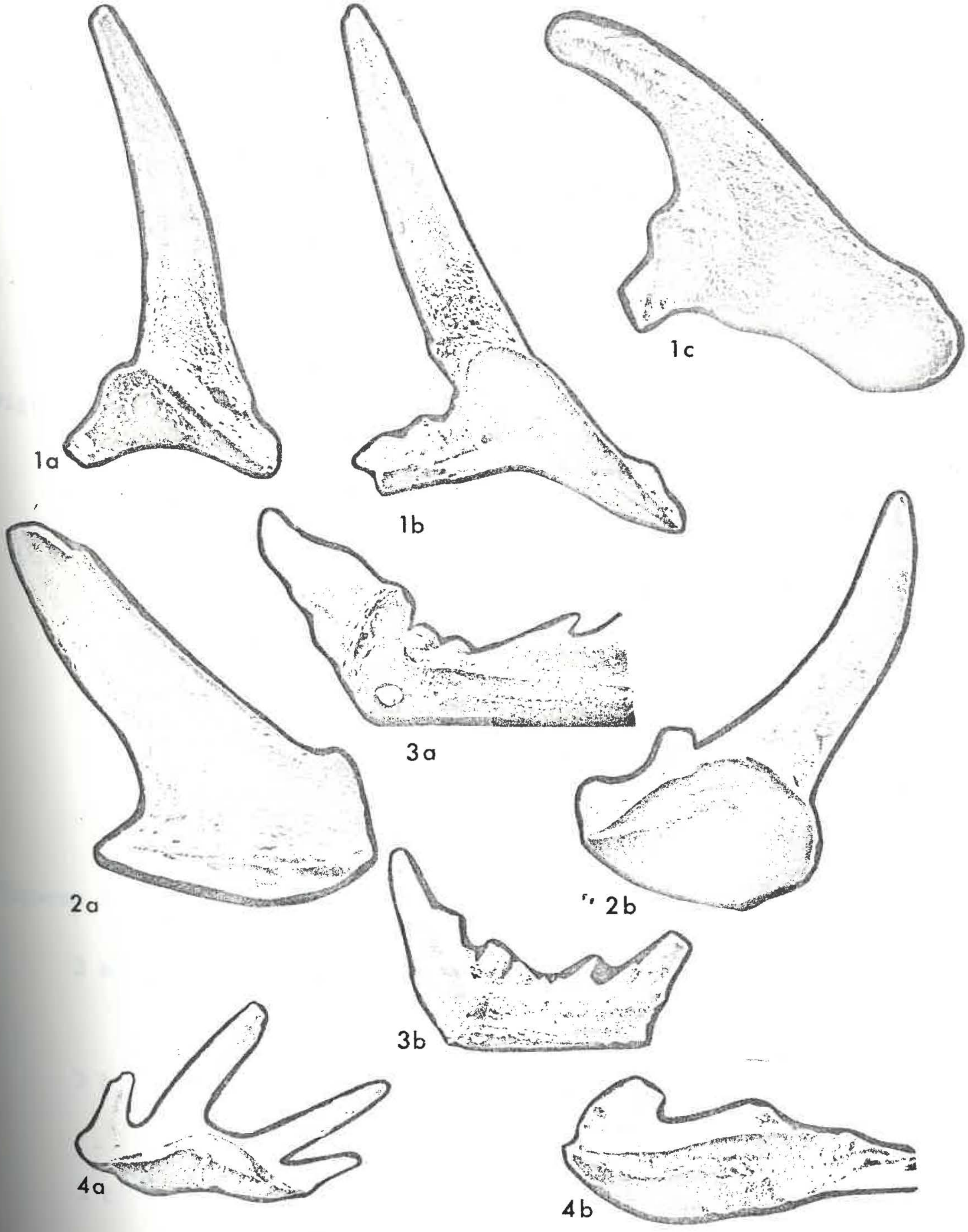
Explanation of Plate 14

Figures 1 a - c	*Ligonodina conflexus* (Ellison), P1 (?) element
1 a	Inner lateral view of immature element showing moderately large basal cavity and a lack of anterior and posterior bars, UKMIP 1,901,068, sample P-1-5 (Plattsmouth Limestone), X222
1 b	Inner lateral view of mature element showing typical lonchodinid basal cavity and anterior and posterior bars, UKMIP 1,901,069, sample Cur-1-1B (Curzon Limestone), X125
1 c	Outer lateral view, UKMIP 1,901,070, sample SB-1-2B (Spring Branch Limestone), X253
Figures 2 a - b	*Ligonodina conflexus* (Ellison), Ne (?) element
2 a	Lateral view, UKMIP 1,901,071, sample Os-1-3 (Oskaloosa Shale), X256
2 b	Aboral view, UKMIP 1,901,072, sample JPS-1-1 (Jones Point Shale), X190
Figures 3 a - b	*Metalonchodina* ? sp.
3 a	Aboral view of anterior portion, UKMIP 1,901,073, sample Hol-1-2A (Holt Shale), X240
3 b	Inner lateral view, UKMIP 1,901,073, X209

Explanation of Plate 14 (Continued)

Figures 4 a - b	*Ligonodina conflexus* (Ellison), Oz (?) element
4 a	Aboral lateral view of dextral element, UKMIP 1,901,074, sample P-1-5 (Plattsmouth Limestone), X93
4 b	Aboral view, UKMIP 1,901,075, sample Heu-1-1, X172

von Bitter, 1971. Plate 14



Explanation of Plate 15

All specimens with the exception of that illustrated in figure 5 are from the Plattsmouth Limestone

Figures 1 a - b	*Trichonodella obtusa* (Murray and Chronic)
1 a	Inner lateral view, UKMIP 1,901,076, sample P-1-1, X73
1 b	Aboral view showing basal cavity and aboral groove, UKMIP 1,901,076, X230
Figures 2 a - c	*Trichonodella plattsmouthi* n.sp.
2 a	Inner lateral view, holotype UKMIP 1,901,077, sample P-1-1, X87
2 b	Aboral view showing basal cavity and aboral groove, holotype UKMIP 1,901,077, X209
2 c	Inner lateral view of variant showing lesser number of denticles and less massive arms, paratype UKMIP 1,901,078, sample P-1-3, X72
Figures 3 a - c	*Trichonodella asymmetrica* n.sp.
3 a	Inner lateral view of mature sinistral (?) element, holotype UKMIP 1,901,079, sample P-1-1, X84
3 b	Inner lateral view of immature dextral (?) element, paratype UKMIP 1,901,080, sample P-1-1, X91
3 c	Inner lateral view of immature sinistral (?) element, UKMIP 1,901,081, sample P-1-1, X163

Explanation of Plate 15 (Continued)

Figures 4 a - b	*Hindeodus* sp. A
4 a	Inner lateral view, UKMIP 1,901,082, sample P-1-1, X125
4 b	Outer lateral view, UKMIP 1,901,083, sample P-1-1, X124
Figure 5	*Ellisonia teicherti* Sweet, Tr element
	Inner lateral view showing typical asymmetry, UKMIP 1,901,084, sample He-1-4A (Heebner Shale), X105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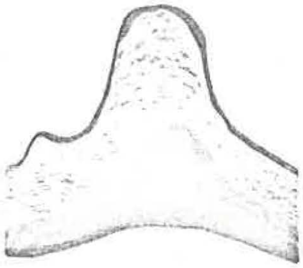
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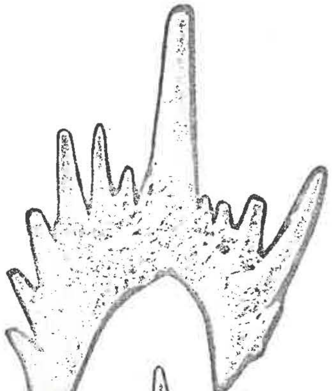
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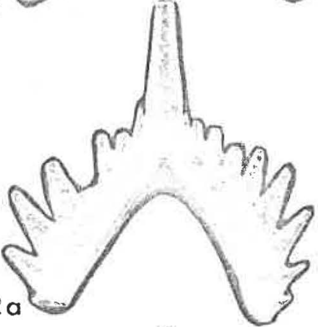
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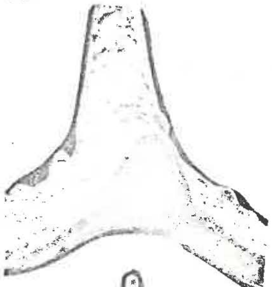
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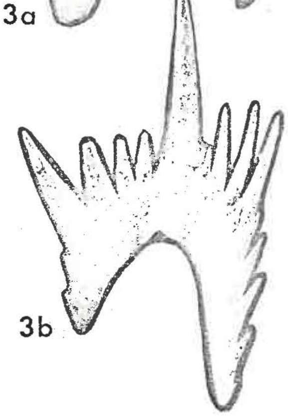
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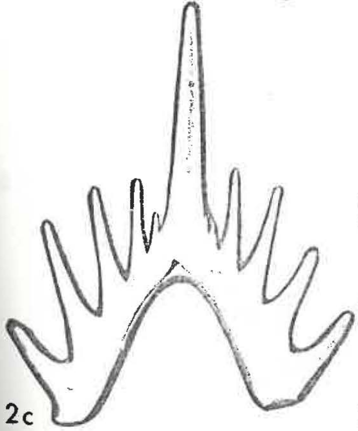
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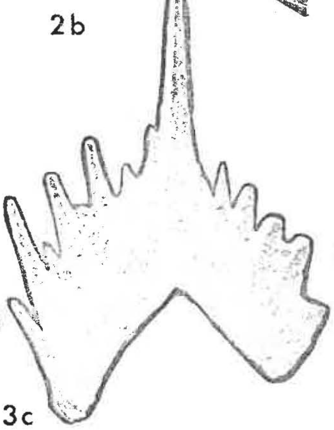
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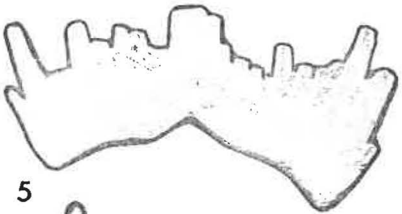
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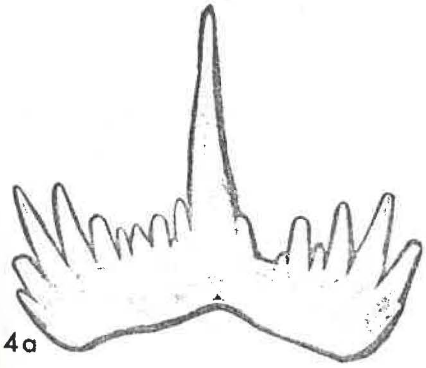
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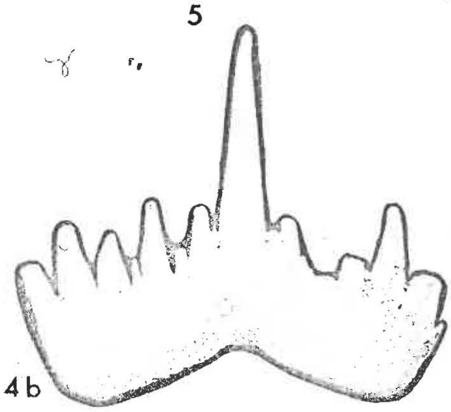
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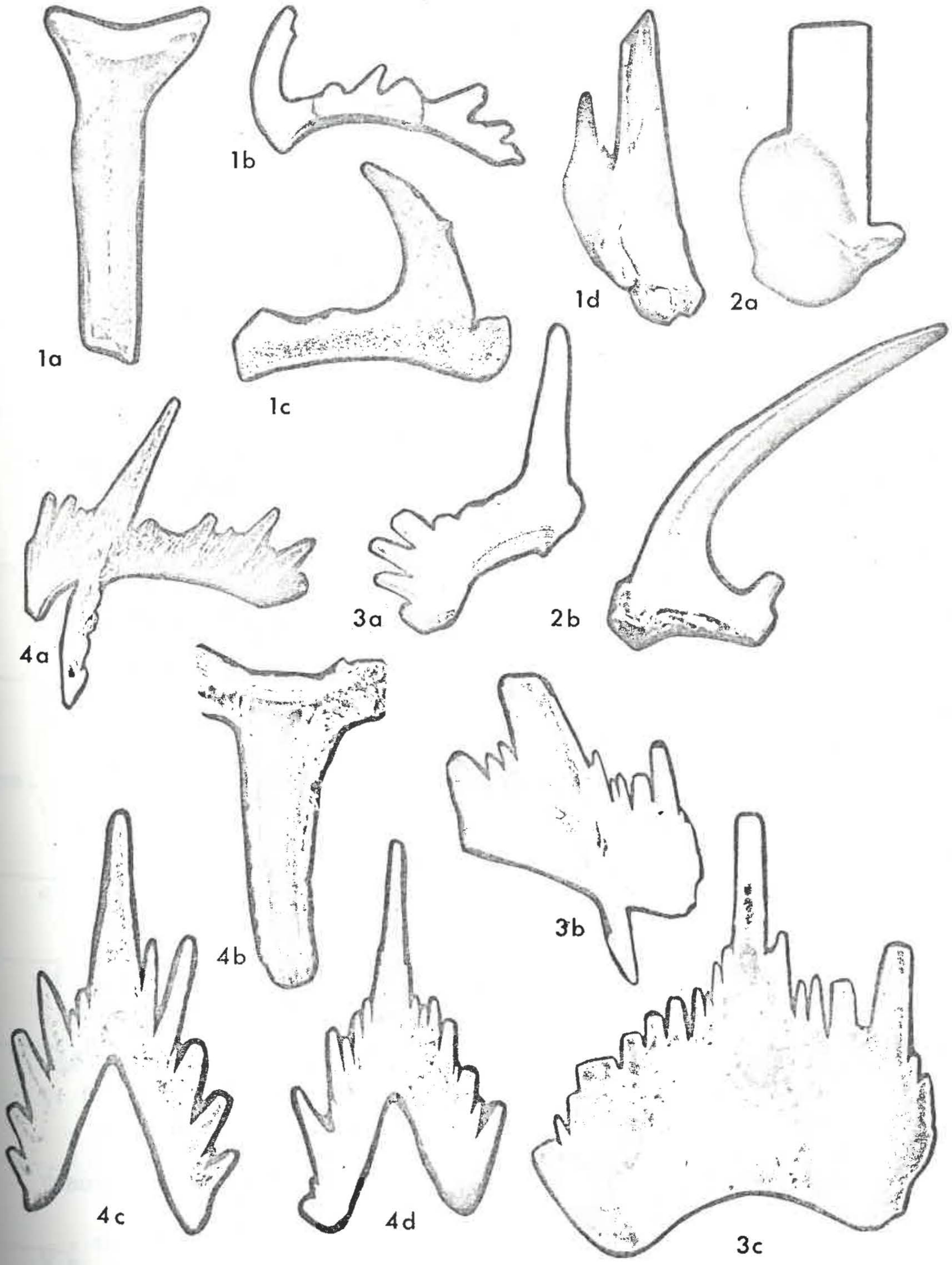
Explanation of Plate 16

Figures 1 a - d	*Ligonodina conflexus* (Ellison), Tr element
1 a	Aboral view showing wide aboral groove, UKMIP 1,901,085, sample LB-1-3B (Larsh-Burroak Shale), X132
1 b	Lateral view; posterior bar broken in two places, UKMIP 1,901,086, sample QH-1-2 (Queen Hill Shale), X26
1 c	Lateral view showing short anterior bar, UKMIP 1,901,087, sample H-1-3D (Hartford Limestone), X85
1 d	Anterior view showing well developed anterior bevel, UKMIP 1,901,088, sample QH-1-2 (Queen Hill Shale), X91
Figures 2 a - b	*Ligonodina subacoda* (Gunnell), Tr element
2 a	Aboral view of main cusp showing characteristic basal cavity, UKMIP 1,901,089, sample He-1-3B (Heebner Shale), X94
2 b	Lateral view showing main cusp and part of the posterior bar, UKMIP 1,901,090, sample He-1-3A (Heebner Shale), X73
Figures 3 a - c	*Cavusgnathus*, Tr element
3 a	Anterior view of a variant specimen, UKMIP 1,901,091, sample Cal-Sp-1 (Calhoun Shale), X106

Explanation of Plate 16 (Continued)

3 b	Lateral view, UKMIP 1,901,092, sample TCS-1-3 (Turner Creek Shale), X294
3 c	Anterior view, UKMIP 1,901,092, X451
Figures 4 a - d	*Streptognathodus* and *Idiognathodus*, Tr element
4 a	Lateral view showing alternating denticulation of posterior bar, UKMIP 1,901,093 sample P-1-6 (Plattsmouth Limestone), X107
4 b	Aboral view showing aboral groove of posterior and anterior bars as well as deep basal cavity, UKMIP 1,901,094, sample EC-1-1C, (Ervine Creek Limestone), X440
4 c	Anterior view of mature element, UKMIP 1,901,095 sample P-1-8 (Plattsmouth Limestone), X114
4 d	Anterior view of immature element, UKMIP 1,901,096 sample P-1-5 (Plattsmouth Limestone), X188

von Bitter, 1971. Plate 16



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APPENDIX A

Collecting Methods

The sampling procedure followed was one adapted from methods described by Collinson (1963, 1965). After the initial selection of the best exposed and complete sections these were sampled by continuous channel sampling normal to the bedding. This type of sampling was classified as search sampling by Krumbein (1965) and involved intensive centimeter-by-centimeter and bed-by-bed sampling, the importance of which was stressed by Rhodes (1968).

The sampling sequence is shown on Figs. 3 to 6 and is described in Appendix B. Samples were generally taken every few centimeters and were taken so as to include a piece of rock from every part of the particular sampling interval. Particular attention was paid to any evidence of lithological or megafaunal changes and a new sample was started wherever such a change occurred. Samples generally varied in weight between 1000 and 3000 grams.

After processing the samples taken by the above methods, it was realized that some of these contained too few conodonts to be meaningful. Some of the sample intervals represented by such samples were recollected as were samples which had been spoiled by such factors as accidental mixing of samples and spillage during laboratory preparation. In addition, several members were found to contain faunas of special interest or significance. These were also recollected.

Laboratory Methods

The laboratory procedures that were used, although differing in detail, were essentially those described by Collinson (1963, 1965). In washing samples broken down with one or more of acetic acid, Stoddard solvent, Quaternary "O" (Zingula, 1968), and sodium hypochlorite (Lindström, 1964), the writer used a 20 or 25 and 170 mesh screen combination. Although Collinson (1963) recommended the use of a lower 100 mesh screen this was felt to be inadequate for retaining small growth stages.

After the samples had been broken down by chemical and physical means they were processed with tetrabromoethane. The heavy portion of each sample was then processed by means of a Franz isodynamic magnetic separator using procedures described by Dow (1960, 1965). A few samples contained a large amount of unaltered pyrite which could not be separated with the magnetic separator. Such samples were either roasted and re-run through the magnetic separator (suggestion of W. Ziegler) or were processed with heavy liquid, methylene iodide (S.G. 3.3) (suggestion of J. Straka II).

Each sample was then picked by normal micropaleontological procedures.

Electron Microscope Procedures

An illustration of conodonts in this study were taken by the writer on a Cambridge scanning electron microscope.

Specimens were mounted on aluminum specimen stubs by means of a variety of adhesive materials. The most effective of these was double-sided Scotch tape. If, in mounting microfossils for scanning electron microscope examination, a wet mounting medium such as gum tragacanth or a solution of the adhesive of Scotch tape in chloroform is used, there is the tendency for the entire specimen to become gummed up in the mounting material. If such a specimen is then coated with a metal coating the outlines that are observed by means of the electron microscope are those of the mounting medium rather than those of the specimen underneath. Double-sided Scotch tape is essentially a dry mounting medium and the described problems were avoided by using it. Further, this type of tape cracked very little when coated under vacuum. Gum tragacanth, on the other hand, cracked considerably under these conditions. Such cracking is undesirable when taking microphotographs of entire microfossils, although it matters less when a detail view of a microfossil is photographed at high magnifications.

Subsequent to mounting, specimens were given one to two gold coatings. Initially a few specimens were coated with aluminum.

Figured specimens were removed from the aluminum stubs by means of chloroform.

Microphotographs of entire conodont elements were taken at as great a magnification as possible. The great resolution of this type of microscope made it possible to show very small immature specimens at the same size and with the same clarity as mature specimens (plates 1 to 16).

Curation of Collections

All figured and unfigured material of this study was deposited in the University of Kansas Museum of Invertebrate Paleontology, Lawrence, Kansas. Representative collections of unfigured specimens were given to the Geologisch-paläontologisches Institut, Philipps Universität, Marburg, West Germany and to the Department of Invertebrate Palaeontology, Royal Ontario Museum, Toronto, Canada by the University of Kansas Museum of Invertebrate Paleontology.

All specimens of a particular element type in a sample were placed in a separate micropaleontological slide and were generally given unique UKMIP (University of Kansas Museum of Invertebrate Paleontology) numbers. Figured specimens (Plates 1 to 16) were given numbers from UKMIP 1,900,901 to 1,901,096. The numbers assigned to unfigured paratypes ranged from UKMIP 1,901,097 to 1,901,145. The unfigured non-type specimens remaining at the University of Kansas were given numbers from UKMIP 1,901,146 to 1,927,102.

APPENDIX B

Locality Index

The members sampled at particular localities are indicated on Figures 3 to 6 and are described in this appendix.

Locality	Location	Description	References
1	NW sec. 21, T. 12 S., R. 19 E. Douglas Co., Kansas	Kansas Turnpike, 3 miles west of West Lawrence Interchange; sampled on north side of turnpike; Plattsmouth Limestone sampled approximately .25 miles west.	Moore (1964) Moore and Merriam (1965) Troell (1965) Locality 22 Evans (1966) Locality 10 Toomey (1964, 1969) Locality 18
2	NW NW sec. 24, T. 12 S., R. 18 E. Douglas Co., Kansas	Kansas Turnpike, 6 miles west of West Lawrence Interchange; strata below Big Springs Limestone sampled on south side of turnpike 0.3 miles east.	Moore (1964) Moore and Merriam (1965)

Locality	Location	Description	References
3	NE NW NW sec. 22, T. 12 S., R. 18 E. Douglas Co., Kansas	Kansas Turnpike, 8 miles west of West Lawrence Interchange; strata below Larsh-Burroak Shale sampled on north side of turnpike; above, with exception of sample EC-1-2 sampled on south side of turnpike.	Moore (1964) Moore and Merriam (1965)
4	SE SW sec. 2, T. 12 S., R. 16 E. Shawnee Co., Kansas	Kansas Turnpike, at Topeka Service Area; sampled on north side of turnpike.	Moore and Merriam (1965)
5	NW SW sec. 35, T. 11 S., R. 18 E. Douglas Co., Kansas	Limestone quarry; between Lecompton and Kansas River.	Jewett (1949) Stop 8 O'Connor (1960) Pl. 6 a

Locality	Location	Description	References
6	NW SE sec. 14, T. 11 S., R. 16 E. Shawnee Co., Kansas	U.S. Highway 24, fine exposure approximately 3.5 miles east of North Topeka; strata below Jones Point Shale sampled on south side of highway; above Jones Point Shale sampled on north side of highway.	Johnson and Adkison (1967)
7	SE NW SE sec. 8, T. 11 S., R. 18 E. Jefferson Co., Kansas.	Perry Dam, north-west end.	Koepnick (1969) Locality 7

Abbreviations Used in Measured Sections and Description of Sampling Units

(Adapted in Part from Webster (1969))

abdt(ly)	abundant(ly)
abve	above
alng	along
altng	alternating
app	apparently
approx	approximate
bd(s)	bed(s)
bdd	bedded
bddg	bedding
betw	between
bf	buff
bioclas	bioclastic
bky	blocky
bl	blue
blish	bluish
blk(ish)	black(ish)
bott	bottom
brach(s)	brachiopod(s)
brk	break
brn(ish)	brown(ish)
bry	bryozoa
calc	calcareous
carb	carbonaceous
charact	characterized
choc	chocolate
chrt(y)	chert(y)
cly	clayey
clylk	claylike
clyst	claystone
colr	color
col(s)	columnal(s)
com	common
conc	concretion
contg	containing
conts	contains
cor	corals
cr	cream
crin	crinoid
crshd	crushed
deb	debris
defnd	defined
dev	developed
diag	diagnostic
dk(er)	dark(er)

ear	earthy
ech	echinoid
echin	echinoderm
elong	elongated
f	fine
fnly	finely
fiss	fissile
flky	flaky
fos	fossils
fract	fracture
fract(s)(d)	fracture(s)(d)
frag(s)	fragment(s)
frsh	fresh
fri	friable
fus	fusulines, fusulinid
gastro	gastropod
gen	general
gn(ish)	green(ish)
gr(d)	grain(ed)
grad	gradational
gry(ish)	gray(ish)
gyp	gypsum
hkly	hackly
hd(r)	harder
hsh	hash
hvy	heavy
irrg	irregular
jt(d)	joint(ed)
lamin	laminated
lnses	lenses
lim	limey
limon	limonite
lk	like
lr	lower
lrg(ly)	large(ly)
ls	limestone
lt(r)	light(er)
lyr	layer
m	more
mkd	marked
mass	massive
matl	material
matt	matter
med	medium
microfos	microfossil
mid	middle
mott	mottled
nodl	nodular
nod(s)	nodule(s)
nonfos	nonfossiliferous
nonlamin	nonlaminated
nr	near

num	numerous
obsc	obscure
ol	olive
ool	oolitic
p	poor
pbbl(s)(y)	pebble(s)(y)
pelecy(s)	pelecypod(s)
phos	phosphatic
plstic	plastic
plty	platy
poss	possible
pres	present
prl(y)	poor(ly)
prog(ly)	progressive(ly)
pt(ly)	part(ly)
ptg(s)	parting(s)
pts	parts
r	rare
rd	round(ed)
rd(ish)	reddish
resist	resistant
rus	rusty
s	some
sd(y)	sand(y)
sft	soft
sgl	single
sh	shale
shly	shaly
silicif	silicified
sim	similar
sl	slightly
slt(y)	silt(y)
sltst	siltstone
sml	small
smplg	sampling
spi	spines
ss	sandstone
stn(d)	stain(ed)
stains	stains
strks	streaks
stylo	stylolites
surf	surface
tn	tan
thk(ness)	thick(ness)
thn(ly)	thin(ly)
u	upper
undlg	underlying
unt	unit
upwd(s)	upward(s)
v	very
vt	vertically
w	with
wea	weathers
wh(ish)	white(ish)

wvy	wavy
xl(n)	crystal(line)
xls	crystals
yel(ish)	yellow(ish)
z	zone

MEASURED SECTIONS AND DESCRIPTION OF SAMPLING UNITS

LOCALITY 1

Lawrence Shale

La-Sp-1	1	15.2 cm.	Sh, irrg bddg, lt gry mott w wh flecks; app nonfos.

Toronto Limestone

T-1-1	2	30.5 cm.	Ls, thn bdd, lt gry, wea yel brn; brachs, fus, crin cols.
T-1-2	3	20.3 cm.	Ls, thn bdd, lt gry, wea yel brn; brachs, fus, crin cols.
T-1-3	4	27.9 cm.	Ls, thn bdd, lt gry, wea yel brn; brachs, fus, crin cols.
T-1-4	5	43.2 cm.	Ls, thk bdd, mass, tn to gry, wea bky, wea yel brn; abdt crin cols, s fus.
T-1-5A	6	40.6 cm.	Ls, med to thk bdd, mass, lt gry to tn, wea bf to tn, wea hkly; abdt crin cols.
T-1-5B	7	17.8 cm.	Ls, med to thk bdd, mass, lt gry to tn, wea bf to tn, wea hkly; abdt crin cols, wea as distinct bd.
T-1-6	8	1.14 cm.	Ls, mass, thk bdd, bddg prly dev, lt tn gry, wea dk tn to brn.

T-1-7	9	63.5 cm.	Ls, mass, bddg prly dev, lt tn gry, wea dk tn to brn w hkly fract.

GRADATIONAL CONTACT WITH SNYDERVILLE SHALE

Snyderville Shale

Sn-1-1	10 and 11	27.9 cm.	Sn-1-1A (lr 5 cm.) Sh, gn w calc nods. Sn-1-1B (u 22.9 cm.) Sh, gn cly, mass, prly bdd.
Sn-1-2	12 and 13	1.22 cm.	Sn-1-2A (lr half) Sh, cly, mass, dk gn to dk gry gn, nodl, bddg prly dev; app nonfos. Sn-1-2B (u half) Sh, cly, mass, dk gn to dk gry gn, nodl, bddg prly dev; app nonfos. Thn coaly lyr betw Sn-1-2A and Sn-1-2B.
Sn-1-3	14	137.2 cm.	Sh, cly, mass, dk gn, dker nr top; app nonfos.
Sn-1-4A	15	15.2 cm.	Sh, gn to gry, wea brn, calc.
Sn-1-4B	16	10.2 cm.	Sh, gry, wea brn to yel, thnly lamin; brachs.

Leavenworth Limestone

L-1-1	17	53.5 cm.	Ls, dk bl to gry, f grd, sgl vt jtd bd, mass; brachs, fus.

Heebner Shale

He-1-1	18	3.8 cm.	Sh, blk to blkish brn, thn bdd, flky to ear, v fri; brachs.
He-1-2	19 and 20	152.4 cm.	Sh, blk, thn bdd, fiss, plty, phos conc; nr top bds cly and m mass bdd. Sample He-1-2A conts fiss hd sh; sample He-1-2B conts m cly sft matl.
He-1-3	21 and 22	48.3 cm.	Sh, gn to gry, cly, bddg prly dev; fos, brachs?. Lr pt m mass and dk gn to blk (He-1-3A); prog ltr upwds (He-1-3B).
He-1-4	23 and 24	35.6 cm.	Sh, sdy, yel to brn, hd, bddg prly dev app nonfos. He-1-4A = lr half; He-1-4B = u half.

Plattsmouth Limestone

P-1-1	25	101.6 cm.	Ls, lt gry, wea tn to bf, bddg approx 30 cm thk, nodl, f grd, wvy bddg; fos, brachs, cor, crin cols.

P-1-2	26	129.5 cm.	Ls, lt gry, wea tn to bf, nodl, f grd, wvy bddg; fos brachs, cor, abdt crin deb.
P-1-3	27	22.9 cm.	Ls, lt gry, wea tn to bf, nodl, f grd, wvy bddg, abdt chrt nods; cor, crin cols. Lr chrt z of Moore and Merriam (1965).
P-1-4	28	25.4 cm.	Sh, ear.
P-1-5	29	30.5 cm.	Ls, lt gry, wea tn to bf, nodl, f grd, wvy bddg; abdt fus, s crin cols and silicif (?) brachs.
P-1-6	30	43.2 cm.	Ls lt gry, wea tn to bf, nodl, f grd, wvy bddg, abdt chrt nods; abdt crin cols. U chrt z of Moore and Merriam (1965).
P-1-7	31	38.1 cm.	Ls, lt gry, wea dk brn, nodl, med bdd, abdt crin frags and sml brachs.
P-1-8	32	43.2 cm.	Ls, lt gry, wea irrg tn to gry, thn, to med bddg; v abdt fus, few crin cols.

LOCALITY 5

Heumader Shale

Lowest 2" of Heu Sh. at Lecompton	33	5.1 cm.	Sh, gry to bl, hvy Fe stn, abdt sml gyp xls.

Heu-1-1	34	12.7 cm.	Sh, gry to bl, hvy Fe stn, abdt sml gyp xls; sml fos.
Heu-1-2	35	27.9 cm.	Sh, gry to bl, well bdd to mass, Fe stn, abdt sml gyp xls.
Heu-1-3A	36	27.9 cm.	Sh, gryish-gn to bl, obsc bddg on frsh surf, bddg m app on wea surf.
Heu-1-3B	37	2.5 cm.	Sh, brnish, prly bdd non-lamin; crshd brachs and bry.
Kereford Limestone			
Ke-1-1	38	8.9 cm.	Ls, blish gry, sl mass, irrg bddg, ptly shly, wea rdish brn; fos - brachs and crin cols.
Ke-1-2A	39	15.2 cm.	Ls, lt to dk gry, mass, bds 5-7 cm. thk, wea brnish bf, w num shly ptgs, contg ls nods; fos - brachs, bry, fus.
Ke-1-2B	40	27.9 cm.	Same as Ke-1-2A; Top of smplg unt mkd by 2.5 cm. thk sh unt.
Ke-1-3	41	15.2 cm.	Ls, bky, gry, 5-7 cm. thk, altng w brn non -lamin sh contg pelecys. Unt charact by thn gry sh altng w thn ls.

Ke-1-4	42	63.5 cm.	Ls, gry bky, mass, slty, wea brn bf; 2.5 cm. thk sh unt at base; fos - brachs, crin frags.
Ke-1-5	43	15.2 cm.	Sh, gryish gn, sdy, hd, thn bddg; app nonfos.
Ke-1-6	44	92.7 cm.	Ls, gry, irrg bd sl mass, bddg 12.7 to 15.2 cm. thk, wea brn-bf; fos - fus, brachs; nr top shly and thnly bdd (2.5 to 5 cm.); app nonfos.
Ke-1-7	45	17.8 cm.	Ls, gry, med bdd; fos abdt nr top - brachs, crin cols, bry hsh.
Kanwaka Shale			
Jap-1-1	46	15.2 cm.	Sh, gry sdy, app nonfos.
LOCALITY 2			
Kanwaka Shale			
Kan-Sp-1	47	15.2 cm.	Sh, tn, cly, lamin, abdt brachs and pelecys (*Chonetes*, *Juresania*, *Derbia*, *Aviculopecten*, *Edmondia*) (Description adapted from Moore and Merriam, 1965).

LECOMPTON FORMATION

Spring Branch Limestone

SB-1-1	48 to 52	160 cm.	Ls, gry, f grd, mass, thk bdd, wea bf; abdt fus, s brachs and crin cols. Samples SB-1-1A to SB-1-1E from base up.
SB-1-2A	53 and 54	20.3 cm.	Ls, lt gry, brn, v shly sft w v abdt fus. 2 samples taken; SB-1-2A (SS) = shaly part; SB-1-2 (AA) = ls.
SB-1-2B	55	35.6 cm.	Ls, gry, sl m mass, wea brn to bf; conts abdt fus; Shly z in mid.
SB-1-3	56	25.4 cm.	Sh, blish gn, lamin, sft; abdt fus in lr half.
SB-1-4A	57	24.1 cm.	Ls, v shly, gn, thnly bdd, nonlamin app nonfos.
SB-1-4B	58	55.9 cm.	Ls, gry, shly, wea sl nodl and brnish; app nonfos.
SB-1-4C	59	5.1 cm.	Ls, gry, wea tn, breccia.
SB-1-5A	60	6.3 cm.	Sh, brn, cly, nonlamin; nonfos.
SB-1-5B	61	12.7 cm.	Sh, gryish blk.
SB-1-5C	62	12.7 cm.	Sh, yel, plstic, nonlamin; app nonfos.
SB-1-5D	63	12.7 cm. to 15.2 cm.	Same as SB-1-5C
SB-1-6	64	35.6 cm.	Ls, gry, mass, wea rdish brn; fos r gastro; nr top is a breccia.

SB-1-7	65	60.2 cm.	Ls, gry, mass, wea tn, lrgly intraformational breccia; app nonfos.

Doniphan Shale

Dos-1-1	66	12.7 cm.	Sh, choc brn, plstic, thnly lamin; app nonfos.
Dos-1-1A	67	22.9 cm.	Like Dos-1-1 but ltr in colr.
Dos-1-2	68	22.9 cm.	Sh, lt brn to lt brnish blk, cly, thn (2.5 to 5 cm.) hd unt in mid; fos brachs, pelecys, bry.

Big Springs Limestone

BS-1-1	69	20.3 cm.	Ls, gry, wea brn, med bdd, nod to wvy bddg, sl shly; fos fus.
BS-1-2	70	66 cm.	Ls, blish-gry, f grd wea tn to lt gry, sgl vt jt bd; fos brachs, abdt fus.

Queen Hill Shale

QH-1-1	71	48.3 cm.	Sh, dk blk, fiss.
QH-1-2	72	53.5 cm.	Sh, brn to brnish blk and ear, nr top nods pres; poss pelecys.

Beil Limestone

B-1-1	73	68.6 cm.	Ls, blish-gry, bioclas, thn-med bdd, wea brnish.
B-1-2	74	53.5 cm.	Ls, blish-gry, bioclas, med bdd, fos, wea shly, sim to B-1-1.
B-1-3	75	20.3 cm.	Ls, blish-gry, thn to med bdd, fos, wea gry. Lr pt shly.
B-1-4	76	48.3 cm.	Sh, bl to brn, lim, med to thn irrg bdd; fos?.
B-1-5	77	5.1 cm.	Ls, gry, irrg thkness; fos.
B-1-6	78	71.1 cm.	Sh, brn to blish, cly, contg approx 6 thn (2.5 cm.) ls lnses; ls is nod and irrg in thkness; abdt fos - crin cols, cor, fus, bry, pelecys, etc.
B-1-6 rt under B-1-7	79		Uppermost several cm. of B-1-6.
B-1-7	80	5.1 cm.	Ls, dk brn, limon, fnly lamin, diag. cont.

LOCALITY 7

King Hill Shale

KH-4-1	81	45.7 cm.	Sh, dk ol gn, non cly, sl sdy, elong blky. At base yelish z 12.5 to 15 cm. thk; app nonfos.
KH-4-2	82	91.4 cm.	Ls, cr rd to bf (ochre brn), med bdd (3.7 to 7.6 cm.), fnly lamin, v ear, Mn stnd.

KH-4-3	83	53.5 cm.	Same as KH-4-2 but bddg m mass (10 to 12.5 cm. thk bds).
KH-4-4	84	50.8 cm.	Sh, dk gn, blky; app nonfos.

Avoca Limestone

Av-3-1	85	7.6 to 10.2 cm.	Ls, shly, irrg thn (2.5 cm.) bdd.
Av-3-2	86	2.5 cm.	Sh, calc, poss fus.
Av-3-3	87	88.9 cm.	Ls, lt gry, mass, thk bdd (25 to 62 cm.), f grd, resist ledge former, wea yel to tn w rus stns; lr 1/2 conts - fus, crin cols, pelecys (*Pinna* sp.), brachs; u 1/2 conts oncolitic algae (*Ottonosia* sp.); poss *Amblysiphonella* pres.
Av-3-4	88	12.7 cm.	Sh, cly, dk brn, bddg obsc, contg shell hsh.
Av-3-5	89	12.7 to 15.2 cm.	Ls, dk gry, shly, wea ear; many brachs (*Crurithyris* sp.) on wea surf.

Deer Creek Limestone

LOCALITY 3

Tecumseh Shale

Te-Sp-1	90	76.2 cm.	Ls, impure, shly to sdy; nonfos.
Te-Sp-2	91	30.5 cm.	Sh, calc, gnish gry; nonfos.

Measurements and descriptions of these two units adapted from Moore and Merriam (1965).

Ozawkie Limestone

Oz-1-1	92	76.2 to 83.8 cm.	Ls, lt gry, ool, wea lt brn to tn, mass bddg; fos - brachs, fus.

Oskaloosa Shale

Os-1-1A	93	12.7 cm.	Ls, sft, irrg, limon stnd, wea yel, unusual columnar wea; app nonfos.
Os-1-1B	94	30.5 cm.	Slt, gn, contg pbbls of ls; app nonfos.
Os-1-2A to E	95 to 99	128.5 cm.	Sh, dk gn, bky, mass, underclay-like; app nonfos.
Os-1-3	100	17.8 cm.	Sh brn, bky, cly, lamin; fos - brachs (*Chonetes*).

Rock Bluff Limestone

RB-1-1	101	55.9 cm.	Ls, med gry, v f grd vt jt, semi-conch fract sgl bd w brk approx 15 cm. abve irrg base, wea lt tn; fos abdt fus, crin cols, brachs.

Larsh-Burroak Shale

LB-1-1	102	2.5 cm. ±	Sh, brn to tn, sft, ear; app nonfos.
LB-1-2	103	34.2 cm.	Sh, blk, fiss, thn bdd.
LB-1-3A to E	104 to 108	85.1 cm.	Sh, gn, thn bdd to lamin, wea brn to tn, sft, cly; app nonfos.

Ervine Creek Limestone

EC-1-1 A to M	109 to 121	182.9 cm.	Ls, lt gry, thn to med wvy bddg brn to gry, thn shly ptgs wea to limon, nr top abdt stylo; fos - fus, brachs, cor, crin cols.
EC-1-2	122	45.7 to 61 cm.	Same as EC-1-1 except wea rus. Top of Ervine Creek Limestone not exposed.

LOCALITY 4

Calhoun Shale

Cal-Sp-1	123	30.5 cm.	Slt, gry to ol gn; v fos w abdt pelecys.

Hartford Limestone

H-1-1	124	12.7 cm.	Ls, gry, w limon ptgs, med bdd, wea rus brn; fos - brachs.
H-1-2	125	12.7 cm.	Sh, brn, ear, bddg obsc, f blk carb matl pres; fos.
H-1-3	126 to 134	127 cm.	Ls, lt brn, mass, wea bky and lt brn, conts calcite "eyes" (crin cols); fos abdt fus. Samples H-1-3A to H-1-3I.

LOCALITY 6

Iowa Point Shale

IP-2-1	135	2.5 cm.	Ls, yel to brn, v shly, ear, fri; fos, v abdt fus.
IP-2-2	136	15.2 cm.	Sh, gry to ol gry, thn bdd, ptly lamin, lr 1/2 dker, brn strks alng bddg, app nonfos.
IP-2-3	137	21.6 cm.	Sh, gry, thn bdd (.6 cm.) altng w brn thn bdd sh, not cly; nonfos.
IP-2-4	138	20.3 cm.	Sh, med gry, mass, wea brn, v shly, bddg obsc, nr mid of unt calc nods; nr top fos - fus, brachs.

Curzon Limestone

Cur-1-1 A to C	139 to 143	151.2 cm.	Ls, rdish brn, mass, wea rus brn, f grd, med to thk bdd, approx 30 cm. from top chrt nods pres; fos-crin cols, lrg brachs, fus nr top and bott, gen fos hsh. Samples Cur-1-1A to Cur-1-1E w thknesses of 38.1, 10.2, 8.9, 35.6, and 58.4 cm. respectively. Cur-1-1C is shly ptg contg fos - fus and echin frags.
Cur-1-2	144	25.4 cm.	Ls, slty, brn, thn bdd (1.3 cm.).

Cur-1-3	145	43.2 cm.	Ls, gry, thn bdd, slty, wea brn; fos - fus, crin cols, bry. Samples Cur-1-3A (lr 1/2) and Cur-1-3B (u 1/2).
Cur-1-4	146	35.6 cm.	Ls, hd (xln), m mass than undlg slty ls.

Jones Point Shale

JPS-1-1	147	7.6 cm.	Sltst, brn, ear, clylk, nonlamin; fos - brachs, ech spi, phos matt.
JPS-1-2	148 to 150	152.4 cm.	Sh, blk to gry, plstic, thn-bdded, nonlamin, ptly fos - pelecys. From base upwards: JPS-1-2A 45.7 cm. JPS-1-2B 30.5 cm. JPS-1-2C 76.2 cm.
JPS-1-3	151	7.6 cm.	Sh, slty, lim, yel to gn to brn, thn bdded; app nonfos.

Sheldon Limestone

She-1-1	152	21.6 cm.	Ls, gry, f grd, wea yel brn, sgl bd; fos - brachs.
She-1-2	153	5.1 cm.	Sh, lim.
She-1-3	154	40.6 cm.	Ls, lt gry, fos, u and lr limit defnd by mound lk undulating surf-algal?; u surf bears microfos.

Turner Creek Shale

TCS-1-1	155	22.9 cm.	Sltst, brnish to blk; fos and ls (?) frags v abdt alng bddg, wea blish gry.
TCS-1-2	156	11.4 cm.	Clyst, brn, nod, conts carb matt and sml brachs (?) wea as lt brn band.
TCS-1-3	157	33 cm.	Ls, v fos, thn to med bdd, altng w sh and sltst. Ls v f grd and v fos - abdt pelecys - <u>Aviculopecten</u> and <u>Myalina</u> types and v sml crin cols, bry; lowest and top unts are ls. Shly pts are sdy w abdt pelecy frags. Wea blk and yel mott.
TCS-1-4	158	16.5 cm.	Sh, brn to ol gn, thn bdd, nonlamin fos - brachs, pelecys.

Du Bois Limestone

DB-1-1	159 and 160	33 cm.	Ls, mass, thk bdd, lt gry, wea brn to tn; fos - brachs and pelecys. DB-1-1A, lr half. DB-1-1B, u half.

Holt Shale			
Hol-1-1	161	20.3 cm.	Sh, cly, thn bdd, brn to dk gry; abdt fos - brachs, pelecys, etc.
Hol-1-2	162 and 163	38.1 cm.	Sh, brn, sl m sdy than undlg unt and app few fos Hol-1-2A, lr 30.5 cm. Hol-1-2B, u 7.6 cm.
Coal Creek Limestone			
CC-1-1	164 to 167	100.4 cm.	Ls, lt gry, slty, med to thn bdd, wea nodl, altng w shly bds; abdt fos - brachs, crin cols, bry, etc. CC-1-1A lowest 14 cm. CC-1-1B next higher 30.5 cm. CC-1-1C next higher 25.4 cm. CC-1-1D highest 30.5 cm.
CC-1-2	168	25.4 cm.	Sh, slty, wea gn to yel.
CC-1-3	169	20.3 cm.	Ls, thn (5 cm.) bd overlain by sh which wea yel mott, followed by thn sh w abdt limon and blk carb (?) specks.
CC-1-4	170	15.2 cm.	Ls, mass, wea rdish brn, sgl bd.
Severy Shale			
6" over CC-1	171	15.2 cm.	Sh, slty, gnish mott, app nonfos.

SUMMARIES OF DEPOSITIONAL ENVIRONMENTS

SHAWNEE GROUP

OREAD LIMESTONE

TORONTO LIMESTONE

Megascopic	Massive light yellow brown to gray limestone; on exposure becomes deep yellow brown. (O'Connor, 1960).
Microscopic	Lower half in central Kansas is skeletal mud facies characterized by presence of diverse skeletal grain types; upper half is a fenestrate bryozoan-echinoderm grain facies in central Kansas. (Troell, 1965).
Thickness	About ten feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Tarkio-type (*Triticites*) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Stage C, argillaceous transgressive-regressive marine stage (Wagner, 1964). Deposited during a single advance and retreat of the sea (Troell, 1965, 1969). Lower part transgressive; upper part regressive (Elias, 1964).

Environment of Deposition	Not deepest parts of invading sea but intermediate to greatest distance from sea margins (Moore, 1964). At the writer's locality 1 according to Troell (1969) the basal zone (*Osagia* wackestone) was deposited at the strand line as the marine waters of the Toronto sea transgressed. The next higher depositional unit (mixed biota wackestone) was laid down under open marine conditions. The waters were clear, intermittently agitated with little terrigenous influx and optimum ecologic conditions with normal salinity, good water circulation and good food supply. The third unit (fenestrate bryozoan-echinoderm wackestone facies) was also deposited under marine conditions. The uppermost unit (lime mudstone) was laid down under restricted conditions in shallow nearshore brackish waters (possibly supra to intertidal) which may have been periodically subjected to subaerial exposure.

SNYDERVILLE SHALE

Megascopic	Green to gray, argillaceous to silty shale, claystone and siltstone (O'Connor, 1960). Lower and middle part are unfossiliferous blocky clay. Thin 1' ± fossiliferous zone at top (Moore, 1964).

Thickness	Average 10-15 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Snyderville type (*Neochonetes*) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Stage D continental margin stage; regressive continental (Wagner, 1964).
Environment of Deposition	Lower and middle part is nonmarine; upper part deposited in shallow water where mud bordered shore, although perhaps in a belt many miles wide; little disturbance by currents and waves, with possibly slightly subnormal salinity (Moore, 1964).

LEAVENWORTH LIMESTONE

Megascopic	Single massive bed of hard, gray-blue, fine grained limestone which weathers light gray or creamy gray, and which shows prominent vertical jointing (O'Connor, 1960).
Microscopic	At the writer's locality 1, the lithology is skeletal mudstone (Toomey, 1964).
Thickness	Generally 0.8 to 2 feet in Douglas Co. (O'Connor, 1960).

Ecological Classification	Leavenworth type (*Isogramma*) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Stage E, rapid oscillation marine stage (Wagner, 1964). Deposited during a second comparatively brief cycle in the staggering (sic) Oread oceanic invasion, resulting in maximal depth of waters hardly exceeding the depth at the culmination of the first (Toronto) cycle (Elias, 1964). Deposited as the beginning marine phase in the second of two eustatic sea-level changes (Troell, 1965).
Environment of Deposition	The middle was deposited in more turbulent and shallower water than other parts of the limestone (Dixon, 1960). In relatively clear, shallow to slightly deeper near shore carbonate-rich water (Wagner, 1964). At least the middle Leavenworth was deposited in quiet water (Johnson and Adkison, 1967). Deposited in relatively shallow water on a broad, slowly subsiding carbonate platform (Toomey, 1969).

HEEBNER SHALE

Megascopic	Black fissile shale overlain by clayey, green to gray calcareous shale.
Microscopic	See Evans (1966).
Thickness	5-8 feet in central and southern Douglas Co. South of Worden Fault it is between 14 and 18 feet thick. O'Connor, 1960).
Ecological Classification	Heebner Type (<u>Listracanthus</u>) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Stage F, stagnant water marine stage (Wagner, 1964). Leavenworth, Heebner and Plattsmouth members were deposited during a single major advance and retreat of the sea with no significant regression after deposition of Leavenworth Limestone (Evans, 1966).
Environment of Deposition	Near shore in shallow waters--possibly in lagoons (Moore, 1936). A similar black shale, the Bennett Shale, was interpreted by McCrone (1963) to have been deposited "just below mean lowtide level within a poorly oxygenated basin having restricted internal circulation and lacking free communication with the open seas".

Not marine swamp or marsh. Deposited in shallow water (only a few meters); not in normal open sea with shallow bottom nor in deep water (Moore, 1964).

A time of poorly circulating oxygen deficient seawater. Tidal and current movement was minimal. Seaweed was possibly dominant life form--essentially filling the upper part of shallow sea (Wagner, 1964).

Relatively far from shore; relatively deep, oxygen deficient, below wave base, marine. (Evans, 1966).

Accumulations of black mud, probably in shallow water, under reducing conditions favorable for growth of conodonts with phosphatic nodules. Gray marine shale of upper Heebner deposited in well-aerated gradually deepening sea (Johnson and Adkison, 1967).

PLATTSMOUTH LIMESTONE

Megascopic	Light gray to nearly white wavy bedded limestone, which weathers light gray to light tan; has chert and shale partings (O'Connor, 1960).
Microscopic	Well bedded skeletal calcarenite to calcilutite in north central Kansas (Heckel and Cocke, 1969).
Thickness	About 18 feet thick in Douglas Co. (O'Connor, 1960).
Ecological Classification	Plattsmouth type (*Caninia*) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Normal transgressive marine stage phase (Wagner, 1964). Belonged to culminating marine part of cyclothem (Moore, 1964).
Environment of Deposition	Deposited in clear, shallow (less than 20 meters on the average) water, far from nearest shore (probably 50 to 100 miles distant) (Moore, 1964). In medial and late Plattsmouth time a water depth of about 200 feet--then shallowed (Elias, 1964). Deposited in relatively shallow water; water depth, strand line and sediment source varied repeatedly (Johnson and Adkison, 1967).

HEUMADER SHALE

Megascopic	Gray to green clayey and calcareous shale (O'Connor, 1960).
Thickness	2-4 feet in Douglas Co. Locally slightly thicker (O'Connor, 1960).
Transgressive-Regressive Sea Classification	Regressive, except for minor re-advance in fossiliferous upper part (Johnson and Adkison, 1967).
Environment of Deposition	Nearshore in retreating sea (Johnson and Adkison, 1967).

KEREFORD LIMESTONE

Megascopic	Gray limestone and calcareous shale beds, which weather light gray to tan. The lower limestone beds tend to be flaggy; upper limestone beds are oolitic (O'Connor, 1960).
Microscopic	In Douglas Co. the Kereford consists of biomicrite and fossiliferous micrite, changing upward into biosparite-biomicrite or even an oosparite (Monger, 1961).
Thickness	2.5 to 9 feet in Douglas Co. (O'Connor, 1960).

Ecological Classification	Kereford type (<u>Fenestrellina</u>) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Deposited during the overall regressive phase of the "Oread" megacyclothem (Monger, 1961).
Environment of Deposition	Lower part laid down under quiet marine conditions; upper part was deposited above wave base (Monger, 1961). Similar environment to that of Beil except that water nearer shore with a muddy sea bottom (Moore, 1964). Deposited during shallowing of the Oread Sea (Elias, 1964).

KANWAKA SHALE

Megascopic	Consists of two thick shale members with a thin limestone member in between (O'Connor, 1960).
Thickness	About 60 feet in Douglas Co. (O'Connor, 1960).
Environment of Deposition	Non-marine, except for return of marine environment in middle part of deposition of the formation. Sparse molluscan fauna found in upper part of

Kanwaka shows return of marine condition before deposition of the Lecompton (Johnson and Adkison, 1967).

LECOMPTON LIMESTONE

SPRING BRANCH LIMESTONE

Megascopic	The lower five feet is massive light tan or light-gray brown limestone similar to Toronto Limestone. Overlying the massive limestone are 3 to 8 feet of shaly limestone, shale and limestone (O'Connor, 1960).
Thickness	8 to 14 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Tarkio type (*Triticites*) assemblage (Moore, 1964).
Environment of Deposition	The lower Spring Branch was deposited in quiet water, perhaps deeper than normal marine, but shallow enough for food to be abundant (Yochelson *in* Johnson and Adkison, 1967). The upper Spring Branch was deposited in shallower water (Johnson and Adkison, 1967). Intermediate to greatest distance from the invading sea margins (Moore, 1964).

DONIPHAN SHALE

Megascopic	Dark gray clayey shale; sparingly fossiliferous, containing plant remains and mollusks near top (O'Connor, 1960).
Thickness	2 to 5 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Doniphan type (*Rhombopora*) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Represents the initial parts of a marine sequence (Moore, 1964).
Environment of Deposition	Environment similar to that of the Snyderville Shale, which is in comparable position in the Oread Limestone (Moore and Merriam, 1965). Non-marine, estuarine (Johnson and Adkison, 1967).

BIG SPRINGS LIMESTONE

Megascopic	Dark black to gray limestone; weathers light tan and has prominent vertical joints (O'Connor, 1960).
Thickness	2 to 3 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Tarkio type (*Triticites*) assemblage (Moore, 1964).

Environment of Deposition	After Doniphan Shale deposition, a deepening of sea and deposition of Big Springs Limestone; this member is algal--may indicate shallower water environment in Lower Big Springs time (Johnson and Adkison, 1967). Same or similar environment of deposition as Spring Branch Limestone (Moore, 1964).

QUEEN HILL SHALE

Megascopic	Lower part is a hard black fissile shale; upper part is a gray, tan weathering thin-bedded soft shale (O'Connor, 1960).
Thickness	2 to 5 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Heebner type (Listracanthus) assemblage (Moore, 1964).
Environment of Deposition	Similar to environment of deposition of Heebner Shale. (Moore, 1964; Johnson and Adkison, 1967). Probably postulated depositional environment of Bennett Shale (McCrone, 1963) is similar.

BEIL LIMESTONE

Megascopic	Lower half is a relatively massive, irregularly bedded, light gray fossiliferous limestone; upper half is interbedded, thin nodular limestone, shaly limestone and very calcareous shale (O'Connor, 1960).
Thickness	9 to 10 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Beil type (*Pulchratia*) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	This environment is interpreted to belong in the culminating marine part of the cyclothem (Moore, 1964).
Environment of Deposition	Normal marine with fairly quiet water (Yochelson *in* Johnson and Adkison, 1967). Clear sunlit shallow waters (estimated less than 20 m. on the average) far from the nearest shores probably 50 to 100 miles distant (Moore, 1964).

KING HILL SHALE

Megascopic	Gray, green, yellow clayey and calcareous shale containing a yellow "boxwork" limestone in the upper part and generally one or more thin impure limestones in the middle and lower parts (O'Connor, 1960).
Thickness	In Douglas Co. averages 8 or 9 feet; locally may be as thin as 5 feet (O'Connor, 1960). 8 feet thick in the Kansas River valley and about 11 feet thick in southeastern Shawnee Co. (Johnson and Adkison, 1967).
Environment of Deposition	Lower part may have been continental; upper part deposited in shallow marine waters (Johnson and Adkison, 1967).

AVOCA LIMESTONE

Megascopic	A dense, gray-blue massive limestone which weathers blue-gray to buff (O'Connor, 1960).
Thickness	3 to 4.5 feet in Douglas Co. (O'Connor, 1960). 3 to 4 feet in eastern Shawnee Co. (Johnson and Adkison, 1967).

Ecological Classification	Avoca type (*Amblysiphonella*) assemblage (Moore, 1964).
Environment of Deposition	Deeper marine during deposition of the lower part with shallowing during deposition of the upper part. (Johnson and Adkison, 1967).

TECUMSEH SHALE

Megascopic	Micaceous sandy, silty shales; siltstone; sandstone; plant fossils found in most of member; marine fossils in the upper few feet (O'Connor, 1960).
Thickness	Along the Kansas River about 65 feet thick; southward thins to about 58 feet (O'Connor, 1960).
Environment of Deposition	The basal Tecumseh represents a retreating marine environment. Most of Tecumseh time was a time of continental deposition. The upper Tecumseh represents deposition in a transgressing sea. (Johnson and Adkison, 1967).

DEER CREEK LIMESTONE

OZAWKIE LIMESTONE

Megascopic	Lower part massive gray, brown weathering limestone containing fusulinids and Osagia; upper part massive, light gray to buff, earthy, impure molluscan limestone; weathers to various shades of yellow or brown; locally, upper and lower beds unfossiliferous and middle bed oolitic (O'Connor, 1960).
Thickness	5 to 11 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Ozawkie type (Knightites) assemblage (Moore, 1964).
Environment of Deposition	Lower Ozawkie is fusulinid rich rock of Tarkio type and is considered to mark culminating marine conditions within the Ozawkie cycle. The Knightites assemblage, with associated Osagia, doubtless lived in marginal parts of the retreating Ozawkie sea, though at undeterminable distance from the nearest strand line. (Moore, 1964). Deeper marine during deposition of the lower part changing to extremely shallow water or beach environment during the deposition of the upper part (Johnson and Adkison, 1967).

OSKALOOSA SHALE

Megascopic	Thin bedded shale and blocky clay; gray to greenish when fresh; weathers drab yellow (O'Connor, 1960).
Thickness	2 to 5 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Snyderville type (Neochonetes) assemblage (Moore, 1964).
Environment of Deposition	Upper portion deposited in shallow water where mud bordered the shore, perhaps in belt many miles wide. Little wave or current action and salinity may have been slightly subnormal (Moore, 1964). Lower part, continental; upper part, marine (Johnson and Adkison, 1967).

ROCK BLUFF LIMESTONE

Megascopic	Single bed of hard dense to fine grained dark blue gray limestone characterized by prominent vertical jointing (O'Connor, 1960).
Thickness	About 2 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Leavenworth type (Isogramma) assemblage (Moore, 1964).

Environment of Deposition	Marine (Johnson and Adkison, 1967). Same or similar environment of deposition to that of Leavenworth Limestone (Moore, 1964).

LARSH-BURROAK SHALE

Megascopic	Lower part is black, fissile shale; upper part is dark to light gray thin bedded shale (O'Connor, 1960).
Thickness	2.5 to 5.0 feet; commonly about 3 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Heebner type (*Listracanthus*) assemblage (Moore, 1964).
Environment of Deposition	Lower part reducing marine; upper part normal marine (Johnson and Adkison, 1967). Same or similar to that of the Heebner Shale (Moore, 1964). Probably postulated depositional environment of the Bennett Shale (McCrone, 1963) is similar.

ERVINE CREEK LIMESTONE

Megascopic	Lower 10 to 14 feet consists of light gray to white hard thin, wavy-bedded limestone containing some shale partings; upper part is approximately 4 feet thick, is shalier and may consist of a dark gray shale bed followed by a coquinoid limestone (O'Connor, 1960).
Thickness	13 to 17 feet; averaging about 15 feet in Douglas Co. (O'Connor, 1960).
Ecological Classification	Beil type (Pulchratia) assemblage (Moore, 1964).
Transgressive-Regressive Sea Classification	Environment belongs in the culminating marine part of the cyclothem (Moore, 1964).
Environment of Deposition	Normal marine (Johnson and Adkison, 1967). Clear sunlit shallow waters (estimated less than 20 m. on the average) far from the nearest shores (probably 50-100 miles distant) (Moore, 1964).

Unless indicated otherwise all following information in Appendix B is taken from Johnson and Adkison (1967).

CALHOUN SHALE

Megascopic	Mainly siltstone, sandstone and claystone in eastern Shawnee Co.; some limestone present locally and a thin coal bed occurs near the top.
Thickness	42 to 55 feet.
Environment of Deposition	Lower Calhoun is estuarine or very shallow near-shore marine (Yochelson, *in* Johnson and Adkison, 1967); middle Calhoun is continental. The upper Calhoun is swamp followed by local marine conditions.

TOPEKA LIMESTONE

HARTFORD LIMESTONE

Megascopic	Mostly limestone but with thin claystone bed near base. Limestone is light gray, very fine grained to very finely crystalline, hard and thin-bedded to massive. Limestone characteristically weathers to small moderate-yellowish brown subangular or lens-shaped blocks. Claystone is medium gray to olive gray.
Thickness	3.1 to 8.2 feet in eastern Shawnee Co.

Environment of Deposition	Normal marine with fairly quiet water, to environment in which water was shallow, and circulation was more vigorous.

IOWA POINT SHALE

Megascopic	Light to dark gray clayey to sandy siltstone; light to olive gray silty laminated to platy claystone.
Thickness	0.1 to 1.5 feet but averaging about 1 foot in eastern Shawnee Co.
Environment of Deposition	Mostly marine but estuarine conditions may have existed locally.

CURZON LIMESTONE

Megascopic	Massive to thin bedded limestone and calcareous shale; limestone and shale are light to medium gray when fresh but weather yellow brown; abundant fossils (O'Connor, 1960).

Thickness	4.5 to 10.5 feet but averaging 8.5 feet in Shawnee Co.
Environment of Deposition	Probably similar to the environment of deposition of the Hartford Limestone.

JONES POINT SHALE

Megascopic	Gray silty to locally finely sandy laminated to platy claystone. Sometimes consists of siltstone with sandstone stringers and locally may include lenses of argillaceous limestone.
Thickness	2.4 to 5.8 feet in Shawnee Co.
Environment of Deposition	Local brachiopods and pelecypods suggest marine deposition for those parts; depositional environment for unfossiliferous parts unknown.

SHELDON LIMESTONE

Megascopic	Light to medium gray, finely crystalline, thin bedded, hard compact limestone; argillaceous.

Thickness	1.2 to 3.5 feet but averaging slightly less than 2 feet in Shawnee Co.
Environment of Deposition	Relatively shallow marine and probably clear rather than turbid.

TURNER CREEK SHALE

Megascopic	Claystone and siltstone but containing 2 to 5 thin limestone beds; claystone and siltstone is gray, laminated to very thin bedded; limestone is gray to brown, very finely crystalline to very fine grained.
Thickness	2.7 to 5.4 feet in Shawnee Co.
Environment of Deposition	Basal beds deposited in either fresh water pool or swamp environment, at least locally; upper beds deposited in marine environment.

DU BOIS LIMESTONE

Megascopic	Single, vertically jointed bed of olive to medium gray hard compact, finely crystalline to very fine grained limestone.

Thickness	0.6 to 2.4 feet in Shawnee Co.
Environment of Deposition	Marine.

HOLT SHALE

Megascopic	The lower unit consists of laminated to platy, dark gray to grayish black claystone; the upper thicker unit is olive gray to dark gray slightly silty laminated to platy claystone. Lower part consists of black bituminous shale that is hard and fissile; upper part is bluish and clayey (Moore, 1936).
Thickness	1.7 to 3.5 feet in Shawnee Co.
Environment of Deposition	The lower part was deposited in very shallow, poorly oxygenated waters; the upper part was laid down under deeper marine conditions.

COAL CREEK FORMATION

Megascopic	Limestone interbedded with very thin layers of claystone and siltstone. Limestone is gray, crystalline to fine grained, argillaceous to silty. Limestone beds weather in nodular or platy fashion. Claystone and siltstone are calcareous and are light olive gray to olive gray, and abundantly fossiliferous.
Thickness	About 4.5 feet thick in Shawnee Co.
Environment of Deposition	Marine.

APPENDIX C

Numbers Assigned to Grouped Samples and Used in Q-Mode Cluster Analyses 3A, 3B, 3C, and 3D (Figs. 11-14).

Sample Numbers of Composite (i.e. Grouped) Samples (Barren Samples Omitted[1])	Field Sample Codes (Barren Samples Omitted[1])
1	La-Sp-1
2	T-1-1, T-1-2, T-1-3, T-1-4, T-1-5A, T-1-5B, T-1-6, T-1-7
3	Sn-1-1A, Sn-1-1B
4	Sn-1-4A, Sn-1-4B
5	L-1-1
6	He-1-1, He-1-2A, He-1-2B
7	He-1-3A, He-1-3B, He-1-4A, He-1-4B
8	P-1-1, P-1-2, P-1-3
9	P-1-4
10	P-1-5, P-1-6, P-1-7, P-1-8
11	Bottom 2" of Heu, Heu-1-1, Heu-1-2, Heu-1-3A, Heu-1-3B

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[1] Samples Sn-1-2A, Sn-1-2B, Sn-1-3, SB-1-5B, SB-1-6, SB-1-7, KH-4-1, KH-4-2, KH-4-3, Te-Sp-1, Os-1-1B, Os-1-2A, Os-1-2B, Os-1-2C, Os-1-2D, Os-1-2E, TCS-1-1, and TCS-1-2 were barren of conodonts.
Sample Os-1-1A containing a fragmentary specimen identifiable only as gen. et. sp. indet. was also omitted.

12	Ke-1-1, Ke-1-2A, Ke-1-2B, Ke-1-3, Ke-1-4
13	Ke-1-5
14	Ke-1-6, Ke-1-7
15	Jap-1-1
16	Kan-Sp-1
17	SB-1-1A, SB-1-1B, SB-1-1C, SB-1-1D, SB-1-1E
18	SB-1-2A, SB-1-2B
19	SB-1-3
20	SB-1-4A, SB-1-4B, SB-1-4C
21	SB-1-5A, SB-1-5C, SB-1-5D
22	Dos-1-1, Dos-1-1A, Dos-1-2
23	BS-1-1, BS-1-2
24	QH-1-1
25	QH-1-2
26	B-1-1, B-1-2, B-1-3, B-1-4, B-1-5, B-1-6, B-1-6 (right under B-1-7), B-1-7
27	KH-4-4
28	Av-3-1, Av-3-2, Av-3-3
29	Av-3-4
30	Av-3-5
31	Te-Sp-2
32	Oz-1-1
33	Os-1-3
34	RB-1-1
35	LB-1-1, LB-1-2

36	LB-1-3A, LB-1-3B, LB-1-3C, LB-1-3D, LB-1-3E
37	EC-1-1A, EC-1-1B, EC-1-1C, EC-1-1D, EC-1-1E, EC-1-1F, EC-1-1G, EC-1-1H, EC-1-1I, EC-1-1J, EC-1-1K, EC-1-1L, EC-1-1M, EC-1-2
38	Cal-Sp-1
39	H-1-1
40	H-1-2
41	H-1-3A, H-1-3B, H-1-3C, H-1-3D, H-1-3E, H-1-3F, H-1-3G, H-1-3H, H-1-3I
42	IP-2-1, IP-2-2, IP-2-3, IP-2-4
43	Cur-1-1A, Cur-1-1B, Cur-1-1C, Cur-1-1D, Cur-1-1E, Cur-1-2, Cur-1-3, Cur-1-4
44	JPS-1-1, JPS-1-2A, JPS-1-2B, JPS-1-2C, JPS-1-3
45	She-1-1, She-1-2, She-1-3
46	TCS-1-3, TCS-1-4
47	DB-1-1A, DB-1-1B
48	Hol-1-1, Hol-1-2A, Hol-1-2B
49	CC-1-1A, CC-1-1B, CC-1-1C, CC-1-1D, CC-1-2, CC-1-3, CC-1-4
50	6" over CC-1

Numbers Assigned to 70 Element Types and Used in R-Mode Cluster Analyses 2E, 2F, 3E, 3F (Figs. 15-18)

Streptognathodus elegantulus Stauffer and Plummer, Sp element	1
Streptognathodus Sp. A, sp element	2
Streptognathodus sp. aff. *S.elegantulus* Stauffer and Plummer, Sp element	3
Streptognathodus gracilis Stauffer and Plummer, Sp element	4
Streptognathodus gracilis Stauffer and Plummer [?], Sp element	5
Streptognathodus excelsus Stauffer and Plummer, Sp element	6
Streptognathodus oppletus Ellison, Sp element	7
Streptognathodus wabaunsensis Gunnell, Sp element	8
Streptognathodus simulator Ellison, Sp element	9
Streptognathodus eccentricus Ellison, Sp element	10
Streptognathodus ? sp.	11
Idiognathodus magnificus Stauffer and Plummer, Sp element	12
Idiognathodus delicatus Gunnell, Sp element	13
Idiognathodus antiquus Stauffer and Plummer, Sp element	14
Idiognathodus tersus Ellison, Sp element	15
Cavusgnathus lautus Gunnell, Sp element	16
Cavusgnathus flexus Ellison, Sp element	17
Cavusgnathus merrilli n.sp.	18
Gondolella denuda Ellison, Sp element	19
Anchignathodus minutus (Ellison)	20
Anchignathodus adenticulatus n.sp.	21

Anchignathodus moorei n.sp.	22
Anchignathodus sp. aff. *A.campbelli* Rexroad	23
Streptognathodus and *Idiognathodus* Oz element	24
Ozarkodina sp. A	25
Cavusgnathus Oz element	26
Gondolella denuda, Oz element	27
Gondolella denuda, Hi (?) element	28
Ozarkodina [?] *curvata* Rexroad	29
Ozarkodina ? *kansasensis* n.sp.	30
Ozarkodina ? sp. aff. *O*. ? *kansasensis* n.sp.	31
Streptognathodus and *Idiognathodus* Ne element	32
Synprioniodina sp. A	33
Synprioniodina sp. B	34
Ellisonia teicherti Sweet, Pl element	35
Plectospathodus sp.	36
Hindeodella parva Ellison	37
Ellisonia teicherti Sweet, Hi element	38
Hindeodella sp. B	39
Streptognathodus and *Idiognathodus* Hi element	40
Cavusgnathus Hi element	41
Lonchodus simplex (Pander)	42
Trichonodella obtusa (Murray and Chronic)	43
Trichonodella plattsmouthi n.sp.	44
Trichonodella asymmetrica n.sp.	45
Trichonodella sp.	46
Hindeodus sp. A	47

APPENDIX D

Summarized Abundance Counts

	Oread Limestone[1]	Lecompton Limestone[2]	Deer Creek Limestone[3]	Topeka Limestone[4]	Total of Each Element
Streptognathodus elegantulus, Sp element	2058	3296	2082	7437	14,873
Streptognathodus sp.A, Sp element	-	14	-	-	14
Streptognathodus sp.aff. S.elegantulus, Sp element	13	-	-	1	14
Streptognathodus gracilis, Sp element	5	5	33	16	59
Streptognathodus gracilis [?] Sp element	1	-	7	4	12
Streptognathodus excelsus, Sp element	4	1	14	2	21
Streptognathodus oppletus, Sp element	30	75	1	-	106

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[1] Includes the conodont counts of the samples from the uppermost Lawrence Shale and the lowermost Kanwaka Shale.

[2] Includes the conodont counts of the samples from the uppermost Kanwaka Shale.

[3] Includes the conodont counts of the samples from the uppermost Tecumseh Shale.

[4] Includes the conodont counts of the samples from the uppermost Calhoun Shale and the lowermost Severy Shale.

	Oread Limestone	Lecompton Limestone	Deer Creek Limestone	Topeka Limestone	Total of Each Element
Streptognathodus wabaunsensis, Sp element	18	24	-	-	42
Streptognathodus simulator, Sp element	598	-	-	-	598
Streptognathodus eccentricus, Sp element	38	-	-	-	38
Streptognathodus sp.	529	288	258	628	1,703
Streptognathodus ? sp.	1	-	-	-	1
Idiognathodus magnificus, Sp element	39	-	-	-	39
Idiognathodus delicatus, Sp element	-	1	-	-	1
Idiognathodus antiquus, Sp element	33	197	-	-	230
Idiognathodus tersus, Sp element	120	245	-	-	365
Idiognathodus sp.	28	9	-	-	37
Cavusgnathus lautus, Sp element	481	266	56	1716	2,519
Cavusgnathus flexus, Sp element	7	12	3	32	54
Cavusgnathus sp.	419	100	11	903	1,433
Cavusgnathus merrilli n.sp.	3	26	88	38	155
Gondolella denuda, Sp element	-	23	-	-	23
Anchignathodus minutus	564	207	54	498	1,323

	Oread Limestone	Lecompton Limestone	Deer Creek Limestone	Topeka Limestone	Total of Each Element
Anchignathodus adenticulatus n.sp.	6	14	-	-	20
Anchignathodus moorei n.sp.	59	68	173	56	356
Anchignathodus sp.aff. *A.campbelli*	-	-	1	-	1
Anchignathodus sp.	5	5	7	19	36
Streptognathodus and *Idiognathodus* Oz element	353	324	250	399	1,326
Ozarkodina sp. A	-	2	-	1	3
Cavusgnathus Oz element	13	16	6	144	179
Unidentifiable Oz element	128	51	36	198	413
Gondolella denuda, Oz element	-	12	-	-	12
Gondolella denuda, Hi (?) element	-	6	-	-	6
Ozarkodina [?] *curvata*	147	28	10	97	282
Ozarkodina ? *kansasensis* n.sp.	33	2	-	-	35
Ozarkodina ? sp.aff. *O.*? *kansasensis* n.sp.	2	-	-	-	2
Ozarkodina ? sp.	8	4	-	-	12
Streptognathodus and *Idiognathodus* Ne element	86	77	50	166	379
Synprioniodina sp. A	1	-	6	1	8

	Oread Limestone	Lecompton Limestone	Deer Creek Limestone	Topeka Limestone	Total of Each Element
Unidentifiable Ne element	1	2	-	1	4
Synprioniodina sp. B	-	1	-	-	1
Ellisonia teicherti, Pl element	64	27	10	39	140
Plectospathodus sp.	2	-	5	-	7
Hindeodella parva	33	8	15	15	71
Ellisonia teicherti, Hi element	125	43	20	90	278
Hindeodella sp. B	6	1	-	-	7
Streptognathodus and Idiognathodus Hi element	131	67	50	82	330
Cavusgnathus, Hi element	2	7	2	31	42
Unidentifiable Hi element	53	62	31	60	206
Lonchodus simplex	C	-	-	R	
Trichonodella obtusa	1	-	-	-	1
Trichonodella plattsmouthi n.sp.	9	-	-	-	9
Trichonodella asymmetrica n.sp.	14	-	-	-	14
Trichonodella sp.	6	4	-	-	10
Hindeodus sp. A	11	1	2	1	15

	Oread Limestone	Lecompton Limestone	Deer Creek Limestone	Topeka Limestone	Total of Each Element
Ellisonia teicherti, Tr element	7	2	2	6	17
Lonchodina sp. A	13	1	-	-	14
Lonchodina douglasi n.sp.	21	1	-	-	22
Lonchodina sp. B	7	6	-	-	13
Ligonodina subacoda, Tr element	33	-	-	-	33
Ligonodina conflexus, Tr element	5	5	5	5	20
Cavusgnathus, Tr element	2	3	-	7	12
Streptognathodus and *Idiognathodus*, Tr element	15	9	9	23	56
Unidentifiable Tr elements	36	26	7	21	90
Ligonodina conflexus, Hi element	21	10	9	13	53
Ligonodina lexingtonensis	28	-	-	-	28
Ligonodina subacoda, Hi element	54	-	1	1	56
Cavusgnathus, Ne element	16	10	3	62	91
Ligonodina subacoda, Ne element	45	-	-	-	45
Neoprioniodus sp. A	-	-	18	3	21
Ellisonia teicherti, Ne element	90	39	6	96	231

	Oread Limestone	Lecompton Limestone	Deer Creek Limestone	Topeka Limestone	Total of Each Element
Lonchodus ? sp.	1	-	-	-	1
Ligonodina conflexus, Pl (?) element	4	4	6	4	18
Ligonodina subacoda, Pl element	33	-	-	-	33
Lonchodina ? ponderosa	25	-	-	-	25
Ligonodina conflexus, Oz (?) element	6	1	1	1	9
Ligonodina conflexus, Ne (?) element	2	1	1	1	5
Metalonchodina ? sp.	-	-	-	3	3
Genus and species indeterminate	232	17	2	14	265
	6,984	5,756	3,351	12,935	29,026

	La-Sp-1	T-1-1	T-1-2	T-1-3	T-1-4	T-1-5A	T-1-5B	T-1-6	T-1-7	SN-1-1 A	SN-1-1 B	SN-1-2 A	SN-1-2 B	SN-1-3	SN-1-4 A	SN-1-4 B	L-1-1	He-1-1	He-1-2 A	He-1-2 B	He-1-3 A	He-1-3 B
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Streptognathodus _elegantulus_, Sp element	5	8	7	2	12	5	713	56	22	4						17	60	8	5	7	18	24
Streptognathodus sp. A, Sp element																						
Streptognathodus sp. aff. _S.elegantulus_, Sp element																						
Streptognathodus _gracilis_, Sp element						1	3										1					
Streptognathodus _gracilis_ (?), Sp element																		1				
Streptognathodus _excelsus_, Sp element					1		3															
Streptognathodus _oppletus_ Sp element																						
Streptognathodus _wabaunsensis_, Sp element																						
Streptognathodus _simulator_, Sp element																		38	149	32	151	188
Streptognathodus _eccentricus_, Sp element																		6	8	3	8	6
Streptognathodus sp.	1	4		1	7	3	274	12		3							3		18	6	18	57
Streptognathodus ? sp.																						
Idiognathodus _magnificus_, Sp element																		1		4	5	13
Idiognathodus _delicatus_, Sp element																						
Idiognathodus _antiquus_, Sp element																						
Idiognathodus _tersus_, Sp element																						
Idiognathodus sp.																			3		2	
Cavusgnathus _lautus_, Sp element	12	2					13	14	17	3					2	55	9					
Cavusgnathus _flexus_, Sp element																						
Cavusgnathus sp.	1	1					1		5	2						10	4					
Cavusgnathus _merrilli_ n.sp.										2												
Gondolella _denuda_, Sp element																						
Anchignathodus _minutus_	2			1	2		56	3	14	2						6	15					15
Anchignathodus _adenticulatus_ n.sp.																						
Anchignathodus _moorei_ n.sp.							29	4	4	2							3	10				
Anchignathodus sp. aff. _A.campbelli_																						
Anchignathodus sp.										2	1											

	He-1-4A 23	He-1-4B 24	P-1-1 25	P-1-2 26	P-1-3 27	P-1-4 28	P-1-5 29	P-1-6 30	P-1-7 31	P-1-8 32	lowest Heu 33	Heu-1-1 34	Heu-1-2 35	Heu-1-3 A 36	Heu-1-3 B 37	Ke-1-1 38	Ke-1-2A 39	Ke-1-2 B 40	Ke-1-3 41	Ke-1-4 42	Ke-1-5 43	Ke-1-6 44
Streptognathodus elegantulus, Sp element	52	14	19	19	11	91	211	64	161	52	39	13	58	144	68	4	6	6	5	10	2	11
Streptognathodus sp. A, Sp element																						
Streptognathodus sp. aff. S.elegantulus, Sp element					1	11	1															
Streptognathodus gracilis, Sp element																						
Streptognathodus gracilis (?), Sp element																						
Streptognathodus excelsus, Sp element																						
Streptognathodus oppletus Sp element			2			1	3	2	5			2	5	9	1							
Streptognathodus wabaunsensis, Sp element			1				2				8	3		1						2		1
Streptognathodus simulator, Sp element	31		3			6																
Streptognathodus eccentricus, Sp element	7																					
Streptognathodus sp.	2	1			2	6	31	7	30	9		1		14	3	1	2	2				3
Streptognathodus ? sp.	1																					
Idiognathodus magnificus, Sp element	12					1												1		1		1
Idiognathodus delicatus, Sp element																						
Idiognathodus antiquus, Sp element				1			5	2	2	1	4		1	12	4			1				
Idiognathodus tersus, Sp element			9	1	3	7	20		2	3	18		7	30	6	1	2	4		4	1	1
Idiognathodus sp.	7	1					1	1	2		1			3	1	1	1	2		1		
Cavusgnathus lautus, Sp element											9	19	65	173	18	2	2	2	2	2	2	3
Cavusgnathus flexus, Sp element													4	2								
Cavusgnathus sp.											3	2	56	305	4	1		1				
Cavusgnathus merrilli n.sp.																1						
Gondolella denuda, Sp element																						
Anchignathodus minutus	127	11	17	8	19	19	110	23	44	4	12	4	6	9	4	3	6	4	1	4	2	11
Anchignathodus adenticulatus n.sp.							2		1						1						1	1
Anchignathodus moorei n.sp.														2		2	1					2
Anchignathodus sp. aff. A.campbelli																						
Anchignathodus sp.				2																		

	Ke-1-7 45	Jap-1-1 46	Kan-Sp-1 47	SB-1-1 A 48	SB-1-13 49	SB-1-1 C 50	SB-1-1D 51	SB-1-1 E 52	SB-1-2 (SS) A 53	SB-1-2 SS/AA A 54	SB-1-2 B 55	SB-1-3 56	SB-1-4 A 57	SB-1-4 B 58	SB-1-4 C 59	SB-1-5 A 60	SB-1-5 B 61	SB-1-5 C 62
Streptognathodus elegantulus, Sp element	20	5	22	154	99	179	168	130	130	114	68	66	17			8		1
Streptognathodus sp. A, Sp element						13						1						
Streptognathodus sp. aff. S.elegantulus, Sp element																		
Streptognathodus gracilis, Sp element																		
Streptognathodus gracilis (?), Sp element																		
Streptognathodus excelsus, Sp element																		
Streptognathodus oppletus Sp element					5	7												
Streptognathodus wabaunsensis, Sp element					8	5												
Streptognathodus simulator, Sp element																		
Streptognathodus eccentricus, Sp element																		
Streptognathodus sp.	2	6	6	12	17	14	7	8	9	10	2	5						
Streptognathodus ? sp.																		
Idiognathodus magnificus, Sp element																		
Idiognathodus delicatus, Sp element																		
Idiognathodus antiquus, Sp element				5	26	72	56	3	4				2					
Idiognathodus tersus, Sp element	1		1	5	15	44			19	8	2	2						
Idiognathodus sp.	1				1	2			1									
Cavusgnathus lautus, Sp element	23	32	5		1	3						26	21		1	7		15
Cavusgnathus flexus, Sp element	1															1		3
Cavusgnathus sp.	14	9				1		1				6	5			4		5
Cavusgnathus merrilli n.sp.								1	6	2	6							
Gondolella denuda, Sp element																		
Anchignathodus minutus				5	7	18	10	4	20	8	12	22						2
Anchignathodus adenticulatus n.sp.									3		2	9						
Anchignathodus moorei n.sp.								1		7	6	5	2					
Anchignathodus sp. aff. A.campbelli																		
Anchignathodus sp.			1								1					1		

	SB-1-5 D	SB-1-6	SB-1-7	Dos-1-1	Dos-1-1 R	Dos-1-2	B-1-1	BS-1-2	QH-1-1	QH-1-2	B-1-1	B-1-2	B-1-3	B-1-4	B-1-5	B-1-6	B-1-7	B-1-7	KH4/1	KH 4/2	KH 4/3	KH4-4
	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Streptognathodus elegantulus, Sp element					1	47	13	17	119	678	190	48	10	23	4	33	5					2
Streptognathodus sp. A, Sp element																						
Streptognathodus sp. aff. S. elegantulus, Sp element																						
Streptognathodus gracilis, Sp element																						
Streptognathodus gracilis (?), Sp element																						
Streptognathodus excelsus, Sp element																						
Streptognathodus oppletus Sp element									51	11						1						
Streptognathodus wabaunsensis, Sp element									11													
Streptognathodus simulator, Sp element																						
Streptognathodus eccentricus, Sp element																						
Streptognathodus sp.							3	3	19	23	18	2		2		1						1
Streptognathodus ? sp.																						
Idiognathodus magnificus, Sp element																						
Idiognathodus delicatus, Sp element										1												
Idiognathodus antiquus, Sp element							6		18	5												
Idiognathodus tersus, Sp element									76	73												
Idiognathodus sp.									5													
Cavusgnathus lautus, Sp element	1			3	3	46					1			10	4	39	13					
Cavusgnathus flexus, Sp element					1	6																1
Cavusgnathus sp.				1		15								3	1	8	3					
Cavusgnathus merrilli n.sp.							1		1	9												
Gondolella denuda, Sp element									2	21												
Anchignathodus minutus					1	14	2			2	21	3	2	8		14	8					
Anchignathodus adenticulatus n.sp.																						
Anchignathodus moorei n.sp.									1													
Anchignathodus sp. aff. A. campbelli																						
Anchignathodus sp.								1														

	Av-3-1 85	Av-3-2 86	Av-3-3 87	Av-3-4 88	Av-3-5 89	Te-Sp-1 90	Te-Sp-2 91	Oz-1-1 92	Os-1-1 A 93	Os-1-1 B 94	Os-1-2 A 95	Os-1-2 B 96	Os-1-2 C 97	Os-1-2 D 98	Os-1-2 E 99	Os-1-3 100	RB-1-1 101	LB-1-1 102	LB-1-2 103
Streptognathodus elegantulus, Sp element		5	34	899	12											52	13	732	105
Streptognathodus sp. A, Sp element																			
Streptognathodus sp. aff. S.elegantulus, Sp element																			
Streptognathodus gracilis, Sp element				5														16	1
Streptognathodus gracilis (?), Sp element																		4	1
Streptognathodus excelsus, Sp element				1														5	2
Streptognathodus oppletus Sp element																			
Streptognathodus wabaunsensis, Sp element																			
Streptognathodus simulator, Sp element																			
Streptognathodus eccentricus, Sp element																			
Streptognathodus sp.				126												4	2	86	21
Streptognathodus ? sp.																			
Idiognathodus magnificus, Sp element																			
Idiognathodus delicatus, Sp element																			
Idiognathodus antiquus, Sp element																			
Idiognathodus tersus, Sp element																			
Idiognathodus sp.																			
Cavusgnathus lautus, Sp element				67			2	1								47		5	
Cavusgnathus flexus, Sp element																2			
Cavusgnathus sp.	1			46												8			3
Cavusgnathus merrilli n.sp.																		29	4
Gondolella denuda, Sp element																			
Anchignathodus minutus			4	20												10	2	2	
Anchignathodus adenticulatus n.sp.																			
Anchignathodus moorei n.sp.			10	35	1											2		28	3
Anchignathodus sp. aff. A.campbelli																			
Anchignathodus sp.					1											2			

	LB-1-3 A 104	LB-1-3 B 105	LB-1-3 C 106	LB-1-3 D 107	LB-1-3 E 108	EC-1-1 A 109	EC-1-1 B 110	EC-1-1 C 111	EC-1-1 D 112	EC-1-1 E 113	EC-1-1 F 114	EC-1-1 G 115	EC-1-1 H 116	EC-1-1 I 117	EC-1-1 J 118	EC-1-1 K 119	EC-1-1 L 120	EC-1-1 M 121	EC-1-2 122
Streptognathodus elegantulus, Sp element	224	181	31	194	45	173	31	17	31	33	28	5	69	30	62	10	7	3	6
Streptognathodus sp. A, Sp element																			
Streptognathodus sp. aff. S.elegantulus, Sp element																			
Streptognathodus gracilis, Sp element	1	6	2	5		1		1											
Streptognathodus gracilis (?), Sp element	1			1															
Streptognathodus excelsus, Sp element	2	3		1		1													
Streptognathodus oppletus Sp element				1															
Streptognathodus wabaunsensis, Sp element																			
Streptognathodus simulator, Sp element																			
Streptognathodus eccentricus, Sp element																			
Streptognathodus sp.	18	18	2	23	4	34	6	1	5	5	6		7	2	10	1			3
Streptognathodus ? sp.																			
Idiognathodus magnificus, Sp element																			
Idiognathodus delicatus, Sp element																			
Idiognathodus antiquus, Sp element																			
Idiognathodus tersus, Sp element																			
Idiognathodus sp.																			
Cavusgnathus lautus, Sp element													1						
Cavusgnathus flexus, Sp element				1															
Cavusgnathus sp.																			
Cavusgnathus merrilli n.sp.	54	1																	
Gondolella denuda, Sp element																			
Anchignathodus minutus		4				6	6	1	1	2	2		6		6	2	3	1	
Anchignathodus adenticulatus n.sp.																			
Anchignathodus moorei n.sp.	129		1		1	1		1		1				1	4				1
Anchignathodus sp. aff. A.campbelli						1													
Anchignathodus sp.					2					2									1

	Cal-Sp-1 123	H-1-1 124	H-1-2 125	H-1-3A 126	H-1-3B 127	H-1-3 C 128	H-1-3 D 129	H-1-3 E 130	H-1-3 F 131	H-1-3 G 132	H-1-3 H 133	H-1-3 I 134	IP-2-1 135	IP-2-2 136	IP-2-3 137	IP-2-4 138	Cur-1-1 A 139	Cur-1-1 B 140	Cur-1-1 C 141	Cur-1-1 D 142	Cur-1-1 E 143	Cur-1-2 144
Streptognathodus elegantulus, Sp element	242	1375	1724	770	103	76	74	53	14	237	26	8		28	10	10	10	6	13	19	35	236
Streptognathodus sp. A, Sp element																						
Streptognathodus sp. aff. S.elegantulus, Sp element																						
Streptognathodus gracilis, Sp element	1	1	2							1												
Streptognathodus gracilis (?), Sp element			2							1												
Streptognathodus excelsus, Sp element			1																			
Streptognathodus oppletus Sp element																						
Streptognathodus wabaunsensis, Sp element																						
Streptognathodus simulator, Sp element																						
Streptognathodus eccentricus, Sp element																						
Streptognathodus sp.	27	137	159	81	16	21	11	4	1	44	4	5		3	4	4				1	3	13
Streptognathodus ? sp.																						
Idiognathodus magnificus, Sp element																						
Idiognathodus delicatus, Sp element																						
Idiognathodus antiquus, Sp element																						
Idiognathodus tersus, Sp element																						
Idiognathodus sp.																						
Cavusgnathus lautus, Sp element	97	17	20			3			2	32	1	15	1	66	27	34			1		3	39
Cavusgnathus flexus, Sp element	1	1												10								
Cavusgnathus sp.	93		3						1	7		14	4	31	6	28	1	1				27
Cavusgnathus merrilli n.sp.				1			1	2								1	2			1		3
Gondolella denuda, Sp element																						
Anchignathodus minutus	16	97	62	21		3	3	13		20	2	4				2		1		4	5	49
Anchignathodus adenticulatus n.sp.																						
Anchignathodus moorei n.sp.		6																		1		
Anchignathodus sp. aff. A.campbelli																						
Anchignathodus sp.				7					1			1				3	1	1		1		

	Cur-1-3 145	Cur-1-4 146	JPS-1-1 147	SPS-1-2 A 148	SPS-1-2 B 149	SPS-1-2 C 150	SPS-1-3 151	She-1-1 152	She-1-2 153	She-1-3 154	TCS-1-1 155	TCS-1-2 156	TCS-1-3 157	TCS-1-4 158	DB-1-1 A 159	DB-1-1 B 160	Hol-1-1 161	Hol-1-2 A 162	Hol-1-2 B 163	CC-1-1 A 164	CC-1-1 B 165
Streptognathodus elegantulus, Sp element	7		1						1				1			51	245	1054	454	137	351
Streptognathodus sp. A, Sp element																					
Streptognathodus sp. aff. S.elegantulus, Sp element																	1				
Streptognathodus gracilis, Sp element																	2	8			1
Streptognathodus gracilis (?), Sp element																					1
Streptognathodus excelsus, Sp element																					1
Streptognathodus oppletus Sp element																					
Streptognathodus wabaunsensis, Sp element																					
Streptognathodus simulator, Sp element																					
Streptognathodus eccentricus, Sp element																					
Streptognathodus sp.	1															7	1	34	13	12	21
Streptognathodus ? sp.																					
Idiognathodus magnificus, Sp element																					
Idiognathodus delicatus, Sp element																					
Idiognathodus antiquus, Sp element																					
Idiognathodus tersus, Sp element																					
Idiognathodus sp.																					
Cavusgnathus lautus, Sp element	2	29	823	6	1		4	220	5	16			58	2	2	108	5		1	1	8
Cavusgnathus flexus, Sp element			12	1				3		3			1								
Cavusgnathus sp.	1	3	469				2	128	4	14					1	30					2
Cavusgnathus merrilli n.sp.													8					1			1
Gondolella denuda, Sp element																					
Anchignathodus minutus		12	103					1								57		3	1	1	5
Anchignathodus adenticulatus n.sp.																					
Anchignathodus moorei n.sp.																		41	7		1
Anchignathodus sp. aff. A.campbelli																					
Anchignathodus sp.		1															2				

	cc-1-1C 166	cc-1-1D 167	cc-1-2 168	cc-1-3 169	cc-1-4 170	6" ove cc-1 171
Streptognathodus elegantulus, Sp element	46	13	3	4		
Streptognathodus sp. A, Sp element						
Streptognathodus sp. aff. S.elegantulus, Sp element						
Streptognathodus gracilis, Sp element						
Streptognathodus gracilis (?), Sp element						
Streptognathodus excelsus, Sp element						
Streptognathodus oppletus Sp element						
Streptognathodus wabaunsensis, Sp element						
Streptognathodus simulator, Sp element						
Streptognathodus eccentricus, Sp element						
Streptognathodus sp.	1					
Streptognathodus ? sp.						
Idiognathodus magnificus, Sp element						
Idiognathodus delicatus, Sp element						
Idiognathodus antiquus, Sp element						
Idiognathodus tersus, Sp element						
Idiognathodus sp.						
Cavusgnathus lautus, Sp element	6	10	15	23	1	12
Cavusgnathus flexus, Sp element						
Cavusgnathus sp.	2	1	1	22		7
Cavusgnathus merrilli n.sp.	16		1			
Gondolella denuda, Sp element						
Anchignathodus minutus	4	5	3	1		
Anchignathodus adenticulatus n.sp.						
Anchignathodus moorei n.sp.						
Anchignathodus sp. aff. A.campbelli						
Anchignathodus sp.				1		

	La-Sp-1 1	T-1-1 2	T-1-2 3	T-1-3 4	T-1-4 5	T-1-5 A 6	T-1-5 B 7	T-1-6 8	T-1-7 9	SN-1-1 A 10	SN-1-1 B 11	SN-1-2 A 12	SN-1-2 B 13	SN-1-3 14	SN-1-4 15	SN-1-4 B 16	L-1-1 17	He-1-1 18	He-1-2 A 19	He-1-2 B 20	He-1-3 A 21	He-1-3 B 22
Streptognathodus and Idiognathodus Oz element							17	9	8	1							8	4	14	10	43	59
Ozarkodina sp. A																						
Cavusgnathus Oz element									1							5						
Unidentifiable Oz element	1						78		3	1	2					1						
Gondolella denuda, Oz element																						
Gondolella denuda, Hi (?) element																						
Ozarkodina [?] curvata							27		4	1							4					
Ozarkodina ? kansasensis n.sp.																						
Ozarkodina ? sp. aff. O. ? kansasensis n. sp.																						
Ozarkodina ? sp.								1														1
Streptognathodus and Idiognathodus Ne element							12		1	1							2		1	1	6	10
Synprioniodina sp. A																					1	
Unidentifiable Ne element																						
Synprioniodina sp. B																						
Ellisonia teicherti, Pl element							3		1								4					1
Plectospathodus sp.																						
Hindeodella parva							2												3		4	7
Ellisonia teicherti Hi element					1	1	21	3	1								7				1	4
Hindecdella sp. B								1														
Streptognathodus and Idiognathodus Hi element							16	3	1								3	1	5	1	6	9
Cavusgnathus Hi element																1	1					
Unidentifiable Hi element	1	1	1				6	1		3	1					1		3	2	4		
Lonchodus simplex																		C	C	C	C	C
Trichonodella obtusa																						
Trichonodella plattsmouthi n.sp.																						
Trichonodella asymmetrica n.sp.																						

	He-1-4 A 23	He-1-4 B 24	P-1-1 25	P-1-2 26	P-1-3 27	P-1-4 28	P-1-5 29	P-1-6 30	P-1-7 31	P-1-8 32	Heu Bott. 33	Heu-1-1 34	Heu-1-2 35	Heu-1-3 36	Heu-1-3 37	Ke-1-1 38	Ke-1-2 A 39	Ke-1-2 B 40	Ke-1-3 41	Ke-1-4 42	Ke-1-5 43	Ke-1-6 44
Streptognathodus and Idiognathodus Oz element	48	6	7		4	12	38	13	19	7	3	5	4	2		2	6	2				2
Ozarkodina sp. A																						
Cavusgnathus Oz element														2	3		1					
Unidentifiable Oz element					1		13							24	3							
Gondolella denuda, Oz element																						
Gondolella denuda, Hi (?) element																						
Ozarkodina [?] curvata	22	3	4	1	5	12	25	8	15	3	1		1	2	3		2	2		1		1
Ozarkodina ? kansasensis n.sp.	10	4	7	1	1		8		2													
Ozarkodina ? sp. aff. O. ? kansasensis n. sp.			2																			
Ozarkodina ? sp.	4																		1	1		
Streptognathodus and Idiognathodus Ne element	7		1	3	1	2	16	3	3			1		9	3		1					
Synprioniodina sp. A																						
Unidentifiable Ne element																						1
Synprioniodina sp. B																						
Ellisonia teicherti, Pl element	6	1	4	3	1	4	16	7	8						2		1				1	1
Plectospathodus sp.	2																					
Hindeodella parva	7	1				1	3	1	2					2								
Ellisonia teicherti Hi element	15		8	2	2	5	18	10	15	1				2	5		1					1
Hindeodella sp. B			1				2	1	1													
Streptognathodus and Idiognathodus Hi element	11	1	11	6	3	4	12	5	14	5				6	1		1	1			1	3
Cavusgnathus Hi element																						
Unidentifiable Hi element	3	2			1	4	4		2		2	1	2	1	3			1		1		
Lonchodus simplex	C		P		P	P			P													
Trichonodella obtusa			1																			
Trichonodella plattsmouthi n.sp.			5		3	1																
Trichonodella asymmetrica n.sp.	3		5		3		3															

	Ke-1-7 45	Jap-1-1 46	Kan-Sp-1 47	SB-1-1 A 48	SB-1-1 B 49	SB-1-1 C 50	SB-1-1 D 51	SB-1-1 E 52	SB-1-2 (SS) A 53	SB-1-2 (SS/AA) A 54	SB-1-2 B 55	SB-1-3 56	SB-1-4 A 57	SB-1-4 B 58	SB-1-4 C 59	SB-1-5 A 60	SB-1-5 B 61	SB-1-5 C 62
Streptognathodus and Idiognathodus Oz element				15	31	16	7	9	8	10	10	8	2					1
Ozarkodina sp. A																		
Cavusgnathus Oz element		1																
Unidentifiable Oz element	1		2						5									
Gondolella denuda, Oz element																		
Gondolella denuda, Hi (?) element																		
Ozarkodina [?] curvata						1		5	4		1	5						
Ozarkodina ? kansasensis n.sp.								1										
Ozarkodina ? sp. aff. O. ? kansasensis n. sp.																		
Ozarkodina ? sp.										3								
Streptognathodus and Idiognathodus Ne element	1	1	2	1	3	4	1	3	4	1	2							
Synprioniodina sp. A																		
Unidentifiable Ne element										1		1						
Synprioniodina sp. B											1							
Ellisonia teicherti, Pl element						2		3	3	2	1	3						
Plectospathodus sp.																		
Hindeodella parva										1	1							
Ellisonia teicherti Hi element		1				5		1		6	5	9						1
Hindeodella sp. B							1											
Streptognathodus and Idiognathodus Hi element		1	1	2	8	4	1	2		2	6	1						
Cavusgnathus Hi element													1					2
Unidentifiable Hi element	1	1	1	3	3		4		5	5	3		1	1				1
Lonchodus simplex																		
Trichonodella obtusa																		
Trichonodella plattsmouthi n.sp.																		
Trichonodella asymmetrica n.sp.																		

	SB-1-5 D	SB-1-6	SB-1-7	Dos-1-1	Dos-1-1 A	Dos-1-2	BS-1-1	BS-1-2	QH-1-1	QH-1-2	B-1-1	B-1-2	B-1-3	B-1-4	B-1-5	B-1-6	B-1-6 RI under B-1-7	B-1-7	KH-4-1	KH-4-2	KH-4-3	KH-4-4
	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Streptognathodus and Idiognathodus Oz element						5	1		13	39	21	5	1	1								
Ozarkodina sp. A																2						
Cavusgnathus Oz element					1											11						
Unidentifiable Oz element									27								1	1				
Gondolella denuda, Oz element									2	9	1											
Gondolella denuda, Hi (?) element									2	4												
Ozarkodina [?] curvata						2				2	2											
Ozarkodina ? kansasensis n.sp.												1										
Ozarkodina ? sp. aff. O. ? kansasensis n. sp.																						
Ozarkodina ? sp.						1																
Streptognathodus and Idiognathodus Ne element								1	3	6	4											
Synprioniodina sp. A																						
Unidentifiable Ne element																						
Synprioniodina sp. B																						
Ellisonia teicherti, Pl element						1					3				1							
Plectospathodus sp.																						
Hindeodella parva									2													
Ellisonia teicherti Hi element						2					4			2		1						
Hindeodella sp. B																						
Streptognathodus and Idiognathodus Hi element							1	2	5		5											
Cavusgnathus Hi element														1		2						
Unidentifiable Hi element					1	3			1	17		1	1		1	3	1					
Lonchodus simplex																						
Trichonodella obtusa																						
Trichonodella plattsmouthi n.sp.																						
Trichonodella asymmetrica n.sp.																						

	He-3-1 85	Av-3-2 86	Av-3-3 87	Av-3-4 88	Av-3-5 89	TeSp-1 90	TeSp-2 91	OzH 92	Ds-1-1 A 93	Ds-1-1 B 94	Ds-1-2 A 95	Ds-1-2 B 96	Ds-1-2 C 97	Ds-1-2 D 98	Ds-1-2 E 99	Ds-1-3 100	RB-1-1 101	LB-1-1 102	LB-1-2 103
Streptognathodus and *Idiognathodus* Oz element				119	2											1	2	123	7
Ozarkodina sp. A																			
Cavusgnathus Oz element				4												6			
Unidentifiable Oz element		1	3	9	2														9
Gondolella denuda, Oz element																			
Gondolella denuda, Hi (?) element																			
Ozarkodina [?] *curvata*			3	3												1	1	1	
Ozarkodina ? *kansasensis* n.sp.																			
Ozarkodina ? sp. aff. O. ? *kansasensis* n. sp.																			
Ozarkodina ? sp.																			
Streptognathodus and *Idiognathodus* Ne element			1	41												1	1	10	3
Synprioniodina sp. A																		4	
Unidentifiable Ne element																			
Synprioniodina sp. B																			
Ellisonia teicherti, Pl element			2	6															
Plectospathodus sp.																		2	
Hindeodella parva				4														2	
Ellisonia teicherti Hi element				6	1											2		3	
Hindeodella sp. B																			
Streptognathodus and *Idiognathodus* Hi element			3	24													3	8	3
Cavusgnathus Hi element			1													2			
Unidentifiable Hi element				5	1											1	1	1	4
Lonchodus simplex																			
Trichonodella obtusa																			
Trichonodella plattsmouthi n.sp.																			
Trichonodella asymmetrica n.sp.																			

	LB-1-3 A 104	LB-1-3 B. 105	LB-1-3 C 106	LB-1-3 D 107	LB-1-3 E 108	EC-1-1 A 109	EC-1-1 B 110	EC-1-1 C 111	EC-1-1 D 112	EC-1-1 E .113	EC-1-1 F 114	EC-1-1 G 115	EC-1-1 H 116	EC-1-1 I 117	EC-1-1 J 118	EC-1-1 K 119	EC-1-1 L 110	EC-1-1 M 121	EC-1-2 122
Streptognathodus and *Idiognathodus* Oz element	33	9	1	9	4	21	6	2	3	3	3	1	7	2	5	1	4		3
Ozarkodina sp. A																			
Cavusgnathus Oz element																			
Unidentifiable Oz element	27																		
Gondolella denuda, Oz element																			
Gondolella denuda, Hi (?) element																			
Ozarkodina [?] *curvata*		2				1			1	1					1	1			
Ozarkodina ? *kansasensis* n.sp.																			
Ozarkodina ? sp. aff. *O.* ? *kansasensis* n. sp.																			
Ozarkodina ? sp.																			
Streptognathodus and *Idiognathodus* Ne element	17					1	3	1	1	3		1	2	1	3		2		
Synprioniodina sp. A	1										1								
Unidentifiable Ne element																			
Synprioniodina sp. B																			
Ellisonia teicherti, P1 element					1		3	1	1				1		2				1
Plectospathodus sp.	1																1	1	
Hindeodella parva	8						1		2				1		1				
Ellisonia teicherti Hi element				1		1	1	1	2	3		1			2	3			
Hindeodella sp. B																			
Streptognathodus and *Idiognathodus* Hi element	16			1	1	1	5	1		4	2		2	1	2				
Cavusgnathus Hi element																			
Unidentifiable Hi element	10	4	1		1			1	2					1			1	2	1
Lonchodus simplex																			
Trichonodella obtusa																			
Trichonodella plattsmouthi n.sp.																			
Trichonodella asymmetrica n.sp.																			

	Cal-Sp-1 123	H-1-1 124	H-1-2 125	H-1-3 A 126	H-1-3 B 127	H-1-3 C 128	H-1-3 D 129	H-1-3 E 130	H-1-3F 131	H-1-3 G 132	H-1-3 H 133	H-1-3I 134	IP-2-1 135	IP-2-2 136	IP-2-3 137	IP-2-4 138	Cur-1-1 A 139	Cur-1-1 B 140	Cur-1-1 C 141	Cur-1-1 D 142	Cur-1-1 E 143	Cur 12 144
Streptognathodus and Idiognathodus Oz element	8	46	124	36	8	4	4	8		7	2										1	
Ozarkodina sp. A																						
Cavusgnathus Oz element	17											1				2						
Unidentifiable Oz element	29	71	32	21			1					2	1	7	1	1	1				2	20
Gondolella denuda, Oz element																						
Gondolella denuda, Hi (?) element																						
Ozarkodina [?] curvata	8	12	19	10	2			3		6	1											11
Ozarkodina ? kansasensis n.sp.																						
Ozarkodina ? sp. aff. O. ? kansasensis n. sp.																						
Ozarkodina ? sp.																						
Streptognathodus and Idiognathodus Ne element	10	33	14	32		1	1	1		2												12
Synprioniodina sp. A																						
Unidentifiable Ne element																						
Synprioniodina sp. B																						
Ellisonia teicherti, Pl element	3	4		6						2	1						1			1	1	2
Plectospathodus sp.																						
Hindeodella parva	1	2		2				1														
Ellisonia teicherti Hi element	9	19	6	9		2	2	2		3						1						6
Hindeodella sp. B																						
Streptognathodus and Idiognathodus Hi element	7	18	3	12			1	2		1	1						1					6
Cavusgnathus Hi element	5	1							1													1
Unidentifiable Hi element	2	8	4	1	1							1		1	2	2	1	1		1	2	2
Lonchodus simplex										P												
Trichonodella obtusa																						
Trichonodella plattsmouthi n.sp.																						
Trichonodella asymmetrica n.sp.																						

	Cur-1-3 A+B	Cur-1-4	JFS-1-1	JFS-1-2 A	JFS-1-2 B	JTS-1-2 C	JFS-1-3	She-1-1	She-1-2	She-1-3	TCS-1-1	TCS-1-2	TCS-1-3	TCS-1-4	DB-1-1 A	DB-1-1 B	Hol-1-1	Hol-1-2	Hol-1-2	CC-1-1 A	CC-1-1 B
	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
Streptognathodus and *Idiognathodus* Oz element																12	15	86	25	7	2
Ozarkodina sp. A																					
Cavusgnathus Oz element	1	7.	52			3	1	12					9			28					
Unidentifiable Oz element	1																	1		3	
Gondolella denuda, Oz element																					
Gondolella denuda, Hi (?) element																					
Ozarkodina [?] *curvata*			2													12			1	4	4
Ozarkodina ? *kansasensis* n.sp.																					
Ozarkodina ? sp. aff. *O.* ? *kansasensis* n. sp.																					
Ozarkodina ? sp.																					
Streptognathodus and *Idiognathodus* Ne element																8	2	35	9	4	1
Synprioniodina sp. A																			1		
Unidentifiable Ne element																			1		
Synprioniodina sp. B																					
Ellisonia teicherti, Pl element		2														7				1	3
Plectospathodus sp.																					
Hindeodella parva																2	1	3	2		
Ellisonia teicherti Hi element		3	1													9		2		3	9
Hindeodella sp. B																					
Streptognathodus and *Idiognathodus* Hi element																5		16	6	1	
Cavusgnathus Hi element		5						3					3			4					
Unidentifiable Hi element		2	8	1		4	1			1			1			3	4	1	2		
Lonchodus simplex																					
Trichonodella obtusa																					
Trichonodella plattsmouthi n.sp.																					
Trichonodella asymmetrica n.sp.																					

	166 cc-1-1C	cc-1-1D 167	cc-1-2 168	cc-1-3 169	cc-1-4 170	6" over cc-1 171
Streptognathodus and Idiognathodus Oz element	3		1			
Ozarkodina sp. A	1					
Cavusgnathus Oz element	7			2		2
Unidentifiable Oz element	3					1
Gondolella denuda, Oz element						
Gondolella denuda, Hi (?) element						
Ozarkodina [?] curvata	1	1				
Ozarkodina ? kansasensis n.sp.						
Ozarkodina ? sp. aff. O. ? kansasensis n. sp.						
Ozarkodina ? sp.						
Streptognathodus and Idiognathodus Ne element	1					
Synprioniodina sp. A						
Unidentifiable Ne element						
Synprioniodina sp. B						
Ellisonia teicherti, Pl element	4			1		
Plectospathodus sp.						
Hindeodella parva	1					
Ellisonia teicherti Hi element	4					
Hindeodella sp. B						
Streptognathodus and Idiognathodus Hi element	2					
Cavusgnathus Hi element	5	1	2			
Unidentifiable Hi element		1		1		1
Lonchodus simplex						
Trichonodella obtusa						
Trichonodella plattsmouthi n.sp.						
Trichonodella asymmetrica n.sp.						

	La-Sp-1 1	T-1-1 2	T-1-2 3	T-1-3 4	T-1-4 5	T-1-5 6	T-1-5B 7	T-1-6 8	T-1-7 9	SN-1-18 10	SN-1-18 11	SN-1-28 12	SN-1-28 13	SN-1-3 14	SN-1-4A 15	SN-1-4B 16	L-1-1 17	He-1-1 18	He-1-2 19	He-1-2 20	He-1-3 21	He 22
Trichonodella sp.																						
Hindeodus sp. A							1															
Ellisonia teicherti, Tr element										1												
Lonchodina sp. A																						
Lonchodina douglasi n. sp.																						
Lonchodina sp. B																						
Ligonodina subacoda, Tr element																		2	1	2	5	1
Ligonodina conflexus, Tr element								1								1						
Cavusgnathus, Tr element																						
Streptognathodus and Idiognathodus, Tr element							2										4					1
Unidentifiable Tr elements							1		3	2						1		1			4	3
Ligonodina conflexus, Hi element																1						
Ligonodina lexingtonensis																				3	5	7
Ligonodina subacoda, Hi element																		2	2	6	3	2
Cavusgnathus Ne element									3							4	3					
Ligonodina subacoda, Ne element																		1	5	4	3	1
Neoprioniodus sp. A																						
Ellisonia teicherti, Ne element			1				10		2	1							2					1
Lonchodus ? sp																						
Ligonodina conflexus, Pl (?) element																	1					
Ligonodina subacoda, Pl element																			3	1	4	1
Lonchodina ? ponderosa																		1		1	2	1
Ligonodina conflexus, Oz (?) element										1						2						
Ligonodina conflexus, Ne (?) element																1						
Metalonchodina ? sp.																						
Genus and species indeterminate							8		2	1								2	13	10	32	4

	He-1-1 23	He-1-2 24	P-1-1 25	P-1-2 26	P-1-3 27	P-1-4 28	P-1-5 29	P-1-6 30	P-1-7 31	P-1-8 32	Hen-1-1 33	Hen-1-1 34	Hen-1-2 35	Hen-1-3A 36	Hen-1-3B 37	Ke-1-1 38	Ke-1-2A 39	Ke-1-2B 40	Ke-1-3 41	Ke-1-4 42	Ke-1-5 43	Ke 4
Trichonodella sp.							3	2	1													
Hindeodus sp. A			2	1			5		1													1
Ellisonia teicherti, Tr element	3		2					1														
Lonchodina sp. A	9	1	2					1														
Lonchodina douglasi n.sp.	1		7		4	5	3		1													
Lonchodina sp. B	2		2				1		2													
Ligonodina subacoda, Tr element	1					7								1								
Ligonodina conflexus, Tr element	1												1	1								
Cavusgnathus, Tr element														2								
Streptognathodus and Idiognathodus, Tr element			1	1			1	3	1	1												
Unidentifiable Tr elements	3			1			2					1		12	1							1
Ligonodina conflexus, Hi element							1				5			8	3			1	1			
Ligonodina lexingtonensis	7	1		1		2	1		1													
Ligonodina subacoda, Hi element	9	2	2			5	2											1				
Cavusgnathus Ne element													2	3	1							
Ligonodina subacoda, Ne element	12					6																
Neoprioniodus sp. A																						
Ellisonia teicherti, Ne element	11		4	1	5	3	16	8	8	1	2		1	7	4					1	1	
Lonchodus ? sp							1															
Ligonodina conflexus, Pl (?) element							1					1			1							
Ligonodina subacoda, Pl element	9	2		1		1	1	1														
Lonchodina ? ponderosa	5					4																
Ligonodina conflexus, Oz (?) element							1					1										1
Ligonodina conflexus, Ne (?) element														1								
Metalonchodina ? sp.																						
Genus and species indeterminate	47	6	3	3	2	18	18	3	12	1				4								

	[illegible] 45	[illegible] 46	[illegible] 47	SB-[illegible] 48	[illegible] 49	[illegible] 50	SB-[illegible] 51	SB-1-1B 52	SB-1-2A 53	SB-1-2 A 54	SB-1-2 B 55	SB-1-3 56	SB-1-4A 57	SB-1-4B 58	SB-1-4C 59	SB-1-5A 60	SB-1-5B 61	SB-1-5C 62
Trichonodella sp.						1	2		1									
Hindeodus sp. A								1										
Ellisonia teicherti, Tr element						1												
Lonchodina sp. A											1							
Lonchodina douglasi n.sp.										1								
Lonchodina sp. B									1	2	2	1						
Ligonodina subacoda, Tr element																		
Ligonodina conflexus, Tr element																		
Cavusgnatnus, Tr element																		
Streptognathodus and Idiognathodus, Tr element				1		1		1										
Unidentifiable Tr elements									1	1		1						
Ligonodina conflexus, Hi element	1					1							1			1		
Ligonodina lexingtonensis																		
Ligonodina subacoda, Hi element																		
Cavusgnathus Ne element			1									1						
Ligonodina subacoda, Ne element																		
Neoprioniodus sp. A																		
Ellisonia teicherti, Ne element						2		1	7		2	5						
Lonchodus ? sp																		
Ligonodina conflexus, Pl (?) element											1	1						
Ligonodina subacoda, Pl element																		
Lonchodina ? ponderosa																		
Ligonodina conflexus, Oz (?) element																		
Ligonodina conflexus, Ne (?) element												1						
Metalonchodina ? sp.																		
Genus and species indeterminate		1	3						1	1	3		1					

	SB-1-5 D 63	SB-1 64	SB-1 65	[illegible] 66	[illegible] 67	BS-1-2 68	BS-1-1 69	BS-1-2 70	QH-1-1 71	QH-1-2 72	B-1-1 73	B-1-2 74	B-1-3 75	B-1-4 76	B-1-5 77	B-1-6 78	B-1-6 under B-1-7 79	B-1-7 80	[illegible] 81	[illegible] 82	[illegible] 83	
Trichonodella sp.																						
Hindeodus sp. A																						
Ellisonia teicherti, Tr element																						
Lonchodina sp. A																						
Lonchodina douglasi n.sp.																						
Lonchodina sp. B																						
Ligonodina subacoda, Tr element																						
Ligonodina conflexus, Tr element						1				3								1				
Cavusgnathus, Tr element															1	1						
Streptognathodus and *Idiognathodus*, Tr element												1			1							
Unidentifiable Tr elements									3							1						
Ligonodina conflexus, Hi element						2				2	2											
Ligonodina lexingtonensis																						
Ligonodina subacoda, Hi element																						
Cavusgnathus Ne element																3						
Ligonodina subacoda, Ne element																						
Neoprioniodus sp. A																						
Ellisonia teicherti, Ne element						1		1			1	1				2						
Lonchodus ? sp																						
Ligonodina conflexus, Pl (?) element						1				1												
Ligonodina subacoda, Pl element																						
Lonchodina ? *ponderosa*																						
Ligonodina conflexus, Oz (?) element										1												
Ligonodina conflexus, Ne (?) element																						
Metalonchodina ? sp.																						
Genus and species indeterminate									3													

									Os [illegible]	Os-1-[illegible]	Os-1-24	Os-1-28	Os-1-2C	Os-1-2[illegible]	Os-1-23	Os-1-3	RC-1-1	LB-1-1	LB-1-2
	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Trichonodella sp.																			
Hindeodus sp. A																			
Ellisonia teicherti, Tr element				1															
Lonchodina sp. A																			
Lonchodina douglasi n.sp.																			
Lonchodina sp. B																			
Ligonodina subacoda, Tr element																			
Ligonodina conflexus, Tr element																	1			
Cavusgnathus, Tr element				1															
Streptognathodus and *Idiognathodus*, Tr element			3	1													1	3	
Unidentifiable Tr elements			2	17															2
Ligonodina conflexus, Hi element				1														1	1
Ligonodina lexingtonensis																			
Ligonodina subacoda, Hi element																			
Cavusgnathus Ne element				5												2			
Ligonodina subacoda, Ne element																			
Neoprioniodus sp. A																		1	
Ellisonia teicherti, Ne element			3	12	1											2			
Lonchodus ? sp																			
Ligonodina conflexus, Pl (?) element																1		2	
Ligonodina subacoda, Pl element																			
Lonchodina ? *ponderosa*																			
Ligonodina conflexus, Oz (?) element																1			
Ligonodina conflexus, Ne (?) element																1			
Metalonchodina ? sp.																			
Genus and species indeterminate			1	4						1									

	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122
Trichonodella sp.																			
Hindeodus sp. A										1			1						
Ellisonia teicherti, Tr element		1													1				
Lonchodina sp. A																			
Lonchodina douglasi n.sp.																			
Lonchodina sp. B																			
Ligonodina subacoda, Tr element																			
Ligonodina conflexus, Tr element		2	1												1				
Cavusgnathus, Tr element																			
Streptognathodus and *Idiognathodus*, Tr element							1	3		1									
Unidentifiable Tr elements	2					1							2						
Ligonodina conflexus, Hi element						2	1		1				1		1				1
Ligonodina lexingtonensis																			
Ligonodina subacoda, Hi element													1						
Cavusgnathus Ne element															1				
Ligonodina subacoda, Ne element																			
Neoprioniodus sp. A	17																		
Ellisonia teicherti, Ne element						2	1			1									
Lonchodus ? sp																			
Ligonodina conflexus, Pl (?) element	1					1									1				
Ligonodina subacoda, Pl element																			
Lonchodina ? *ponderosa*																			
Ligonodina conflexus, Oz (?) element																			
Ligonodina conflexus, Ne (?) element																			
Metalonchodina ? sp.																			
Genus and species indeterminate																			1

Trichonodella sp.	Cal-Sp-1 123	H-1-1 124	H-1-2 125	H-1-3A 126	H-1-3B 127	H-1-3C 128	H-1-3D 129	H-1-3E 130	H-1-3F 131	H-1-3G 132	H-1-3H 133	H-1-3I 134	IP-2-1 135	IP-2-2 136	IP-2-3 137	IP-2-4 138	Car-1-A 139	Car-1-B 140	Car-1-C [illegible]	[illegible] 142	[illegible] 143	[illegible]
Hindeodus sp. A				1																		
Ellisonia teicherti, Tr element		1	1																			2
Lonchodina sp. A																						
Lonchodina douglasi n.sp.																						
Lonchodina sp. B																						
Ligonodina subacoda, Tr element																						
Ligonodina conflexus, Tr element			1	1			1															
Cavusgnathus, Tr element	1																					
Streptognathodus and Idiognathodus, Tr element		6		4		1														1		5
Unidentifiable Tr elements	2	2	1	4			1					1										1
Ligonodina conflexus, Hi element	2	1	3	1			1			1					1							
Ligonodina lexingtonensis																						
Ligonodina subacoda, Hi element			1																			
Cavusgnathus Ne element	15	3										2			1	3						2
Ligonodina subacoda, Ne element																						
Neoprioniodus sp. A							1					1										
Ellisonia teicherti, Ne element	3	21	4	12	1	2	1	1								1				1	1	16
Lonchodus ? sp																						
Ligonodina conflexus, Pl (?) element		2								1								1				
Ligonodina subacoda, Pl element																						
Lonchodina ? ponderosa																						
Ligonodina conflexus, Oz (?) element				1																		
Ligonodina conflexus, Ne (?) element																						
Metalonchodina ? sp.												2										
Genus and species indeterminate	1		1									1										3

	A+B 145	146	147	JPS 148	3 149	150	151	Shc-1-1 152	Shc-1-2 153	Shc-1-3 154	155	TCS-1-2 156	TCS-1-3 157	TCS-1-4 158	DB-1-1A 159	DB-1-1B 160	Hol-1-1 161	162	163	CC-1-1 164	CC-1-1B 165
Trichonodella sp.																					
Hindeodus sp. A																					
Ellisonia teicherti, Tr element																				1	
Lonchodina sp. A																					
Lonchodina douglasi n.sp.																					
Lonchodina sp. B																					
Ligonodina subacoda, Tr element																					
Ligonodina conflexus, Tr element			1							1											
Cavusgnathus, Tr element		1											1			4					
Streptognathodus and Idiognathodus, Tr element																5	1				
Unidentifiable Tr elements			1															4			
Ligonodina conflexus, Hi element								2		1											
Ligonodina lexingtonensis																					
Ligonodina subacoda, Hi element																					
Cavusgnathus Ne element	1	5	4										1			16					
Ligonodina subacoda, Ne element																					
Neoprioniodus sp. A																					
Ellisonia teicherti, Ne element		3	1													17				4	3
Lonchodus ? sp																					
Ligonodina conflexus, Pl (?) element																					
Ligonodina subacoda, Pl element																					
Lonchodina ? ponderosa																					
Ligonodina conflexus, Oz (?) element																					
Ligonodina conflexus, Ne (?) element			1																		
Metalonchodina ? sp.																		1			
Genus and species indeterminate		2	1																	1	4

		CC-7 16 166		167		168	CC-7 169	CC-7 170	CC-7 171													
Trichonodella sp.																						
Hindeodus sp. A																						
Ellisonia teicherti, Tr element		1																				
Lonchodina sp. A																						
Lonchodina douglasi n.sp.																						
Lonchodina sp. B																						
Ligonodina subacoda, Tr element																						
Ligonodina conflexus, Tr element																						
Cavusgnathus, Tr element																						
Streptognathodus and Idiognathodus, Tr element																						
Unidentifiable Tr elements		3		1																		
Ligonodina conflexus, Hi element																						
Ligonodina lexingtonensis																						
Ligonodina subacoda, Hi element																						
Cavusgnathus Ne element		3				3	2		1													
Ligonodina subacoda, Ne element																						
Neoprioniodus sp. A		1																				
Ellisonia teicherti, Ne element		3		1																		
Lonchodus ? sp																						
Ligonodina conflexus, Pl (?) element																						
Ligonodina subacoda, Pl element																						
Lonchodina ? ponderosa																						
Ligonodina conflexus, Oz (?) element																						
Ligonodina conflexus, Ne (?) element																						
Metalonchodina ? sp.																						
Genus and species indeterminate																						