

THE UNIVERSITY OF KANSAS  
PALEONTOLOGICAL CONTRIBUTIONS

## ARTICLE 59

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

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“The recognition of more than 100 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 (1966)

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## ABSTRACT

Biofacies analysis of Upper Pennsylvanian conodont faunas from the classic Shawnee Group cyclothem 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 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 that 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. Their fauna 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; 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 *Neoproniodus conjunctus*, 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 *Lonchodina* 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*, *A. edentulus* and *A. moorei*, and one of *Cavusgnathus*, *C. merrilli*, are recognized. R-mode cluster analysis was not only useful in defining conodont biofacies, but also in delineating original element associations.

Some elements, including a new species of *Lonchodina*, *L. douglasensis*, and a new species questionably assigned to *Ozarkodina*, *O. ? kansasensis*, could not be classified in terms of a multielement species taxonomy.

## INTRODUCTION

## PURPOSE AND SCOPE OF 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 high 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 is partially an outcome of the evaluation of biofacies, is to determine what conodont elements belong together as component parts of multielement species.

The results of studies in environmental control of conodont distributions have important implications in

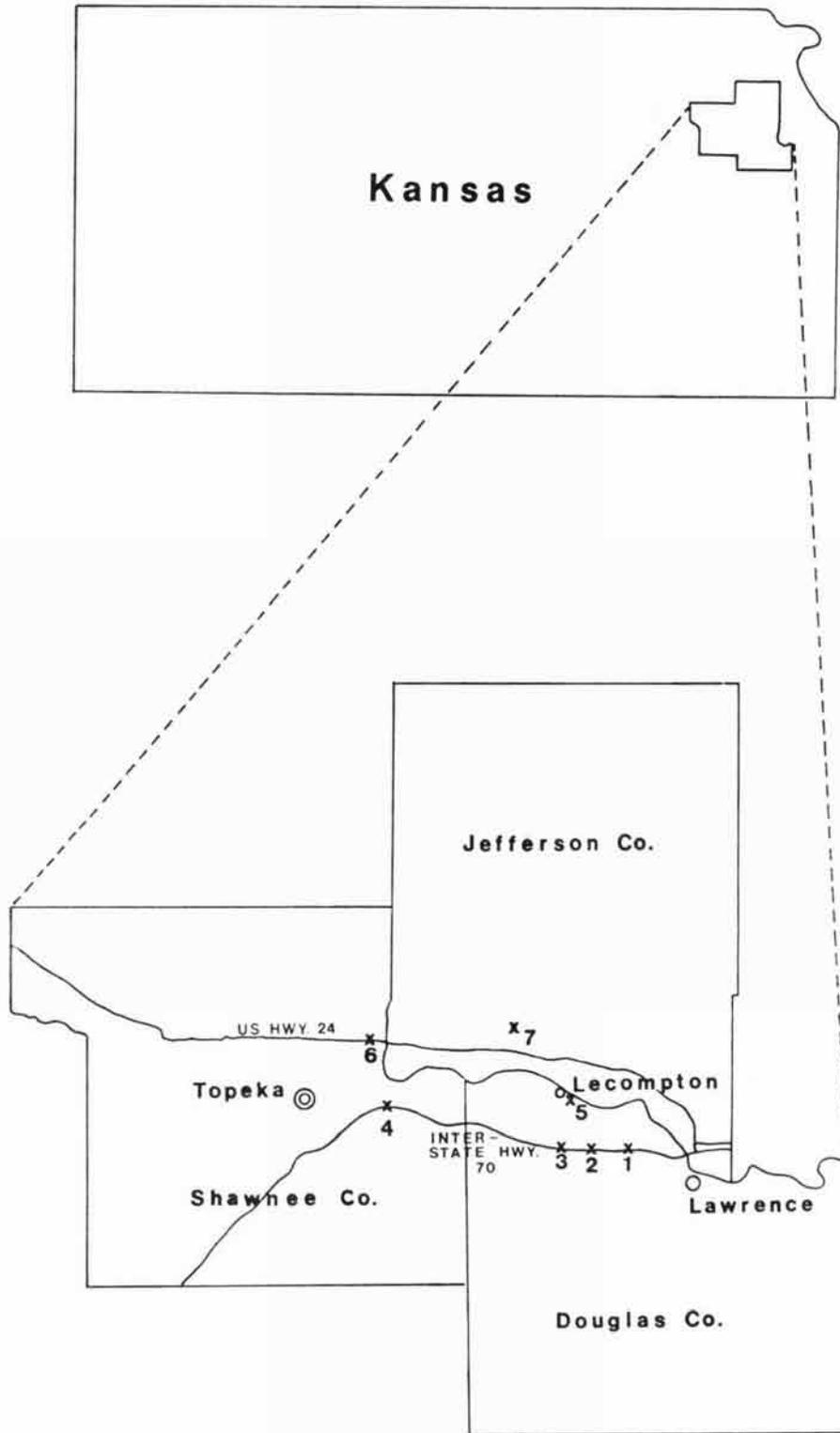


FIG. 1. Study area in northeastern Kansas showing localities sampled. Scale 1:500,000. (X=Locality.)

chronostratigraphic correlation and will encourage conodont workers to continue to reexamine 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 preceding, essentially nonquantitative methods both were utilized with varying degrees of success by Merrill (1968; 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 megacyclothem (Moore, 1936) lithologies, 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 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 Figures 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 that are believed to have been component parts of the apparatuses of natural conodont species.

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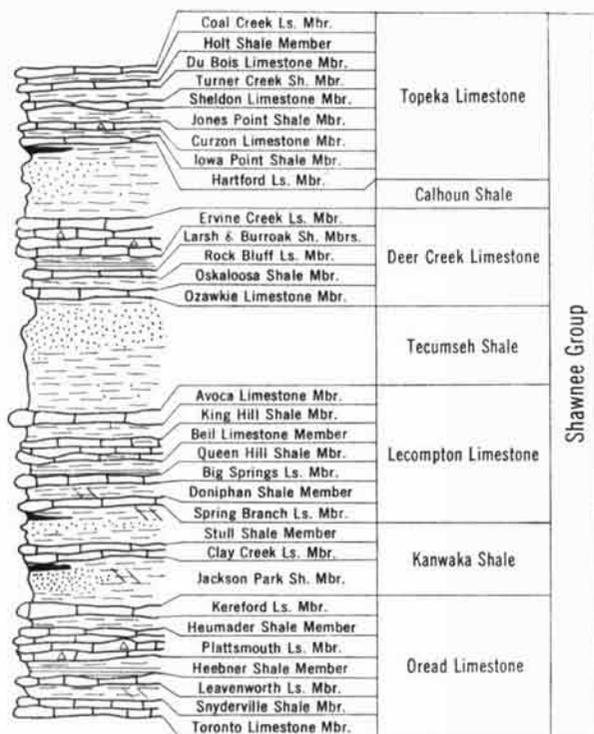


FIG. 2. Stratigraphic sequence of the Shawnee Group in eastern Kansas. Figure from plate 1 of Jewett, *et al.* (1968).

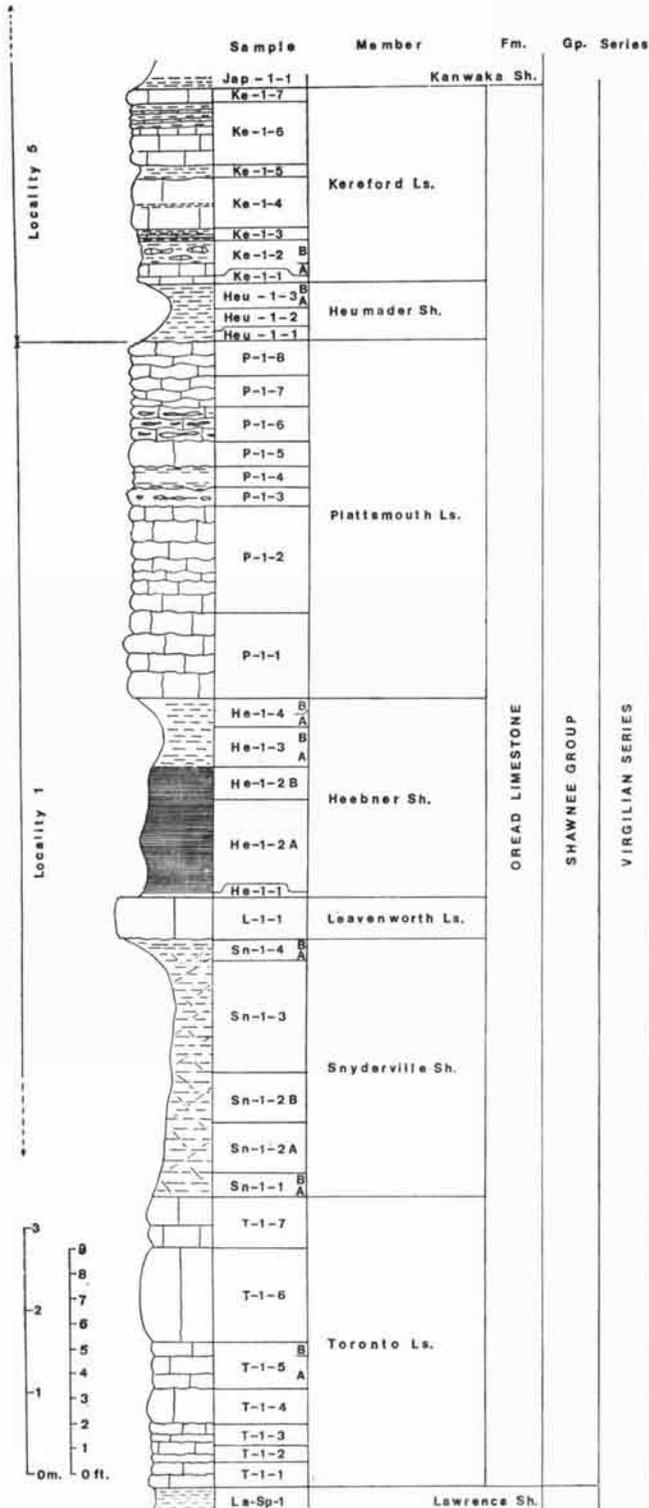


FIG. 3. Composite section of the Oread Limestone at Localities 1 (NW sec. 21, T. 12 S., R. 19 E., Douglas Co.) and 5 (NW SW sec. 35, T. 11 S., R. 18 E., Douglas Co.) showing units sampled.

tesies shown me. While at Marburg, I benefited greatly from discussions with Professors Lindström and Ziegler, as well as with Dr. Samuel P. Ellison, Jr., of the University of Texas and Dr. Peter Bender of Philipps Universität. Drs. C. Barnes of the University of Waterloo and L. Jeppsson of Lund University discussed various technical and taxonomic points with me.

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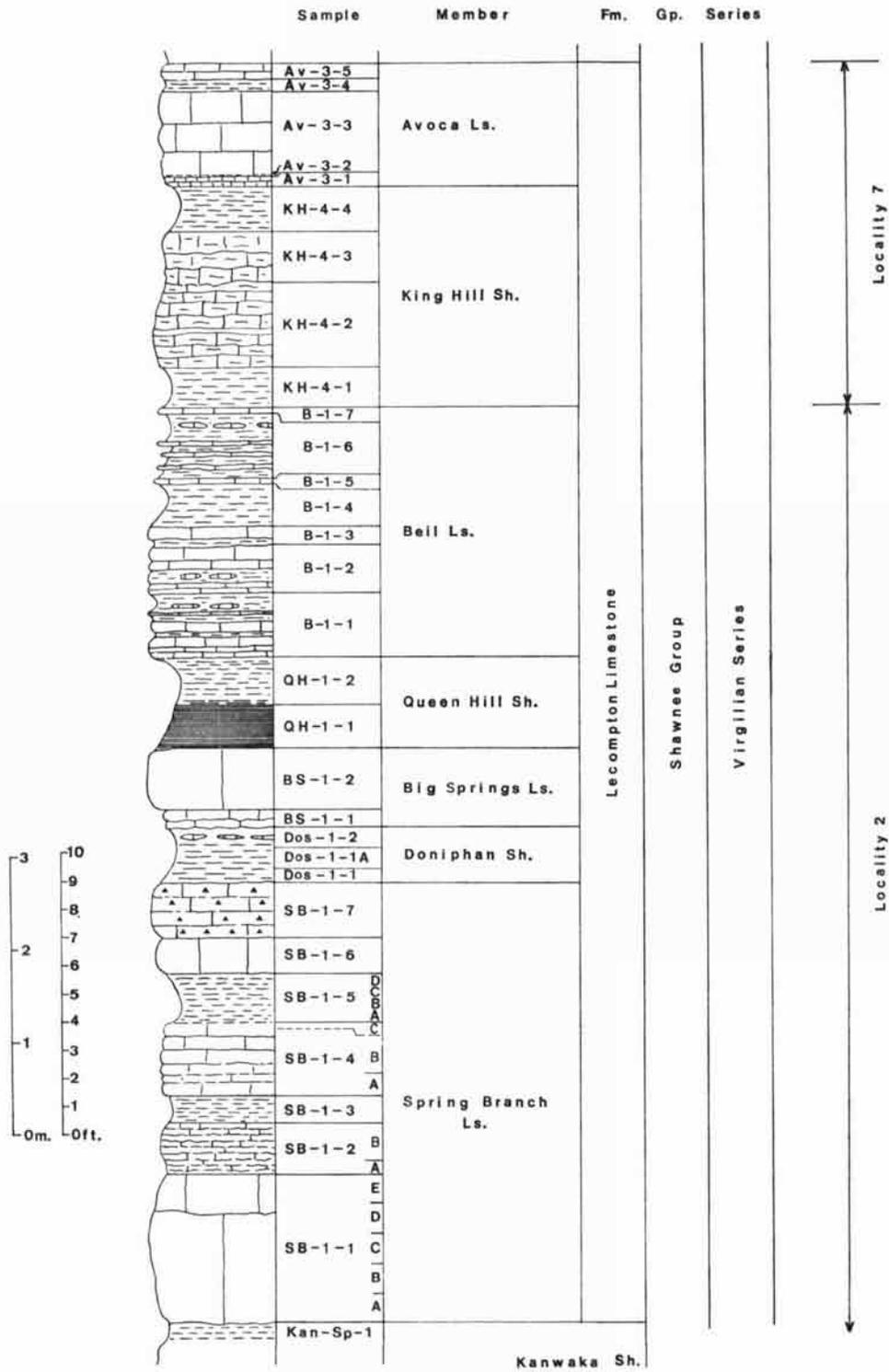


FIG. 4. Composite section of the Lecompton Limestone at Localities 2 (NW NW sec. 24, T. 12 S., R. 18 E., Douglas Co.) and 7 (SE NW SE sec. 8, T. 11 S., R. 18 E., Jefferson Co.) showing units sampled.

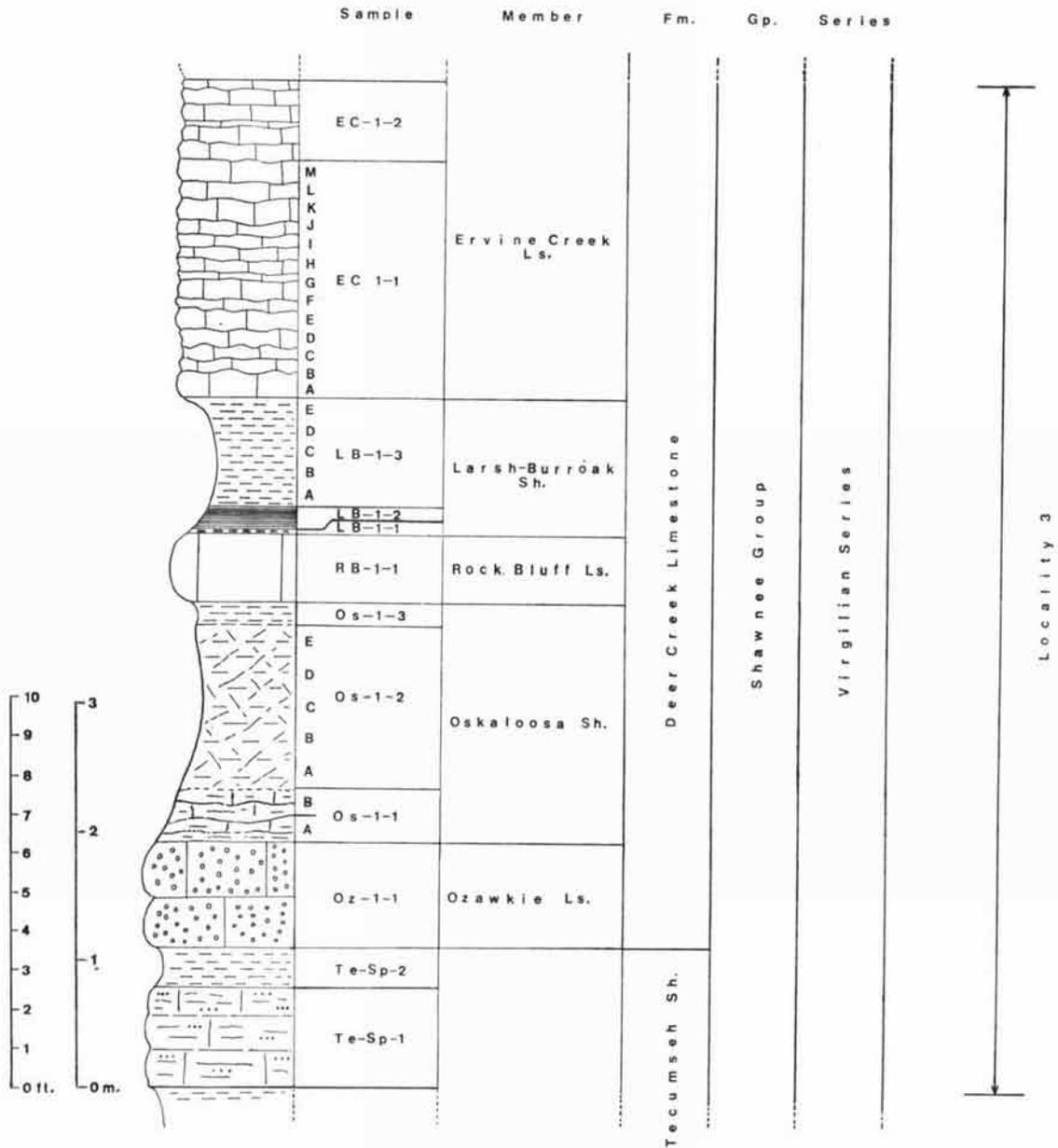


FIG. 5. Section of the Deer Creek Limestone at Locality 3 (NE NW NW sec. 22, T. 12 S., R. 18 E., Douglas Co.) showing units sampled.

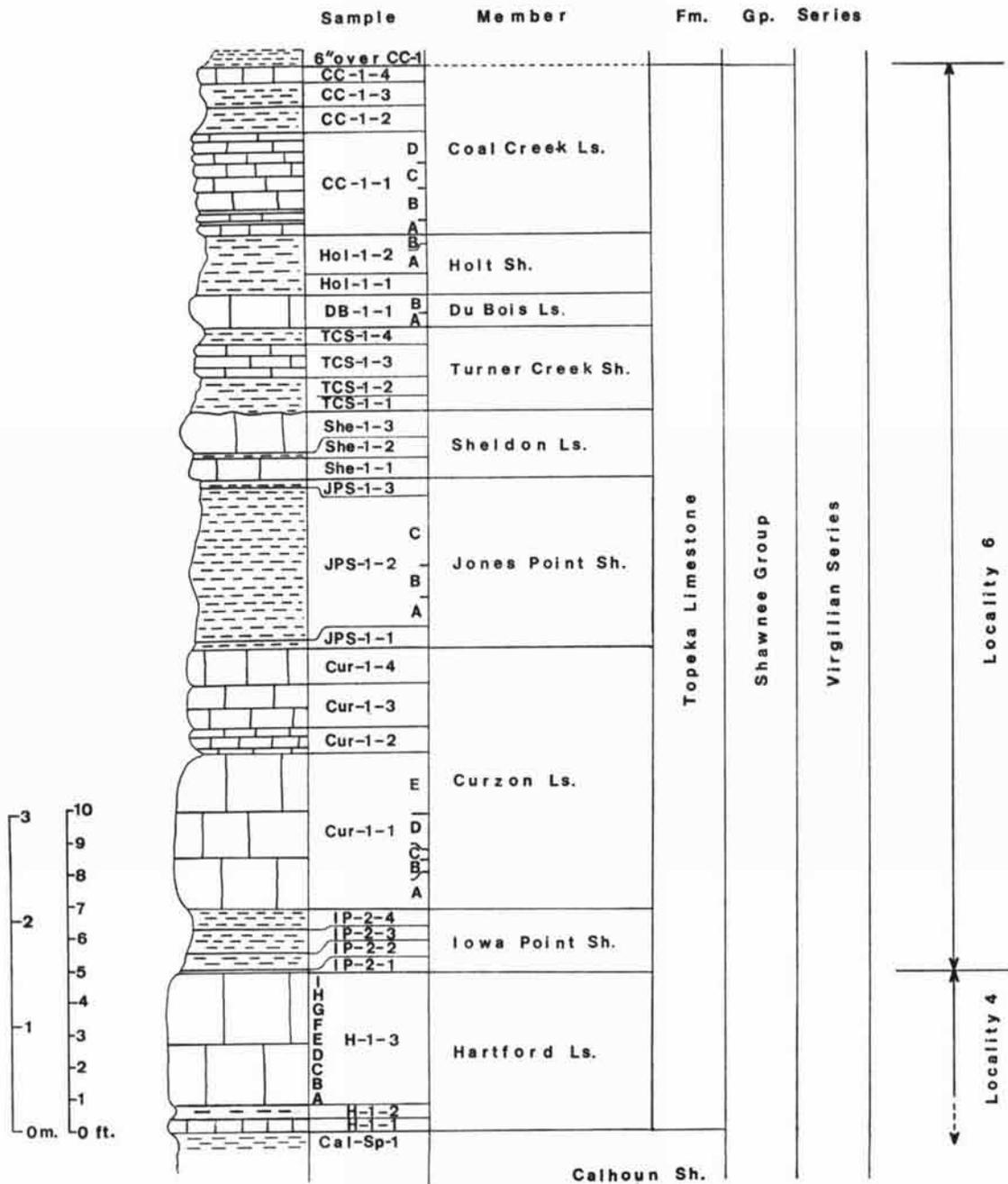


FIG. 6. Composite section of the Topeka Limestone at Localities 4 (SE SW sec. 2, T. 12 S., R. 16 E., Shawnee Co.) and 6 (NW SE sec. 14, T. 11 S., R. 16 E., Shawnee Co.) showing units sampled.

## PREVIOUS WORK IN 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 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 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 many species have a worldwide 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 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 reexamined. 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 some mixing of faunal elements from different environments would be expected. This may, in part, also represent postmortem transport.

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, how-

ever, will modify applications in biostratigraphy. Thus, Druce (1970, p. 386) 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 by 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 faunas of similar age 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. It is preferable to separate these two aspects and a discussion appears on page 17.

### PROVINCIALISM

Rexroad & 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 & Bergström (1962), Mosher (1968, 1970), Collinson (1970), and Aldridge, Austin, & 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 taxa within the particular rock type deposited in that environment. Müller (1956, p. 1334) 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 & 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, p. 274) 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 that may have been related to tectonic instability.

Varker (1967, p. 139) 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, & Husri (1968) in England and Ireland.

Druce (1970), discussing Lower Carboniferous faunas, defined a deepwater conodont faunal assemblage consisting of *Siphonodella* and *Pseudopolygnathus* of the *triangularis* type associated with *Dinodus*, *Doliognathus*, *Dollymae*, *Scaliognathus*, and *Staurogathus*, 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 from the Illinois Basin by Merrill & 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 that 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, p. 378) 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, p. 27) 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 mega-

cyclothems 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, 1966). The interested reader is referred to Weller (1960, 1966) for an extensive discussion of this problem.

Moore (1966, p. 287) 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 nonoceanic, epicontinental sea which spread inland for many hundreds of miles. Similarly Toomey (1966, p. 5) 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 & Adkison (1967, p. 81) 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 & Merriam (1965), and Reed & Burchett (1966). The diachroneity

of cyclic sediments, particularly those of Pennsylvanian age was discussed by Shaw (1966).

A significant feature is that although sediments representing a multitude of depositional environments were deposited, none of these apparently represent deep water, nonplatform 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 (1966), Moore & Merriam (1965), and Jewett, *et al.* (1968). The term "Larsh-Burroak" is used in the sense of Moore (1966) and Moore & 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, commonly 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 it is likely that the faunas present in northeastern Kansas can 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 paleoenvironmental rather than biostratigraphic correlations. For the most part faunas recur 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, although correlations based on these two criteria do not necessarily imply time equivalency of the units concerned. In the Shawnee Group of northeastern Kansas several members fit this description and their characteristics will be described briefly. These members contain faunas that are dominant in that particular member and that generally have 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 *Neoprioniodus conjunctus*. 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* von Bitter, n. sp., unidentified Tr elements, types A, B, and C, *Lonchodina douglasensis* von Bitter, n. sp., *Hindeodella* sp. B, *Ozarkodina? curvata*, *Anchignathodus minutus*, *Anchignathodus edentulus* von Bitter, n. sp., *Ellisonia teichertii?*, 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 *Gondolella* (Ellison, 1941; this study). Elements belonging to species of *Gondolella* were also found 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, have not been found above the Queen Hill Shale in the midcontinent area by Ellison (1941), by Perlmutter (1971), or by me. Related to this is an interesting distribution of *Idiognathodus tersus*, *Idiognathodus antiquus*, *Streptognathodus wabaunsensis* and *Streptognathodus opletus*. 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 opletus* were found above the Queen Hill Shale.

It should be noted that *Streptognathodus* sp. A has

been recovered only from the Spring Branch Member of the Lecompton Limestone. *Anchignathodus edentulus* von Bitter, 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.

For a summary of the distribution of conodonts in the Shawnee Group, see Appendix D.

## BIOFACIES ANALYSIS

### INTRODUCTION

In this paper the term biofacies analysis is used as defined by Kaesler (1966, p. 1) who defined it as "the study of assemblages of organisms, their area and chronologic distribution, and the environmental factors that affect them." In biofacies analysis a distinction is often made between biotopes and biofacies. Kaesler (1966, p. 3) 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. Kaesler defined biofacies 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 (1966, p. 2) 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 & Buzas (1968) felt that Kaesler's use of the term biofacies was too restrictive. They used the term biofacies for 1) an area which is defined by species and 2) the species that are contained in it. Mello & 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 (p. 103) that "in some instances quantitative measures and statistical techniques 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; in press), Seddon (1970a, 1970b), and Druce (1970). Merrill defined a number of conodont biofacies in the Allegheny Group (Middle Pennsylvanian) of Ohio, adjacent Pennsylvania, and Kentucky (see Table 1).

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 referred to them as faunas rather than biofacies.

Merrill (1968; in press) concluded that the *Cavusgnathus* biofacies is more commonly restricted to shales that, 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 that were deposited in offshore rather than nearshore conditions. Merrill (in press) postulated, at least for the Midcontinent (an area that includes the study area), that, characteristically, the Midcontinent fauna was dominant only in thin, often black, fissile shale units and in the thin limestones that immediately underlie them. The Appalachian fauna was reported to occur predominantly in the thicker and 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. Some elements of the ubiquitous

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

Cavusgnathus BIOFACIES (Merrill, in press)	APPALACHIAN FAUNA (Merrill, 1968)	MIDCONTINENT <sup>1</sup> FAUNA (Merrill, in press)	UBIQUITOUS FORMS <sup>2</sup> Merrill (1968)
<i>Cavusgnathus</i> spp.	<i>Hibbardella</i> n. sp. 2	<i>Hibbardella subacoda</i>	<i>Gnathodus</i> spp.
<i>Hibbardella</i> 2 new species	<i>Hindeodus</i> spp.	<i>Ligonodina lexingtonensis</i>	<i>Idiognathodus</i> spp.
<i>Ligonodina</i> 1 new species	<i>Ligonodina</i> n. sp. 4	<i>Ligonodina typa</i>	<i>Streptognathodus</i> spp.
<i>Neoprioniodus</i> 2 new species	<i>Neoprioniodus</i> n. sp. 7	<i>Lonchodina clarkii</i>	<i>Ozarkodina</i> spp.
<i>Ozarkodina</i> 1 new species	New genus A, n. sp. 3 New genus B, n. sp. 1	<i>Lonchodina ponderosa</i> <i>Metalonchodina bidentata</i> <i>Neoprioniodus conjunctus</i> <i>Neoprioniodus bulbosus</i>	<i>Spathognathodus</i> spp. Others

<sup>1</sup> *Gondolella* spp. was not found in the Appalachians by Merrill (1964, 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.

<sup>2</sup> Some of the members of this group were also grouped in an offshore *Idiognathodus* biofacies by Merrill (1968). Merrill (in press) called this the *Streptognathodus* biofacies and it is so designated in this paper.

group were also defined as part of the *Streptognathodus* biofacies (Merrill, in press).

Examination of the plates and descriptions of Merrill (1968) convinced me 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 me to equate tentatively some of the taxa of this study with those of Merrill (1968; in press) (Tables 2 and 3).

On the basis of the following criteria, the presence of the *Cavusgnathus* and *Gondolella* biofacies, as well as the Midcontinent fauna of Merrill, was recognized (1966; in press):

- Constant mutual association of conodont elements in a particular lithology.
- Constant abundance of an element type in a particular lithology.
- Similar vertical distribution of two or more elements.

- Similar morphology in associated elements, i.e., similar color, transparency, denticle arrangement, and white matter distribution.
- Comparison with the element composition of Mississippian and Pennsylvanian natural assemblages that have been described by a number of authors including Scott (1942), Rhodes (1952), and Schmidt & 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.

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

MERRILL (in press)	THIS STUDY
<i>Cavusgnathus</i> biofacies	
<i>Hibbardella</i> 2 new species	= <i>Delotaxis? conflexa</i> , Tr element* <i>Cavusgnathus</i> Tr element
<i>Ligonodina</i> 1 new species	= <i>Delotaxis? conflexa</i> , Hi element
<i>Neoprioniodus</i> 2 new species	= <i>Cavusgnathus</i> Ne element + possibly unidentified Ne element
<i>Ozarkodina</i> 1 new species	= <i>Cavusgnathus</i> Oz element

\* Element symbols designated by Jeppsson (1971) for elements of multielement species are explained on p. 51.

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

MERRILL (1968)	THIS STUDY
<i>Hibbardella</i> , n. sp. 2	= <i>Streptognathodus</i> and <i>Idiognathodus</i> Tr element
<i>Hindeodus</i> spp.	= <i>Hindeodus</i> sp. A <i>Ellisonia teichertii?</i> , Tr element Unidentified Tr element, type A Unidentified Tr element, type B Unidentified Tr element, type C Unidentifiable Tr element, type A
New genus A, n. sp. 3	= <i>Ozarkodina? curvata</i>
<i>Ligonodina</i> , n. sp. 4	= ? <i>Streptognathodus</i> and <i>Idiognathodus</i> Hi element
New genus B, n. sp. 1	= <i>Lonchodina douglasensis</i> , n. sp.
<i>Neoprioniodus</i> , n. sp. 7	= <i>Ellisonia teichertii?</i> , Ne element

## RELATIVE ABUNDANCE ANALYSIS

A method of conodont biofacies analysis 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 that of 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 collections of this study. 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 arched or elongated blades and platform elements, for example, would lead to unreliable results. Ellison (1968) explained the discrepancies 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, caused by such variables 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 fines 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. In such situations smaller lighter elements such as hindeodellid or neoprioniodid elements would have less of an opportunity to settle out than the larger, more compact platform elements and would be suspended 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 calculated for each conodont-bearing sample is:  $C/C + I + S \times 100 =$  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; 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 that 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 more thinly 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 *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 nonmarine 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, 1966; Johnson & Adkison, 1967).

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, whereas *Cavusgnathus* is rare or completely absent.

On the basis of various opinions that have been expressed by several authors (see Appendix B) on the depositional environments in which the rocks of the Shawnee Group were deposited, I agree with Merrill (1968; in press) that generally green conodont-bearing shales in which the Sp element of *Cavusgnathus* predominates usually represent 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 lagoonal. This interpretation appears to be the most reasonable of the various existing opinions. It, taken together with the interpretations of McCrone (1963) for the Permian Bennett Shale, and of Moore (1966) for the Pennsylvanian black shales, leads to the conclusion 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.

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 by this method.

In the discussion of relative abundances which follows, for simplification, references to *Cavusgnathus*, *Streptognathodus*, and *Idiognathodus* are made instead of to the Sp elements of these genera.

The right-hand curve of Figure 7 was taken from Elias' (1966) 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 (1966) 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 that directly overlie them are dominated instead by *Streptognathodus* and *Idiognathodus*.

Curves similar to those of Elias (1966) have been drawn for the Oread Limestone by Troell (1969) and for Pennsylvanian and Permian cyclothem by Moore (1966).

#### RELATIVE ABUNDANCE ANALYSIS OF CONODONTS 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) 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) is 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, 1966) 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, suggesting that the environment represented by this interval is transitional and probably represents marginal nearshore marine conditions. Only charophytes were recovered in the middle part of the Snyderville and these beds have been interpreted as nonmarine (Moore, 1966). 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, 1966; 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 during a slight regression under nearshore, shallow water, restricted (possibly lagoonal) conditions (Moore, 1936, 1966). *Cavusgnathus* was evidently unable to tolerate these environmental conditions because *Streptognathodus* and *Idiognathodus* are abundant to the complete exclusion of *Cavusgnathus*.

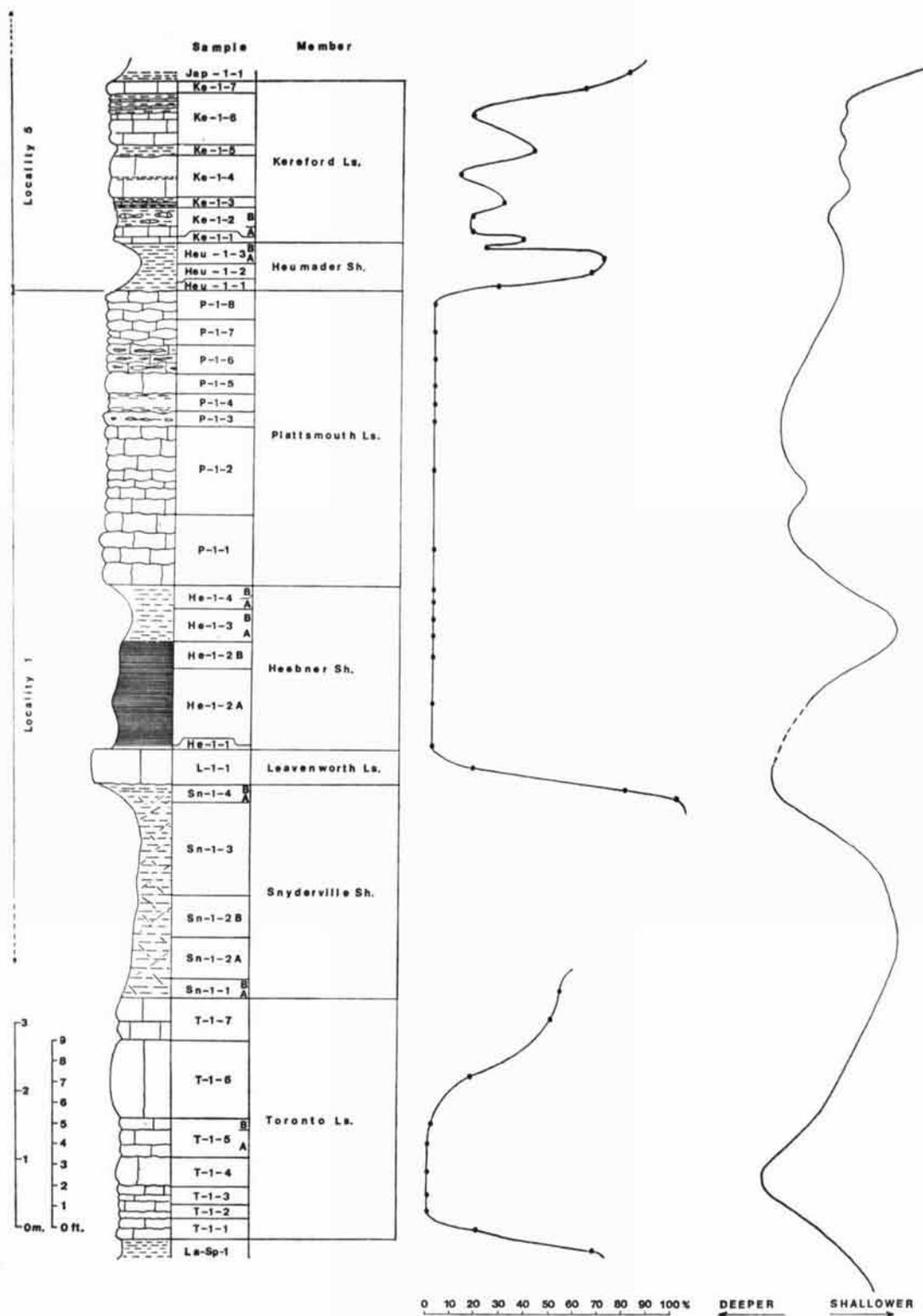


FIG. 7. Stratigraphic section of the Oread Limestone at Localities 1 and 5 showing relative abundance curve of the Sp elements of *Streptognathodus*, *Idiognathodus* and *Cavusgnathus* on the left curve. Increase in percent reflects increase in the Sp element of *Cavusgnathus*. Gap in the curve is due to lack of conodonts in the corresponding units. Water depth fluctuation curve on extreme right after Elias (1966).

A return to open marine deposition in clear, shallow water allowed the deposition of the Plattsmouth Limestone (Moore, 1966). 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 & 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 (1966) interpreted the environment to have been similar to that of the Beil Limestone in the Lecompton megacycle except that the Beil was deposited nearer shore where the sea had a muddy bottom.

The overlying Kanwaka Shale is largely nonmarine (Johnson & 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 CONODONTS OF THE LECOMPTON LIMESTONE

The upper part of the Kanwaka Shale, the Stull Shale Member, was deposited under marine conditions (Johnson & 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, 1966). It is the cyclothem 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 & Adkison, 1967). The upper Spring Branch Limestone becomes increasingly shaly and was, according to Johnson & 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 (?intraclasts), 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 by Johnson & Adkison (1967) to represent nonmarine, estuarine deposition. Moore & Merriam (1965) interpreted it as having had an environment similar to that of the Snyderville Shale. *Cavusgnathus*, rather than *Streptognathodus* or *Idiognathodus*, predominates and on the basis of com-

parison with the Snyderville Shale of the Oread Limestone, this would suggest that the member was deposited in a nearshore marginal marine environment.

The Big Springs Limestone was deposited in a deeper sea than the Doniphan Shale (Johnson & Adkison, 1967) in an environment identical with or similar to that in which the Spring Branch Limestone was deposited (Moore, 1966). 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 under which the Heebner Shale was deposited (Moore, 1966; Johnson & Adkison, 1967). Like the Heebner Shale, the Queen Hill is dominated by *Streptognathodus*, to the virtual exclusion of *Cavusgnathus* (Fig. 8).

The Beil Limestone was deposited in quiet, normal marine waters (Yochelson, 1960, in Johnson & Adkison, 1967) far from the shore (Moore, 1966). Its fauna 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 & 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 & Adkison's interpretation. Lack of conodonts is responsible for the breaks 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 & Adkison and Lokke & Van Sant (1966) that the upper part was deposited under marine conditions. The shale lithology, a biota 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 & Adkison, 1967) indicate that the uppermost shale unit of the King Hill Shale was deposited under the marginal marine conditions described by Moore (1966). 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 *Cavusgnathus* and one to a species of *Streptognathodus*.

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 & Adkison (1967) interpreted the lower Avoca to have been deposited under deeper marine conditions. The upper

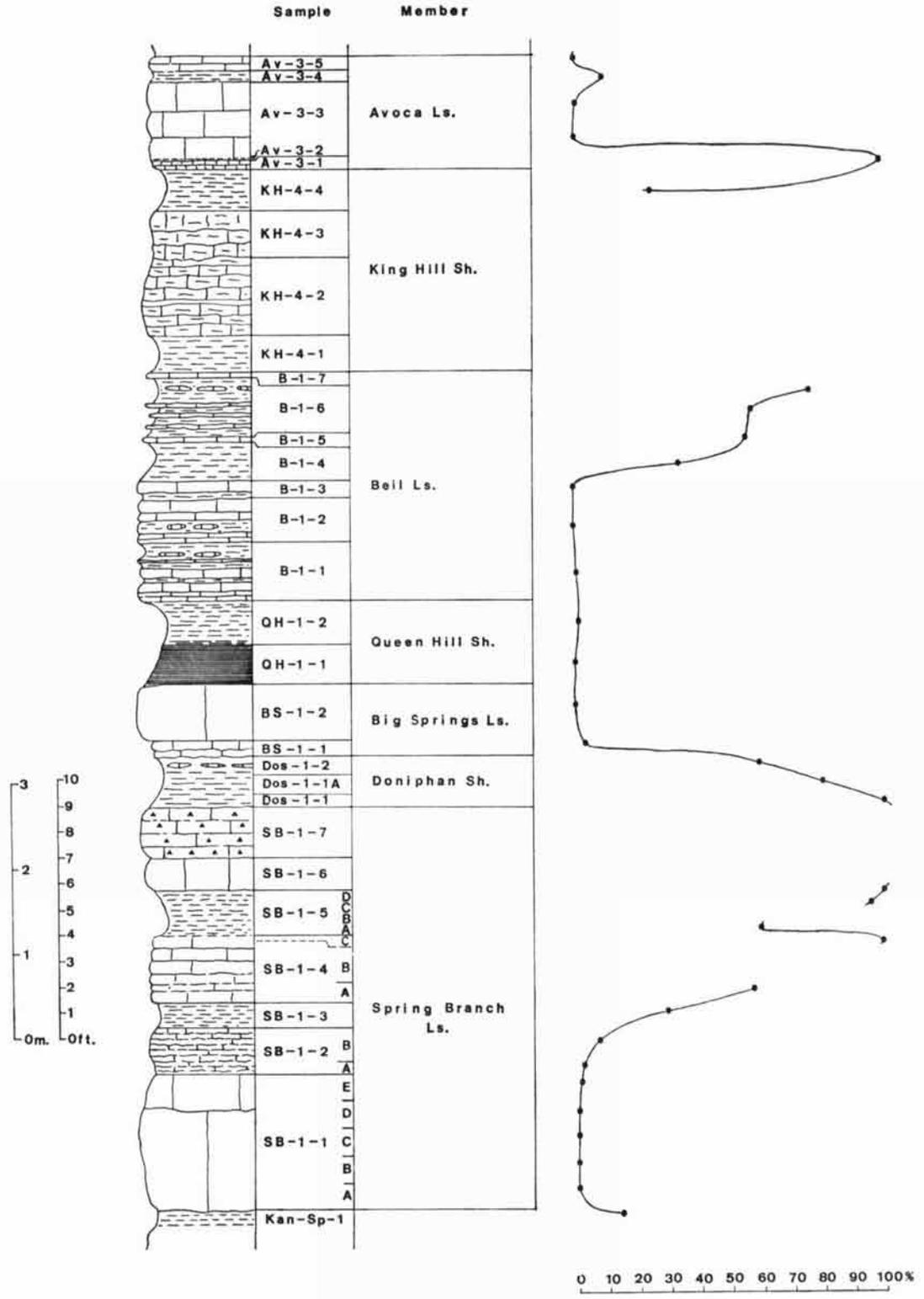


FIG. 8. Stratigraphic section of the Lecompton Limestone at Localities 2 and 7 showing relative abundance curve of the Sp elements of *Streptognathodus*, *Idiognathodus*, and *Cavusgnathus*. Increase in percent reflects increase in the Sp element of *Cavusgnathus*. Gaps in curve are due to lack of conodonts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

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 CONODONTS 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 was deposited in a transgressing sea

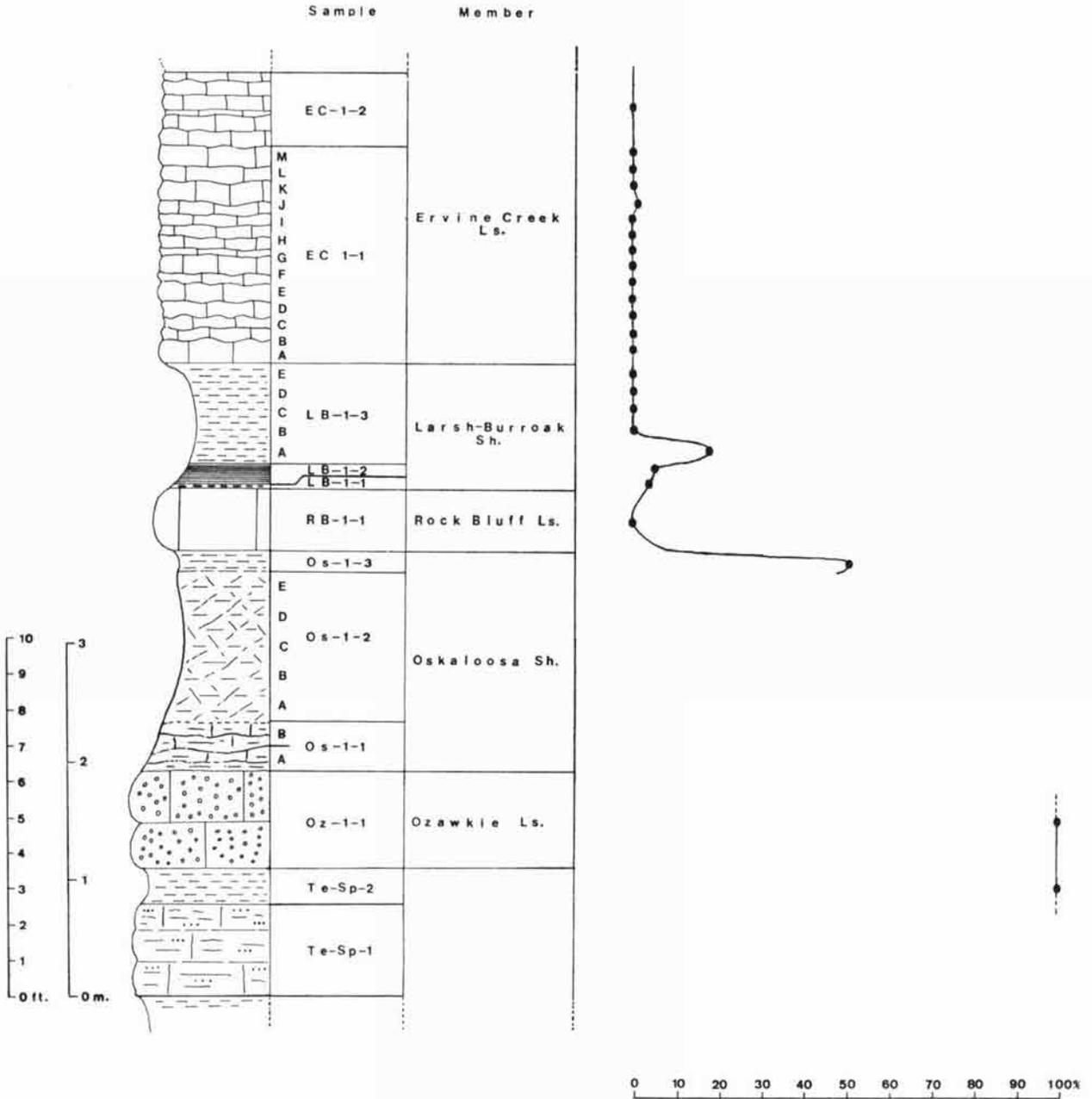


FIG. 9. Stratigraphic section of the Deer Creek Limestone at Locality 3 showing relative abundance of the Sp elements of *Streptognathodus* and *Cavusgnathus*. Increase in percent reflects increase in the Sp element of *Cavusgnathus*. Gap in curve is due to lack of conodonts in corresponding units.

(Johnson & Adkison, 1967). Only two conodonts, both Sp elements of *Cavusgnathus*, were found in samples from the Tecumseh Shale. Environmentally the 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 cyclothem equivalent of the Spring Branch and the Toronto Limestones of the Leocompton and Oread megacycles, respectively.

Moore (1966) 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, and the fact that the lithology is an oolitic limestone, Moore (1966, p. 341) 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 & 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, 1966) and the continental deposition represented by the beds of the middle Oskaloosa Shale (Johnson & 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, 1966). These nearshore shales contain a megafauna of *Chonetes*, *Juresania*, *Derbyia*, and *Aviculopecten* (Moore, 1966). 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 & 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, 1966). 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* von Bitter, n. sp., is more common in the Larsh-Burroak and Queen Hill Shales than is *Cavusgnathus lautus*, a species more common in the nonrestricted nearshore marine shales such as those of the upper Snyderville or Oskaloosa. Black shales and the shales that 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 *C. merrilli* 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 & Adkison, 1967) in shallow waters far from the shore (Moore, 1966). These offshore marine conditions were accompanied by a dominance of *Streptognathodus* and a near absence of *Cavusgnathus* (Fig. 9).

#### RELATIVE ABUNDANCE ANALYSIS OF CONODONTS 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 cyclothem equivalent of the Clay Creek Limestone of the Kanwaka Shale and the upper part of the Iowa Point Shale is the cyclothem 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 & 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 & Adkison, 1967) and there is a noticeable increase in *Streptognathodus* over *Cavusgnathus* in this unit.

Johnson & Adkison (1967) interpreted the Iowa Point Shale to have been deposited under generally marine, though locally 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 cyclothem equivalent of the Toronto, the Spring Branch, and the Ozawkie Limestones of the three lower megacyclothems of the Shawnee Group, respectively. Johnson & 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 *Cavusgnathus* and an increase in *Streptognathodus* (Fig. 10). In the more thinly 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

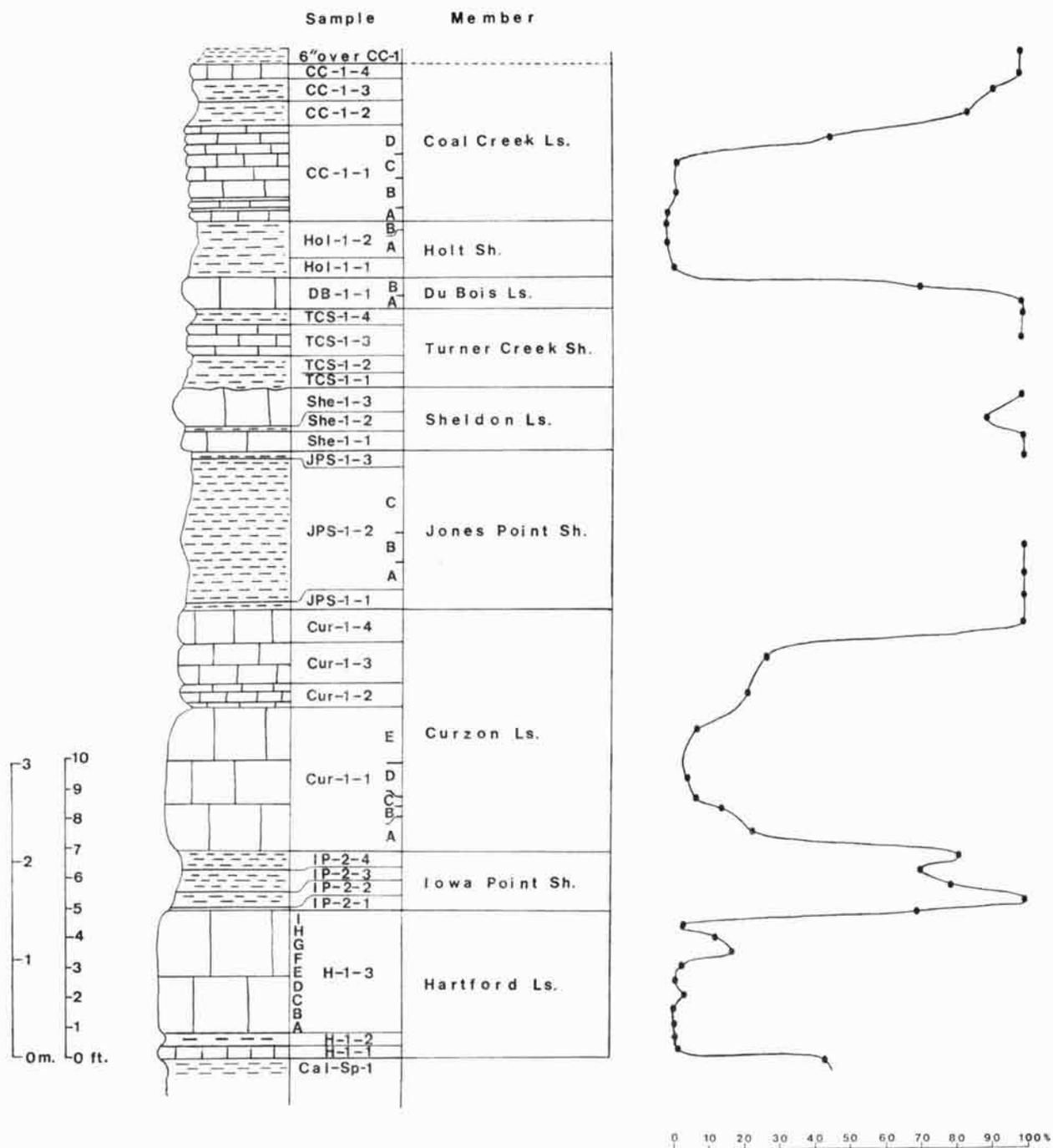


FIG. 10. Stratigraphic section of the Topeka Limestone at Localities 4 and 6 showing relative abundance of the Sp elements of *Streptognathodus* and *Cavusgnathus*. Increase in percent reflects increase in the Sp element of *Cavusgnathus*. Gap in curve is due to lack of conodonts in corresponding units.

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 & Adkison, 1967). When compared with the conodont faunas of most marine limestones the Sheldon contains an unusually high ratio of *Cavusgnathus* to *Streptognathodus* (393:1). This

limestone probably represents intermediate to nearshore deposition.

The basal beds of the Turner Creek Shale were found to be barren of conodonts and this supports Johnson & Adkison (1967) in their interpretation that the basal beds of this member were 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 & 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). I am 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, 1966) 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 Le-compton megacycle. It, like the Beil, was apparently deposited under normal marine conditions far from the 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; in press) and by Merrill & King (1971).

Attempts at evaluating other relative abundance relationships such as

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

where *An* = number of elements of *Anchignathodus*, *C* = number of Sp elements of *Cavusgnathus*, *S* = number of Sp elements of *Streptognathodus*, and *I* = number of Sp elements of *Idiognathodus*, proved to be unsuccessful; that is, no regular variation corresponding to lithologic 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 preceding 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* von Bitter, 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 deposited under restricted, probably lagoonal, nearshore marine conditions.

## CLUSTER ANALYSIS

### INTRODUCTION

While the groups of associated conodont taxa defined by Merrill (1968; in press) and at least partially supported here 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 & Sneath, 1963), factor analysis (Imbric, 1964), recurrent group analysis (Kohut, 1969; Sweet, 1970b), and association analysis (Vilks, Anthony, & Williams, 1970). In addition, the chi square statistic was used very effectively by Johnson (1962) and Valentine & Mallory (1965) for defining species association. The work of Johnson (1962) is of particular interest in that he investigated faunal associations in Pennsylvanian cyclothems. For this study cluster analysis was selected.

Cluster analysis groups variables such as species and samples according to the magnitudes and interrelationships among their similarity coefficients (Sokal & Rohlf, 1969). The analysis involves two major steps: 1) similarity coefficients are calculated between all pairs of categories, and 2) similar categories are clustered to form groups (Valentine & 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, p. 3237).

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 & McBride (in press) used cluster analysis to test the existence of faunal provinces in the Permian and Cambrian, respectively. Valentine & Peddicord (1967), Scott (1970), Gould (1970), Oltz

(1971), Kaesler & Taylor (1971), and recently, Druce, Rhodes, and Austin (1972) working on conodonts 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 are used in this study. Cheetham & 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, p. 29) 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, and  $n$  is the total number of comparisons.

The Jaccard coefficient was given by Kaesler (1966, p. 31) and Scott (1970, p. 90) 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, and  $c$  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 & 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, p. 31) 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 & Buzas (1968) concurred with this reasoning, as do I.

As already suggested, negative matches may be significant in Q-mode (sample by sample) biotope analysis. I agree with Kaesler (1966, p. 31), who wrote that, "If the study area is relatively small (e.g., Todos Santos Bay), or if it comprises an ecologic unit in 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 Q-mode (biotope) analysis of this study.

The Jaccard coefficient was also used in Q-mode analysis so that the results of using both types of coefficient on paleontological data could be compared. Such a comparison is desirable, particularly since Mello & 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).

A great number of binary coefficients have been proposed (Cheetham & Hazel, 1969), and a number of them could possibly have been used in place of the simple matching and Jaccard coefficient. Among them is the Fager coefficient, which was effectively used by Valentine & 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 the Jaccard coefficient makes it of interest, at a later date, to analyze data of this study 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 & 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 (p. 3238) that "for many, perhaps most, purposes, the amount of distortion is the most important

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 & Buzas, 1968, p. 749).	Places "more emphasis, as one does intuitively, on those samples which contain many individuals and of course, at the same time, many species" (Mello & Buzas, 1968, p. 749).
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, p. 47).	"Relative to other coefficients the Jaccard coefficient tends to emphasize difference" (Hazel, 1970, p. 3239).
Yields "erratic results" (Hazel, 1970, p. 3240).	"Informational distortions are demonstrated for a number of functions that have been widely recommended. These include the product-moment correlation coefficient, distance coefficients and the similarity coefficients of Jaccard and Czekanowski" (Hall, 1969, p. 328). Hall advocated a system of weighting.

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 UPGMA and WPGMA methods in Q- and R-mode analyses were used because of the factors discussed above as well as the fact that Kaesler (1966), Maddocks (1966), and Mello & 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 my analyses there exist natural discontinuities that more or less objectively define groups of samples or elements as belonging together (Mello & Buzas, 1968); however, these discontinuities are positioned so that no single phenon line serves to effectively separate the clusters. Although Sokal & 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 possi-

bility and one recognized by Mello & Buzas (1968) is to select several levels of demarcation. These authors wrote (p. 751) that: "we are not sure that there is any compelling reason to use a single level of demarcation in non-taxonomic 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, p. 33) 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 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.

In this study several levels of demarcation were used and phenon lines were not drawn.

#### ORGANIZATION OF DATA

The abundance and distribution of 79 element types in 171 samples were 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  $79 \times 153$  data matrix (Table 5).

Secondly, both Q- and R-mode analyses were done on the same data as above; however, nine element categories were omitted. These categories were: *Streptognathodus* spp., *Idiognathodus* spp., *Cavusgnathus* spp., *Anchignathodus* spp., *Ozarkodina?* spp., unidentifiable Oz element, unidentifiable Hi element, unidentifiable Ne element, and genus and species indeterminate. These elements had been broken and damaged by geological and laboratory factors, and their distribution is judged to have little or no paleoecological significance. The elimination of nine element categories resulted in five samples, those containing only one or more of these element types, having to be omitted; this resulted in a  $70 \times 148$  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, they were grouped together as one composite sample (Appendix C). The composite samples were separated either at stratigraphic (i.e., member) boundaries or at lithologic boundaries (Appendix B). The grouping of the 148 samples resulted in a  $70 \times 50$  data matrix. Table 5 summarizes the ways in which the data were organized and shows the coefficients and clustering methods used. Each of the 18

cluster analyses computed were assigned an analysis number (e.g., 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.

TABLE 5.—*Summary of Organization of Data, showing Coefficients and Clustering Methods Used.*

	DATA MATRIX 1 79 × 153 Distribution data of 79 element types in 153 ungrouped samples.	DATA MATRIX 2 70 × 148 Distribution data of 70 element types in 148 ungrouped samples; nine element categories and five samples were omitted.	DATA MATRIX 3 70 × 50 Distribution data of 70 element types in 50 grouped or composite samples.
Q-MODE CLUSTER ANALYSIS	Jaccard Coefficient <ul style="list-style-type: none"> <li>UPGMA — 1A</li> <li>WPGMA — 1B</li> </ul>	Jaccard Coefficient <ul style="list-style-type: none"> <li>UPGMA — 2A</li> <li>WPGMA — 2B</li> </ul>	Jaccard Coefficient <ul style="list-style-type: none"> <li>UPGMA — 3A</li> <li>WPGMA — 3B</li> </ul>
	Simple Matching Coefficient <ul style="list-style-type: none"> <li>UPGMA — 1C</li> <li>WPGMA — 1D</li> </ul>	Simple Matching Coefficient <ul style="list-style-type: none"> <li>UPGMA — 2C</li> <li>WPGMA — 2D</li> </ul>	Simple Matching Coefficient <ul style="list-style-type: none"> <li>UPGMA — 3C</li> <li>WPGMA — 3D</li> </ul>
R-MODE CLUSTER ANALYSIS	Jaccard Coefficient <ul style="list-style-type: none"> <li>UPGMA — 1E</li> <li>WPGMA — 1F</li> </ul>	Jaccard Coefficient <ul style="list-style-type: none"> <li>UPGMA — 2E</li> <li>WPGMA — 2F</li> </ul>	Jaccard Coefficient <ul style="list-style-type: none"> <li>UPGMA — 3E</li> <li>WPGMA — 3F</li> </ul>

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

### COPHENETIC CORRELATION COEFFICIENT

The cophenetic correlation coefficient was developed by Sokal & 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, p. 1261). Kaesler pointed out (p. 1261) 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."

Further, he wrote (p. 1264):

"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 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 rearranging clusters, dissimilar rather than similar species or samples may be grouped together. Kaesler (1970) stated that the practice 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 1B and 2B have low cophenetic correlation coefficients. Both of 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 1B and 2B, although some of the other analyses such as 1D have nearly as low cophenetic correlation coefficients. With the exception of analysis 2F, 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 1B, 1D, 2A, and 2B gives support to the decision not to use the Q-mode analyses of data sets 1 and 2 for further paleoecologic analysis.

It should be noted, however, that analyses 3D and 3F, both using the WPGMA clustering method, appear to

give the most satisfactory results in the Q- and R-mode analyses, respectively, although only small differences could be noted between analyses 3C and 3D and between 3E and 3F. The decision on 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 on whether or not the clusters made sense. In the 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, kinds of conodont elements. 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 3 where grouped data were 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 is concerned with results obtained from analysis of data matrix 3. In each of the four Q-mode analyses (analyses 3A, 3B, 3C, and 3D) there is a recurrence of groups. These groups or clusters are generally composed of the same samples and were consistently identified on different dendrograms (Fig. 11 to 14).

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. Many larger groups are divisible into smaller subclusters, which are labelled on the dendrograms (Fig. 11-14) 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 3A to 3D (Fig. 11 to 14). Of the four analyses, analyses 3B and 3D, 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.

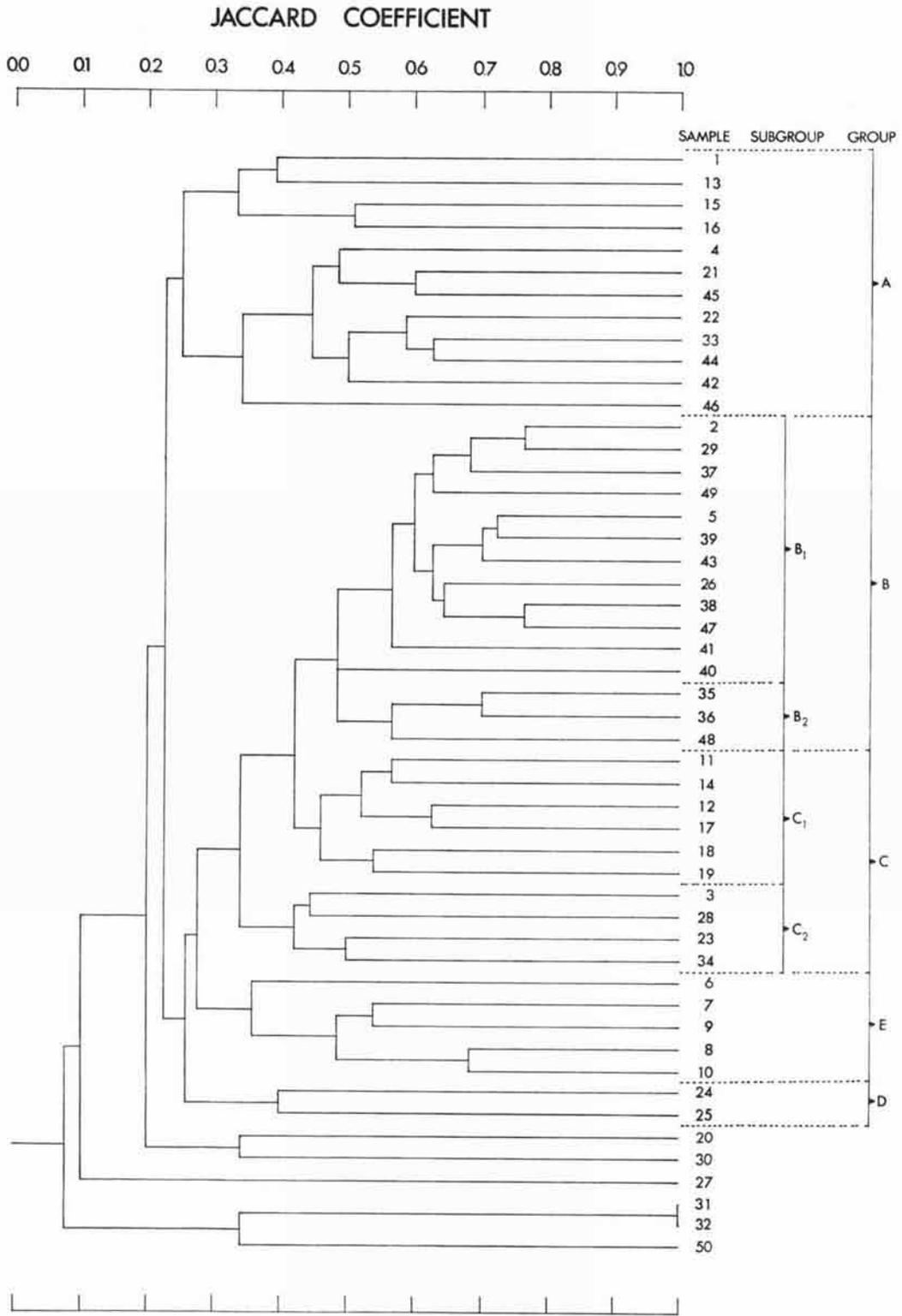


FIG. 11. Dendrogram of Q-mode cluster analysis 3A of grouped samples using the Jaccard coefficient and the UPGMA clustering method. For sample codes see Appendix C.

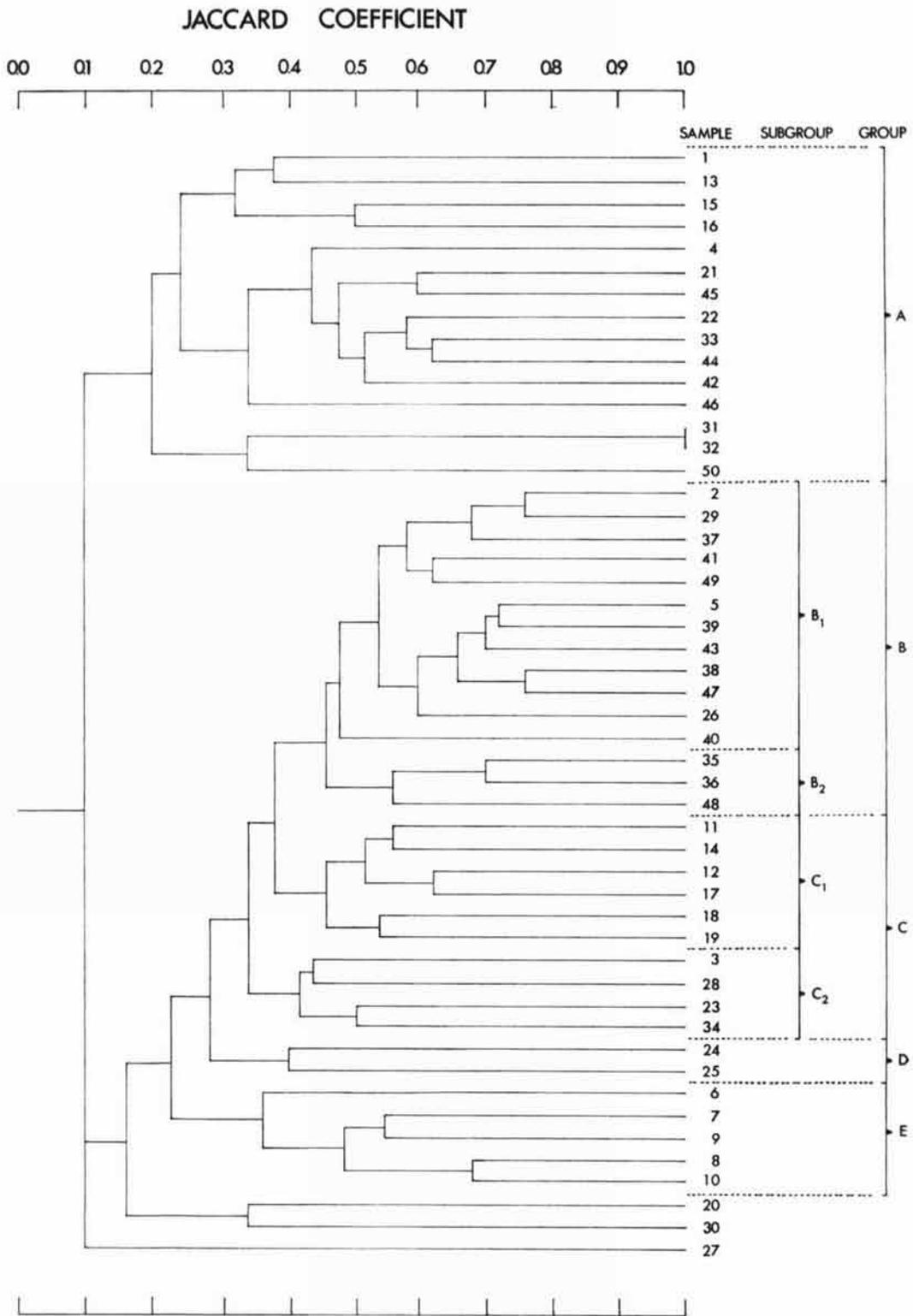


FIG. 12. Dendrogram of Q-mode cluster analysis 3B of grouped samples using the Jaccard coefficient and the WPGMA clustering method. For sample codes see Appendix C.

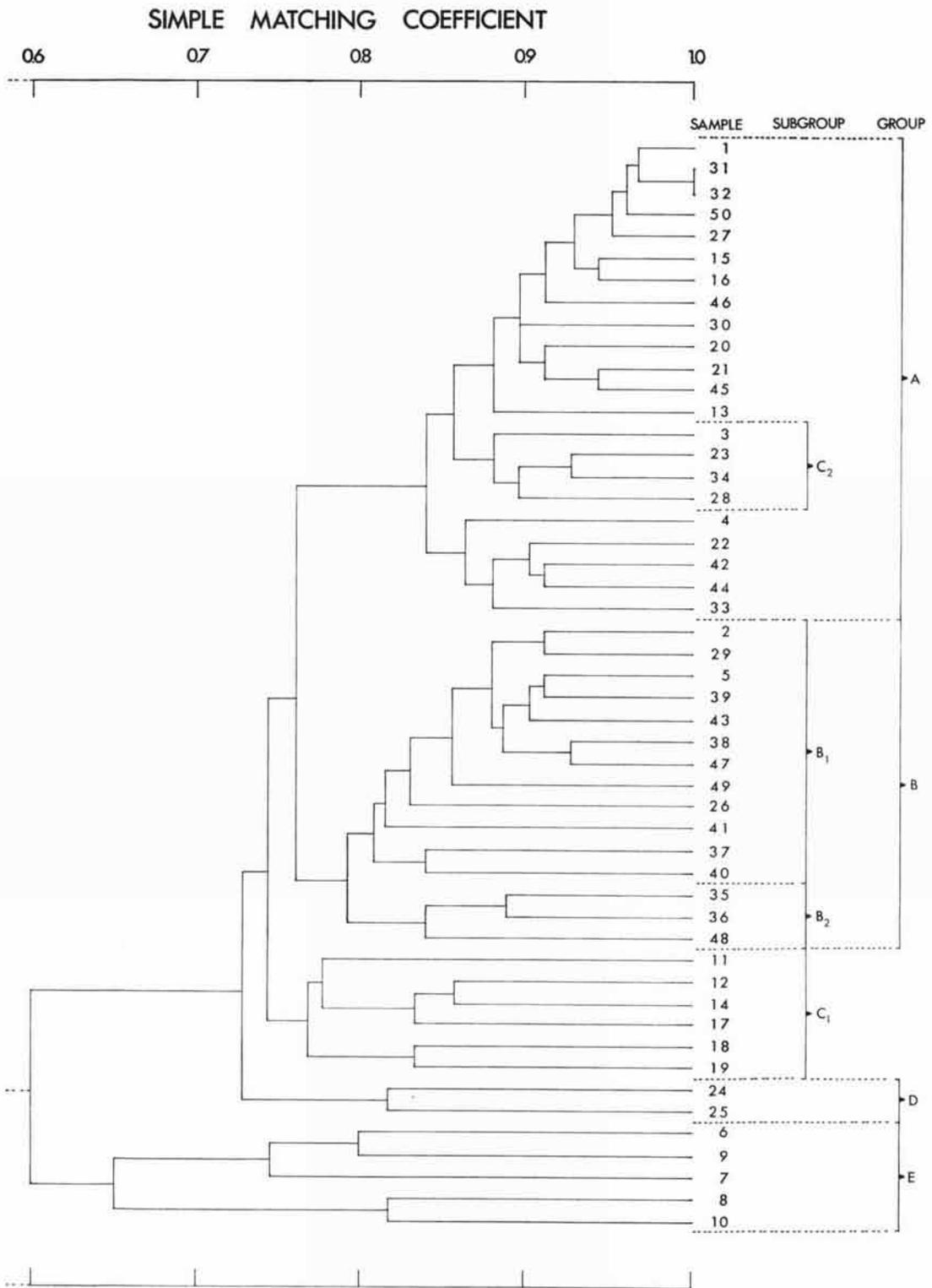


FIG. 13. Dendrogram of Q-mode cluster analysis 3C of grouped samples using the simple matching coefficient and the UPGMA clustering method. For sample codes see Appendix C.

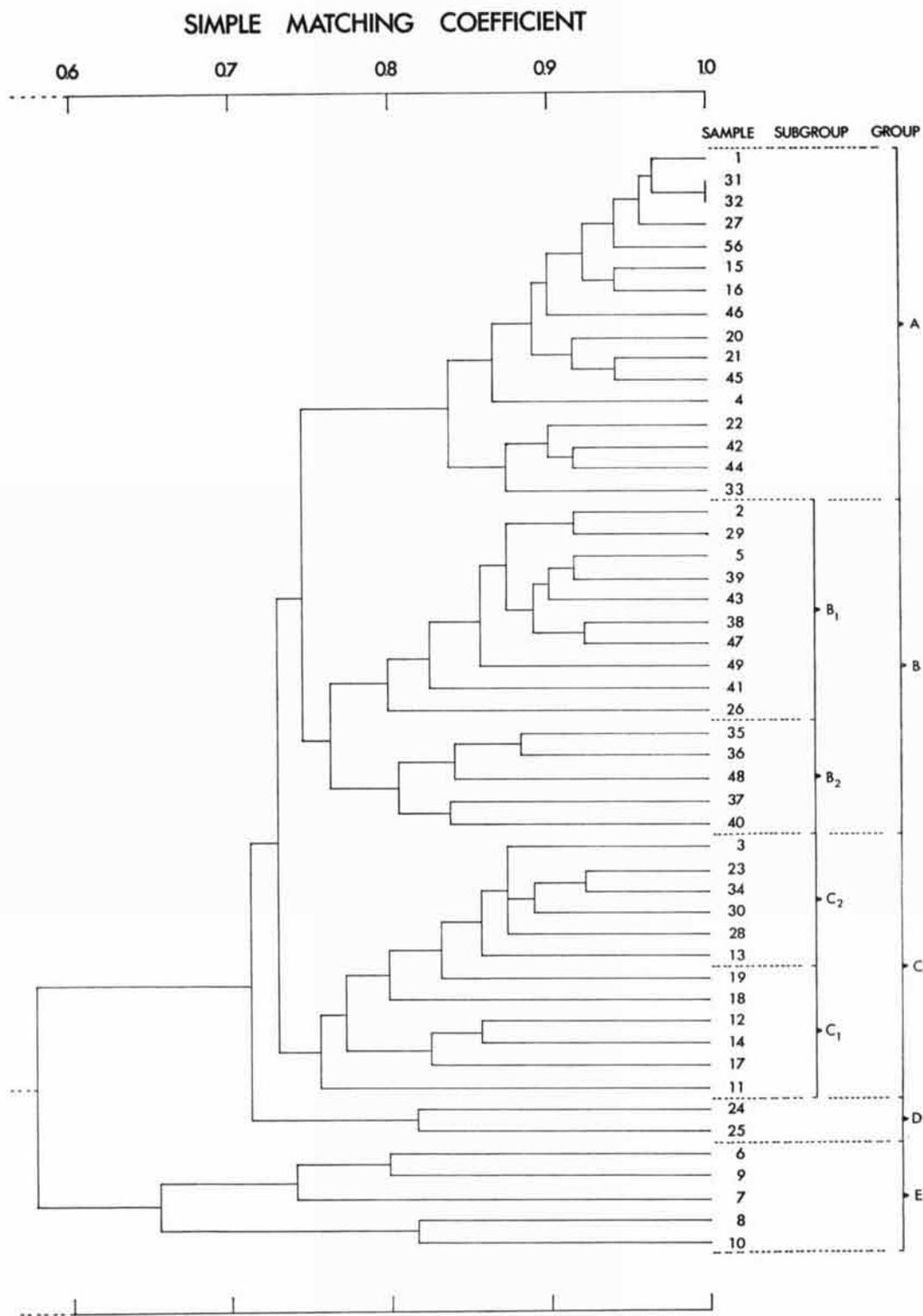


FIG. 14. Dendrogram of Q-mode cluster analysis 3D of grouped samples using the simple matching coefficient and the WPGMA clustering method. For sample codes see Appendix C.

The 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-1-4A 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-1-4A 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 studied indicates a certain faunal similarity and a recurrence of fauna. As indicated previously, these shales are believed to represent near-shore marginal marine deposition in a transgressive or regressive cycle.

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

SAMPLE	MEMBER	ANALYSIS			
		3A	3B	3C	3D
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	(up. King Hill Sh.)			27	27
6" over CC-1	(low. Severy Sh.)		50	50	50
Jap-1-1	(low. Jackson Point Sh.)	15	15	15	15
Kan-Sp-1	(up. Stull Sh.)	16	16	16	16
TCS-1-3 + 4	(up. Turner Creek Sh.)	46	46	46	46
SB-1-4 A to C	(mid. Spring Branch Ls.)			20	20
SB-1-5 A to D	(mid. Spring Branch Ls.)	21	21	21	21
She-1-1 to 3	(Sheldon Ls.)	45	45	45	45
Sn-1-4 A + B	(low. 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	(up. Oskaloosa Sh.)	33	33	33	33
Ke-1-5	(up. Kereford Ls.)	13	13	13	
Av-3-5	(up. Avoca Ls.)			30	

The environmental aspects of the Ozawkie Limestone (sample Oz-1-1) were discussed above (p. 25). 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 (p. 25), the Ozawkie was probably deposited under near-shore 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, Fig. 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<sub>1</sub>, Offshore Limestone Biotope

This subgroup (Table 8) contains most of the significant thick-bedded and nodular limestone units and reflects the faunal similarity of these units. A number of these units are of similar lithology and occupy similar posi-

TABLE 8.—Comparison of Samples Included in Sample Group B, Which Includes Sample Subgroup B<sub>1</sub> (Offshore Limestone Biotope) and B<sub>2</sub> (Larsh-Burroak Biotope) on Dendrograms (Fig. 11 to 14) Produced by Q-mode Analyses 3A to 3D.

SAMPLE	MEMBER	ANALYSIS			
		3A	3B	3C	3D
SUBGROUP B <sub>1</sub> OFFSHORE LIMESTONE BIOTOPE					
T-1-1 to 7	(Toronto Ls.)	2	2	2	2
Av-3-4	(up. Avoca Ls.)	29	29	29	29
L-1-1	(Leavenworth Ls.)	5	5	5	5
H-1-1	(low. Hartford Ls.)	39	39	39	39
Cur-1-1 to 4	(Curzon Ls.)	43	43	43	43
Cal-Sp-1	(up. 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	(mid. and up. 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	(low. Hartford Ls.)	40*	40	40	
SUBGROUP B <sub>2</sub> LARSH-BURROAK BIOTOPE					
LB-1-1 to 2	(low. Larsh-Burroak Sh.)	35	35	35	35
LB-1-3 A to E	(up. 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	(low. Hartford Ls.)				40

\* In analysis 3A (Fig. 11) this sample can also be considered to be a part of subgroup B<sub>2</sub>.

tion 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 that occur in similar positions in three formations. The Plattsmouth Limestone, which is the cyclothem 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) that are included in subgroup B<sub>1</sub>, the first two are from thin partings between 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, although 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, in terms of both fauna and environment, between nearshore and offshore conditions.

Subgroup B<sub>2</sub>, 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 that 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 (Fig. 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<sub>1</sub> 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<sub>1</sub> and C<sub>2</sub>. There is a gradation between the two subgroups in analysis 3D (Fig. 14), and in analysis 3C (Fig. 13) subgroup C<sub>2</sub> is, for unknown reasons, placed in sample Group A.

Subgroup C<sub>1</sub>

With the exception of several gaps the members represented by samples of this subgroup (Table 9, and Fig. 11-14) 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 that occurred in various environments, the groups obtained through cluster analysis will reflect this; i.e., different rock types representing various depositional environments will be grouped together.

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 (Fig. 7, 8).

TABLE 9.—Comparison of Samples Included in Sample Group C, Which Includes Sample Subgroups C<sub>1</sub> and C<sub>2</sub>, on Dendrograms (Fig. 11 to 14) Produced by Q-mode Analyses 3A to 3D.

SAMPLE	MEMBER	ANALYSIS			
		3A	3B	3C	3D
SUBGROUP C <sub>1</sub>					
SB-1-3	(mid. Spring Branch Ls.)	19	19	19	19
SB-1-2 A + B	(mid. Spring Branch Ls.)	18	18	18	18
Ke-1-1 to 4	(low. Kereford Ls.)	12	12	12	12
Ke-1-6 to 7	(up. Kereford Ls.)	14	14	14	14
SB-1-1 A to E	(low. Spring Branch Ls.)	17	17	17	17
Bot. 2" of Heu,					
Heu-1-1 to 3	(Heumader Sh.)	11	11	11	11
SUBGROUP C <sub>2</sub>					
Sn-1-1 A + B	(low. 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	(up. Avoca Ls.)				30
Av-3-1 to 3	(low. Avoca Ls.)	28	28	28	28
Ke-1-5	(up. Kereford Ls.)				13

This cluster, in a peculiar sense, could be considered to represent a biotope, which, rather than being defined by only one set of environmental conditions, is characterized instead by several depositional environments of quite different character. However, it seems preferable to use biotope for an area of relatively uniform environmental conditions (Kaesler, 1966) and consequently not consider the beds represented by the samples of this cluster to constitute a biotope. Samples representative of a variety of depositional environments are clustered together apparently because they consistently contain similar faunal elements. 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<sub>2</sub>

This cluster (Table 9) is erratic and difficult to interpret. It, like cluster C<sub>1</sub>, 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, Fig. 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 (Fig. 11 to 14) Produced by Q-mode Analyses 3A to 3D.

SAMPLE	MEMBER	ANALYSIS			
		3A	3B	3C	3D
QH-1-1	(low. Queen Hill Sh.)	24	24	24	24
QH-1-2	(up. Queen Hill Sh.)	25	25	25	25

#### SAMPLE GROUP E, HEEBNER-PLATTSMOUTH BIOTOPE

Group E (Table 11, and Fig. 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.

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

SAMPLE	MEMBER	ANALYSIS			
		3A	3B	3C	3D
He-1-1 to 2	(low. Heebner Sh.)	6	6	6	6
P-1-4	(mid. Plattsmouth Ls.)	9	9	9	9
He-1-3 to 4	(up. Heebner Sh.)	7	7	7	7
P-1-1 to 3	(low. Plattsmouth Ls.)	8	8	8	8
P-1-5 to 8	(up. Plattsmouth Ls.)	10	10	10	10

#### 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.

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 Figures 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 (Fig. 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 (Fig. 15-18) is presumed to be the result of using different clustering methods and different data matrices.

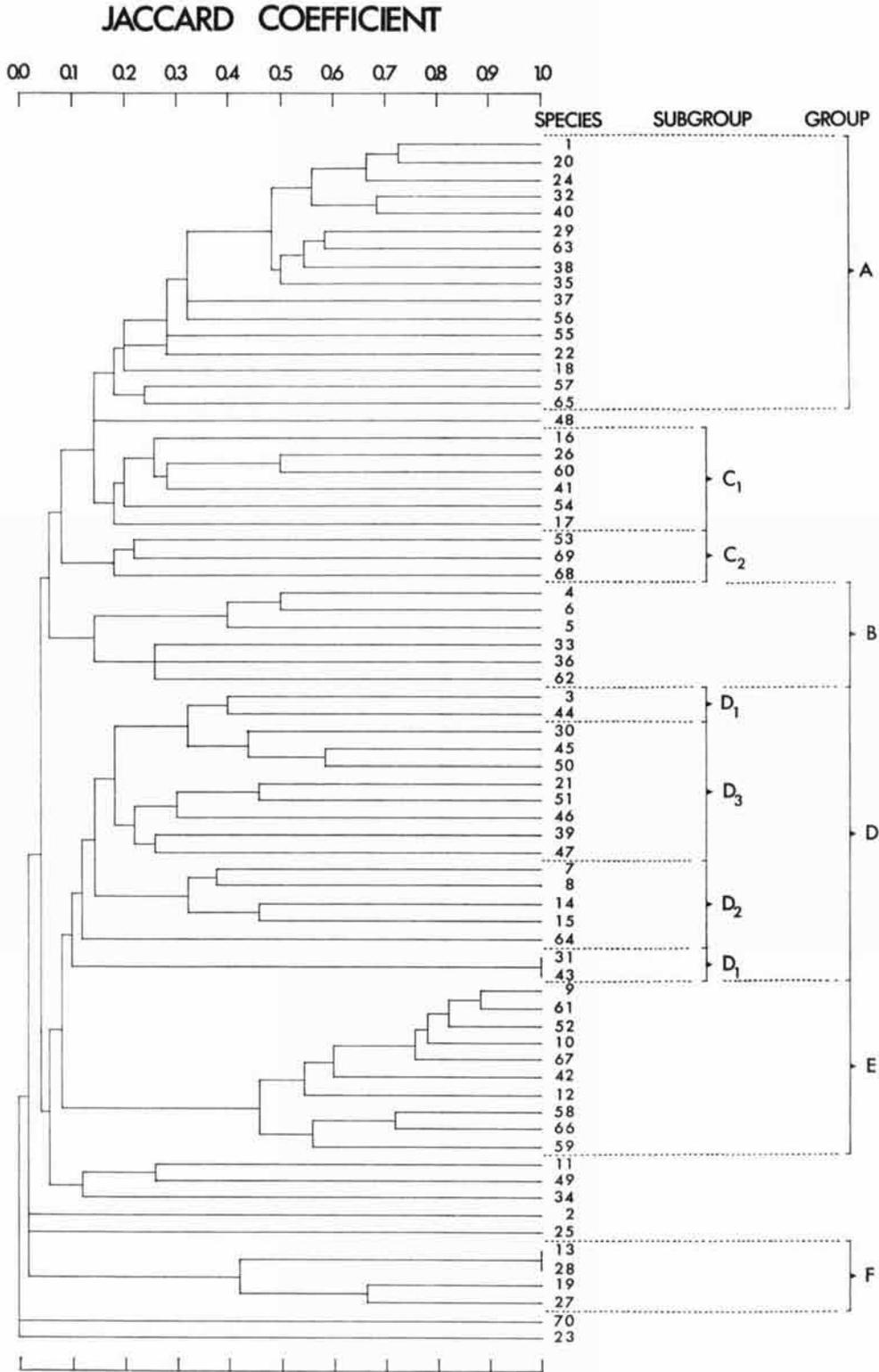


FIG. 15. Dendrogram of R-mode cluster analysis 2E of ungrouped samples using the Jaccard coefficient and the UPGMA clustering method. For species names see Appendix C.

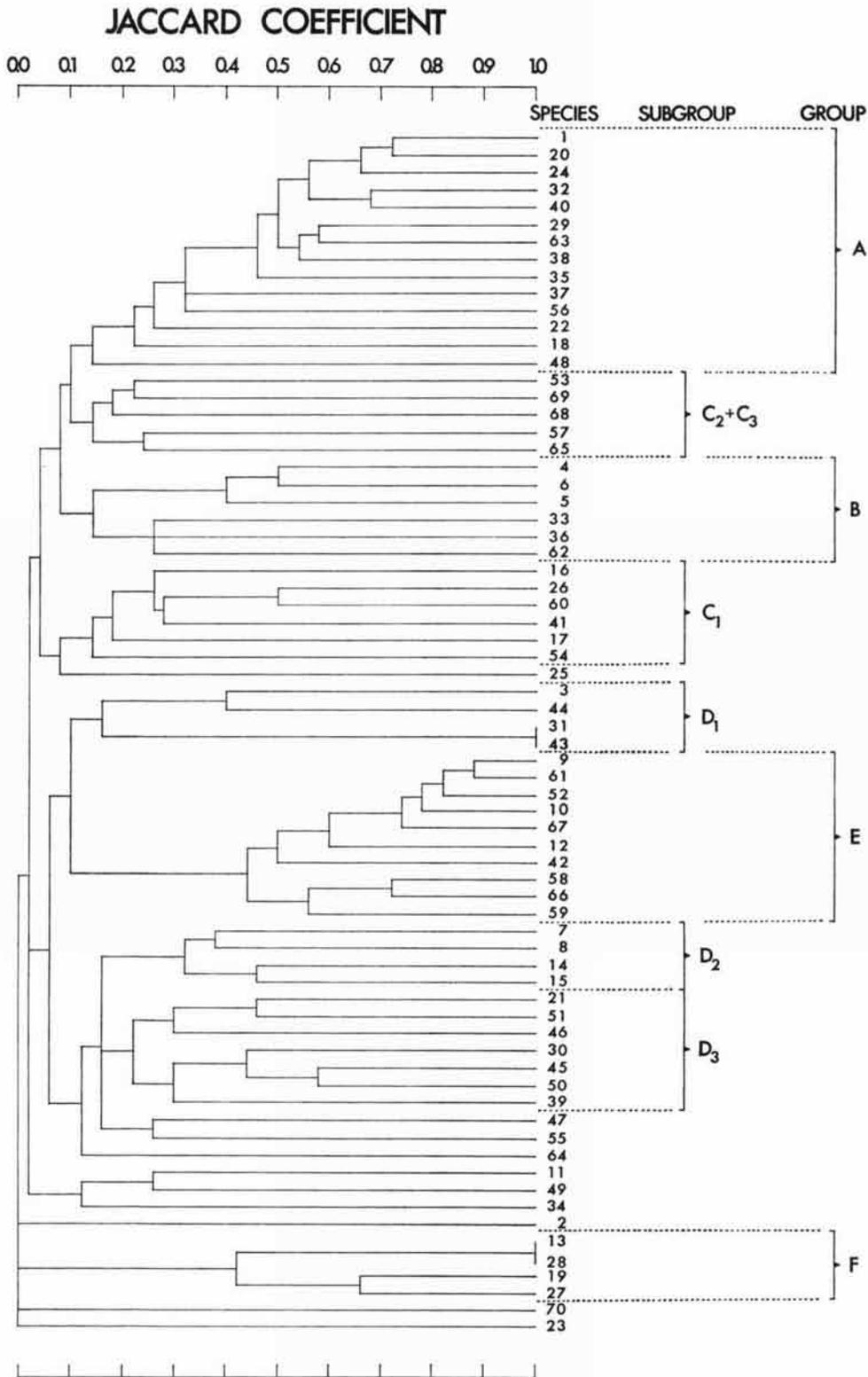


FIG. 16. Dendrogram of R-mode cluster analysis 2F of ungrouped samples using the Jaccard coefficient and the WPGMA clustering method. For species names see Appendix C.

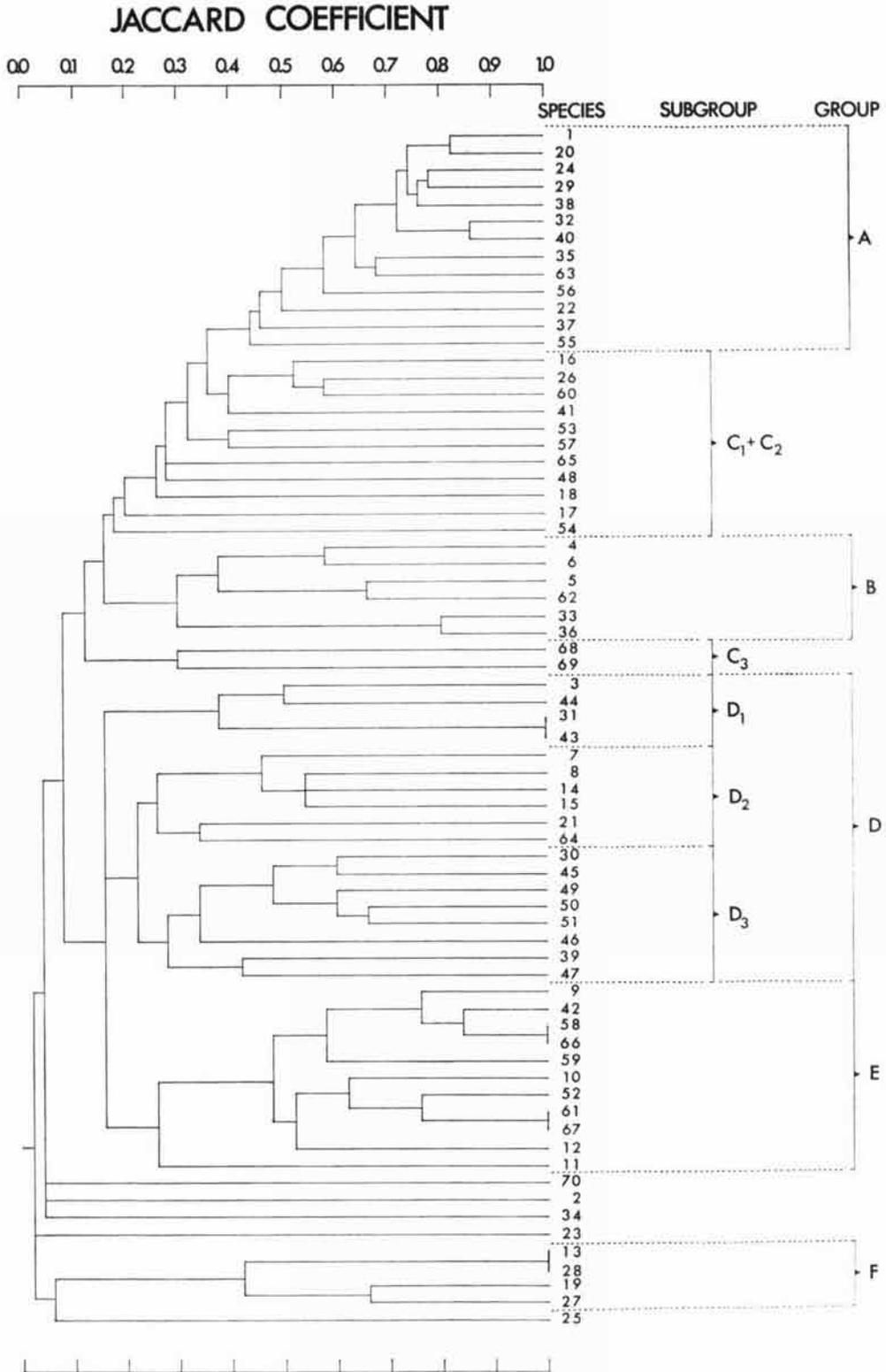


FIG. 17. Dendrogram of R-mode cluster analysis 3E of grouped samples using the Jaccard coefficient and the UPGMA clustering method. For species names see Appendix C.

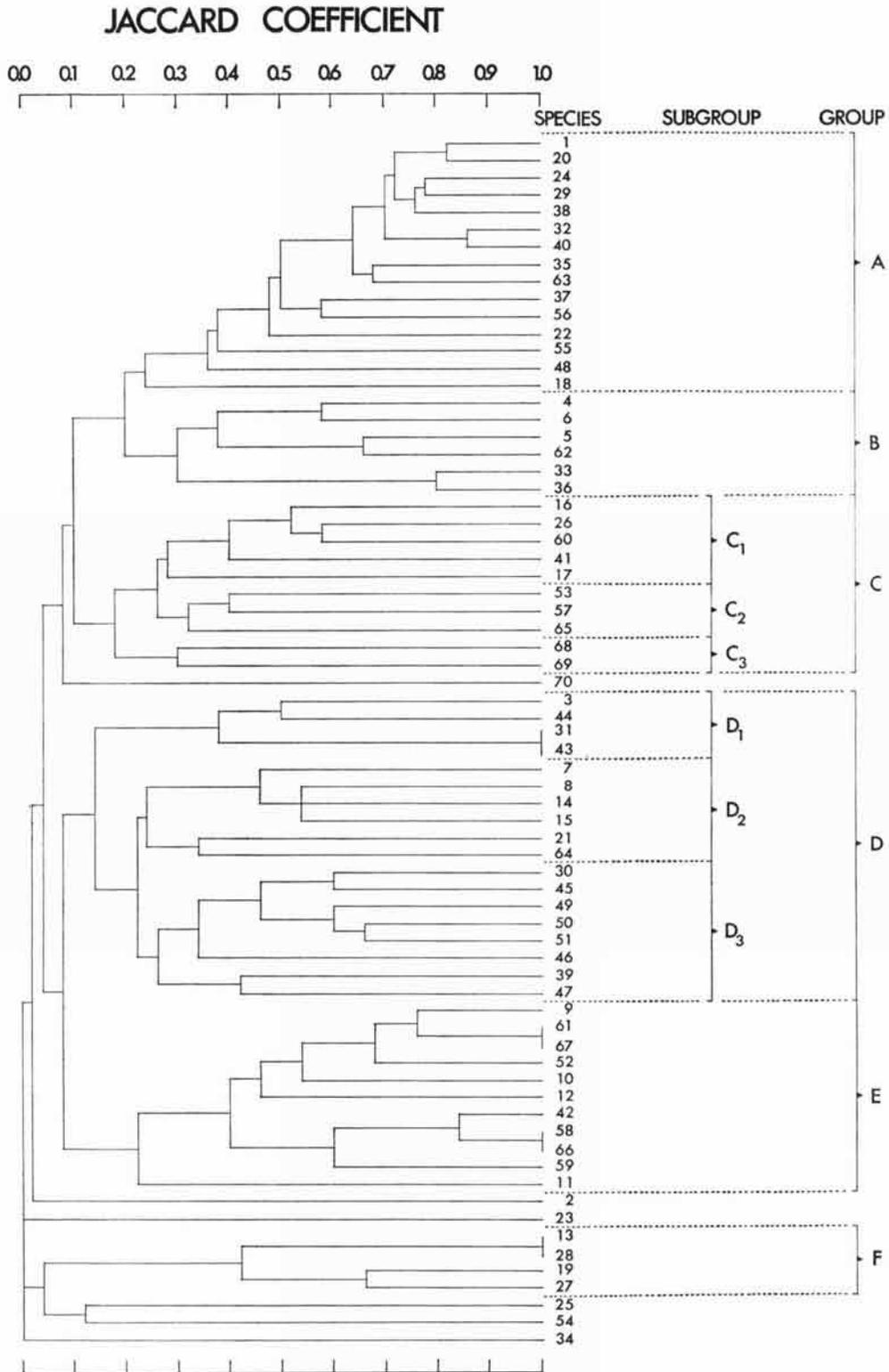


FIG. 18. Dendrogram of R-mode cluster analysis 3F of grouped samples using the Jaccard coefficient and the WPGMA clustering method. For species names see Appendix C.

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 they 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 sub-biofacies.

**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 conodont species or B) elements belonging to several environmentally associated conodont species. Associations A and B, upon examination of the distribution data, may be found to occur consistently in rocks representing a restricted number of depositional environments.

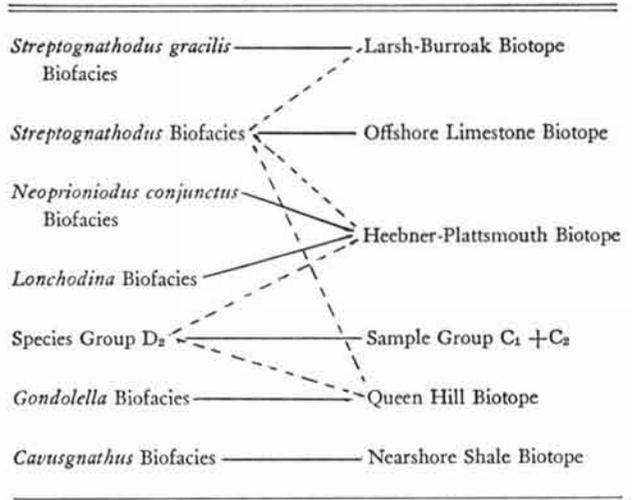
The groups of associated taxa defined by cluster analysis must be compared with the distribution of the individual taxa to determine the "reasonableness" of the group as well as to see what congruency, if any, exists between biotopes and biofacies established by Q- and R-mode analyses. Kaesler (1966, p. 47) 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 congruency, for as Mello & Buzas (1968, p. 757) have written "hopefully, the R-mode will tell us which species are responsible for the areal [i.e., environmental] units recognized through the Q-mode."

In studying the distribution of recent or subfossil organic remains it is possible in Q-mode analysis to construct a biotope map by joining those stations that are part of well-defined clusters and that 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 time planes 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 able to show only 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 & 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.

TABLE 12.—Primary Links (Solid Lines) Between Biofacies and Biotopes Established by Cluster Analysis. Secondary Links (Broken Lines) Established by Examination of Abundance Counts.



**SPECIES GROUP A, STREPTOGNATHODUS BIOFACIES**

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

As here recognized, the biofacies contains associated conodonts different from those placed in it by Merrill (1968; in press). The elements *Ozarkodina? curvata*; *Ellisonia teichert?*, Pl element; and *Ellisonia teichert?*, 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, p. 28) defined the ubiquitous group as containing conodont elements, some of which are "present in every Pennsylvanian sample coinciding with ranges of individual genera and species." I am 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 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.

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

TAXON	ANALYSIS			
	2E	2F	3E	3F
<i>Streptognathodus elegantulus</i> ,				
Sp element .....	1	1	1	1
<i>Anchignathodus minutus</i> .....	20	20	20	20
<i>Streptognathodus</i> and				
<i>Idiognathodus</i> Oz element .....	24	24	24	24
<i>Ozarkodina? curvata</i> .....	29	29	29	29
<i>?Ellisonia teichertii</i> , Hi element .....	38	38	38	38
<i>Streptognathodus</i> and				
<i>Idiognathodus</i> Ne element .....	32	32	32	32
<i>Streptognathodus</i> and				
<i>Idiognathodus</i> Hi element .....	40	40	40	40
<i>?Ellisonia teichertii</i> , Pl element .....	35	35	35	35
<i>?Ellisonia teichertii</i> , Ne element .....	63	63	63	63
<i>Hindeodella parva</i> .....	37	37	37	37
Unidentifiable Tr element, type B .....	56	56	56	56
<i>Anchignathodus moorei</i> , n. sp. ....	22	22	22	22
<i>Streptognathodus</i> and				
<i>Idiognathodus</i> Tr element .....	55		55	55
<i>?Ellisonia teichertii</i> , Tr element .....	48*	48		48
<i>Cavusgnathus merrilli</i> , n. sp. ....	18	18		18
<i>Delotaxis? conflexa</i> , Hi element .....	57			
<i>Delotaxis? conflexa</i> , Pl ? element .....	65			

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

The distribution and clustering of the rare *Cavusgnathus merrilli* von Bitter, 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 (Fig. 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 & 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 teichertii* Sweet?. The fact that these elements are consistently grouped to-

gether (Table 13) is of interest since Sweet (1970a, 1970b) used recurrent group analysis to define this multielement species. I have been unable to recognize the LB element (terminology of Sweet, 1970a, 1970b) of the species (Sweet, 1970b, pl. 4, fig. 23).

Elements 20 and 22 are interpreted as representing two species of *Anchignathodus*. I have 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. W. 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 & 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* von Bitter, n. sp., is a new species based on characteristic Sp elements.

Element 56, unidentifiable Tr element, type B, 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). I am unable to attach any significance to this, particularly since these two elements are included in the *Cavusgnathus* biofacies in the remaining three analyses (Fig. 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 conclusion is that subtle environmental differences existed in each of these.

#### Taxonomic Interpretation of *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 multi-element species. All the elements are rare and because of this it is not presently possible to define these multi-element 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 unidentified Ne element, *Synprioniodina* sp. A, and unidentified Pl element 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*. I cannot discount this possibility for *Synprioniodina* sp. A and the unidentified Pl element; however, I consider this unlikely for the unidentified Ne element. The possible taxonomic placement of the latter element is discussed in the systematics under *Cavusgnathus merrilli* von Bitter, n. sp.

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

TAXON	ANALYSIS			
	2E	2F	3E	3F
<i>Streptognathodus gracilis</i> .....	4	4	4	4
<i>Streptognathodus excelsus</i> .....	6	6	6	6
<i>Streptognathodus gracilis?</i> .....	5	5	5	5
Unidentified Ne element .....	62	62	62	62
<i>Synprioniodina</i> sp. A .....	33	33	33	33
Unidentified Pl element .....	36	36	36	36

SPECIES GROUP C, CAVUSGNATHUS BIOFACIES

The *Cavusgnathus* biofacies of Merrill (1968; in press) was well defined by cluster analysis (Fig. 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 (Fig. 7-10).

Taxonomic Interpretation of 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<sub>1</sub>

Subgroup C<sub>1</sub> (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 *C. flexus*. The element composition of these two multielement species is homologous to that of the natural assemblage genus *Lewis-tonella* 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* von Bitter, n. sp., and *Ellisonia teichertii?* Tr element, respectively, are for unknown reasons part of subgroup C<sub>1</sub> in analysis 3E (Fig. 17). This is considered anomalous since in the remaining three analyses (Fig. 15, 16, 18) they are clustered in the *Streptognathodus* biofacies (Species Group A).

Subgroups C<sub>2</sub> and C<sub>3</sub>

These two subgroups (Table 15) must be considered together since they are combined into a single cluster in at least one of the analyses (Fig. 15 to 18).

Elements 53, 57, 65, 68, and 69 are interpreted, on the basis of cluster analysis, morphological similarity, and

TABLE 15.—Comparison of Elements Included in Species Group C (*Cavusgnathus* Biofacies), Which Includes Species Subgroups C<sub>1</sub>, C<sub>2</sub>, and C<sub>3</sub> Shown on Dendrograms (Fig. 15-18) Produced by R-mode Analyses 2E & 2F and 3E & 3F.

TAXON	ANALYSIS			
	2E	2F	3E	3F
SUBGROUP C <sub>1</sub>				
<i>Cavusgnathus lautus</i> , Sp element .....	16	16	16	16
<i>Cavusgnathus</i> Oz element .....	26	26	26	26
<i>Cavusgnathus</i> Ne element .....	60	60	60	60
<i>Cavusgnathus</i> Hi element .....	41	41	41	41
<i>Cavusgnathus flexus</i> , Sp element .....	17	17	17	17
<i>Cavusgnathus</i> Tr element .....	54	54	54	
? <i>Ellisonia teichertii?</i> , Tr element .....				48
<i>Cavusgnathus merrilli</i> , n. sp. ....				18
SUBGROUP C <sub>2</sub>				
<i>Delotaxis?</i> <i>conflexa</i> , Tr element .....	53	53	53	53
<i>Delotaxis?</i> <i>conflexa</i> , Hi element .....		57	57	57
<i>Delotaxis?</i> <i>conflexa</i> , Pl? element .....		65	65	65
<i>Delotaxis?</i> <i>conflexa</i> , Oz? element .....	68	68		
<i>Delotaxis?</i> <i>conflexa</i> , Ne? element .....	69	69		
SUBGROUP C <sub>3</sub>				
<i>Delotaxis?</i> <i>conflexa</i> , Oz? element .....			68	68
<i>Delotaxis?</i> <i>conflexa</i> , Ne? element .....			69	69

Part of Subgroup C<sub>1</sub>

Combined with Subgroup C<sub>4</sub>

Combined with Subgroup C<sub>3</sub>

other features considered in the systematics, to be the elements of the multielement species *Delotaxis? conflexa* (Ellison).

#### SPECIES GROUP D, LONCHODINA BIOFACIES

The *Lonchodina* biofacies (Table 16, and Fig. 15-18) is a somewhat complex grouping of three smaller subgroups, the faunal elements of two of which, subgroups D<sub>1</sub> and D<sub>3</sub>, generally correspond to most of the elements placed in the Appalachian fauna of Merrill (1968; in press). The term "Appalachian fauna" should be suppressed, since it, like the term "Midcontinent fauna," implies provincialism. Elements of species of the *Lonchodina* biofacies have been found in the Pennsylvanian of Colorado by Murray & Chronic (1965), in the Appalachians by Merrill (1968; in press), and in Kansas. Species subgroups D<sub>1</sub> and D<sub>3</sub> 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 teichertii?*, have been found to have a wider distribution than previously thought. These are better included in the *Streptognathodus* rather than the *Lonchodina* biofacies, a decision supported by cluster analysis. The two subgroups D<sub>1</sub> and D<sub>3</sub> of the *Lonchodina* biofacies are best developed in the Plattsmouth Limestone, and many of the species of this study have been found only 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<sub>1</sub> and D<sub>3</sub> of the *Lonchodina* 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 Heebner Shale, respectively. The *Neoprioniodus conjunctus* biofacies was dominant during deposition of the Heebner Shale, whereas the *Lonchodina* 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, like the Heebner and the Plattsmouth, are faunally similar to one another, there is apparently little faunal similarity between the Larsh-Burroak-Ervine Creek and the Heebner-Plattsmouth sequences.

Subgroup D<sub>2</sub>, strictly speaking, is not considered to belong to the *Lonchodina* biofacies. The subgroup is apparently grouped with subgroups D<sub>1</sub> and D<sub>3</sub> because the Sp elements of the multielement species *Streptognathodus opletus*, *Streptognathodus wabaunsensis*, *Idiognathodus tersus*, and *Idiognathodus antiquus* occur as associates of the *Lonchodina* biofacies in the Platt-

smouth 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.

TABLE 16.—Comparison of Elements Included in Species Group D (*Lonchodina* Biofacies), Which Includes Species Subgroups D<sub>1</sub>, D<sub>2</sub>, and D<sub>3</sub> Shown on Dendrograms (Fig. 15-18) Produced by R-mode Analyses 2E & 2F and 3E & 3F.

TAXON	ANALYSIS			
	2E	2F	3E	3F
SUBGROUP D <sub>1</sub>				
<i>Streptognathodus</i> sp. aff.				
<i>S. elegantulus</i> .....	3	3	3	3
Unidentified Tr element, type B.....	44	44	44	44
<i>Ozarkodina?</i> sp. aff. <i>O.? kansasensis</i> , n. sp.	31	31	31	31
Unidentified Tr element, type A .....	43	43	43	43
SUBGROUP D <sub>2</sub>				
<i>Streptognathodus opletus</i> , Sp element ....	7	7	7	7
<i>Streptognathodus wabaunsensis</i> ,				
Sp element .....	8	8	8	8
<i>Idiognathodus antiquus</i> , Sp element .....	14	14	14	14
<i>Idiognathodus tersus</i> , Sp element .....	15	15	15	15
<i>Anchignathodus edentulus</i> , n. sp. ....			21	21
<i>Lonchodus?</i> sp. ....	64		64	64
SUBGROUP D <sub>3</sub>				
<i>Ozarkodina? kansasensis</i> , n. sp. ....	30	30	30	30
Unidentified Tr element, type C .....	45	45	45	45
<i>Lonchodina</i> sp. A .....			49	49
<i>Lonchodina</i> sp. B .....	51	51	51	51
<i>Lonchodina douglasensis</i> , n. sp. ....	50	50	50	50
Unidentifiable Tr element, type A .....	46	46	46	46
<i>Hindeodella</i> sp. B .....	39	39	39	39
<i>Hindeodus</i> sp. A .....	47		47	47
<i>Anchignathodus edentulus</i> , n. sp. ....	21	21		

#### Taxonomic Interpretations of *Lonchodina* Biofacies

##### Subgroups D<sub>1</sub> and D<sub>3</sub>

*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, 49, 50, 51, *Hindeodella* sp. B, unidentified Tr elements, types A, B, and C, unidentifiable Tr element, type A, *Lonchodina* sp. A, *L. douglasensis* von Bitter, n. sp., and *L. sp. B*, respectively, may have been part of the same multielement species. Unfortunately, these elements are of infrequent occurrence and as a result I am unable to prove this association.

In a similar manner, *Ozarkodina? kansasensis* von Bitter, n. sp., and *Ozarkodina? sp. aff. O.? kansasensis*,

elements 30 and 31, respectively, may have been associated as part of the same apparatus. *O.?* *kansasensis* 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 edentulus* von Bitter, 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 animal (Sweet, 1970a; 1970b).

Subgroup D<sub>2</sub>

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<sub>2</sub> is not considered significant.

SPECIES GROUP E, NEOPRIONIODUS CONJUNCTUS BIOFACIES

This biofacies (Table 17) is well defined and is consistent in its taxa content (Fig. 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 *Neoprioniodus conjunctus* 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 parts of the Appalachians (Merrill, 1968; 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 *Neoprioniodus conjunctus* biofacies is most strongly represented, and it is concluded that there is a strong congruence between the *N. conjunctus* biofacies and the Heebner-Plattsmouth biotope.

Merrill (in press) postulated, at least for the Midcontinent area, that his Midcontinent fauna is dominant only 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 conodonts characteristic of Merrill's 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 *Neoprioniodus conjunctus* biofacies lived farther offshore than did that containing *Gondolella*, the *Gondolella* biofacies. In the Shawnee Group, the *N. conjunctus* and *Gondolella* biofacies occur independently 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 seems 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).

TABLE 17.—Comparison of Elements Included in Species Group E (*Neoprioniodus conjunctus* Biofacies) Shown on Dendrograms (Fig. 15-18) Produced by R-mode Analyses 2E & 2F and 3E & 3F.

TAXON	ANALYSIS			
	2E	2F	3E	3F
<i>Streptognathodus simulator</i> , Sp element ....	9	9	9	9
<i>Neoprioniodus conjunctus</i> , Ne element ....	61	61	61	61
<i>Lonchodina? ponderosa</i> .....	67	67	67	67
<i>Neoprioniodus conjunctus</i> , Tr element ....	52	52	52	52
<i>Streptognathodus eccentricus</i> , Sp element .....	10	10	10	10
<i>Idiognathodus magnificus</i> , Sp element .....	12	12	12	12
<i>Lonchodus simplex</i> .....	42	42	42	42
<i>Ligonodina lexingtonensis</i> .....	58	58	58	58
<i>Neoprioniodus conjunctus</i> , Pl element .....	66	66	66	66
<i>Neoprioniodus conjunctus</i> , Hi element .....	59	59	59	59
<i>Streptognathodus?</i> sp. ....			11	11

Taxonomic Interpretation of *Neoprioniodus conjunctus* Biofacies

Elements 52, 59, 66, and 61 (Table 17) are interpreted as the elements of multielement species, *Neoprioniodus conjunctus* (Gunnell). (See page 00 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 *Neoprioniodus conjunctus* (Gunnell), are not interpreted to be part of the same apparatus.

*Lonchodus simplex* (Pander), a category used for comblike 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 nonplatform 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 paleoecological 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 Fig. 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 Shale was probably, like the lithologically similar Heebner and Larsh-Burroak shales, deposited under shallow nearshore, possibly lagoonal conditions (Moore, 1936, 1966).

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

TAXON	ANALYSIS			
	2E	2F	3E	3F
<i>Idiognathodus delicatus</i> , Sp element .....	13	13	13	13
<i>Gondolella denuda</i> , Hi? element .....	28	28	28	28
<i>Gondolella denuda</i> , Sp element .....	19	19	19	19
<i>Gondolella denuda</i> , Oz element .....	27	27	27	27

Merrill (in press) suggested that this biofacies might represent the nearshore portion of the Midcontinent fauna (the *Neoprioniodus conjunctus* biofacies of this study) 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 ecological differences 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.

#### Taxonomic Interpretation of *Gondolella* Biofacies

Cluster analysis confirms my 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 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 & 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 one 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 & 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 & King.

TABLE 19.—Elements Not Placed in Definite Species Groups on Dendrograms (Fig. 15-18) Produced by R-mode Analyses 2E & 2F and 3E & 3F.

TAXON	ANALYSIS			
	2E	2F	3E	3F
<i>Metalonchodina?</i> sp. ....	70	70	70	70
<i>Streptognathodus</i> sp. A, Sp element .....	2	2	2	2
<i>Anchignathodus</i> sp. aff. <i>A. campbelli</i> .....	23	23	23	23
<i>Ozarkodina</i> sp. A .....	25	25	25	25
<i>Synprioniodina</i> sp. B .....	34	34	34	34

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 compare 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 seems likely, they are both parts of the same apparatus, 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. There are invariably rare taxa that 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.

### 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 animals living on the craton in shallow Pennsylvanian seas.

2) The Shawnee Group sediments of eastern Kansas are excellently suited 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, unlike the Upper Pennsylvanian and Lower Permian beds studied by Perlmutter (1971), have 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 and life history of the conodont animal are completely unknown. Although the ecologic model based on a planktonic mode of life, suggested by Seddon & Sweet (1971) for Ordovician and Devonian conodont faunas, may apply to Pennsylvanian conodonts, an alternate model may also explain Pennsylvanian conodont distri-

butions. 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 & Sweet (1971). No filter effect such as that described by Seddon & Sweet (1971) has been recognized; however, both models would produce identical conodont distributions.

Some biotopes and their contained biofacies are restricted in occurrence in the section studied. It is necessary to examine similar rocks for their conodont faunas both geographically and stratigraphically.

5) The grouping of conodonts into biofacies causes special problems, and both zoological and ecological meanings of biofacies must be examined. The biofacies defined by Merrill (1968; in press) were presented by him as lists of discrete conodont elements; however, the elements contained in a particular biofacies were the component parts of conodont 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 species that are dominant in a particular biotope than as merely lists of associated elements.

6) The applicability of cluster analysis to biofacies evaluation 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 more easily 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. Cluster groups may occur in similar lithologies, denoting a single, possibly repeating environment, or they may occur in unlike lithologies, representing a variety of depositional environments. If a single or two closely related depositional environments are represented by the samples of a cluster, the cluster or sample group may represent a biotope.

Q-mode cluster analysis of data matrices 1 and 2 (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 3 (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 (Fig. 13, 14) seem slightly better defined.

8) R-mode analysis of conodont distribution data groups taxonomic units into groups or clusters which may be the component parts of a single conodont animal or of more than one environmentally associated conodont animal. Study of distributional data may show these situations can be linked to certain lithologies representing particular depositional environments. If a particular species group cannot be related to a particular biotope, 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 (Fig. 17, 18), which, although seeming to be slightly better defined than those using upgrouped data (analyses 2E and 2F), are in other respects very similar to the latter (Fig. 15, 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 making 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. I agree with Mello & Buzas (1968) that, in a nontaxonomic context, there can be several levels at which clusters would reasonably reflect sample or species arrangement. As a consequence, I have followed the suggestion of Kaesler (1966) and have 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 delimitating biotopes is undesirable because of the many uncertainties involved (Kaesler, 1966). The distribution of specimens of the nine taxonomic categories (p. 29) which were omitted in data matrices 2 and 3 (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 be clustered only at one point on the dendrogram, despite the fact that it is believed to have been associated with a number of multielement species. For example, 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*; however, the cluster analysis can place it only 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 reexamines his data matrix and has a knowledge of his fauna so he can detect secondary 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 Off-shore 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, because of its very high concentrations of the Sp element of *Cavusgnathus*, was most similar faunally to some of the green shales considered to have been deposited in a nearshore 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. Despite the fact that a sample contains several thousand Sp elements of *Cavusgnathus* and a

single one of *Streptognathodus*, this cannot be weighted even though it may be significant. This may be judged a negative feature; however, presence-absence data are available from a variety of published sources and 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. Of course, it is 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

I have 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 some Upper Pennsylvanian conodonts. Along with many other workers (e.g., Lindström, 1970; Jeppsson, 1969, 1971; Sweet & Bergström, 1970; Sweet, 1970a, 1970b), I feel that it is desirable to reconstruct the apparatuses of conodont animals, whenever feasible.

The techniques and criteria for grouping have been developed at a somewhat faster pace than the resulting nomenclatural and taxonomic problems have been solved. For a discussion of different points of view, the reader is referred to Sinclair (1953), Rhodes (1953, 1962), Hass (1962a), Moore (1962), Müller (1956), and Schmidt & Müller (1964).

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 animals. In some cases the symbols could be only 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*, shared identical nonplatform components. In such situations there was little recourse but to place the descriptions of the nonplatform elements after

the descriptions of platform elements to which they are common.

In the following descriptions, UKMIP stands for University of Kansas Museum of Invertebrate Paleontology.

### Order CONODONTOPHORIDA Eichenberg, 1930

#### Superfamily POLYGNATHACEA Bassler, 1925

#### Family IDIOGNATHODONTIDAE Harris & Hollingsworth, 1933

#### Genus STREPTOGNATHODUS Stauffer & Plummer, 1932

TYPE SPECIES.—*Streptognathodus excelsus* Stauffer & Plummer, 1932, by 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 elements of species included in *Streptognathodus* have a large, flaring gnathodid basal cavity, and on the oral surface, a longitudinal oral trough that in mature (i.e., large) elements contains on the anterior portion a carina that is an extension of the blade. In immature (i.e., small) Sp elements of some species, the carina extends to near the posterior end. The oral surface is ornamented with transverse ridges that are truncated 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 truncated only in the central portion of the platform by an oral groove (i.e., a hairline discontinuity in the ridges).

Rhodes (1952) indicated that idiognathodid and streptognathodid 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 factor which is of enough significance to warrant recognition at the generic rather than the specific level.

**STREPTOGNATHODUS ELEGANTULUS** Stauffer & Plummer,  
Sp element  
Plate 1, figures 1a-c

- Streptognathodus elegantulus* Stauffer & Plummer, 1932, p. 47, pl. 4, fig. 6-7, 22, 27.  
*Polygnathus pawhuskaensis* Harris & Hollingsworth, 1933, p. 199, pl. 1, fig. 12, a, b.  
*Streptognathodus sulcatus* Gunnell, 1933, p. 280, pl. 32, fig. 10.  
*Streptognathodus elegantulus* Stauffer & Plummer; Ellison, 1941, p. 127, pl. 22, fig. 1-6, 10.  
*Streptognathodus sulcatus* Gunnell; Ellison, 1941, p. 130, pl. 22, fig. 8 [non fig. 12].  
*Streptognathodus elegantulus* Stauffer & Plummer; Branson, 1944, p. 327, pl. 46, fig. 1-6, 10.  
*Streptognathodus sulcatus* Gunnell; Branson, 1944, p. 327, pl. 46, fig. 8 [non fig. 12].  
*Streptognathodus elegantulus* Stauffer & Plummer; Rhodes, 1952, p. 893, pl. 127, fig. 11, 12.  
*Streptognathodus* cf. *S. elongatus* Gunnell; Rhodes, 1952, p. 894, pl. 127, fig. 3, 4, 8.  
*Streptognathodus elegantulus* Stauffer & Plummer; Stone, 1959, p. 158, text fig. 14.  
*Streptognathodus elegantulus* Stauffer & Plummer; Jennings, 1959, p. 995, pl. 124, fig. 6.  
*Streptognathodus elegantulus* Stauffer & Plummer; Koike, 1967, p. 311, pl. 3, fig. 13-15.  
*Streptognathodus elegantulus* Stauffer & Plummer; Higgins & Bouckaert, 1968, p. 46, pl. 5, fig. 8, 10.  
 [non *Streptognathodus elegantulus* Stauffer & Plummer; Hass 1962b (in Mamay & Yochelson), p. 209, pl. 34, fig. 44.]  
 [non *Streptognathodus elegantulus* Stauffer & Plummer; Stibane, 1967, p. 336, pl. 36, fig. 19-22.]

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 subcentral to central carina extending from the anterior to the posterior portion of the platform (Pl. 1, fig. 1a). 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 length. In addition, there is also a tendency for the posterior tip to become more rounded (Pl. 1, fig. 1d, e).

Among immature specimens of the Sp element of *Streptognathodus elegantulus* there are some that are similar to *S. elongatus* Gunnell. The fact that they fit into ontogenetic series of the Sp element of *S. elegantulus* plus the fact that Ellison (1941) reported only *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*, the former being more slender and having a V-shaped trough in cross section, are somewhat subjective. *S. elongatus* may have to be placed in synonymy with *S. elegantulus* at a later date.

**MORPHOLOGIC VARIATION.**—Mature Sp elements of *Streptognathodus elegantulus* generally fit the concepts for this element as established by Stauffer & 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 & Plummer (1932) illustrated specimens which showed the rounded and flattened lateral margins, or parapets, together with a corresponding rounding of the transverse ridges. These features are shown by some specimens (Pl. 1, fig. 1e) from the Shawnee Group. As a rule specimens of the Sp element of *S. elegantulus* from the Shawnee Group show relatively abrupt and nonflattened 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, fig. 1d, e). These forms are similar to, and transitional with, the Sp element of *Streptognathodus oppletus* (*sensu* Merrill, 1964).

**SYMMETRY VARIATION.**—This term is applied to variation occurring between sinistral and dextral forms of a conodont element.

Both sinistral and dextral specimens of the Sp element of *Streptognathodus 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 particularly if the blade is broken. The platform is commonly curved more on the outer side than the inner side so as to produce a slight asymmetry (Pl. 1, fig. 1c). 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**

Plate 1, figures 2a-c

Some platform elements differ from the Sp elements of *Streptognathodus 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. *S. lateralis*, a platform species, was diagnosed as having a short carina that terminates against the transverse ridges of the outer side of the platform and as having an oral trough on the inner side of the platform (Higgins & Bouckaert, 1968). *S. japonicus* also shows a carina, which in its posterior portion merges "into longitudinal ridge of outer side" (Igo & Koike, 1964, p. 189) as does *S. parallelus* of Clarke (1960).

*Streptognathodus lateralis* is probably a synonym of *S. japonicus* and *S. parallelus*; however, Dunn (1970a) placed them in separate specific categories, *Declinognathus lateralis* (Higgins & Bouckaert) and *Declinognathus noduliferus* (Ellison & 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 some of the species considered by Dunn (1966, 1970a, 1971) and to *S. sp. A* 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 & Plummer, Sp element**

Plate 1, figures 3a,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 blades 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 that 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 & Plummer, Sp element**

Plate 2, figures 1a,b

*Streptognathodus gracilis* Stauffer & Plummer, 1932, p. 48, pl. 4, fig. 12, 23.

*Streptognathodus holmesi* Gunnell, 1933, p. 280, pl. 32, fig. 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 & Plummer; Ellison, 1941, p. 128, pl. 22, fig. 7, 11.

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

*Streptognathodus gracilis* Stauffer & Plummer; Branson, 1944, p. 327, pl. 46, fig. 7, 11.

*Streptognathodus gracilis* Stauffer & Plummer; Rhodes, 1952, p. 94, pl. 127, fig. 1, 16.

*Streptognathodus gracilis* Stauffer & Plummer; Stone, 1959, p. 158, text fig. 9.

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

The Sp element of *Streptognathodus 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, 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 *Streptognathodus 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 & Plummer,

##### Sp element

Plate 2, figures 2a-c

*Streptognathodus excelsus* Stauffer & Plummer, 1932, p. 48, pl. 4, fig. 2, 5.

*Streptognathodus increbescens* Stauffer & Plummer, 1932, p. 49, pl. 4, fig. 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, fig. 66-68.

*Streptognathodus clarkii* Gunnell, 1933, p. 283, pl. 33, fig. 3.

*Streptognathodus excelsus* Stauffer & Plummer; Ellison, 1941, p. 130, pl. 22, fig. 15, 17, 20.

*Streptognathodus excelsus* Stauffer & Plummer; Branson & Mehl, 1944, p. 256, pl. 94, fig. 73-74.

*Streptognathodus excelsus* Stauffer & Plummer; Branson, 1944, p. 327, pl. 46, fig. 15, 17, 20.

*Streptognathodus excelsus* Stauffer & Plummer; Rhodes, 1952, p. 893, pl. 127, fig. 5, 6, 14.

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

*Streptognathodus excelsus* Stauffer & Plummer; Stone, 1959, p. 158, text fig. 3.

*Streptognathodus excelsus* Stauffer & Plummer; Hass, 1962a, p. W62, fig. 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 *Streptognathodus 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 Coal Creek Limestone Member, Topeka Limestone; most common in the Larsh-Burroak Shale Member, Deer Creek Limestone.

#### STREPTOGNATHODUS GRACILIS Stauffer & Plummer?,

##### Sp element

Plate 2, fig. 4a-d

Several specimens were recovered that differ from the Sp element of *Streptognathodus 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 *Streptognathodus 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 GRACILIS Stauffer & Plummer?,

Plate 2, figures 5a-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, fig. 13, 14, 16.

*Streptognathodus oppletus* Ellison; Branson, 1944, p. 309, pl. 45, fig. 13, 14, 16.

?*Streptognathodus mucronatus* Youngquist & Downs, 1949, p. 170, fig. 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 & Kenawy, 1966, p. 77, pl. 11, fig. 8, 9.  
*Streptognathodus angustus* Dunn, 1966, p. 1302, pl. 158, fig. 11-13.  
*Streptognathodus parvus* Dunn, 1966, p. 1302, pl. 158, fig. 9, 10.  
*Idiognathodus parvus* (Dunn); Koike, 1967, p. 305, pl. 2, fig. 13 [non fig. 11, 12, 14-17].  
*Streptognathodus parvus* Dunn, 1970a, p. 340, pl. 64, fig. 8-11, 16, 17, text fig. 91.  
*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) following Ellison (1941) 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 a morphological spectrum 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 curves inward, producing a slightly more asymmetrical element.

Merrill (1964) coined the terms "frill" and "collar" for orally flaring parapets on one or both sides, respectively, of the anterior part of the platform. He indicated these to be well-developed features of the Sp element, and they have been observed in a number of specimens of this study (Pl. 2, fig. 5c). Well-developed, rapidly descending sulci are present in the anterior portion bearing the nearly complete transverse ridges. On each side of a moderately deep trough sharply defined parapets bear 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  
 Plate 2, figures 6a-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 jarmeri* 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, fig. 18, 19.  
*Streptognathodus wabaunsensis* Gunnell; Branson, 1944, p. 327, pl. 46, fig. 18, 19, 21, 22.  
 ?*Streptognathodus* cf. *S. wabaunsensis* Gunnell; Rhodes, 1952, p. 804, pl. 127, fig. 2.  
*Streptognathodus wabaunsensis* Gunnell; Jones, 1956, p. 132, fig. 5, 7, 18a, 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 be differentiated from this element only 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 *I. antiquus* are present.

Only incomplete ontogenetic series of *Streptognathodus 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. Only two specimens of this type were found and Merrill's suggestion will be followed. Other specimens bear only one accessory lobe, generally consisting of one to three nodes. The position of the lobe varies, the lobe sometimes being situated farther posteriorly than in forms described by Ellison (1941).

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 Queen Hill Shale Member, Lecompton Limestone.

**STREPTOGNATHODUS SIMULATOR** Ellison, Sp element

Plate 3, figures 2a-e

*Streptognathodus simulator* Ellison, 1941, p. 133, pl. 22, fig. 25, 27-30.*Streptognathodus simulator* Ellison; Branson, 1944, p. 327, pl. 46, fig. 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 fewer 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 *Streptognathodus 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 *Streptognathodus 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 nonlobate 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 *Streptognathodus simulator* is associated.

The Sp elements of both *Streptognathodus 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, Oreod Limestone.

**STREPTOGNATHODUS ECCENTRICUS** Ellison, Sp element

Plate 3, figures 1a-d

*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, fig. 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 *Streptognathodus 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 specimens exhibit this, and particularly in mature specimens the trough is only weakly developed and the transverse ridges are separated only 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.

An attempt was made to determine whether or not *Streptognathodus 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 1,900,926.

**DISTRIBUTION.**—Heebner Shale Member, Oreod Limestone.

**STREPTOGNATHODUS** spp.

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

**MATERIAL.**—1,703 specimens.

**STREPTOGNATHODUS?** sp.

Plate 2, figure 3

A single dextral specimen was recovered that 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*, a smooth, elongated, bowl-shaped depression occupies 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, Oreod Limestone.

## Genus IDIOGNATHODUS Gunnell, 1931

TYPE SPECIES.—*Idiognathodus claviformis* Gunnell, 1931, by 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 that is located in median position, and an oral surface that 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 *Streptognathodus simulator*, *S. eccentricus*, *S. oppletus*, and *Idiognathus 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*, like that of species of *Streptognathodus*, is 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 &amp; Plummer,

## Sp element

Plate 3, figures 3a-c

- ?*Idiognathodus arcuatus* Gunnell, 1931, p. 250, pl. 29, fig. 26.  
*Idiognathodus magnificus* Stauffer & Plummer, 1932, p. 46, pl. 4, fig. 8, 18, 20 [non fig. 19].  
 ?*Idiognathodus expansus* Stauffer & Plummer, 1932, p. 46, pl. 4, fig. 1, 3.  
*Idiognathodus pustulata* Harris & 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 sulcifera* 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, fig. 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 & Plummer; Ellison, 1941, p. 135, pl. 23, fig. 2, 3, 6, 9 [misprinted as fig. 2, 4, 7, 10].

*Idiognathodus magnificus* Stauffer & Plummer; Ellison & Graves, 1941, p. 2, pl. 3, fig. 25-27.

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

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

?*Idiognathodus gomphus* Youngquist & Downs, 1949, p. 167, pl. 31, fig. 14, 15.

*Idiognathodus magnificus* Stauffer & Plummer; McLaughlin, 1952, p. 619, pl. 83, fig. 12-14.

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

*Idiognathodus magnificus* Stauffer & Plummer; Jennings, 1959, p. 995, pl. 124, fig. 1, 2.

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

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

?*Idiognathodus* cf. *I. magnificus* Stauffer & Plummer; Murray & Chronic, 1965, p. 601, pl. 71, fig. 7-12.

*Idiognathodus incurvus* Dunn, 1966, p. 1301, pl. 158, fig. 2, 3.

?*Idiognathodus* sp. Lane, 1967, p. 936, pl. 119, fig. 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 reexamined by Merrill (1964). Webster (1969) had sufficient material to give his view validity; however, collections in this study necessitate a different observation.

Juvenile specimens do not show accessory lobes on either side of the platform, although they may have 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 this indentation 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 specimens it bears a circular pattern of ridges and nodes.

Two accessory lobes are thus present only 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 well set-off accessory lobes.

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. Slightly more slender individuals obviously closely related to the Sp elements of *I. 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 *S. 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.

#### IDIIGNATHODUS DELICATUS Gunnell, Sp element

Plate 3, figure 4

- Idiognathodus delicatus* Gunnell, 1931, p. 250, pl. 29, fig. 23-25.  
*Idiognathodus delicatus* Gunnell; Stauffer & Plummer, 1932, p. 45, pl. 4, fig. 4, 21, 24-26.  
*Idiognathodus magnificus* Stauffer & Plummer, 1932, p. 46, pl. 4, fig. 19 [non fig. 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, fig. 29, 50.  
*Idiognathodus lanceolatus* Gunnell, 1933, p. 273, pl. 31, fig. 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, fig. 59-61.  
*Idiognathodus kansensis* Gunnell, 1933, p. 279, pl. 32, fig. 62-64.  
*Idiognathodus corrugatus* Gunnell, 1933, p. 277, pl. 32, fig. 6, 7.  
*Idiognathodus delicatus* Gunnell; Ellison, 1941, p. 134, pl. 22, fig. 31-36.  
*Idiognathodus delicatus* Gunnell; Ellison & Graves, 1941, p. 2, pl. 3, fig. 20, 23.  
*Idiognathodus delicatus* Gunnell; Branson & Mehl, 1944 (in Shimer and Shrock), p. 246, pl. 94, fig. 56-58.  
*Idiognathodus delicatus* Gunnell; Branson, 1944, p. 309, pl. 46, fig. 31-36.  
*Idiognathodus kansensis* Gunnell; Glaessner, 1945, p. 64, pl. 4, fig. 9a-c.  
*Idiognathodus delicatus* Gunnell; McLaughlin, 1952, p. 619, pl. 83, fig. 8-11.  
*Idiognathodus* cf. *I. delicatus* Gunnell; Rhodes, 1952, p. 895, pl. 127, fig. 15.  
*Idiognathodus magnificus* Stauffer & Plummer; Hass, 1962b (in Mamay & Yochelson), p. 209, pl. 34, fig. 43.  
? *Idiognathodus meekerensis* Murray & Chronic, 1965, p. 601, pl. 71, fig. 13-29.  
*Idiognathodus delicatus* Gunnell; Stibane, 1967, p. 334, pl. 37, fig. 9-11.  
? *Idiognathodus meekerensis* Murray & Chronic; Stibane, 1967, p. 334, pl. 37, fig. 12-22.  
*Idiognathodus delicatus* Gunnell; Koike, 1967, p. 304, pl. 2, fig. 18-23.

A single specimen fits this specific category as described by Ellison (1941) and Merrill (1964). (See p. 57 for the section dealing with the Sp element of

*Idiognathodus magnificus* Stauffer & 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.

#### IDIIGNATHODUS TERSUS Ellison, Sp element

Plate 4, figures 1a-d

*Idiognathodus tersus* Ellison, 1941, p. 134, pl. 23, fig. 4, 5 [misprinted as fig. 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 *Streptognathodus 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 outward.

As pointed out by Merrill (1964), the Sp element of *Idiognathus tersus* is completely intergradational morphologically with that of *Streptognathodus 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 *I. antiquus*. Considerable time was spent arranging growth stages of these Sp elements to determine if these were synonymous; however, it was concluded that this was unlikely because mature individuals of equal size of both species have commonly been found within the same sample. Distributional and ontogenetic information about these species are needed from other parts of the Pennsylvanian.

Merrill (1964) included in *Idiognathus tersus* Sp elements that bore a rudimentary inner accessory node. In this study, such specimens are included in *I. antiquus*.

**MATERIAL.**—365 specimens; figured specimens UKMIP 1,900,938 to 1,900,941.

**DISTRIBUTION.**—Plattsmouth Limestone Member, Oread Limestone to Queen Hill Shale Member, Lecompton Limestone.

#### IDIIGNATHODUS ANTIQUUS Stauffer & Plummer, Sp element

Plate 4, figures 2a-e

- Idiognathodus antiquus* Stauffer & 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 & Plummer; Ellison, 1941, p. 136, pl. 23, fig. 1, 7, 18 [misprinted as fig. 1, 8, 19].

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

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

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

*Idiognathodus humerus* Dunn, 1966, p. 1300, pl. 158, fig. 6, 7.

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

*Idiognathodus sinuosis* Ellison & Graves; Dunn, 1970a, p. 333, pl. 63, fig. 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 increases and the ridges 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 of a single prominent node.

Immature specimens have relatively straight platforms; however, as the element increases in size, a noticeable twist inward of the posterior end develops, producing an asymmetrical platform. Platform elements of this form have been called *Idiognathodus sinuosis* by Ellison & 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 portions of the parapets extending as free edges.

Both sinistral and dextral forms of the Sp element of *Idiognathodus 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 criterion for the definition of a new species, for had Stauffer & Plummer (1932) been more concerned with conodont element pairs, they could just as well have selected a sinistral element, or both a sinistral and a dextral, for their type.

Immature specimens have either a very poorly defined lobe or lack it altogether. Specimens are difficult to distinguish from the Sp elements of *Idiognathodus tersus* when the accessory lobe is missing. If such specimens occur in association with more mature forms clearly assignable to *I. antiquus*, they have been placed in the latter species. The difficulty arises, however, when only immature specimens are present in a sample, a condition possibly resulting from 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, Orcaid Limestone to Queen Hill Shale Member, Lecompton Limestone.

#### IDIognathodus spp.

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 this heading are interpreted to be the non-platform components in the apparatuses of species of *Streptognathodus* and *Idiognathodus* of this study, except possibly those of *Streptognathodus gracilis*, *S. gracilis?*, and *S. 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 multi-element 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 be clustered only 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*, *S. gracilis?*, and *S. 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, unidentified Ne element, and unidentified Pl element (Fig. 15-18; Table 14). Although unlikely, the possibility exists that the apparatuses of *S. gracilis*, *S. gracilis?*, and *S. excelsus* may have contained one or more of these nonplatform elements. This cannot be confirmed in this study.

**STREPTOGNATHODUS and IDIOGNATHODUS Oz element**  
Plate 7, figures 4a-h

For comprehensive synonymies the reader is referred to Rhodes, *et al.* (1969) and Webster (1969), under *Ozarkodina delicatula* (Stauffer & Plummer).

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

Intermediate-sized specimens are more common than smaller 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. 4c).

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

**MATERIAL.**—1,326 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**  
Plate 9, figures 2a,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 & Collinson, 1965, p. 23, pl. 1, fig. 3-5.

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

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

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

*Euprioniodina microdenta* (Ellison); Rhodes, Austin & Druce, 1969, pl. 22, fig. 16a, 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.

Both sinistral and dextral Ne elements were recovered. The existence of "pairs" of this species was evident from the literature. For example, Higgins & Bouckaert (1968, pl. 1, fig. 6) illustrated a sinistral? individual while Igo & Koike (1964, pl. 27, fig. 11-17) figured dextral? specimens.

The detailed morphology of this element has been adequately described by Ellison (1941), Rhodes (1952), Igo & Koike (1964), and Rhodes, *et al.* (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, fig. 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 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**  
Plate 10, figures 4a-d; Plate 11, figures 3a-d

This element has recently been described in detail by Higgins & 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, fig. 4a-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 phenomenon.

Higgins & 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 to 1,901,031 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

Plate 16, figures 4a-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 & Chronic, 1965, p. 598, pl. 73, fig. 3-5.

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

*Hibbardella (Hibbardella) acuta* Rhodes, Austin, & Druce, 1969, p. 112, pl. 25, fig. 19a-20.

A number of the Kansas specimens show one (rarely two) secondary denticle 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 unconfirmable 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, p. 112) stated:

"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, this element is considered to have been the Tr element of the species of *Streptognathodus* and *Idiognathodus* of this study, except possibly those of *S. gracilis*, *S. gracilis?* and *S. excelsus*.

**MATERIAL.**—56 specimens; figured specimens UKMIP 1,901,093 to 1,901,096.

**DISTRIBUTION.**—Toronto Limestone Member, Oread Limestone, to Holt Shale Member, Topeka Limestone.

#### Genus CAVUSGNATHUS Harris & Hollingsworth, 1933

**TYPE SPECIES.**—*Cavusgnathus altus* Harris & Hollingsworth, 1933, by 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, according to Lane, would 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. I concur in this opinion and believe 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 element composition analogous to that reported by Scott (1942) in the natural assemblage genus *Lewistonella*. Although it is probable that the apparatus of *Cavusgnathus merrilli* von Bitter, n. sp., contained nonplatform elements similar to those borne by the other two species of *Cavusgnathus* of this study, this cannot be confirmed.

#### CAVUSGNATHUS LAUTUS Gunnell, Sp element

Plate 4, figures 3a-h; Plate 5, figures 1a-h

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

*Cavusgnathus gigantus* Gunnell, 1933, p. 286, pl. 33, fig. 7, 8.

*Cavusgnathus missouriensis* Gunnell, 1933, p. 286, pl. 33, fig. 10, 11.

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

*Cavusgnathus lauta* Gunnell; Ellison, 1941, p. 126, pl. 21, fig. 47, 48.

*Cavusgnathus giganta* Gunnell; Ellison, 1941, p. 126, pl. 21, fig. 44, 45, 49.

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

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

*Cavusgnathus giganta* Gunnell; Branson, 1944, p. 325, pl. 45, fig. 44, 45, 49.

*Cavusgnathus lauta*, Gunnell; Branson, 1944, p. 325, pl. 45, fig. 47, 48.

*Cavusgnathus giganta* Gunnell; Youngquist & Downs, 1949, p. 162, pl. 30, fig. 18-20.

*Cavusgnathus arca* Sturgeon & Youngquist, 1949, p. 383, pl. 75, fig. 11, 12.

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

*Cavusgnathus unicornis* Youngquist & Miller; Stibane, 1967, p. 333, pl. 35, fig. 1-5.

*Cavusgnathus* cf. *regularis* Youngquist & Miller; Stibane, 1967, p. 333, pl. 35, fig. 6, 7.

- Cavusgnathus regularis* Youngquist & Miller; Stübane, 1967, p. 333, pl. 35, fig. 8-19.
- Adetognathus gigantea* (Gunnell); Lane, 1967, p. 931, pl. 120, fig. 16, 18, 19; pl. 121, fig. 8, 12, 13, 16.
- Adetognathus lauta* (Gunnell); Lane, 1967, p. 933, pl. 121, fig. 1-5, 10, 11, 14, 15, 17, 18.
- Adetognathus* sp. Lane, 1967, p. 934, pl. 122, fig. 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, fig. 2, 3, text fig. 10E.
- Adetognathus lautus* (Gunnell); Dunn, 1970a, p. 327, pl. 61, fig. 1, 4, text fig. 10C.
- Adetognathus inflexus* Dunn, 1970a, p. 327, pl. 61, fig. 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, fig. 9, 10, 14, 26.
- Adetognathus lautus* (Gunnell); Thompson, 1970, p. 1044, pl. 139, fig. 21-23.
- Adetognathus* sp. A Thompson, 1970, p. 1045, pl. 139, fig. 11, 15, 17-19.
- Cavusgnathus gigantus* Gunnell; Merrill & King, 1971, p. 654, pl. 75, fig. 19-22, 30-32.
- Cavusgnathus lautus* Gunnell; Merrill & King, 1971, p. 655, pl. 75, fig. 23-29.

The sinistral Sp component of this species has previously been described usually 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 *Cavusgnathus 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 1,263 sinistral specimens of the *lautus* type and 1,242 dextral specimens of the *gigantus* type in the Shawnee Group collections. The orientation of the remaining 14 specimens could not be determined. On the basis of these similar abundances it was concluded that these two forms represent an asymmetrical conodont pair.

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 *Cavusgnathus lauta* to be a distinct, possibly new species.

Immature specimens of both sinistral and dextral Sp elements have a short, fixed blade (Pl. 4, fig. 3d, e; Pl. 5, fig. 1f, 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. 3a; Pl. 5, fig. 1a, b).

SINISTRAL SP ELEMENT.—(Pl. 4, fig. 3a-h.) In oral

view both mature and immature specimens have an inner parapet that is noticeably higher than the outer 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 center 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 the 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 outward.

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 halfway 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, fig. 1a-i.) As seen in oral view both parapets are of equal height and 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 toward 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.—2,519 specimens; figured specimens UKMIP 1,900,946 to 1,900,960.

DISTRIBUTION.—Lawrence Shale to Severy Shale.

#### CAVUSGNATHUS FLEXUS Ellison, Sp element

Plate 5, figures 2a,b

*Cavusgnathus flexa* Ellison, 1941, p. 126, pl. 21, fig. 42, 43, 46.

*Cavusgnathus flexa* Ellison; Branson, 1944, p. 325, pl. 45, fig. 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 conspicuously 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 *Cavusgnathus flexus* to be a junior synonym of *C. lautus* Gunnell. Although Ellison (1941, pl. 21, fig. 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 Turner Creek Shale Member, Topeka Limestone.

#### CAVUSGNATHUS MERRILLI von Bitter, n. sp.

Plate 5, figures 3a-f

DIAGNOSIS.—Elongate Sp elements that occur as symmetrical sinistral and dextral forms and that are characterized by an oversized, nearly central, free blade, and by symmetrical parapets parallel in immature specimens and bulging slightly outward in mature ones. Although

the species may bear Oz, Ne, Hi, and Tr elements similar or identical to those of *Cavusgnathus 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 outward symmetrically. The parapets are not sinuous or irregular in outline as are the sinistral and dextral Sp elements of *Cavusgnathus 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, 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 that is nearly central, is best observed in oral view. This feature is particularly striking in immature specimens and their orientation (i.e., sinistral or dextral) cannot be determined with certainty.

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 denticles of the free blade increase in height anteriorly from a small initial denticle. However, rather than one denticle being dominant, four or five equally large, sometimes elongate, denticles are present. The anteriormost denticle or two of the blade are smaller 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.

DISCUSSION.—Species of *Cavusgnathus* with median or near median blade are not common. This feature has been found, for example, in *Streptognathodus* [?] *unicornis* of Rexroad & Burton (1961). For a discussion of the latter species and its taxonomic history, the reader is

referred to Lane (1967) and Webster (1969). *Cavusgnathus merrilli* von Bitter, n. sp., is similar to some species of *Idiognathoides* as figured by Lane (1967, pl. 123, fig. 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 assisted 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 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 spp.

Many Sp elements could be identified only as *Cavusgnathus* spp. on the basis of the preserved posterior tip. Most of these fragments probably represent fragments of the platform element of *C. lautus* Gunnell, as redefined in this study.

MATERIAL.—1,433 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 *C. flexus*.

#### CAVUSGNATHUS Oz element

Plate 8, figures 1a-e

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

The entire bladeliike 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 as many as 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 bar 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 bar 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 tip of the basal cavity is inclined anteriorly and the basal cavity is continued anteriorly and posteriorly as a narrow groove along aboral edges of the limbs.

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

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 that the anterior bar is much shorter than the posterior one. It differs from the Oz element of *Streptognathodus* and *Idiognathodus* in being weakly 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

Plate 9, figures 5a,b

The posterior bar, which is long, slender, and delicate in small immature specimens, is stout 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

Plate 11, figures 2a,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, *et al.* (1969).

**MATERIAL.**—42 specimens; figured specimens UKMIP 1,901,035 to 1,901,036.

**DISTRIBUTION.**—Snyderville Shale Members, Oread Limestone to Coal Creek Limestone, Topeka Limestone.

#### CAVUSGNATHUS Tr element

Plate 16, figures 3a-c

*Diplododella alternata* Branson & Mehl; Murray & Chronic, 1965, p. 597, pl. 73, fig. 1, 2.

The 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. 3b). 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 subtriangular 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 & Goebel (1968), Webster (1969), and Rhodes, *et al.* (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 *Delotaxis? conflexus* (Ellison), and bears distinct denticulation on the anterior lateral and posterior bars.

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

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

**DISCUSSION.**—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 *C. flexus*. In this regard it is of possible significance to note that Scott (1942) figured a specimen (pl. 40, fig. 16) that 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 Du Bois Limestone Member, Topeka Limestone.

#### Genus ANCHIGNATHODUS Sweet, 1970

**TYPE SPECIES.**—*Anchignathodus typicalis* SWEET, 1970a, by original designation.

The genus *Anchignathodus* was established by Sweet (1970a, 1970b) for apparatuses "composed solely of paired, individually asymmetric elements that are more or less conspicuously arched, straight or slightly bowed blades" (Sweet, 1970a, p. 7).

In establishing this genus Sweet recognized the fact that Lower Carboniferous and younger Sp elements that had previously been placed in the genus *Spathognathodus* were distinct from older conodonts of the same general morphology, in having a large cuplike 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 Idiognathodontidae.

The analysis of this study 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 multi-element 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 specimens. 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 R-mode cluster analyses of this study as well as by morphological evidence.

#### ANCHIGNATHODUS MINUTUS (Ellison)

Plate 6, figures 2a-i

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

?*Spathognathodus minutus* (Ellison); Ellison & Graves, 1941, p. 3, pl. 2, fig. 1, 3, 5 [misspelled *S. minutis* on p. 3].

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

*Spathognathodus minutus* (Ellison); Sturgeon & Youngquist, 1949, p. 385, pl. 74, fig. 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, fig. 9, 14, 15.

- Spathognathodus minutus?* (Ellison); Hass, 1962b (in Mamay & Yochelson), p. 209, pl. 34, fig. 36.
- Spathognathodus minutus* (Ellison); Rexroad & Burton, 1961, p. 1156, pl. 141, fig. 10, 11.
- Spathognathodus* cf. *S. minutus* (Ellison); Rhodes, 1963, p. 404, pl. 47, fig. 3.
- Spathognathodus echigoensis* Igo & Koike, 1964, p. 187, pl. 28, fig. 24 [non fig. 25].
- Spathognathodus minutus* (Ellison); Dunn, 1965, p. 1149, pl. 140, fig. 15, 21, 24.
- Spathognathodus minutus* (Ellison); Murray & Chronic, 1965, p. 606, pl. 72, fig. 29, 30.
- Spathognathodus minutus* (Ellison); Igo & Koike, 1965, p. 88, pl. 9, fig. 16-18.
- Spathognathodus minutus* (Ellison); Koike, 1967, p. 311, pl. 3, fig. 39-42.
- Spathognathodus coloradoensis* Murray & Chronic; Koike, 1967, p. 310, pl. 3, fig. 23 [non fig. 24].
- Spathognathodus cristula* Youngquist & Miller; Stibane, 1967, p. 335, pl. 35, fig. 21-25.
- Spathognathodus minutus* (Ellison); Webster, 1969, p. 44, pl. 7, fig. 4.
- ?*Spathognathodus rexroadi* Webster, 1969, p. 45, pl. 7, fig. 1-3.
- Spathognathodus minutus* (Ellison); Dunn, 1970a, p. 339, pl. 61, fig. 27, 30.

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

Immature individuals of *Anchignathodus minutus* are characterized by having as few as four to five posterior denticles, a short, stubby, subtriangular outline in lateral view, a main cusp that is not conspicuously larger than the posterior denticles, and a large, subtriangular basal cavity in aboral view. The anterior margin is relatively straight from the tip to the base of the main cusp. At the base of the main cusp there is a change in slope marking the location where the first anterior denticle will develop.

As specimens mature they increase in size, in length, in the number of posterior and anterior denticles, and there is a strengthening of the main cusp. Fourteen to fifteen laterally compressed, posterior denticles that 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 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. 2g).

Both sinistral and dextral forms have been recovered (Pl. 6, fig. 2h, i).

MATERIAL.—1,323 specimens; figured specimens UKMIP 1,900,970 to 1,900,977.

DISTRIBUTION.—Lawrence Shale to Coal Creek Limestone Member, Topeka Limestone.

#### ANCHIGNATHODUS EDENTULUS von Bitter, n. sp.

Plate 7, figures 1a,b

DIAGNOSIS.—This is a species of *Anchignathodus* that 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 that 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 been found only as medium-sized to small specimens. The laterally compressed main cusp is only moderately large and in some specimens is replaced by two thinner, spikelike main cusps of equal height. The anterior margin of the main cusp is nearly vertical. In none of the specimens examined were any denticles observed 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 equal in height to 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 blade 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 & Chronic). *A. coloradoensis* was characterized by Murray & 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 & Chronic, 1965, pl. 72, fig. 11, 12) show no evidence of lack of denticles on the posterior portion of the posterior blade and the authors stated (p. 607) 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. edentulus* differs from *A. coloradoensis* in lacking a denticle depression and having a posterior ridge that is equal in height with the blade denticles, rather than being considerably lower.

*A. edentulus* and *A. moorei* von Bitter, n. sp., are commonly associated and intergradations of the two exist.

ETYMOLOGY.—The name *edentulus* alludes 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, Leocompton Limestone.

#### ANCHIGNATHODUS sp. cf. *A. CAMPBELLI* (Rexroad)

Plate 7, figure 2

cf. *Spathognathodus campbelli* Rexroad, 1957, p. 37, pl. 3, fig. 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 von Bitter, n. sp.

Plate 7, figures 3a-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. 3a). More rarely the third to the fifth denticles are the longest (Pl. 7, fig. 3c). Anterior to the larger anterior denticles there may be one to several small denticles, usually near or at the base of a larger denticle. Posteriorly there is a rapid decrease in height and prominence of the denticles until near the posterior end of the blade, where only very short, compressed denticles are present. A denticle gap or a sudden decrease in height of denticles may be present immediately posterior to the larger anterior denticle(s) (Pl. 7, fig. 3c).

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. 3d).

COMPARISON.—*Anchignathodus moorei* is closely related to *A. edentulus* von Bitter, n. sp.; however, unlike *A. edentulus*, it has denticles extending to the posterior limit of the blade. *A. minutus* (Ellison) has a large, broad, main cusp, denticles that gradually decrease in height posteriorly, nonvertical anterior and posterior edges, and a deeper, more anterior basal cavity clearly showing a basal cavity tip. *Spathognathodus spiculus* of Youngquist & Miller (1949) and *A. moorei* are similar; however, *A. moorei* 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, of the 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 Coal Creek Limestone Member, Topeka Limestone.

#### ANCHIGNATHODUS spp.

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

**MATERIAL.**—36 specimens.

### Superfamily GONDOLELLACEA

Lindström, 1970

#### Family GONDOLELLIDAE Lindström, 1970

##### Genus GONDOLELLA Stauffer & Plummer, 1932

**TYPE SPECIES.**—*Gondolella elegantula* Stauffer & Plummer, 1932, by 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

Plate 6, figures 1a-f; Plate 8, figures 3a,b, 4a,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 (Fig. 15-18), 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

Plate 6, figures 1a-f

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

The elements recovered agree in most respects with previous descriptions (Ellison, 1941; Clark & 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, 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 & 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

Plate 8, figures 3a,b

*Euprioniodina* sp. B Stauffer & 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, fig. 48, 49, 53. [On plate 20, cited as *Prioniodina? camerata* (Stauffer & Plummer).]

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

A description of this element may be found under *Prioniodina? camerata* (Gunnell) in Ellison (1941). 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

Plate 8, figures 4a,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 that are flat on the inside and slightly convex on the outside of the element. The posterior bar bears at least three small denticles having characteristics similar to those of the anterior bar. The main cusp is long and slender, and about halfway up from its base bends slightly posteriorly and inward. 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. 4a).

**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 NEOPRIONIODUS Rhodes & Müller, 1956

**TYPE SPECIES.**—*Prioniodus conjunctus* Gunnell, 1931, by original designation.

## NEOPRIONIODUS CONJUNCTUS (Gunnell)

Plate 9, figures 6a,b; Plate 12, figures 3, 4a-c; Plate 16, figures 2a,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 *Duboisella typica* of Rhodes (1952). Although Rhodes reported a metalonchodininid element as part of his assemblage, such an element was not identified in my collections. Recently, S. Baxter and G. K. Merrill kindly pointed out to me the close morphologic similarity of *Neoprioniodus conjunctus*, Ne element, and the element generally identified as *Metalonchodina bidentata*. This similarity may account for the fact that a metalonchodininid component of *N. conjunctus* was not recognized.

As pointed out by Lindström (1970, p. 434), 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 a 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

Plate 9, figures 6a,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 Plattsmouth Limestone Member, Oread Limestone.

## Hi element

Plate 12, figure 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, fig. 8-11.

*Ligonodina typa* (Gunnell); Rhodes, 1952, p. 897, pl. 128, fig. 1, 4-6.

*Ligonodina typa* (Gunnell); Bischoff & 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 & Koike, 1964, p. 186, pl. 28, fig. 21, 22.

*Ligonodina typa* (Gunnell); Murray & Chronic, 1965, p. 602, pl. 72, fig. 35, 36.

*Ligonodina hanaii* Igo & Koike, 1965, p. 86, pl. 8, fig. 8.

*Ligonodina typa* (Gunnell); Higgins & 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, p. 115) 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 the angle between the planes formed by the two limbs was more often greater than 90 degrees. This seems also to be the case in the specimens illustrated by Ellison (1941, pl. 20, fig. 8-10) and Murray & Chronic (1965, pl. 72, fig. 35, 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 margins, and sometimes the outer, 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 Hartford Limestone Member, Topeka Limestone.

## Pl element

Plate 12, figures 4a-c

*Prioniodus clarki* Gunnell, 1931, p. 247, pl. 29, fig. 8.

*Prioniodus cornutus* Stauffer & Plummer, 1932, p. 27, pl. 3, fig. 23.

?*Prioniodus clarki* Gunnell; Stauffer & Plummer, 1932, p. 27, pl. 3, fig. 27, 28.

*Lonchodina clarki* (Gunnell); Ellison, 1941, p. 116, pl. 20, fig. 21, 27, 30, 31.

*Lonchodina clarki* (Gunnell); Rhodes, 1952, p. 898, pl. 128, fig. 1, 3-6.

*Lonchodina clarki* (Gunnell); Murray & Chronic, 1965, p. 603, pl. 73, fig. 22, 28.

[*non Lonchodina clarki* (Gunnell); Higgins & 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. 4c). Between the crease and the posterior sharp edge of the cusp, near the base of the cusp, there is 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° when seen laterally. At the same time the two bars are directed downward 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 & 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

Plate 16, figures 2a,b

*Prioniodus subacodus* Gunnell, 1931, p. 246, pl. 29, fig. 5.

*Prioniodus missouriensis* Gunnell, 1931, p. 246, pl. 29, fig. 9.

*Idioproniodus striatus* Gunnell, 1933, p. 265, pl. 32, fig. 36, 37.

*Hibbardella subacoda* (Gunnell); Ellison, 1941, p. 118, pl. 20, fig. 22-26.

?*Trichognathus subacoda* (Gunnell); Ellison & Graves, 1941, p. 3, pl. 1, fig. 19.

*Hibbardella subacoda* (Gunnell); Youngquist & Heezen, 1948, p. 768, pl. 118, fig. 13.

*Hibbardella* cf. *H. subacoda* (Gunnell); Rhodes, 1952, p. 897, pl. 128, fig. 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, fig. 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.

## Superfamily UNCERTAIN

### Family UNCERTAIN

#### Genus ELLISONIA Müller, 1956

**TYPE SPECIES.**—*Ellisonia triassica* Müller, 1956a, by original designation.

#### ELLISONIA TEICHERTI Sweet?

Plate 10, figures 1a-d, 2a-f; Plate 11, figures 1a-e; Plate 15, figure 5

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 *Ellisonia teichertii* by Sweet (1970a; 1970b).

Three of the four elements (the Pl, Hi, and Tr element) bear a characteristic callus, a bevelled attachment area (Rexroad & Collinson, 1963). 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 teichertii?* exhibit some variation from those placed in *E. teichertii* by Sweet (1970a; 1970b). The Ne element unlike the three other elements, cannot be shown to possess a callus. The callus is thought to be the same structure that Sweet (1970a, p. 9) termed "an escutcheonlike attachment surface on the inner side of the element." The LA element of *E. teichertii* (Sweet, 1970a; 1970b) could not be identified in the collections of this study 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 teichertii* are opaque and almost uniformly white even in earliest stages of growth to be of considerable significance. Unaltered elements of the species from the Shawnee Group are a transparent light yellowish-brown color except for most or all the denticles, which are a translucent white.

Examination of the primary types of *Ellisonia teichertii* may show that the material from the Shawnee Group, on the basis of morphological and color differences, can be considered a new species.

#### Ne element

Plate 10, figures 1a-d

*Ellisonia teichertii* Sweet, 1970a, p. 8, pl. 1, fig. 4.

*Ellisonia teichertii* Sweet, 1970b, p. 232, LD elements (terminology of Sweet, 1970a, 1970b), pl. 4, fig. 27, 28.

The long slender posterior bar, which is slightly arched and bowed, decreases in width posteriorly (Pl. 10, fig. 1a). It bears numerous, discrete, slightly compressed, sharp denticles that are inclined anteriorly very gently and that alternate in size (Pl. 10, fig. 1c). 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

that reaches nearly the same size as the main cusp. A well-developed spatulate anticusp is present (Pl. 10, fig. 1b-c).

The anterior end of the element curves sharply inward relative to the posterior bar (Pl. 10, fig. 1c).

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, fig. 1a, 1d).

Both sinistral and dextral specimens have been recovered (Pl. 10, fig. 1a, b). Immature specimens apparently differ only in size and robustness from mature specimens.

REMARKS.—The LD element of Sweet (terminology of Sweet, 1970a, 1970b) (1970b, pl. 4, fig. 27, 28) bears a slightly longer main cusp than the writer's specimens. The escutcheonlike scar that Sweet mentions has not been observed, 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 Coal Creek Limestone Member, Topeka Limestone.

#### Pl element

Plate 10, figures 2a-f

*Ellisonia teichertii* Sweet, 1970a, p. 8, pl. 1, fig. 7.

*Ellisonia teichertii* Sweet, 1970b, p. 232, LE element (terminology of Sweet, 1970a, 1970b), pl. 4, fig. 24.

The orientation utilized by Sweet (1970a; 1970b) for this element is also used in this study.

The sharply flexed element is characterized by having a main cusp which is only very slightly inclined and an anterior bar that is directed sharply upward, and which in most specimens is longer than the posterior bar.

The anterior bar bears numerous, anteriorly inclined, compressed needlelike denticles and may in some specimens (Pl. 10, fig. 2c) have a very large, anteriorly inclined, spikelike, terminating cusp that 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, fig. 2a, b) or a large vertical (Pl. 10, fig. 2e) to inclined (Pl. 10, fig. 2c, f) 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, that 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 bevelled attachment surface that runs parallel to the aboral margin (Pl. 10, fig. 2c, d), to the aboral veil, or to the inconspicuous aboral groove is not clear. Seemingly, the aboral veil covers the aboral hooks in immature? specimens (Pl. 10, fig. 2a, 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 hooklike structures (Pl. 10, fig. 2c-f). Further evaluation of the development and relationship of the aboral veil, the aboral hooklike structures, the basal cavity, and the callus is necessary.

Aborally, and directly under the main cusp, a very small, needlelike 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.

DISCUSSION.—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. 2d). 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 in position and function in their respective apparatuses these are analogous to the Pl element of *Ellisonia teichertii*. *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 & Müller, 1966) considered the genus to be a *nomen dubium* and questionably placed it with *Hindeodella*. *H. adunca* of Bischoff & Ziegler (1957) and *H. ? reversa* of Pollock (1968) are morphologically similar to the Pl element of *Ellisonia teichertii*.

MATERIAL.—140 specimens; figured specimens UKMIP 1,901,021 to 1,901,026.

DISTRIBUTION.—Toronto Limestone Member, Oread Limestone, to Coal Creek Limestone Member, Topeka Limestone.

#### Hi element

Plate 11, figures 1a-e

?*Hindeodella* sp. a Bender & Stoppel, 1965, p. 344, pl. 15, fig. 6.

*Ellisonia teichertii* Sweet, 1970a, p. 8, pl. 1, fig. 12.

*Ellisonia teichertii* Sweet, 1970b, p. 232, LB elements (terminology of Sweet, 1970a, 1970b), pl. 4, fig. 21, 22, 25, 26.

This element is characterized by having a large, anteriorly inclined denticle anterior to the main cusp, a spatulate antiscusp, and a callus that runs parallel to the aboral margin of the posterior bar and the antiscusp.

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. 1a, 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, fig. 1a, 1c). 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. 1c). 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, fig. 1a, e).

The anterior end of the element curves sharply inward relative to the posterior bar (Pl. 11, fig. 1b).

The anterior edge of the anteriormost denticle curves downward and gives rise to an antiscusp. The shape of the antiscusp varies from being broad (Pl. 11, fig. 1c) to spatulate (Pl. 11, fig. 1e). The shape of the antiscusp may be a function of maturity and spatulate antiscusps are more common in larger mature specimens.

Aborally, a small needlelike 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. 1b).

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 *Hindeodella megadenticulata* of Murray & 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 *Hindeodella 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

Plate 15, figure 5

*Ellisonia teichertii* Sweet, 1970a, p. 8, pl. 1, fig. 3.

*Ellisonia teichertii* 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 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, is recurved posteriorly, and is twisted slightly.

The aboral edge is sharp and as 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 teichertii*?. 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 *H. sp. A* away from the other elements of *E. teichertii*? in R-mode cluster analysis.

The angle at which the bars meet is less than that of *H. sp. A* but is greater than that of *Synprioniodina? compressa* of Ellison & Graves (1941).

MATERIAL.—17 specimens; figured specimen UKMIP 1,901,084.

DISTRIBUTION.—Toronto Limestone Member, Oread Limestone, to the Hartford Limestone Member, Topeka Limestone.

#### Genus DELOTAXIS Klapper & Philip, 1971

TYPE SPECIES.—*Ligonodina elegans* Walliser, 1964, by original designation.

#### DELOTAXIS? CONFLEXA (Ellison)

Plate 12, figures 1a-c; Plate 14, figures 1a-c, 2a,b, 4a,b;

Plate 16, figures 1a-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. 4B). 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. 3E). 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-1). It is probable that the Oz?, Ne?, and Pl? elements are part of the same series.

#### Hi element

Plate 12, figures 1a-c

This element consists of a short anterior bar and a long posterior bar on the aboral side of which a distinctive, long, wide groove extends the full length of both bars. Unlike the Hi element of *Neoprioniodus conjunctus* (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. 1c). There are one to two discrete denticles on the anterior bar and two on the posterior bar. There is a characteristic spikelike 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, fig. 1a, b).

COMPARISON.—The element is most similar to the Hi element of *Neoprioniodus conjunctus* and to *L. 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 Sheldon Limestone Member, Topeka Limestone.

#### Pl? element

Plate 14, figures 1a-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. 1a). 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. 1b).

Both sinistral and dextral specimens were recovered.

COMPARISON.—*Lonchodina festiva* of Bender & 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 Curzon Limestone Member, Topeka Limestone.

#### Ne? element

Plate 14, figures 2a,b

This is a simple, laterally compressed, hornlike 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, unlike the posterior side, is 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

Plate 14, figures 4a,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. 4b). 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 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 from 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 toward 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 Hartford Limestone Member, Topeka Limestone.

#### Tr element

Plate 16, figures 1a-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. 1c).

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. 1d), which may be large or small, is present.

Aborally, a wide, moderately deep groove extending the full length of the posterior bar occurs (Pl. 16, fig. 1a). 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 Sheldon 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 *International Code of Zoological Nomenclature*.

#### Genus OZARKODINA Branson & Mehl, 1933

TYPE SPECIES.—*Ozarkodina typica* Branson & Mehl, 1933b, by original designation.

#### OZARKODINA sp. A

Plate 8, figures 2a,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 toward both ends.

In the best preserved of the three 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. 2b).

COMPARISON.—The species is similar to the Oz ele-

ment of *Cavusgnathus lautus* and *C. 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 *Ozarkodina huddlei* of Druce (1969).

MATERIAL.—3 specimens; figured specimen UKMIP 1,900,996.

DISTRIBUTION.—Beil Limestone Member, Lecompton Limestone.

#### OZARKODINA? CURVATA Rexroad

Plate 8, figures 5a-f

*Bryantodus?* sp. Gunnell, 1933, p. 267, pl. 31, fig. 40.

*Ozarkodina curvata* Rexroad, 1958, p. 24, pl. 4, fig. 1-3.

*Ozarkodina curvata* Rexroad; Rexroad & Burton, 1961, p. 1156, pl. 141, fig. 13, 14.

*Ozarkodina curvata* Rexroad; Rexroad & Furnish, 1964, p. 674, pl. 111, fig. 10 [non fig. 11].

*Ozarkodina curvata* Rexroad; Rexroad & Nicoll, 1965, p. 25, pl. 2, fig. 1, 2.

*Ozarkodina* sp. aff. *O. curvata* Rexroad; Murray & Chronic, 1965, p. 605, pl. 73, fig. 29.

*Ligonodina* sp. Murray & Chronic, 1965, p. 603, pl. 73, fig. 16.

*Ozarkodina* sp. Murray & Chronic, 1965, p. 605, pl. 73, fig. 18.

*Ozarkodina curvata* Rexroad; Globensky, 1967, p. 446, pl. 56, fig. 20.

*Ozarkodina curvata* Rexroad; Thompson & Goebel, 1968, p. 40, pl. 4, fig. 19 [non pl. 3, fig. 11].

*Ozarkodina curvata* Rexroad; Rhodes, Austin & Druce, 1969, p. 168, pl. 27, fig. 6.

*Ozarkodina curvata* Rexroad; Webster, 1969, p. 42, pl. 7, fig. 10.

?*Hindeodus* sp. Rhodes, Austin & Druce, 1969, p. 130, pl. 22, fig. 17a-20b.

The abundant well-preserved specimens recovered agree in almost every detail with the original description of Rexroad (1958).

Both sinistral and dextral forms of this species have been recovered. In addition, good suites of specimens of growth stages were studied.

The smallest specimens of *Ozarkodina? curvata* (Pl. 8, fig. 5f) have a very slender, delicate, posterior bar which 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 and inward with an increase in size.

Medium-sized individuals (Pl. 8, fig. 5d) 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, fig. 5a, b) are more robust and not so bladeliike. 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 Coal Creek Limestone Member, Topeka Limestone.

**OZARKODINA? KANSASSENSIS** von Bitter, n. sp.

Plate 9, figures 1b-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 halfway 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, hooklike, compressed denticles. The posterior bar bears seven or more laterally compressed, sharp, discrete denticles, all, with the exception of the most posterior ones, of 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 occurring during growth. In the smallest specimens (Pl. 9, fig. 1c), 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 that 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. 1c) on the denticles. Unlike *O.? curvata* Rexroad, however, it has a main cusp which is bent and not straight, has more regular, heavier posterior bar denticles, a much larger basal cavity, and lacks the long and numerous anterior bar denticles.

**ETYMOLOGY.**—The species is named after the state of Kansas where it was 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 Beil Limestone Member, Lecompton Limestone.

**OZARKODINA? sp. aff. OZARKODINA? KANSASSENSIS**

von Bitter

Plate 9, figure 1a

One sinistral specimen and one dextral 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 stublike. 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, rounded anteriorly and elongated posteriorly, is present. The basal cavity is continued into both the anterior and posterior bars as an aboral groove. The aboral groove is wider and better developed in the posterior bar.

**DISCUSSION.**—It is impossible to determine if the specimens described are very large individuals of *Ozarkodina? kansasensis* von Bitter, 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*.

**MATERIAL.**—2 specimens; figured specimen UKMIP 1,901,004.

DISTRIBUTION.—Plattsmouth Limestone Member, Oread Limestone.

**OZARKODINA? spp.**

Broken or poorly preserved specimens that could not be identified specifically but that were recognizable as being fragmentary remains of either *Ozarkodina? curvata*, or *O.? kansasensis*, or *O.? sp. aff. O.? kansasensis* were placed in this taxonomic category.

MATERIAL.—12 specimens.

**Genus LIGONODINA Bassler, 1925**

TYPE SPECIES.—*Ligonodina pectinata* Bassler, 1925, by original designation.

**LIGONODINA LEXINGTONENSIS (Gunnell)**  
Plate 12, figures 2a,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 & Plummer, 1932, p. 28, pl. 3, fig. 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, fig. 13-15.

?*Ligonodina aff. L. lexingtonensis* (Gunnell); Sturgeon & Youngquist, 1949, p. 384, pl. 14, fig. 14, 15.

The reader is referred to Ellison (1941) for a description of this species.

MATERIAL.—28 specimens; figured specimens UKMIP 1,901,048 to 1,901,049.

DISTRIBUTION.—Heebner Shale Member to Kereford Limestone Member, Oread Limestone.

**Genus SYNPRIONIODINA Bassler, 1925**

TYPE SPECIES.—*Synprioniodina alternata* Bassler, 1925, by original designation.

The reader is referred to Huddle (1968) for a review of this genus.

**SYNPRIONIODINA sp. A**  
Plate 9, figures 4a,b

?*Euprioniodina caverna* (Collinson & Druce); Rhodes, Austin, & Druce, 1969, p. 90, pl. 22, fig. 11a, b.

?*Euprioniodina sp.* Rhodes, Austin, & Druce, 1969, p. 91, pl. 22, fig. 15a, 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 partially or entirely in all the specimens studied; however, it is stout like the anterior bar and the denticles are noticeably larger (Pl. 9, fig. 4a). 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 & Liebe (1962).

Aborally, a moderately large basal cavity is present under the main cusp. The basal cavity narrows toward the bars and continues in these as a narrow aboral groove.

COMPARISON.—The Ne element of *Streptognathodus* and *Idiognathodus* (Pl. 9, fig. 2a, 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 conclusively at this time.

MATERIAL.—8 specimens; figured specimens UKMIP 1,901,011 to 1,901,012.

DISTRIBUTION.—Heebner Shale Member, Oread Limestone, to Holt Shale Member, Topeka Limestone.

**SYNPRIONIODINA sp. B**  
Plate 9, figure 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, fig. 2a, b) and *Synprioniodina sp. A* (Pl. 9, fig. 4a, b).

MATERIAL.—1 specimen; figured specimen UKMIP 1,901,010.

DISTRIBUTION.—Spring Branch Limestone Member, Lecompton Limestone.

**Genus HINDEODELLA Bassler, 1925**

TYPE SPECIES.—*Hindeodella subtilis* Bassler, 1925, by original designation.

The reader is referred to Huddle (1968) for a discussion and description of this genus.

**HINDEODELLA PARVA Ellison**  
Plate 11, figures 4a-d

*Hindeodella parva* Ellison, 1941, p. 117, pl. 20, fig. 29.

*Hindeodella pulchra* Ellison; Murray & 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 the 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, & Druce, in Rhodes, *et al.* (1969).

*Hindeodella uncatata* Hass, in Hass (1959).

*Hindeodella uncatata* (Hass), in Higgins & Bouckaert (1968) and Druce (1969).

*Hindeodella brevis* Branson & Mehl, in Branson & Mehl (1934), Bischoff & Ziegler (1956), Bischoff (1957), Higgins (1961, 1962), Wolska (1967), and Spassov & 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 Coal Creek Limestone, Topeka Limestone.

#### HINDEODELLA sp. B

Plate 11, figure 5

This species possesses an anterior bar that 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 downward 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 inward is very slight, being in the order of 5 to 10 degrees.

A moderately large, deep basal cavity, which is continued as a deep aboral groove posteriorly and anteriorly, is present under the main cusp.

DISCUSSION.—Transitional forms between this species and the Hi element of *Streptognathodus* and *Idiognathodus* exist (Pl. 11, fig. 3a); 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 *Lonchodina* 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 Plattsmouth Limestone Member, Oread Limestone.

#### Genus LONCHODUS Pander, 1856

TYPE SPECIES.—*Centrodus simplex* Pander, 1856, by subsequent designation of Ulrich & Bassler (1926).

The reader is referred to Ulrich & Bassler (1926), Stauffer & 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 that are believed to be fragments of other better defined branch and bar type conodonts. Rhodes (in Rhodes & Müller, 1966) reported finding Pennsylvanian forms which fit the generic description and which he considered to be complete.

#### LONCHODUS SIMPLEX (Pander)

Plate 11, figure 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 Hartford Limestone Member, Topeka Limestone. Most common in the Plattsmouth Limestone.

#### LONCHODUS? sp.

Plate 11, figures 6a,b

This element is a slightly arched and very gently flexed element that is comblike 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 sub-circular 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. 6b). 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 perfectly preserved, with the exception of the possibly incomplete anterior inner lateral projection. 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 & 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 DOUGLASENSIS von Bitter, n. sp.

Plate 13, figures 1a-g

*Hibbardella?* sp. Gunnell, 1933, p. 369, pl. 31, fig. 46.

DIAGNOSIS.—*Lonchodina douglasensis* bears a typical lonchodinid basal cavity, a straight anterior bar that twists slightly, exposing the aboral groove in inner lateral view, and a posterior bar that 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 inward slightly, showing in lateral view a narrow aboral groove that extends the full length of the bar. Above the groove, a fairly well-developed callus (Rexroad & Collinson, 1963) is present on the inner side of the conodont. Four to seven well-developed, subtriangular, 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, fig. 1a-d). Although no flaring apron is present, the rim of the basal cavity is expanded inward 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, fig. 3a, b) rather than being *Lonchodina* sp. A, may be small specimens of *L. douglasensis* von Bitter, n. sp.

ETYMOLOGY.—The species name is derived from Douglas County, Kansas, where the species is found.

MATERIAL.—22 specimens; figured specimens, holotype UKMIP

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 Spring Branch Limestone Member, Lecompton Limestone.

## LONCHODINA sp. A

Plate 13, figures 3a,b, 4a,b

This species, which is sharply arched and laterally bowed, has an anterior bar that is strongly directed downward and a posterior bar that is usually twisted inward and downward rather sharply immediately behind the main cusp.

The anterior bar bears up to seven or more apparently discrete, laterally compressed denticles that 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. 4a).

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 douglasensis* von Bitter, 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 downward more sharply. As indicated under *L. douglasensis*, the specimens illustrated on Plate 13, figures 3a, b, may be small specimens of that species.

MATERIAL.—14 specimens; figured specimens UKMIP 1,901,064 to 1,901,067.

DISTRIBUTION.—Plattsmouth Limestone Member, Oread Limestone, to Spring Branch Limestone Member, Lecompton Limestone.

## LONCHODINA sp. B

Plate 13, figures 2a,b

This species bears two asymmetrical lateral bars, the anteriors of which are short, broad, and bear only a few denticles, and the posteriors of which are longer and bear numerous denticles. Both bars are directed downward so that an acute angle is formed between them. The main cusp is sharp-edged, laterally compressed and is noticeably twisted. It is recurved inward. The bar denticles are generally broken in the specimens available; however, they are apparently compressed and discrete. The bars curve inward 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 douglasensis* von Bitter, 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 Spring Branch Limestone Member, Lecompton Limestone.

#### LONCHODINA? PONDEROSA Ellison

Plate 12, figures 5a-c

*Lonchodina? ponderosa* Ellison, 1941, p. 116, pl. 20, fig. 37-39.

The reader is referred to Ellison (1941) for a description of this species.

Mature specimens of this species are subsymmetric to symmetrical (Pl. 12, fig. 5a). 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 Plattsmouth Limestone Member, Oread Limestone.

#### Genus METALONCHODINA Branson & Mehl, 1941

TYPE SPECIES.—*Prioniodus bidentatus* Gunnell, 1931, by original designation.

The reader is referred to Branson & Mehl (1941) for a description of the genus.

#### METALONCHODINA? sp.

Plate 14, figures 3a,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 that is sharply twisted inward. 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 that deepens under the main cusp (Pl. 14, fig. 3a).

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 *Delotaxis? conflexa* (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 HINDEODUS Rexroad & Furnish, 1964

TYPE SPECIES.—*Trichonodella imperfecta* Rexroad, 1957, by original designation.

The reader is referred to Rexroad and Furnish (1964) for a description of this genus.

#### HINDEODUS sp. A

Plate 15, figures 4a,b

?*Hindeodus imperfectus* (Rexroad); Rexroad & 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 unequal 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 in between. The bar denticles increase in length distally except for one or two that 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 calluslike 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 by the cross section of the main cusp. *Synprionodina? compressa* of Ellison & 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 *S.? compressa* Ellison & Graves extends an equal distance on the inner and outer side, whereas in *H.* sp. A the basal cavity is almost entirely on the inner side.

There is a possibility that this is the Tr element of *Ellisonia teichertii?* Possible reasons that this element was not grouped with other elements of *E. teichertii?* in the R-mode cluster analyses have been discussed in the section dealing with the Tr element of *E. teichertii?*

MATERIAL.—15 specimens; figured specimens UKMIP 1,901,082 to 1,901,083.

DISTRIBUTION.—Toronto Limestone Member, Oread Limestone, to Hartford Limestone Member, Topeka Limestone.

#### UNIDENTIFIED Ne element

Plate 9, figures 7a,b

This element differs from the Ne element of *Cavusgnathus lautus* and *C. 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 this element may have been one of the component elements of one or all of *Streptognathodus gracilis*, *S. gracilis?* and *S. excelsus*. This seems unlikely since the color and morphology of this element is much more like the Ne element of *Cavusgnathus lautus* and *C. flexus* than the Ne element of other species of *Streptognathodus*. It appears likely, but cannot be definitely established in this study, that the element is the Ne element of *Cavusgnathus merrilli* von Bitter, n. sp. Of five samples containing this element, four contain *C. merrilli*. In sample LB-1-3A from the Larsh-Burroak Shale an increase in the abundance of the Sp element of *C. merrilli* is accompanied by a similar increase in the abundance of the unidentified Ne element. 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 Coal Creek Limestone Member, Topeka Limestone.

#### UNIDENTIFIED Pl element

Plate 10, figures 3a-c

The orientation used here is opposite to that employed by Rhodes, *et al.* (1969) for *Plectospathodus*, 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 bears 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 that gets progressively narrower.

**DISCUSSION.**—R-mode cluster analysis suggests that this element may have been one of the component elements of one (or all) of *Streptognathodus gracilis*, *S. gracilis?*, and *S. 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 Ervine Creek Limestone Member, Deer Creek Limestone.

#### UNIDENTIFIED Tr elements

##### Unidentified Tr element, type A

Plate 15, figures 1a,b

This Tr element 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.**—This element is similar to *Trichonodella excavata* Branson & Mehl, 1933, but the latter differs in the characteristics of the basal cavity and in the depth of the arch.

**MATERIAL.**—1 specimen; figured specimen UKMIP 1,901,076.

**DISTRIBUTION.**—Plattsmouth Limestone Member, Oread Limestone.

##### Unidentified Tr element, type B

Plate 15, figures 2a-c

This Tr element is 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.

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 bladelike toward their tips. The bars are bowed posteriorly more than that of *Hibbardella obtusa* Murray & 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 element differs from *Hibbardella obtusa* Murray & 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.

MATERIAL.—9 specimens; figured specimens UKMIP 1,901,077 to 1,901,078.

DISTRIBUTION.—Plattsmouth Limestone Member, Oread Limestone.

#### Unidentified Tr element, type C

Plate 15, figures 3a-c

This Tr element is characterized by having an asymmetric arch, and by having lateral bars of noticeably different length. The bars are turned inward toward 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.

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 tips of the bars. The main cusp is recurved and biconvex in cross section.

Aborally, a rounded subtriangular basal cavity is present. The basal cavity expands posteriorly and continues into the bars as an aboral groove. The aboral groove continues about halfway along the bars and then dies out.

COMPARISON.—The element is most similar to unidentified Tr element type B, which has a similar distribution, but differs from the latter in possessing lateral bars which are turned inward toward one another, in having distinct lateral bar denticulation, and in having bars of noticeably different length.

MATERIAL.—14 specimens; figured specimens UKMIP 1,901,079 to 1,901,081.

DISTRIBUTION.—Heebner Shale Member to Plattsmouth Limestone Member, Oread Limestone.

#### UNIDENTIFIABLE Oz ELEMENT

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 ELEMENT

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 ELEMENT

Fragmentary remains of Hi elements of the type belonging to species of *Streptognathodus*, *Idiognathodus* and *Cavusgnathus* were placed in this category.

MATERIAL.—206 specimens.

#### UNIDENTIFIABLE Tr ELEMENT, TYPE A

A number of fragments, although recognizable as Tr elements that lacked posterior bars, could not be recognized as belonging to unidentified Tr elements A, B, or C.

MATERIAL.—10 specimens.

#### UNIDENTIFIABLE Tr ELEMENT, TYPE B

Broken or poorly preserved Tr elements recognizable as having possessed posterior bars 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 completely unrecognizable 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 Limestone. This increase for the most part reflects the fragmentation of elements placed in *Neoprioniodus conjunctus* (Gunnell). These elements, once broken, are difficult or impossible to identify.

MATERIAL.—265 specimens.

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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 centimeter-by-centimeter and bed-by-bed sampling, the importance of which was stressed by Rhodes (1968).

The sampling sequence is shown on Figures 3 to 6 and is described in Appendix B. Samples 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 lithologic or megafaunal change and a new sample was started wherever such a change occurred. Samples ranged in weight from 1000 to 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 intervals represented by such samples were recollected as were samples that 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), a 20- or 25- and 170-mesh screen combination was used. Although Collinson (1963) recommended the use of a lower 100-mesh screen, this was found 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 that 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

All illustrations of conodonts in this study were taken on a Cambridge Mark II 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 that 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 photomicrographs of entire microfossils, although it matters less when a detailed 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.

Photomicrographs of entire conodont elements were taken at magnifications as great 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 (Pl. 1-16).

## 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 (Pl. 1-16) 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 1,901,136. The unfigured non-type specimens remaining at the University of Kansas were given numbers UKMIP 1,901,137 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 mi west of West Lawrence Interchange; sampled on north side of turnpike; Plattsmouth Limestone sampled approximately .25 mi west.	Moore (1966) Moore & Merriam (1965) Troell (1965, 1969) 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 mi west of West Lawrence Interchange; strata below Big Springs Limestone sampled on south side of turnpike 0.3 mi east.	Moore (1966) Moore & Merriam (1965)
3	NE NW NW sec. 22, T. 12 S., R. 18 E. Douglas Co., Kansas	Kansas Turnpike, 8 mi 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 (1966) Moore & 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 & 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. 6a
6	NW SE sec. 14, T. 11 S., R. 16 E. Shawnee Co., Kansas	US Highway 24, fine exposure approximately 3.5 mi 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 & Adkinson (1967)
7	SE NW SE sec. 8, T. 11 S., R. 18 E. Jefferson Co., Kansas	Perry Dam, northwest end.	Koepnick & Kaesler (1971) Locality 7

### MEASURED SECTIONS AND DESCRIPTION OF SAMPLING UNITS

UNIT SAMPLED	NO. OF SAMPLE	DESCRIPTION	THICKNESS
<b>LOCALITY 1</b>			
<b>Lawrence Shale</b>			
La-Sp-1	1	Shale, irregular bedded, light gray mottled with white flecks; apparently unfossiliferous.	15.2 cm
<b>Toronto Limestone</b>			
T-1-1	2	Limestone, thin-bedded, light gray, weathers yellow brown; brachiopods, fusulinids, crinoid columnals abundant.	30.5 cm
T-1-2	3	Limestone, thin-bedded, light gray, weathers yellow brown; brachiopods, fusulinids, crinoid columnals abundant.	20.3 cm
T-1-3	4	Limestone, thin-bedded, light gray, weathers yellow brown; brachiopods, fusulinids, crinoid columnals abundant.	27.9 cm
T-1-4	5	Limestone, thick-bedded, massive, tan to gray, weathers yellow brown; abundant crinoid columnals, some fusulinids.	43.2 cm
T-1-5A	6	Limestone, medium to thick-bedded, massive, light gray to tan, weathers buff to tan, with a hackly fracture; crinoid columnals abundant.	40.6 cm
T-1-5B	7	Limestone, medium to thick-bedded, massive, light gray to tan, weathers buff to tan, and with a hackly fracture; crinoid columnals abundant.	17.8 cm
T-1-6	8	Limestone, thick-bedded, massive, poorly developed bedding, light tan to gray, weathers dark tan to brown.	114 cm
T-1-7	9	Limestone, thick-bedded, massive, little evidence of bedding, light tan to gray, weathers dark tan to rusty brown with a hackly fracture.	63.5 cm

**GRADATIONAL CONTACT WITH SNYDERVILLE SHALE**

**Snyderville Shale**

Sn-1-1A	10	Shale, green, containing calcareous nodules.	5 cm
Sn-1-1B	11	Shale, green, clayey, massive, poorly bedded.	22.9 cm
Sn-1-2A	12	Shale, dark green to dark grayish-green, clayey, massive with poorly developed bedding, nodular; apparently unfossiliferous. Thin coaly layer between Sn-1-2A and Sn-1-2B.	61 cm
Sn-1-2B	13	Shale, dark green to dark grayish-green, nodular, massive with poorly developed bedding; apparently unfossiliferous.	61 cm
Sn-1-3	14	Shale, dark green, clayey, massive; apparently unfossiliferous.	137.2 cm
Sn-1-4A	15	Shale, green to gray, weathers brown, calcareous.	15.2 cm
Sn-1-4B	16	Shale, gray, thinly laminated, weathers brown to yellow; chonetid brachiopods present.	10.2 cm

**Leavenworth Limestone**

L-1-1	17	Limestone, fine-grained, massive, dark blue to gray, single vertically-jointed bed; brachiopods and fusulinids present.	53.5 cm
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**Heebner Shale**

He-1-1	18	Shale, black to blackish-brown, thin-bedded, flaky to earthy, very friable; brachiopods present.	3.8 cm
He-1-2	19-20	Shale, black, thin-bedded, fissile, platy, containing phosphatic concretions; near top beds become more clayey; Sample He-1-2A is black fissile shale; He-1-2B is more clayey soft shale.	152.4 cm
He-1-3A	21	Shale, dark green to grayish-black, soft, clayey, poorly developed bedding; brachiopods present.	24.1 cm
He-1-3B	22	Shale, grayish-black to yellowish-brown, clayey, soft, poorly developed bedding.	24.1 cm
He-1-4	23-24	Shale, yellow to brown, sandy, hard, bedding poorly developed; He-1-4A=lower half; He-1-4B=upper half.	35.6 cm

**Plattsmouth Limestone**

P-1-1	25	Limestone, light gray, nodular, wavy bedding, fine-grained, weathers tan to buff, bedding approxi-	101.6 cm
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mately 30 cm thick; brachiopods, corals, crinoid columnals present.

P-1-2	26	Limestone, light gray, nodular, wavy bedding, fine-grained, weathers tan to buff; brachiopods, corals, abundant crinoid debris present.	129.5 cm
P-1-3	27	Limestone, light gray, nodular, wavy bedding, fine-grained, weathers tan to buff, abundant chert nodules; corals, brachiopods present. This is the lower chert zone of Moore & Merriam (1965).	22.9 cm
P-1-4	28	Shale, earthy.	25.4 cm
P-1-5	29	Limestone, light gray, nodular, wavy bedding, fine-grained, weathers tan to buff; abundant fusulinids, some crinoid columnals and possible silicified ?brachiopods present.	30.5 cm
P-1-6	30	Limestone, light gray, nodular, wavy bedding, fine-grained, weathers tan to buff, abundant chert nodules; crinoid columnals abundant. This is the upper chert zone of Moore & Merriam (1965).	43.2 cm
P-1-7	31	Limestone, light gray, nodular, medium-bedded; abundant crinoid columnals and small brachiopods.	38.1 cm
P-1-8	32	Limestone, light gray, thin to medium-bedded, weathers tan to gray; abundant fusulinids, and a few crinoid columnals present.	43.2 cm
		Top of section	

**LOCALITY 5**

**Heumader Shale**

Lowest 2" of Heumader Shale at Lecompton	33	Shale, gray to blue, heavily iron-stained, abundant small gypsum crystals present.	5.1 cm
Heu-1-1	34	Shale, gray to blue, heavily iron-stained, small gypsum crystals present.	12.7 cm
Heu-1-2	35	Shale, gray to blue, well bedded, iron-stained, small gypsum crystals abundant.	27.9 cm
Heu-1-3A	36	Shale, grayish-green to blue, bedding obscure on fresh surface but more apparent on weathered surface.	27.9 cm
Heu-1-3B	37	Shale, brown, poorly bedded, nonlaminated; crushed brachiopods and bryozoans present.	2.5 cm

**Kereford Limestone**

Ke-1-1	38	Limestone, bluish-gray, irregular-bedded, massive to partly shaly,	8.9 cm
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		weathers reddish-brown; brachiopods and crinoid columnals present.		SB-1-2A	53-54	Limestone, nodular, soft, brown weathering, shaly; crowded with fusulinids; shaly part sampled as SB-1-2A (SS)=Sample 53; Limestone sampled as SB-1-2A (AA)=Sample 54.	20.3 cm
Ke-1-2A	39	Limestone, light to dark gray, bedding 5-7 cm thick with numerous shaly partings which contain limestone nodules, weathers brownish buff; brachiopods, bryozoans, fusulinids present.	15.2 cm	SB-1-2B	55	Limestone, gray, slightly more massive than SB-1-2A but with shaly zone in middle, weathers brown to buff; abundant fusulinids.	35.6 cm
Ke-1-2B	40	Same description as for Ke-1-2A; top of Ke-1-2B marked by 2.5 cm thick shale unit.	27.9 cm	SB-1-3	56	Shale, bluish-green, soft, laminated; abundant fusulinids in lower half.	25.4 cm
Ke-1-3	41	Limestone, gray, blocky beds 5-7 cm thick alternating with brown nonlaminated shale containing pelecypods.	15.2 cm	SB-1-4A	57	Limestone, green, very shaly, thin-bedded, nonlaminated; apparently unfossiliferous.	24.1 cm
Ke-1-4	42	Limestone, gray, silty, blocky beds, weathers brown to buff; brachiopods and crinoid fragments present; 2.5 cm thick shale unit at base.	63.5 cm	SB-1-4B	58	Limestone, gray, shaly, weathers slightly nodular; apparently unfossiliferous.	55.9 cm
Ke-1-5	43	Shale, grayish-green, thin-bedded, sandy, hard; apparently unfossiliferous.	15.2 cm	SB-1-4C	59	Limestone, gray, brecciated, weathers tan.	5.1 cm
Ke-1-6	44	Limestone, gray, irregularly-bedded, bedding 12.7 to 15.2 cm thick, weathers brown to buff; fusulinids and brachiopods present; near top becomes shaly and more thinly bedded (2.5 to 5 cm).	92.7 cm	SB-1-5A	60	Shale, brown, clayey, nonlaminated; apparently unfossiliferous.	6.3 cm
Ke-1-7	45	Limestone, gray, medium-bedded; near top abundantly fossiliferous containing brachiopods, crinoid columnals, and bryozoan debris.	17.8 cm	SB-1-5B	61	Shale, grayish-black.	12.7 cm
				SB-1-5C	62	Shale, yellow, clayey, nonlaminated; apparently unfossiliferous.	12.7 cm
				SB-1-5D	63	Description same as for SB-1-5C.	12.7 to 15.2 cm
				SB-1-6	64	Limestone, gray, massive bedding, weathers reddish-brown; rare gastropods; upper portion is brecciated.	35.6 cm
				SB-1-7	65	Limestone, gray, massive bedding, intraformational breccia; apparently unfossiliferous.	60.2 cm
<b>Kanwaka Shale</b>							
Jap-1-1	46	Shale, gray, sandy; apparently unfossiliferous.	15.2 cm	<b>Doniphan Shale</b>			
				Dos-1-1	66	Shale, chocolate-brown, clayey, laminated.	12.7 cm
				Dos-1-1A	67	Same description as Dos-1-1 but unit is slightly lighter in color.	22.9 cm
				Dos-1-2	68	Shale, light brown to light brownish-black, clayey, thin (2.5 to 5 cm) harder unit in middle; brachiopods, pelecypods, bryozoans present.	22.9 cm
<b>LOCALITY 2</b>							
<b>Kanwaka Shale</b>							
Kan-Sp-1	47	Shale, tan, clayey, laminated; abundant compressed brachiopods (especially <i>Chonetes</i> , <i>Juresania</i> , <i>Derbyia</i> ) and pelecypods ( <i>Myalina</i> , <i>Aviculopecten</i> , <i>Edmondia</i> ). Description from Moore & Merriam (1965).	15.2 cm	<b>Big Springs Limestone</b>			
				BS-1-1	69	Limestone, gray, medium-bedded, nodular to wavy-bedding, weathers brown and slightly shaly; fusulinids present.	20.3 cm
				BS-1-2	70	Limestone, bluish-gray, fine-grained, weathers tan to light gray, single vertically jointed bed; abundant fusulinids.	66 cm
<b>Spring Branch Limestone</b>							
SB-1-1	48-52	Limestone, gray, fine-grained, massive, thick-bedded, weathers buff; abundant fusulinids, some brachiopods and crinoid columnals; Samples SB-1-1A to SB-1-1E from base up.	160 cm				

<b>Queen Hill Shale</b>							
QH-1-1	71	Shale, black, fissile.	48.3 cm				tan with rusty stains; lower half contains abundant fusulinids, pelecypods, and crinoid columnals; upper half contains oncolitic algae ( <i>Ottonosia</i> ) and possibly <i>Ambly-siphonella</i> .
QH-1-2	72	Shale, brown to brownish-black, earthy, nodular near top; possible pelecypods present.	53.5 cm				
<b>Beil Limestone</b>							
B-1-1	73	Limestone, bluish-gray, thin- to medium-bedded, bioclastic, weathers brownish.	68.6 cm	Av-3-4	88	Shale, dark brown, clayey, poorly bedded; contains shell debris.	12.7 cm
B-1-2	74	Limestone, bluish-gray, medium-bedded, bioclastic, shaly weathering.	53.5 cm	Av-3-5	89	Limestone, dark gray, shaly, abundant brachiopods ( <i>Cru-rithyris</i> ).	12.7 to 15.2 cm
B-1-3	75	Limestone, bluish-gray, thin- to medium-bedded, weathers gray and shaly; fossiliferous.	20.3 cm	<b>LOCALITY 3</b>			
B-1-4	76	Shale, black to brown, calcareous, irregularly thin- to medium-bedded; fossiliferous.	48.3 cm	<b>Tecumseh Shale</b>			
B-1-5	77	Limestone, gray, irregular thickness; fossiliferous.	5.1 cm	Te-Sp-1	90	Limestone, shaly to sandy; unfossiliferous.	76.2 cm
B-1-6	78	Shale, brown to bluish, clayey, containing approximately 6 thin (2.5 cm) irregular, nodular limestone lenses; abundant corals, fusulinids, bryozoans, pelecypods, crinoid columnals, etc.	71.1 cm	Te-Sp-2	91	Shale, greenish-gray, calcareous; unfossiliferous.	30.5 cm
B-1-6 right under B-1-7	79	Uppermost several centimeters of B-1-6; description same as B-1-6.		<b>Ozawkie Limestone</b>			
B-1-7	80	Limestone, dark brown, limonitic, finely laminated.	5.1 cm	Oz-1-1	92	Limestone, light gray, massive bedding, weathers light brown to tan; brachiopods and fusulinids present.	76.2 to 83.8 cm
<b>LOCALITY 7</b>				<b>Oskaloosa Shale</b>			
<b>King Hill Shale</b>				Os-1-1A	93	Limestone, gray, soft, weathers yellow, limonite-stained, irregular columnar weathering; apparently unfossiliferous.	12.7 cm
KH-4-1	81	Shale, dark olive-green, slightly sandy, somewhat blocky and breaking in elongated fragments; apparently unfossiliferous.	45.7 cm	Os-1-1B	94	Siltstone, green, contains limestone nodules; apparently unfossiliferous.	30.5 cm
KH-4-2	82	Limestone, reddish to ochre-brown, medium-bedded (3.7 to 7.6 cm), finely laminated, very earthy, Mn stained.	91.4 cm	Os-1-2	95-99	Siltstone, dark green, blocky and massive, underclay-like; apparently unfossiliferous; five samples Os-1-2A to Os-1-2E taken from the base up.	128.5 cm
KH-4-3	83	Description same as KH-4-2 except for more massive bedding (10-12.5 cm thick).	53.5 cm	Os-1-3	100	Shale, brown, laminated, clayey; contains abundant brachiopods ( <i>Chonetes</i> ).	17.8 cm
KH-4-4	84	Shale, dark green, blocky; apparently unfossiliferous.	50.8 cm	<b>Rock Bluff Limestone</b>			
<b>Avoca Limestone</b>				RB-1-1	101	Limestone, medium gray, very fine-grained, vertically jointed, semiconchoidal fracture, single bed with break approximately 15 cm above irregular base, weathers light tan; fusulinids abundant; crinoid columnals and brachiopods present.	55.9 cm
Av-3-1	85	Limestone, shaly, irregular and thinly (2.5 cm) bedded.	7.6 to 10.2 cm	<b>Larsh-Burroak Shale</b>			
Av-3-2	86	Shale, calcareous.	2.5 cm	LB-1-1	102	Shale, brown to tan, soft, earthy; apparently unfossiliferous.	2.5 cm
Av-3-3	87	Limestone, light gray, massive and thick-bedded (25 to 62 cm), fine-grained; unit is a resistant ledge-former; weathers yellow to	88.9 cm	LB-1-2	103	Shale, black, fissile, hard.	34.2 cm
				LB-1-3	104-108	Shale, green, soft, clayey, thin-bedded to laminated, weathers	85.1 cm

brown to tan, apparently unfossiliferous; five samples LB-1-3A to LB-1-3E taken from the base up.

**Ervine Creek Limestone**

- EC-1-1 109-121 Limestone, light gray, thin to medium wavy bedding, thin shaly limonitized partings present, near top stylolites abundant, fusulinids, corals, brachiopods and crinoid columnals present; samples EC-1-1A to EC-1-1M from base up. 182.9 cm
- EC-1-2 122 Same description as for EC-1-1 except unit weathers rustier. 45.7 to 61 cm

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**LOCALITY 4****Calhoun Shale**

- Cal-Sp-1 123 Siltstone, gray to olive-green; very fossiliferous with abundant pelecypods. 30.5 cm

**Hartford Limestone**

- H-1-1 124 Limestone, gray, medium-bedded, limonitic partings present, weathers rusty brown; brachiopods present. 12.7 cm
- H-1-2 125 Shale, brown, earthy, bedding obscure. 12.7 cm
- H-1-3 126-134 Limestone, light brown, massive, weathers dark brown and very blocky, contains large white calcite "eyes" (crinoid columnals); abundant fusulinids present. Samples H-1-3A to H-1-3I from base up. 127 cm

**LOCALITY 6****Iowa Point Shale**

- IP-2-1 135 Limestone, yellow to brown, earthy, very shaly. 2.5 cm
- IP-2-2 136 Shale, gray to olive-green, thin-bedded, partly laminated, lower half darker with brown streaks along bedding; apparently unfossiliferous. 15.2 cm
- IP-2-3 137 Shale, gray to brown, thin-bedded (0.6 cm), sandy; apparently unfossiliferous. 21.6 cm
- IP-2-4 138 Shale, medium-gray, massive, lacking bedding, weathers brown, calcareous nodules in center of unit; fusulinids and brachiopods present near top. 20.3 cm

**Curzon Limestone**

- Cur-1-1 139-143 Limestone, reddish-brown, fine-grained, massive, medium to thick-bedded, weathers rusty brown; approximately 30 cm from top a prominent chert zone is present; crinoid columnals, large brachiopods, and fusulinids prominent near top and bottom; fossil debris throughout; samples Cur-1-1A to Cur-1-1E from the base up with thicknesses of 38.1, 10.2, 8.9, 35.6, and 58.4 cm, respectively; Cur-1-1C is a shaly parting containing fusulinids and echinoderm fragments. 151.2 cm
- Cur-1-2 144 Limestone, brown, silty, thin-bedded (1.3 cm). 25.4 cm
- Cur-1-3 145 Limestone, gray, thin-bedded, silty, weathers brown; fusulinids, bryozoans and crinoid columnals present. 43.2 cm
- Cur-1-4 146 Limestone, gray, massive-bedded, weathers brown. 35.6 cm

**Jones Point Shale**

- JPS-1-1 147 Siltstone, brown, earthy to clayey, nonlaminated; brachiopods, echinoid spines and phosphatic matter present. 7.6 cm
- JPS-1-2 148-150 Shale, black to gray, clayey, thin-bedded, nonlaminated, pelecypods present; samples JPS-1-2A to JPS-1-2C from base up with thicknesses of 45.7, 30.5, 76.2 cm, respectively. 152.4 cm
- JPS-1-3 151 Shale, yellow to green to brown, calcareous, thin-bedded; apparently unfossiliferous. 7.6 cm

**Sheldon Limestone**

- She-1-1 152 Limestone, gray, fine-grained, weathers yellowish brown; brachiopods present. 21.6 cm
- She-1-2 153 Shale, calcareous. 5.1 cm
- She-1-3 154 Limestone, light gray, upper and lower contact defined by mound-like undulating surface (algal?); upper surface covered with abundant microfossils (ostracodes, gastropods, etc.). 40.6 cm

**Turner Creek Shale**

- TCS-1-1 155 Siltstone, brown to black, fossils and limestone nodules abundant along bedding, weathers bluish gray. 22.9 cm

TCS-1-2	156	Siltstone, brown, nodular, hard, clayey, weathers as light brown band, contains carbonaceous matter and small brachiopods.	11.4 cm
TCS-1-3	157	Limestone, light gray, fine-grained, thin to medium-bedded, alternating with sandy shale and siltstone; contains very abundant pelecypods ( <i>Aviculopecten</i> and <i>Myalina</i> ) plus small crinoid columnals and bryozoans; weathers black and yellow mottled.	33 cm
TCS-1-4	158	Shale, brown to olive-green, thin-bedded, nonlaminated; brachiopods and pelecypods present.	16.5 cm

**Du Bois Limestone**

DB-1-1	159-160	Limestone, light gray, fine-grained, thick-bedded, vertically jointed, weathers brown to tan; brachiopods and pelecypods present; sample DB-1-1A=lower half; sample DB-1-1B=upper half.	33 cm
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**Holt Shale**

Hol-1-1	161	Shale, brown to dark gray, clayey, thin-bedded; brachiopods and pelecypods abundant.	20.3 cm
Hol-1-2	162-163	Shale, brown, slightly more sandy and less fossiliferous than Hol-1-1; sample Hol-1-2A=lower 30.5 cm; Hol-1-2B=upper 7.6 cm.	38.1 cm

**Coal Creek Limestone**

CC-1-1	164-167	Limestone, light gray, medium to thin-bedded, weathers nodular, sandy, alternates with shaly beds; brachiopods, bryozoans, crinoid columnals, etc. abundant; samples CC-1-1A to CC-1-1D from base up with thicknesses of 14, 30.5, 25.4, and 30.5 cm, respectively.	100.4 cm
CC-1-2	168	Shale, sandy, weathers green to yellow.	25.4 cm
CC-1-3	169	Limestone, thin (5 cm) bed overlain by yellow-weathering shale followed by thin shale with abundant limonite.	20.3 cm
CC-1-4	170	Limestone, gray, medium-bedded, weathers reddish-brown.	15.2 cm

**Severy Shale**

6" over CC-1	171	Shale, greenish-mottled, silty; apparently unfossiliferous.	15.2 cm
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**SUMMARY OF PUBLISHED  
OBSERVATIONS AND OPINIONS  
ABOUT UNITS SAMPLED**

**SHAWNEE GROUP**

**OREAD LIMESTONE**

**Toronto Limestone Member**

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 ft in Douglas Co. (O'Connor, 1960).
Ecological Classification	Tarkio-type ( <i>Triticites</i> ) assemblage (Moore, 1966).
Transgressive- Regressive Sea Classification	Stage C, argillaceous transgressive-regressive marine stage (Wagner, 1966). Deposited during a single advance and retreat of the sea (Troell, 1965, 1969). Lower part transgressive; upper part regressive (Elias, 1966).
Environment of Deposition	Not deepest parts of invading sea but intermediate to greatest distance from sea margins (Moore, 1966). At Locality 1, according to Troell (1969), the basal zone ( <i>Osagia</i> 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.
	<b>Snyderville Shale Member</b>
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, 1966).
Thickness	Average 10-15 ft in Douglas Co. (O'Connor, 1960).
Ecological Classification	Snyderville type ( <i>Neochonetes</i> ) assemblage (Moore, 1966).
Transgressive- Regressive Sea Classification	Stage D continental margin stage; regressive continental (Wagner, 1966).

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, 1966).	interpreted by McCrone (1963, p. 65) 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."
	<b>Leavenworth Limestone Member</b>	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, 1966).
Megascopeic	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).	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, 1966).
Microscopic	At Locality 1, the lithology is skeletal mudstone (Toomey, 1964).	Relatively far from shore; relatively deep, oxygen deficient, below wave-base, marine (Evans, 1966).
Thickness	Generally 0.8 to 2 ft in Douglas Co. (O'Connor, 1960).	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 & Adkison, 1967).
Ecological Classification	Leavenworth type ( <i>Isogramma</i> ) assemblage (Moore, 1966).	
Transgressive-Regressive Sea Classification	Stage E, rapid oscillation marine stage (Wagner, 1966). Deposited during a second comparatively brief cycle in the staggering [ <i>sic</i> ] Oread oceanic invasion, resulting in maximal depth of waters hardly exceeding the depth at the culmination of the first (Toronto) cycle (Elias, 1966). 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 nearshore carbonate-rich water (Wagner, 1966). At least the middle Leavenworth was deposited in quiet water (Johnson & Adkison, 1967). Deposited in relatively shallow water on a broad, slowly subsiding carbonate platform (Toomey, 1969).	
	<b>Heebner Shale Member</b>	
Megascopeic	Black, fissile shale overlain by clayey, green to gray calcareous shale.	Megascopeic Light gray to nearly white, wavy-bedded limestone, which weathers light gray to light tan; has chert and shale partings (O'Connor, 1960).
Microscopic	See Evans (1966).	Microscopic Well-bedded skeletal calcarenite to calcilitite in north-central Kansas (Heckel & Cocke, 1969).
Thickness	5-8 ft in central and southern Douglas Co. South of Worden Fault it is between 14 and 18 ft thick (O'Connor, 1960).	Thickness About 18 ft thick in Douglas Co. (O'Connor, 1960).
Ecological Classification	Heebner Type ( <i>Listracanthus</i> ) assemblage (Moore, 1966).	Ecological Classification Plattsmouth type ( <i>Caninia</i> ) assemblage (Moore, 1966).
Transgressive-Regressive Sea Classification	Stage F, stagnant-water marine stage (Wagner, 1966). 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).	Transgressive-Regressive Sea Classification Normal, transgressive marine stage phase (Wagner, 1966). Belonged to culminating marine part of cyclothem (Moore, 1966).
Environment of Deposition	Near shore in shallow waters—possibly in lagoons (Moore, 1936). A similar black shale, the Bennett Shale, was	Environment of Deposition Deposited in clear, shallow (less than 20 m on the average) water, far from nearest shore (probably 50 to 100 mi distant) (Moore, 1966). In medial and late Plattsmouth time a water depth of about 200 ft—then shallowed (Elias, 1966). Deposited in relatively shallow water; water depth, strand line, and sediment source varied repeatedly (Johnson & Adkison, 1967).
	<b>Heumader Shale Member</b>	
Megascopeic	Gray to green clayey and calcareous shale (O'Connor, 1960).	Megascopeic Gray to green clayey and calcareous shale (O'Connor, 1960).
Thickness	2-4 ft in Douglas Co. Locally slightly thicker (O'Connor, 1960).	Thickness 2-4 ft in Douglas Co. Locally slightly thicker (O'Connor, 1960).
Transgressive-Regressive Sea Classification	Regressive, except for minor readvance in fossiliferous upper part (Johnson & Adkison, 1967).	Transgressive-Regressive Sea Classification Regressive, except for minor readvance in fossiliferous upper part (Johnson & Adkison, 1967).
Environment of Deposition	Nearshore in retreating sea (Johnson & Adkison, 1967).	Environment of Deposition Nearshore in retreating sea (Johnson & Adkison, 1967).

**Kereford Limestone Member**

**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 ft in Douglas Co. (O'Connor, 1960).

**Ecological Classification** Kereford-type (*Fenestrellina*) assemblage (Moore, 1966).

**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, 1966).  
Deposited during shallowing of the Oread Sea (Elias, 1966).

**Thickness** 2 to 5 ft in Douglas Co. (O'Connor, 1960).

**Ecological Classification** Doniphan type (*Rhombopora*) assemblage (Moore, 1966).

**Transgressive-Regressive Sea Classification** Represents the initial parts of a marine sequence (Moore, 1966).

**Environment of Deposition** Environment similar to that of the Snyderville Shale, which is in comparable position in the Oread Limestone (Moore & Merriam, 1965).  
Nonmarine, estuarine (Johnson & Adkison, 1967).

**Big Springs Limestone Member**

**Megascopic** Black to gray limestone; weathers light tan and has prominent vertical joints (O'Connor, 1960).

**Thickness** 2 to 3 ft in Douglas Co. (O'Connor, 1960).

**Ecological Classification** Tarkio type (*Triticites*) assemblage (Moore, 1966).

**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 early Big Springs time (Johnson & Adkison, 1967).  
Same or similar environment of deposition as Spring Branch Limestone (Moore, 1966).

**KANWAKA SHALE**

**Megascopic** Consists of two thick shale members with a thin limestone member in between (O'Connor, 1960).

**Thickness** About 60 ft in Douglas Co. (O'Connor, 1960).

**Environment of Deposition** Nonmarine, 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 & Adkison, 1967).

**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 ft in Douglas Co. (O'Connor, 1960).

**Ecological Classification** Heebner Type (*Listracanthus*) assemblage (Moore, 1966).

**Environment of Deposition** Similar to environment of deposition of Heebner Shale (Moore, 1966; Johnson & Adkison, 1967).  
Probably, postulated depositional environment of Bennett Shale (McCrone, 1963) is similar.

**Queen Hill Shale Member**

**LECOMPTON LIMESTONE**

**Spring Branch Limestone Member**

**Megascopic** The lower five ft is massive light tan or light gray-brown limestone similar to Toronto Limestone. Overlying the massive limestone are 3 to 8 ft of shaly limestone, shale and limestone (O'Connor, 1960).

**Thickness** 8 to 14 ft in Douglas Co. (O'Connor, 1960).

**Ecological Classification** Tarkio type (*Triticites*) assemblage (Moore, 1966).

**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 & Adkison, 1967).  
The upper Spring Branch was deposited in shallower water (Johnson & Adkison, 1967).  
Intermediate to greatest distance from the invading sea margins (Moore, 1966).

**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 ft in Douglas Co. (O'Connor, 1960).

**Ecological Classification** Beil Type (*Pulchratia*) assemblage (Moore, 1966).

**Transgressive-Regressive Sea Classification** This environment is interpreted to belong in the culminating marine part of the cyclothem (Moore, 1966).

**Environment of Deposition** Normal marine with fairly quiet water (Yochelson in Johnson & Adkison, 1967).  
Clear sunlit shallow waters (estimated less than 20 m on the average) far from the nearest shores (probably 50 to 100 mi distant) (Moore, 1966).

**Doniphan Shale Member**

**Megascopic** Dark gray, clayey shale; sparingly fossiliferous, containing plant remains and mollusks, near top (O'Connor, 1960).

**Megascopic** **King Hill Shale Member**  
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 ft; locally may be as thin as 5 ft (O'Connor, 1960).  
8 ft thick in the Kansas River valley and about 11 ft thick in southeastern Shawnee Co. (Johnson & Adkison, 1967).
- Environment of Deposition Lower part may have been continental; upper part deposited in shallow marine waters (Johnson & Adkison, 1967).

#### Avoca Limestone Member

- Megascopic A dense, gray-blue, massive limestone, which weathers blue-gray to buff (O'Connor, 1960).
- Thickness 3 to 4.5 ft in Douglas Co. (O'Connor, 1960).  
3 to 4 ft in eastern Shawnee Co. (Johnson & Adkison, 1967).
- Ecological Classification Avoca Type (*Amblysiphonella*) assemblage (Moore, 1966).
- Environment of Deposition Deeper marine during deposition of the lower part with shallowing during deposition of the upper part (Johnson & 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 ft thick; southward thins to about 58 ft (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 & Adkison, 1967).

#### DEER CREEK LIMESTONE

##### Ozawkie Limestone Member

- 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 ft in Douglas Co. (O'Connor, 1960).
- Ecological Classification Ozawkie Type (*Knightites*) assemblage (Moore, 1966).
- 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*, doubtlessly lived in marginal parts of the retreating Ozawkie sea, though at undeterminable distance from the nearest strand line (Moore, 1966).  
Deeper marine during deposition of the lower part changing to extremely shallow water or

beach environment during deposition of the upper part (Johnson & Adkison, 1967).

##### Oskaloosa Shale Member

- Megascopic Thin-bedded shale and blocky clay; gray to greenish when fresh; weathers drab yellow (O'Connor, 1960).
- Thickness 2 to 5 ft in Douglas Co. (O'Connor, 1960).
- Ecological Classification Snyderville Type (*Neochonetes*) assemblage (Moore, 1966).
- 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, 1966).  
Lower part, continental; upper part, marine (Johnson & Adkison, 1967).

##### Rock Bluff Limestone Member

- Megascopic Single bed of hard, dense to fine-grained, dark blue-gray limestone characterized by prominent vertical jointing (O'Connor, 1960).
- Thickness About 2 ft in Douglas Co. (O'Connor, 1960).
- Ecological Classification Leavenworth Type (*Isogramma*) assemblage (Moore, 1966).
- Environment of Deposition Marine (Johnson & Adkison, 1967).  
Environment of deposition same or similar to that of Leavenworth Limestone (Moore, 1966).

##### Larsh-Burroak Shale Member

- 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 ft; commonly about 3 ft in Douglas Co. (O'Connor, 1960).
- Ecological Classification Heebner Type (*Listracanthus*) assemblage (Moore, 1966).
- Environment of Deposition Lower part reducing marine; upper part normal marine (Johnson & Adkison, 1967).  
Same or similar to that of the Heebner Shale (Moore, 1966).  
Probably postulated depositional environment of the Bennett Shale (McCrone, 1963) is similar.

##### Ervine Creek Limestone Member

- Megascopic Lower 10 to 14 ft consists of light gray to white, hard, thin, wavy-bedded limestone containing some shale partings; upper part is approximately 4 ft thick, is shalier and may consist of a dark gray shale bed followed by a coquinoid limestone (O'Connor, 1960).
- Thickness 13 to 17 ft; averaging about 15 ft in Douglas Co. (O'Connor, 1960).
- Ecological Classification Beil Type (*Pulchratia*) assemblage (Moore, 1966).
- Transgressive-Regressive Sea Classification Environment belongs in the culminating marine part of the cyclothem (Moore, 1966).

Environment of Deposition Normal marine (Johnson & Adkison, 1967). Clear, sunlit shallow waters (estimated less than 20 m on the average) far from the nearest shores (probably 50-100 mi distant) (Moore, 1966).

Unless indicated otherwise all following information in Appendix B is taken from Johnson & 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 ft.

Environment of Deposition Lower Calhoun was estuarine or very shallow nearshore marine (Yochelson, in Johnson & Adkison, 1967); middle Calhoun was continental. The upper Calhoun was swamp followed by local marine conditions.

**TOPEKA LIMESTONE**

**Hartford Limestone Member**

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 ft 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 Member**

Megascopic Light to dark gray, clayey to sandy siltstone; light to olive-gray, silty, laminated to platy claystone.

Thickness 0.1 to 1.5 ft but averaging about 1 ft in eastern Shawnee Co.

Environment of Deposition Mostly marine but estuarine conditions may have existed locally.

**Curzon Limestone Member**

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 ft but averaging 8.5 ft in Shawnee Co.

Environment of Deposition Probably similar to the environment of deposition of the Hartford Limestone.

**Jones Point Shale Member**

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 ft in Shawnee Co.

Environment of Deposition Local brachiopods and pelecypods suggest marine deposition for those parts; depositional environment for unfossiliferous parts unknown.

**Sheldon Limestone Member**

Megascopic Light to medium gray, finely crystalline, thin-bedded, hard, compact limestone; argillaceous.

Thickness 1.2 to 3.5 ft but averaging slightly less than 2 ft in Shawnee Co.

Environment of Deposition Relatively shallow marine and probably clear rather than turbid.

**Turner Creek Shale Member**

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 ft 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 Member**

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 ft in Shawnee Co.

Environment of Deposition Marine.

**Holt Shale Member**

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 ft 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 Limestone Member**

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 ft 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 (FIG. 11-14)**

SAMPLE NUMBERS OF COMPOSITE SAMPLES	FIELD SAMPLE CODES (barren samples omitted <sup>1</sup> )
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
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

<sup>1</sup> 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.

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 (FIG. 15-18)**

<i>Streptognathodus elegantulus</i> Stauffer & Plummer, Sp element	1
<i>Streptognathodus</i> sp. A, Sp element	2
<i>Streptognathodus</i> sp. aff. <i>S. elegantulus</i>	
Stauffer & Plummer, Sp element	3
<i>Streptognathodus gracilis</i> Stauffer & Plummer, Sp element	4
<i>Streptognathodus gracilis</i> Stauffer & Plummer?, Sp element	5
<i>Streptognathodus excelsus</i> Stauffer & Plummer, Sp element	6
<i>Streptognathodus oppletus</i> Ellison, Sp element	7
<i>Streptognathodus wabaunsensis</i> Gunnell, Sp element	8
<i>Streptognathodus simulator</i> Ellison, Sp element	9
<i>Streptognathodus eccentricus</i> Ellison, Sp element	10
<i>Streptognathodus?</i> sp.	11
<i>Idiognathodus magnificus</i> Stauffer & Plummer, Sp element	12
<i>Idiognathodus delicatus</i> Gunnell, Sp element	13
<i>Idiognathodus antiquus</i> Stauffer & Plummer, Sp element	14
<i>Idiognathodus tersus</i> Ellison, Sp element	15
<i>Cavusgnathus lautus</i> Gunnell, Sp element	16
<i>Cavusgnathus flexus</i> Ellison, Sp element	17
<i>Cavusgnathus merrilli</i> von Bitter, n. sp.	18
<i>Gondolella denuda</i> Ellison, Sp element	19
<i>Anchignathodus minutus</i> (Ellison)	20
<i>Anchignathodus edentulus</i> von Bitter, n. sp.	21
<i>Anchignathodus moorei</i> von Bitter, n. sp.	22
<i>Anchignathodus</i> sp. aff. <i>A. campbelli</i> (Rexroad)	23
<i>Streptognathodus</i> and <i>Idiognathodus</i> Oz element	24
<i>Ozarkodina</i> sp. A	25
<i>Cavusgnathus</i> Oz element	26
<i>Gondolella denuda</i> Ellison, Oz element	27
<i>Gondolella denuda</i> Ellison, Hi? element	28
<i>Ozarkodina? curvata</i> Rexroad	29
<i>Ozarkodina? kansansensis</i> von Bitter, n. sp.	30
<i>Ozarkodina? sp. aff. O.? kansansensis</i> von Bitter, n. sp.	31
<i>Streptognathodus</i> and <i>Idiognathodus</i> Ne element	32
<i>Synprioniodina</i> sp. A	33

<i>Synprioniodina</i> sp. B .....	34	<i>Delotaxis? conflexa</i> (Ellison), Tr element .....	53
<i>Ellisonia teichertii</i> Sweet?, Pl element .....	35	<i>Cavusgnathus</i> Tr element .....	54
Unidentified Pl element .....	36	<i>Streptognathodus</i> and <i>Idiognathodus</i> Tr element .....	55
<i>Hindeodella parva</i> Ellison .....	37	Unidentifiable Tr element, type B .....	56
<i>Ellisonia teichertii</i> Sweet?, Hi element .....	38	<i>Delotaxis? conflexa</i> (Ellison), Hi element .....	57
<i>Hindeodella</i> sp. B .....	39	<i>Ligonodina lexingtonensis</i> (Gunnell) .....	58
<i>Streptognathodus</i> and <i>Idiognathodus</i> Hi element .....	40	<i>Neopriodontus conjunctus</i> (Gunnell), Hi element .....	59
<i>Cavusgnathus</i> Hi element .....	41	<i>Cavusgnathus</i> Ne element .....	60
<i>Lonchodus simplex</i> (Pander) .....	42	<i>Neopriodontus conjunctus</i> (Gunnell), Ne element .....	61
Unidentified Tr element, type A .....	43	Unidentified Ne element .....	62
Unidentified Tr element, type B .....	44	<i>Ellisonia teichertii</i> Sweet?, Ne element .....	63
Unidentified Tr element, type C .....	45	<i>Lonchodus?</i> sp. ....	64
Unidentifiable Tr element, type A .....	46	<i>Delotaxis? conflexa</i> (Ellison), Pl? element .....	65
<i>Hindeodus</i> sp. A .....	47	<i>Neopriodontus conjunctus</i> (Gunnell), Pl element .....	66
<i>Ellisonia teichertii</i> Sweet?, Tr element .....	48	<i>Lonchodina? ponderosa</i> Ellison .....	67
<i>Lonchodina</i> sp. A .....	49	<i>Delotaxis? conflexa</i> (Ellison), Oz? element .....	68
<i>Lonchodina douglasensis</i> von Bitter, n. sp. ....	50	<i>Delotaxis? conflexa</i> (Ellison), Ne? element .....	69
<i>Lonchodina</i> sp. B .....	51	<i>Metalonchodina?</i> sp. ....	70
<i>Neopriodontus conjunctus</i> (Gunnell), Tr element .....	52		

APPENDIX D

SUMMARIZED ABUNDANCE COUNTS<sup>1</sup>

	OREAD LIMESTONE <sup>2</sup>	LECOMPTON LIMESTONE <sup>3</sup>	DEER CREEK LIMESTONE <sup>4</sup>	TOPEKA LIMESTONE <sup>5</sup>	TOTAL OF EACH ELEMENT
<i>Streptognathodus elegantulus</i> , Sp element .....	2,058	3,296	2,082	7,437	14,873
<i>Streptognathodus</i> sp. A, Sp element .....	....	14	....	....	14
<i>Streptognathodus</i> sp. aff. <i>S. elegantulus</i> , Sp element .....	13	....	....	1	14
<i>Streptognathodus gracilis</i> , Sp element .....	5	5	33	16	59
<i>Streptognathodus gracilis?</i> , Sp element .....	1	....	7	4	12
<i>Streptognathodus excelsus</i> , Sp element .....	4	1	14	2	21
<i>Streptognathodus oppletus</i> , Sp element .....	30	75	1	....	106
<i>Streptognathodus wabaunsensis</i> , Sp element .....	18	24	....	....	42
<i>Streptognathodus simulator</i> , Sp element .....	598	....	....	....	598
<i>Streptognathodus eccentricus</i> , Sp element .....	38	....	....	....	38
<i>Streptognathodus</i> spp. ....	529	288	258	628	1,703
<i>Streptognathodus?</i> sp. ....	1	....	....	....	1
<i>Idiognathodus magnificus</i> , Sp element .....	39	....	....	....	39
<i>Idiognathodus delicatus</i> , Sp element .....	....	1	....	....	1
<i>Idiognathodus antiquus</i> , Sp element .....	33	197	....	....	230
<i>Idiognathodus tersus</i> , Sp element .....	120	245	....	....	365
<i>Idiognathodus</i> spp. ....	28	9	....	....	37
<i>Cavusgnathus lautus</i> , Sp element .....	481	266	56	1,716	2,519
<i>Cavusgnathus flexus</i> , Sp element .....	7	12	3	32	54
<i>Cavusgnathus</i> spp. ....	419	100	11	903	1,433
<i>Cavusgnathus merrilli</i> , n. sp. ....	3	26	88	38	155
<i>Gondolella denuda</i> , Sp element .....	....	23	....	....	23
<i>Anchignathodus minutus</i> .....	564	207	54	498	1,323
<i>Anchignathodus edentulus</i> , n. sp. ....	6	14	....	....	20
<i>Anchignathodus moorei</i> , n. sp. ....	59	68	173	56	356
<i>Anchignathodus</i> sp. aff. <i>A. campbelli</i> .....	....	....	1	....	1
<i>Anchignathodus</i> spp. ....	5	5	7	19	36
<i>Streptognathodus</i> and <i>Idiognathodus</i> Oz element .....	353	324	250	399	1,326
<i>Ozarkodina</i> sp. A .....	....	2	....	1	3
<i>Cavusgnathus</i> Oz element .....	13	16	6	144	179
Unidentifiable Oz element .....	128	51	36	198	413

<i>Gondolella denuda</i> , Oz element .....	....	12	....	....	12
<i>Gondolella denuda</i> , Hi? element .....	....	6	....	....	6
<i>Ozarkodina? curvata</i> .....	147	28	10	97	282
<i>Ozarkodina? kansasensis</i> , n. sp. ....	33	2	....	....	35
<i>Ozarkodina?</i> sp. aff. <i>O.? kansasensis</i> , n. sp. ....	2	....	....	....	2
<i>Ozarkodina?</i> spp. ....	8	4	....	....	12
<i>Streptognathodus</i> and <i>Idiognathodus</i> Ne element .....	86	77	50	166	379
<i>Synprioniodina</i> sp. A .....	1	....	6	1	8
Unidentifiable Ne element .....	1	2	....	1	4
<i>Synprioniodina</i> sp. B .....	....	1	....	....	1
<i>Ellisonia teichertii?</i> , Pl element .....	64	27	10	39	140
Unidentified Pl element .....	2	....	5	....	7
<i>Hindeodella parva</i> .....	33	8	15	15	71
<i>Ellisonia teichertii?</i> , Hi element .....	125	43	20	90	278
<i>Hindeodella</i> sp. B .....	6	1	....	....	7
<i>Streptognathodus</i> and <i>Idiognathodus</i> Hi element .....	131	67	50	82	330
<i>Cavusgnathus</i> Hi element .....	2	7	2	31	42
Unidentifiable Hi element .....	53	62	31	60	206
<i>Lonchodus simplex</i> .....	C*	....	....	R**	....
Unidentified Tr element, type A .....	1	....	....	....	1
Unidentified Tr element, type B .....	9	....	....	....	9
Unidentified Tr element, type C .....	14	....	....	....	14
Unidentifiable Tr element, type A .....	6	4	....	....	10
<i>Hindeodus</i> sp. A .....	11	1	2	1	15
<i>Ellisonia teichertii?</i> , Tr element .....	7	2	2	6	17
<i>Lonchodina</i> sp. A .....	13	1	....	....	14
<i>Lonchodina douglasensis</i> , n. sp. ....	21	1	....	....	22
<i>Lonchodina</i> sp. B .....	7	6	....	....	13
<i>Neoproniodus conjunctus</i> , Tr element .....	33	....	....	....	33
<i>Delotaxis? conflexa</i> , Tr element .....	5	5	5	5	20
<i>Cavusgnathus</i> Tr element .....	2	3	....	7	12
<i>Streptognathodus</i> and <i>Idiognathodus</i> Tr element .....	15	9	9	23	56
Unidentifiable Tr element, type B .....	36	26	7	21	90
<i>Delotaxis? conflexa</i> , Hi element .....	21	10	9	13	53
<i>Ligonodina lexingtonensis</i> .....	28	....	....	....	28
<i>Neoproniodus conjunctus</i> , Hi element .....	54	....	1	1	56
<i>Cavusgnathus</i> Ne element .....	16	10	3	62	91
<i>Neoproniodus conjunctus</i> , Ne element .....	45	....	....	....	45
Unidentified Ne element .....	....	....	18	3	21
? <i>Ellisonia teichertii</i> , Ne element .....	90	39	6	96	231
<i>Lonchodus?</i> sp. ....	1	....	....	....	1
<i>Delotaxis? conflexa</i> , Pl ? element .....	4	4	6	4	18
<i>Neoproniodus conjunctus</i> , Pl element .....	33	....	....	....	33
<i>Lonchodina? ponderosa</i> .....	25	....	....	....	25
<i>Delotaxis? conflexa</i> , Oz ? element .....	6	1	1	1	9
<i>Delotaxis? conflexa</i> , Ne ? element .....	2	1	1	1	5
<i>Metalonchodina?</i> sp. ....	....	....	....	3	3
Genus and species indeterminate .....	232	17	2	14	265
	6,984	5,756	3,351	12,935	29,026

<sup>1</sup> Detailed charts of abundance counts are on file in Department of Geology, University of Kansas, and copies may be obtained on request, on a cost basis.

<sup>2</sup> Includes the conodont counts of the samples from the uppermost Lawrence Shale and the lowermost Kanwaka Shale.

<sup>3</sup> Includes the conodont counts of the sample from the uppermost Kanwaka Shale.

<sup>4</sup> Includes the conodont counts of the samples from the uppermost Tecumseh Shale.

<sup>5</sup> Includes the conodont counts of the samples from the uppermost Calhoun Shale and the lowermost Severy Shale.

\* C = common.

\*\* R = rare.

## EXPLANATION OF PLATES

## PLATE 1

## FIGURE

1. *Streptognathodus elegantulus* STAUFFER & 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 shortening of the carina with maturity.—1a. UKMIP 1,900,901, sample LB-1-1,  $\times 254$ .—1b. UKMIP 1,900,902, sample LB-1-3A,  $\times 136$ .—1c. UKMIP 1,900,903, sample LB-1-3A,  $\times 86$ .—1d. UKMIP 1,900,904, sample LB-1-3A,  $\times 67$ .—1e. UKMIP 1,900,905, sample LB-1-1,  $\times 64$ .
2. *Streptognathodus* sp. A, Sp element; all specimens from the Spring Branch Limestone.—2a,b. Oral views of dextral element, UKMIP 1,900,906, sample SB-1-1C,  $\times 50$  and  $\times 61$ , respectively.—2c. Oral view of sinistral element, UKMIP 1,900,907, sample SB-1-1C,  $\times 43$ .—2d. Oral view of dextral element showing radiating transverse ridges at anterior end of platform, UKMIP 1,900,908, sample SB-1-3,  $\times 42$ .—2e. Inner lateral view of blade denticles showing striations, UKMIP 1,900,906, sample SB-1-1C,  $\times 290$ .
3. *Streptognathodus* sp. aff. *S. elegantulus* STAUFFER & PLUMMER, Sp element from Plattsmouth Limestone.—3a. Oral view; UKMIP 1,900,909, sample P-1-4,  $\times 82$ .—3b. Lateral view; UKMIP 1,900,909,  $\times 76$ .

## PLATE 2

## FIGURE

1. *Streptognathodus gracilis* STAUFFER & PLUMMER, Sp element; both specimens from Larsh-Burroak Shale.—1a. Oral view of sinistral element showing inner accessory lobe, UKMIP 1,900,910, sample LB-1-3B,  $\times 123$ .—1b. Oral view of dextral element showing inner accessory lobe, UKMIP 1,900,911, sample LB-1-1,  $\times 53$ .
2. *Streptognathodus excelsus* STAUFFER & PLUMMER, Sp element; all specimens from the Larsh-Burroak Shale.—2a. Oral view of sinistral element showing two accessory lobes, UKMIP 1,900,912, sample LB-1-3B,  $\times 37$ .—Oral view of dextral element showing two accessory lobes, UKMIP 1,900,913, sample LB-1-1,  $\times 50$ .—2c. Posterior portion of UKMIP 1,900,913,  $\times 984$ .
3. *Streptognathodus?* sp. from Heebner Shale. Posterior oral view showing eccentrically located blade, UKMIP 1,900,914, sample He-1-4A,  $\times 38$ .
4. *Streptognathodus gracilis* STAUFFER & PLUMMER?, from Heebner Shale (4a-c) and Larsh-Burroak Shale (4d).—4a. Outer accessory lobe, UKMIP 1,900,915,  $\times 1,024$ .—4b. Oral view of anterior part of platform showing outer accessory lobe, UKMIP 1,900,915,  $\times 101$ .—4c. Oral view of sinistral element, UKMIP 1,900,915,  $\times 37$ .—4d. Oral view of dextral element showing outer accessory lobe, UKMIP 1,900,916, sample LB-1-3D,  $\times 40$ .
5. *Streptognathodus oppletus* ELLISON, Sp element, from Plattsmouth Limestone (5a) and Queen Hill Shale (5b,c). 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.—5a. Sinistral element UKMIP 1,900,917, sample P-1-6,  $\times 67$ .—5b. Dextral element UKMIP 1,900,918, sample QH-1-2,  $\times 82$ .—5c. Ele-

ment showing frill (i.e., orally and laterally flaring parapet), UKMIP 1,900,919, sample QH-1-2,  $\times 153$ .

6. *Streptognathodus wabaunsensis* GUNNELL, Sp element, from Kereford Limestone (6a) and Spring Branch Limestone (6b,c). Oral views of ontogenetic growth series from largest to smallest showing discontinuous transverse ridges, the poorly defined oral groove, and the inner accessory lobe.—6a. Dextral element, UKMIP 1,900,920, sample Ke-1-6,  $\times 61$ .—6b. Dextral element UKMIP 1,900,921, sample SB-1-1C,  $\times 86$ .—6c. Sinistral element UKMIP 1,900,922, sample SB-1-1B,  $\times 105$ .

## PLATE 3

## FIGURE

1. *Streptognathodus eccentricus* ELLISON, Sp element; all specimens from the Heebner Shale.—1a. Sinistral element UKMIP 1,900,923, sample He-1-4A,  $\times 40$ .—1b. Sinistral element UKMIP 1,900,924, sample He-1-3A,  $\times 31$ .—1c. Sinistral element UKMIP 1,900,925, sample He-1-4A,  $\times 40$ .—1d. Dextral element UKMIP 1,900,926, sample He-1-4A,  $\times 74$ .
2. *Streptognathodus simulator* ELLISON, Sp element; all specimens from Heebner Shale. Oral views of ontogenetic growth series arranged from largest to smallest element showing eccentrically located oral groove and one accessory lobe on inner side (absent in smallest element).—2a. Sinistral element UKMIP 1,900,927, sample He-1-1,  $\times 53$ .—2b. Sinistral element UKMIP 1,900,928, sample He-1-3A,  $\times 69$ .—2c. Immature element lacking accessory lobe, UKMIP 1,900,929, sample He-1-3A,  $\times 79$ .—2d. Oral view of dextral element showing some complete transverse ridges making it transitional with *Idiognathodus*, UKMIP 1,900,930, sample He-1-3A,  $\times 79$ .—2e. Element broken parallel to oral groove UKMIP 1,900,931, sample He-1-3A,  $\times 43$ .
3. *Idiognathodus magnificus* STAUFFER & PLUMMER, Sp element; all specimens from Heebner Shale. Oral views of ontogenetic growth series from largest to smallest element.—3a. Mature dextral element showing two accessory lobes, UKMIP 1,900,932, sample He-1-2B,  $\times 46$ .—3b. Mature dextral element with outer accessory lobe poorly developed, UKMIP 1,900,933, sample He-1-3D,  $\times 34$ .—3c. Immature dextral element with poor outer accessory lobe development, UKMIP 1,900,934, sample He-1-3B,  $\times 59$ .—3d. Immature dextral element with well-developed inner accessory lobe, UKMIP 1,900,935, sample He-1-3B,  $\times 77$ .—3e. 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,  $\times 60$ .
4. *Idiognathodus delicatus* GUNNELL, Sp element, from Queen Hill Shale. Sinistral element, oral view showing two accessory lobes set off from the platform, UKMIP 1,900,937, sample QH-1-2,  $\times 114$ .

## PLATE 4

## FIGURE

1. *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 posteriorly against transverse ridges, and lack of both an accessory lobe and a

trough.—1a. Mature sinistral element, UKMIP 1,900,938, sample SB-1-1C (Spring Branch Limestone),  $\times 64$ .—1b. Immature dextral element, UKMIP 1,900,939, sample QH-1-2 (Queen Hill Shale),  $\times 76$ .—1c. Immature element, UKMIP 1,900,940, sample QH-1-2 (Queen Hill Shale),  $\times 118$ .—1d. Immature dextral element, UKMIP 1,900,941, sample QH-1-2 (Queen Hill Shale),  $\times 103$ .

2. *Idiognathodus antiquus* STAUFFER & PLUMMER, Sp element; all specimens from Spring Branch Limestone. Oral views of ontogenetic growth series arranged from largest to smallest element showing complete transverse ridges and an inner accessory lobe.—2a. Mature dextral element, UKMIP 1,900,942, sample SB-1-1C,  $\times 52$ .—2b. Mature sinistral element, UKMIP 1,900,943, sample SB-1-1B,  $\times 86$ .—2c. Magnified view of platform of UKMIP 1,900,943,  $\times 174$ .—2d. Immature sinistral element, UKMIP 1,900,944, sample SB-1-1C,  $\times 88$ .—2e. Immature sinistral specimen, UKMIP 1,900,945, sample SB-1-1C,  $\times 102$ .
3. *Cavusgnathus lautus* GUNNELL, sinistral Sp element; specimens from the Du Bois Limestone (3a-e) and from the Oskaloosa Shale (3f-h). Inner lateral views of ontogenetic growth series of sinistral element (3a-e); note variation in blade denticulation and development of a fixed blade and a longer inner parapet with increase in size.—3a. UKMIP 1,900,946, sample DB-1-1B,  $\times 86$ .—3b. UKMIP 1,900,947, sample DB-1-1B,  $\times 115$ .—3c. UKMIP 1,900,948, sample on DB-1-1B,  $\times 123$ .—3d. UKMIP 1,900,949, sample DB-1-1B,  $\times 123$ .—3e. UKMIP 1,900,950, sample DB-1-1B,  $\times 189$ .—3f. Oral view of sinistral element, UKMIP 1,900,951, sample Os-1-3,  $\times 60$ .—3g. Outer lateral view of blade denticle of sinistral element, UKMIP 1,900,952, sample Os-1-3,  $\times 1980$ .—3h. Outer lateral view of sinistral element, UKMIP 1,900,952,  $\times 89$ .

## PLATE 5

## FIGURE

1. *Cavusgnathus lautus* GUNNELL, dextral Sp element. Elements illustrated are from the Jones Point Shale (1a-b), the Du Bois Limestone (1c-g), and the Oskaloosa Shale (1h).—1a-g. Inner lateral views of dextral elements arranged in an ontogenetic series from largest to smallest elements. Note development of the main cusp, the fixed blade, and the inner parapet with an increase in size; 1a, UKMIP 1,900,953, sample JPS-1-1,  $\times 52$ ; 1b, UKMIP 1,900,954, sample JPS-1-1,  $\times 63$ ; 1c, UKMIP 1,900,955, sample DB-1-1B,  $\times 71$ ; 1d, UKMIP 1,900,956, sample DB-1-1B,  $\times 81$ ; 1e, UKMIP 1,900,957, sample DB-1-1B,  $\times 90$ ; 1f, UKMIP 1,900,958, sample DB-1-1B,  $\times 156$ ; 1g, UKMIP 1,900,959, sample DB-1-1B,  $\times 236$ .—1h. Oral view of dextral element, UKMIP 1,900,960, sample Os-1-3,  $\times 57$ .
2. *Cavusgnathus flexus* ELLISON, Sp element, from Larsh-Burroak Shale (2a) and Oskaloosa Shale (2b).—2a. Oral view of sinistral element, UKMIP 1,900,961, sample LB-1-3D,  $\times 121$ .—2b. Oral view of dextral element, UKMIP 1,900,962, sample Os-1-3,  $\times 92$ .
3. *Cavusgnathus merrilli* VON BITTER, n. sp.; all specimens from Larsh-Burroak Shale.—3a. Oral view of immature dextral element showing low, nearly parallel parapets and nearly central blade, holotype UKMIP 1,900,963, sample LB-1-3A,  $\times 98$ .—3b. 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,  $\times 65$ .—3c. Aboral view of paratype UKMIP 1,900,964,  $\times 108$ .—

3d. Inner lateral view of dextral element, paratype UKMIP 1,900,965, sample LB-1-1,  $\times 75$ .—3e. Magnified view of outer transverse ridges showing microstructure, UKMIP 1,900,966, sample LB-1-1,  $\times 1,045$ .—3f. Outer lateral view of blade denticle, paratype UKMIP 1,900,965,  $\times 741$ .

## PLATE 6

## FIGURE

1. *Gondolella denuda* ELLISON, Sp element; all specimens from sample QH-1-2 from the Queen Hill Shale. Figures 1a, 1c, and 1e show an ontogenetic growth series from largest to smallest element.—1a. Lateral view, UKMIP 1,900,967,  $\times 48$ .—1b. Aboral lateral view, UKMIP 1,900,967,  $\times 75$ .—1c. Lateral view of dextral? element, UKMIP 1,900,968,  $\times 68$ .—1d. Oral view of dextral? element, UKMIP 1,900,968,  $\times 100$ .—1e. Lateral view, UKMIP 1,900,969,  $\times 78$ .—1f. Oral view, UKMIP 1,900,969,  $\times 115$ .
2. *Anchignathodus minutus* (ELLISON). Specimen figured in 2a from the Heebner Shale; remainder from the Plattsmouth Limestone; 2a-f show lateral views of ontogenetic growth series from largest to smallest elements; note elongation and increase in number of denticles with increase in size as well as rounding and coalescing of denticles in mature individuals.—2a. Large mature element, UKMIP 1,900,970, sample He-1-4B,  $\times 41$ .—2b. Mature element, UKMIP 1,900,971, sample P-1-7,  $\times 86$ .—2c. Mature element, UKMIP 1,900,972, sample P-1-5,  $\times 138$ .—2d. Immature element showing striations on denticles, UKMIP 1,900,973, sample P-1-5,  $\times 227$ .—2e. Immature element, UKMIP 1,900,974, sample P-1-5,  $\times 317$ .—2f. Immature element, UKMIP 1,900,975, sample P-1-5,  $\times 370$ .—2g. Detail of main cusp of UKMIP 1,900,971,  $\times 919$ .—2h. Sinistral element, UKMIP 1,900,976, sample P-1-7,  $\times 16$ .—2i. Dextral element, UKMIP 1,900,977, sample P-1-7,  $\times 114$ .

## PLATE 7

## FIGURE

1. *Anchignathodus edentulus* VON BITTER, n. sp., from Spring Branch Limestone (1a) and Plattsmouth Limestone (1b).—1a. 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,  $\times 267$ .—1b. 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,  $\times 97$ .
2. *Anchignathodus* sp. cf. *A. campbelli* (REXROAD), from Ervine Creek Limestone. Lateral view, UKMIP 1,900,980, sample EC-1-1,  $\times 116$ .
3. *Anchignathodus moorei* VON BITTER, n. sp., from Larsh-Burroak Shale (3a-d), Kereford Limestone (3e), and Ervine Creek Limestone (3f).—3a. Lateral view showing characteristic irregular denticulation and large posteriorly extending basal cavity, holotype UKMIP 1,900,981, sample LB-1-1,  $\times 289$ .—3b. Lateral view showing variation in denticulation, paratype UKMIP 1,900,982, sample LB-1-1,  $\times 160$ .—3c. Lateral view showing variation in denticulation, paratype UKMIP 1,900,983, sample LB-1-1,  $\times 158$ .—3d. Magnified view of the two largest denticles of paratype UKMIP 1,900,983,  $\times 1192$ .—3e. Aboral view, paratype UKMIP 1,900,984, sample Kc-1-6,  $\times 154$ .—3f. Oral view of sinistral? element, paratype UKMIP 1,900,985, sample EC-1-1J,  $\times 217$ .

4. *Idiognathodus* and *Streptognathodus* Oz element, from Plattsmouth Limestone (4a,d) and Larsh-Burroak Shale (4b,c,e-h). Figures 4a-f show lateral views of ontogenetic growth series from largest to smallest element. Note increase in number of denticles with size.—4a. UKMIP 1,900,986, sample P-1-3,  $\times 40$ .—4b. UKMIP 1,900,987, sample LB-1-1,  $\times 49$ .—4c. UKMIP 1,900,988, sample LB-1-1,  $\times 62$ .—4d. UKMIP 1,900,989, sample P-1-3,  $\times 69$ .—4e. UKMIP 1,900,990, sample LB-1-1,  $\times 80$ .—4f. UKMIP 1,900,991, sample LB-1-1,  $\times 100$ .—4g. Aboral view of UKMIP 1,900,987,  $\times 90$ .—4h. Magnified view of anterior part of main cusp, UKMIP 1,900,991,  $\times 1,968$ .

PLATE 8

FIGURE

- Cavusgnathus laetus* GUNNELL, Oz element, from Oskaloosa Shale (1a,b,c), Jones Point Shale (1c), and Turner Creek Shale (1d).—1a. Lateral view of mature element in which most of the posterior blade is missing, UKMIP 1,900,992, sample Os-1-3,  $\times 91$ .—1b. Magnified view of first denticle posterior to main cusp of UKMIP 1,900,992,  $\times 1324$ .—1c. Lateral view of immature element UKMIP 1,900,993, sample JPS-1-2C,  $\times 83$ .—1d. Lateral view of immature element showing relatively straight aboral margin, short anterior and long posterior blade, UKMIP 1,900,994, sample TCS-1-3,  $\times 97$ .—1e. Aboral view, UKMIP 1,900,995, sample Os-1-3,  $\times 205$ .
- Ozarkodina* sp. A, from Beil Limestone.—2a. Lateral view, UKMIP 1,900,996, sample B-1-6,  $\times 77$ .—2b. Magnified view of part of main cusp, UKMIP 1,900,996,  $\times 697$ .
- Gondolella denuda* ELLISON, Oz element, from Queen Hill Shale.—3a. Aboral view of dextral specimen showing basal cavity expanded on outer side; short posterior blade is broken off. UKMIP 1,900,997, sample QH-1-2,  $\times 176$ .—3b. Outer lateral view of dextral specimen UKMIP 1,900,997,  $\times 84$ .
- Gondolella denuda* ELLISON, Hi ? element, from Queen Hill Shale.—4a. Aboral view, UKMIP 1,900,998, sample QH-1-2,  $\times 190$ .—4b. Inner lateral view, UKMIP 1,900,998,  $\times 132$ .
- Ozarkodina? curvata* REXROAD, from the Plattsmouth Limestone (5a-d,f) and Ervine Creek Limestone (5e); 5a-b,d-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.—5a. Mature dextral element, UKMIP 1,900,999, sample P-1-4,  $\times 54$ .—5b. Mature sinistral element, UKMIP 1,901,000, sample P-1-1,  $\times 71$ .—5c. Aboral lateral view of basal cavity and aboral groove, UKMIP 1,901,000,  $\times 476$ .—5d. Immature sinistral element, UKMIP 1,901,001, sample P-1-5,  $\times 84$ .—5e. Immature sinistral element, UKMIP 1,901,002, sample EC-1-1J,  $\times 125$ .—5f. Immature sinistral element, UKMIP 1,901,003, sample P-1-6,  $\times 153$ .

PLATE 9

FIGURE

- Ozarkodina?* sp. aff. *O. ? kansasensis* VON BITTER, n. sp. (1a) and *Ozarkodina? kansasensis* VON BITTER, n. sp. (1b-c), from Plattsmouth Limestone.—1a. Inner lateral view of mature dextral element, UKMIP 1,901,004, sample P-1-1,  $\times 71$ .—1b-e. 1b,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; 1b, mature dextral element, holotype UKMIP

- 1,901,005, sample P-1-7,  $\times 98$ ; 1c, magnified view of main cusp and first posterior bar denticle, holotype UKMIP 1,901,005,  $\times 488$ ; 1d, immature sinistral element, paratype UKMIP 1,901,006, sample P-1-5,  $\times 139$ ; 1e, immature sinistral element, paratype UKMIP 1,901,007, sample P-1-7,  $\times 191$ .
- Streptognathodus* and *Idiognathodus* Ne element, from Ervine Creek Limestone (2a) and Plattsmouth Limestone (2b).—2a. Inner lateral view of sinistral? element, UKMIP 1,901,008, sample EC-1-1D,  $\times 73$ .—2b. Inner lateral view of dextral? element, UKMIP 1,901,009, sample P-1-6,  $\times 73$ .
- Synprioniodina* sp. B from Spring Branch Limestone. Inner lateral view of sinistral? element showing anterior deflection of the long anterior bar, UKMIP 1,901,010, sample SB-1-2B,  $\times 115$ .
- Synprioniodina* sp. A, specimens from Larsh-Burroak Shale.—4a. Dextral? element, showing strong elongated anterior bar; posterior bar partially broken, UKMIP 1,901,011, sample LB-1-1,  $\times 120$ .—4b. Sinistral? element, showing strong, elongated anterior bar; posterior bar is missing, UKMIP 1,901,012, sample LB-1-1,  $\times 136$ .
- Cavusgnathus* Ne element, specimens from Heumader Shale (5a) and Curzon Limestone (5b).—5a. Inner lateral view of sinistral specimen, UKMIP 1,901,013, sample Heu-1-2,  $\times 104$ .—5b. Inner lateral view of dextral specimen, UKMIP 1,901,014, sample Cur-1-4,  $\times 163$ .
- Neoprioniodus conjunctus* (GUNNELL), Ne element, from Plattsmouth Limestone.—6a. Outer lateral view of dextral specimen, UKMIP 1,901,015, sample P-1-4,  $\times 56$ .—6b. Inner lateral view of UKMIP 1,901,015,  $\times 46$ .
- Unidentified Ne element, specimens from Larsh-Burroak Shale.—7a. Inner lateral view of sinistral specimen, UKMIP 1,901,016, sample LB-1-3A,  $\times 111$ .—7b. Outer lateral view of dextral specimen, UKMIP 1,901,017, sample LB-1-3A,  $\times 110$ .

PLATE 10

FIGURE

- Ellisonia teichertii* SWEET?, Ne element; all specimens from the Plattsmouth Limestone, Oread Limestone.—1a. Inner lateral view of a sinistral element, UKMIP 1,901,018, sample P-1-1,  $\times 106$ .—1b. Inner lateral view of a dextral element, UKMIP 1,901,019, sample P-1-5,  $\times 86$ .—1c. Inner lateral view of sinistral element showing recurving main cusp, UKMIP 1,901,018,  $\times 121$ .—1d. Aboral lateral view of dextral element showing basal cavity, UKMIP 1,901,020, sample P-1-5,  $\times 213$ .
- Ellisonia teichertii* SWEET?, Pl element, from Ervine Creek Limestone (2a,e), Plattsmouth Limestone (2b,c,f), and Larsh-Burroak Shale (2d).—2a. Inner lateral view of mature dextral element showing long anterior and short posterior bar, UKMIP 1,901,021, sample EC-1-1B,  $\times 90$ .—2b. Inner lateral view of immature dextral element, UKMIP 1,901,022, sample P-1-3,  $\times 126$ .—2c. Inner lateral view of sinistral element, a variant, showing an aboral hooklike extension at end of anterior bar, UKMIP 1,901,023, sample P-1-6,  $\times 137$ .—2d. Inner lateral view of posterior bar of a stout sinistral element, UKMIP 1,901,024, sample LB-1-3E,  $\times 84$ .—2e. 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,  $\times 112$ .—2f. Inner lateral view of posterior bar of a sinistral element showing variation in the orientation and number of the distal denticles, UKMIP 1,901,026, sample P-1-6,  $\times 96$ .

3. Unidentified Pl element, specimens from Heebner Shale (3a,c) and Ervine Creek Limestone (3b).—3a. Lateral view of main cusp and posterior bar, UKMIP 1,901,027, sample He-1-4A,  $\times 67$ .—3b. Lateral view of main cusp and anterior bar, UKMIP 1,901,028, sample EC-1-1L,  $\times 90$ .—3c. Aboral view, UKMIP 1,901,027,  $\times 142$ .
4. *Streptognathodus* and *Idiognathodus* Hi element, specimens from Larsh-Burrok Shale (4a,c,d) and Toronto Limestone (4b).—4a. Inner lateral view of an incomplete sinistral element showing swelling of central part of posterior bar, UKMIP 1,901,029, sample LB-1-3A,  $\times 132$ .—4b. Inner lateral view of incomplete dextral element showing swelling of central part of posterior bar, UKMIP 1,901,030, sample T-1-5B,  $\times 109$ .—4c,d. Aboral views of incomplete element showing swelling of posterior bar, UKMIP 1,901,031, sample LB-1-1,  $\times 118$  and  $\times 251$ , respectively.

## PLATE 11

## FIGURE

1. *Ellisonia teichertii* SWEET?, Hi element, from Plattsouth Limestone (1a,b) and Leavenworth Limestone (1c-e).—1a. Inner lateral view of a mature sinistral element, UKMIP 1,901,032, sample P-1-6,  $\times 119$ .—1b. Inner lateral view of anterior cusp, UKMIP 1,901,032,  $\times 83$ .—1c. Inner lateral view of immature sinistral element, UKMIP 1,901,033, sample L-1-1,  $\times 201$ .—1d. Inner lateral view of mature dextral element, UKMIP 1,901,034, sample L-1-1,  $\times 79$ .—1e. Inner lateral view of main cusp, anterior denticles and anticusp, UKMIP 1,901,034,  $\times 148$ .
2. *Cavusgnathus* Hi element, from Beil Limestone (2a) and Hartford Limestone (2b).—2a. Inner lateral view of incomplete mature dextral element, UKMIP 1,901,035, sample B-1-4,  $\times 92$ .—2b. Inner lateral view of complete immature sinistral element, UKMIP 1,901,036, sample H-1-3F,  $\times 135$ .
3. *Streptognathodus* and *Idiognathodus* Hi element, specimens from Big Springs Limestone (3a), and Plattsouth Limestone (3b-d).—3a. Inner lateral view of dextral element which is transitional with *Hindeodella* sp. B, UKMIP 1,901,037, sample BS-1-1,  $\times 62$ .—3b. Inner lateral view of anterior part of dextral element, UKMIP 1,901,038, sample P-1-3,  $\times 159$ .—3c. Inner lateral view of dextral element, UKMIP 1,901,038,  $\times 52$ .—3d. Inner lateral view of sinistral element, UKMIP 1,901,039, sample P-1-4,  $\times 31$ .
4. *Hindeodella parva* ELLISON, specimens from Ervine Creek Limestone (4a,c,d) and Heumader Shale (4b).—4a. Inner lateral view of anterior bar of sinistral element; small remnant of posterior bar present, UKMIP 1,901,040, sample EC-1-1J,  $\times 116$ .—4b. Inner lateral view of anterior bar of dextral element; anterior portion of posterior bar preserved, UKMIP 1,901,041, sample Heu-1-3A,  $\times 138$ .—4c. Lateral oral view of element in which both the anterior and posterior bars are preserved, UKMIP 1,901,042, sample EC-1-1D,  $\times 55$ .—4d. Aboral view of UKMIP 1,901,042,  $\times 62$ .
5. *Hindeodella* sp. B, from Plattsouth Limestone. Lateral inner view; note almost complete lack of inward curvature of anterior bar, UKMIP 1,901,043, sample P-1-5,  $\times 86$ .
6. *Lonchodus?* sp., specimen from Plattsouth Limestone.—6a. Inner lateral view, UKMIP 1,901,044, sample P-1-5,  $\times 52$ .—6b. Magnified view of anterior? end, UKMIP 1,901,044,  $\times 255$ .
7. *Lonchodus simplex* (PANDER) from Heebner Shale. Lateral view of a fragment, UKMIP 1,901,045, sample He-1-3A,  $\times 46$ .

## PLATE 12

## FIGURE

1. *Delotaxis? conflexa* (ELLISON), Hi element, specimens from Hartford Limestone (1a) and Ervine Creek Limestone (1b,c).—1a. Inner lateral view of incomplete mature sinistral element; posterior bar broken, UKMIP 1,901,046, sample H-1-3D,  $\times 51$ .—1b. Inner lateral view of immature dextral element, showing characteristic denticulation, UKMIP 1,901,047, sample EC-1-1B,  $\times 82$ .—1c. Aboral lateral view showing characteristic aboral groove and basal cavity, UKMIP 1,901,047,  $\times 82$ .
2. *Ligonodina lexingtonensis* (GUNNELL) from Plattsouth Limestone (2a) and Heebner Shale (2b).—2a. Inner lateral view of dextral element, UKMIP 1,901,048, sample P-1-2,  $\times 113$ .—2b. Aboral view of dextral element, UKMIP 1,901,049, sample He-1-4A,  $\times 146$ .
3. *Neoprioniodus conjunctus* (GUNNELL), Hi element, from Heebner Shale. Inner lateral view of dextral element, UKMIP 1,901,050, sample He-1-2B,  $\times 78$ .
4. *Neoprioniodus conjunctus* (GUNNELL), Pl element, from Heebner Shale.—4a. Aboral view, UKMIP 1,901,051, sample He-1-4A,  $\times 184$ .—4b. Inner lateral view, UKMIP 1,901,052, sample He-1-4A,  $\times 135$ .—4c. Outer lateral view, UKMIP 1,901,053, sample He-1-4B,  $\times 86$ .
5. *Lonchodina? ponderosa* ELLISON from the Heebner Shale, Oread Limestone.—5a. Inner lateral view, UKMIP 1,901,054, sample He-1-4A,  $\times 70$ .—5b. Outer lateral view, UKMIP 1,901,055, sample He-1-4A,  $\times 70$ .—5c. Aboral view, UKMIP 1,901,056, sample He-1-3B,  $\times 185$ .

## PLATE 13

## FIGURE

1. *Lonchodina douglasensis* VON BITTER, n. sp., all specimens from Plattsouth Limestone, with exception of 1f from Spring Branch Limestone.—1a. Inner lateral view of incomplete mature sinistral? element showing a well-developed twisted anterior bar, holotype UKMIP 1,901,057, sample P-1-4,  $\times 63$ .—1b. Outer lateral view showing tendency of anterior bar denticles to fuse, holotype UKMIP 1,901,057,  $\times 61$ .—1c. Inner lateral view of a dextral? element, paratype UKMIP 1,901,058, sample P-1-1,  $\times 84$ .—1d. Aboral view showing lonchodininid basal cavity, paratype UKMIP 1,901,058,  $\times 134$ .—1e. Inner lateral view of sinistral? element, paratype UKMIP 1,901,059, sample P-1-1,  $\times 115$ .—1f. 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),  $\times 116$ .—1g. Inner lateral view of large mature sinistral? element, paratype UKMIP 1,901,061, sample P-1-4,  $\times 56$ .
2. *Lonchodina* sp. B from Plattsouth Limestone (2a) and Spring Branch Limestone (2b).—2a. Inner lateral view, UKMIP 1,901,062, sample P-1-7,  $\times 175$ .—2b. Aboral lateral view, UKMIP 1,901,063, sample SB-1-2B,  $\times 196$ .
- 3,4. *Lonchodina* sp. A from Plattsouth Limestone (3a,b) and Heebner Shale (4a,b).—3a. Inner lateral view of an immature sinistral? element, UKMIP 1,901,064, sample P-1-1,  $\times 251$ .—3b. Inner lateral view of an immature dextral? element, UKMIP 1,901,065, sample P-1-1,  $\times 95$ .—4a. Inner lateral view of anomalous nearly complete dextral element, UKMIP

1,901,066, sample He-1-4A,  $\times 157$ .—4b. Inner lateral view of sinistral element, UKMIP 1,901,067, sample He-1-4A,  $\times 125$ .

PLATE 14

FIGURE

1. *Delotaxis? conflexa* (ELLISON), Pl? element from Plattsmouth Limestone (1a), Curzon Limestone (1b) and Spring Branch Limestone (1c).—1a. 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,  $\times 222$ .—1b. Inner lateral view of mature element showing typical lonchodid basal cavity and anterior and posterior bars, UKMIP 1,901,069, sample Cur-1-1B,  $\times 125$ .—1c. Outer lateral view, UKMIP 1,901,070, sample SB-1-2B,  $\times 253$ .
2. *Delotaxis? conflexa* (ELLISON), Ne? element from Oskaloosa Shale (2a) and Jones Point Shale (2b).—2a. Lateral view, UKMIP 1,901,071, sample Os-1-3,  $\times 256$ .—2b. Aboral view, UKMIP 1,901,072, sample JPS-1-1,  $\times 190$ .
3. *Metalonchodina?* sp. from Holt Shale.—3a. Aboral view of anterior portion, UKMIP 1,901,073, sample Hol-1-2A,  $\times 240$ .—3b. Inner lateral view, UKMIP 1,901,073,  $\times 209$ .
4. *Delotaxis? conflexa* (ELLISON), Oz? element from Plattsmouth Limestone (4a) and Heumader Shale (4b).—4a. Aboral lateral view of dextral element, UKMIP 1,901,074, sample P-1-5,  $\times 93$ .—4b. Aboral view, UKMIP 1,901,075, sample Heu-1-1,  $\times 172$ .

PLATE 15

All specimens with the exception of that illustrated in Figure 5 are from the Plattsmouth Limestone.

FIGURE

1. Unidentified Tr element, type A.—1a. Inner lateral view, UKMIP 1,901,076, sample P-1-1,  $\times 73$ .—1b. Aboral view showing basal cavity and aboral groove, UKMIP 1,901,076,  $\times 230$ .
2. Unidentified Tr element, type B.—2a. Inner lateral view, UKMIP 1,901,077, sample P-1-1,  $\times 87$ .—2b. Aboral view showing basal cavity and aboral groove, UKMIP 1,901,077,  $\times 209$ .—2c. Inner lateral view of variant showing lesser number of denticles and less massive arms, UKMIP 1,901,078, sample P-1-3,  $\times 72$ .
3. Unidentified Tr element, type C.—3a. Inner lateral view of

mature sinistral? element, UKMIP 1,901,079, sample P-1-1,  $\times 84$ .—3b. Inner lateral view of immature dextral? element, UKMIP 1,901,080, sample P-1-1,  $\times 91$ .—3c. Inner lateral view of immature sinistral? element, UKMIP 1,901,081, sample P-1-1,  $\times 163$ .

4. *Hindeodus* sp. A.—4a. Inner lateral view, UKMIP 1,901,082, sample P-1-1,  $\times 125$ .—4b. Outer lateral view, UKMIP 1,901,083, sample P-1-1,  $\times 124$ .
5. *Ellisonia teichertii* SWEET?, Tr element, from Heebner Shale. Inner lateral view showing typical asymmetry, UKMIP 1,901,084, sample He-1-4A,  $\times 105$ .

PLATE 16

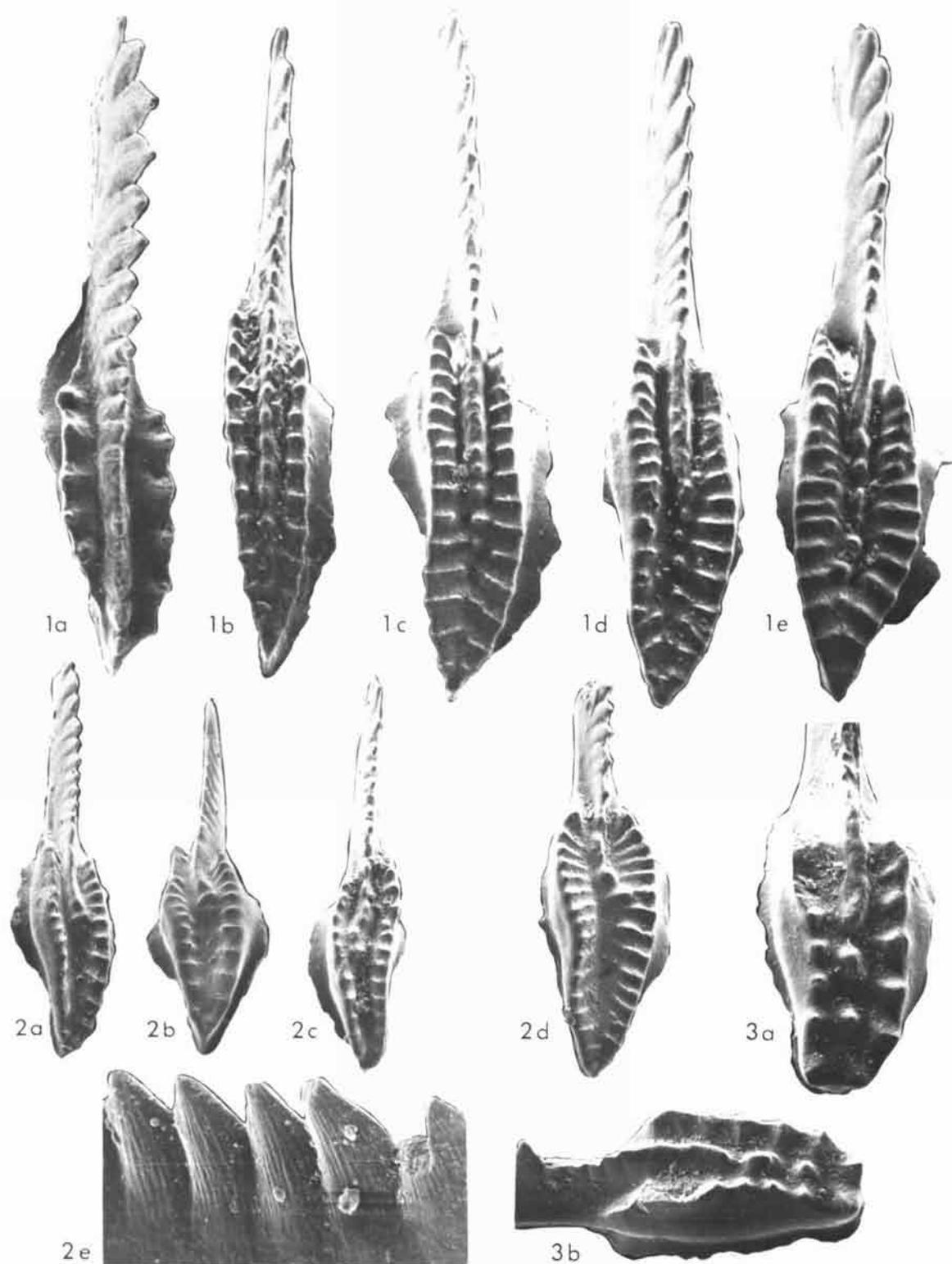
FIGURE

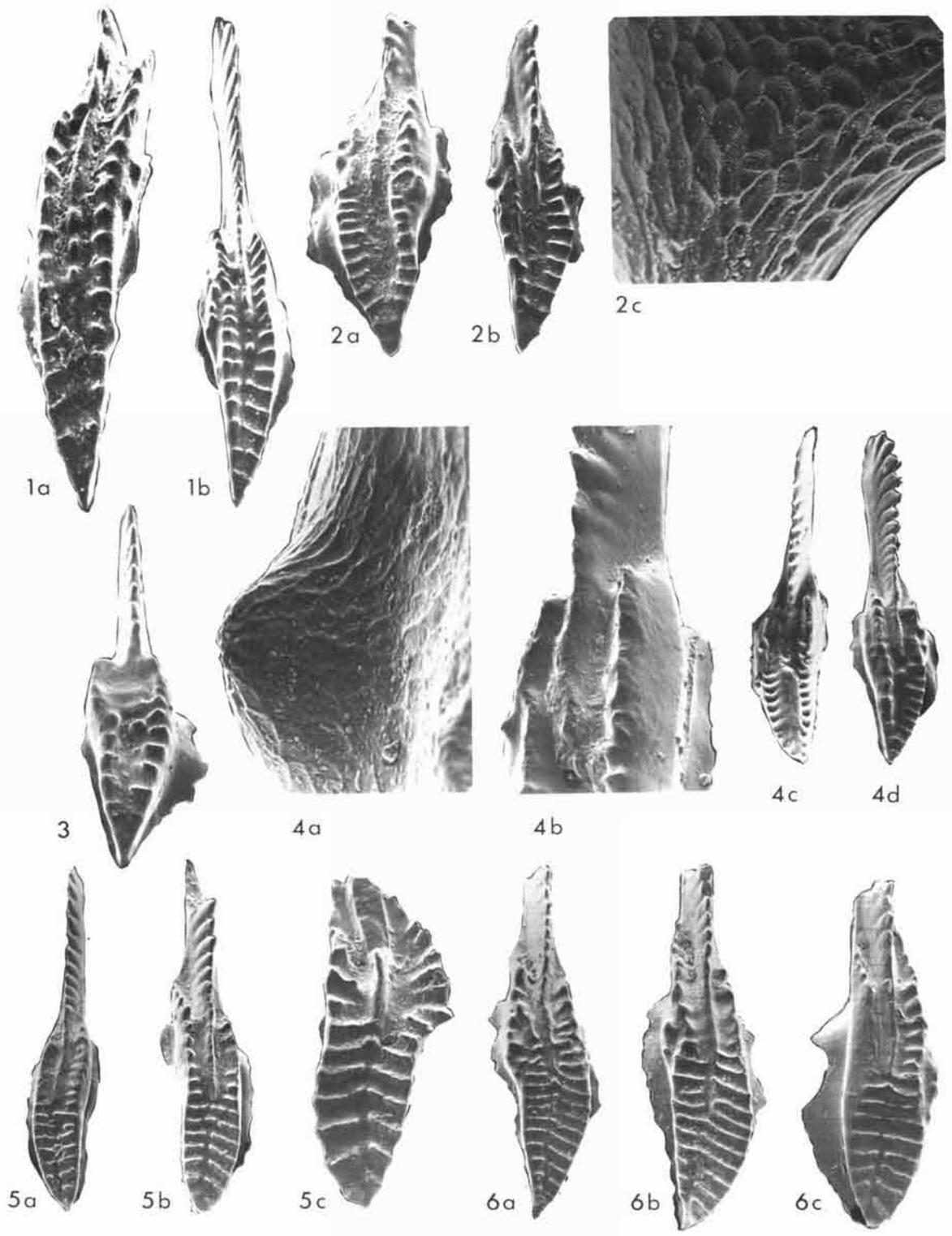
1. *Delotaxis? conflexa* (ELLISON), Tr element, specimens from Larsh-Burroak Shale (1a), Queen Hill Shale (1b,d) and Hartford Limestone (1c).—1a. Aboral view showing wide aboral groove, UKMIP 1,901,085, sample LB-1-3B,  $\times 132$ .—1b. Lateral view; posterior bar broken in two places, UKMIP 1,901,086, sample QH-1-2,  $\times 26$ .—1c. Lateral view showing short anterior bar, UKMIP 1,901,087, sample H-1-3D,  $\times 85$ .—1d. Anterior view showing well-developed anterior bevel, UKMIP 1,901,088, sample QH-1-2,  $\times 91$ .
2. *Neoprioniodus conjunctus* (GUNNELL), Tr element, from Heebner Shale.—2a. Aboral view of main cusp showing characteristic basal cavity, UKMIP 1,901,089, sample He-1-3B,  $\times 94$ .—2b. Lateral view showing main cusp and part of the posterior bar, UKMIP 1,901,090, sample He-1-3A,  $\times 73$ .
3. *Cavusgnathus* Tr element, from Calhoun Shale (3a) and Turner Creek Shale (3b,c).—3a. Anterior view of a variant specimen, UKMIP 1,901,091, sample Cal-Sp-1,  $\times 106$ .—3b. Lateral view, UKMIP 1,901,092, sample TCS-1-3,  $\times 294$ .—3c. Anterior view, UKMIP 1,901,092,  $\times 451$ .
4. *Streptognathodus* and *Idiognathodus* Tr element, from Plattsmouth Limestone (4a,c,d) and Ervine Creek Limestone (4b).—4a. Lateral view showing alternating denticulation of posterior bar, UKMIP 1,901,093, sample P-1-6,  $\times 107$ .—4b. Aboral view showing aboral groove of posterior and anterior bars as well as deep basal cavity, UKMIP 1,901,094, sample EC-1-1C,  $\times 440$ .—4c. Anterior view of mature element, UKMIP 1,901,095, sample P-1-8,  $\times 114$ .—4d. Anterior view of immature element, UKMIP 1,901,096, sample P-1-5,  $\times 188$ .

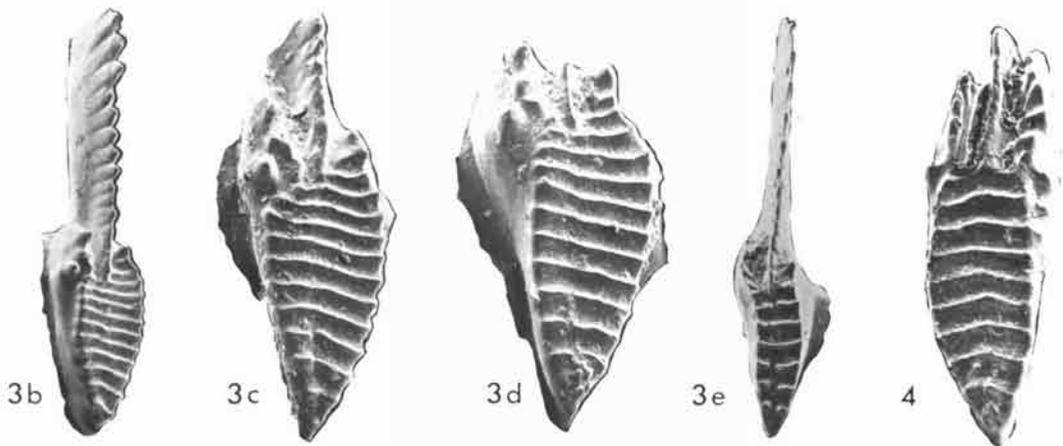
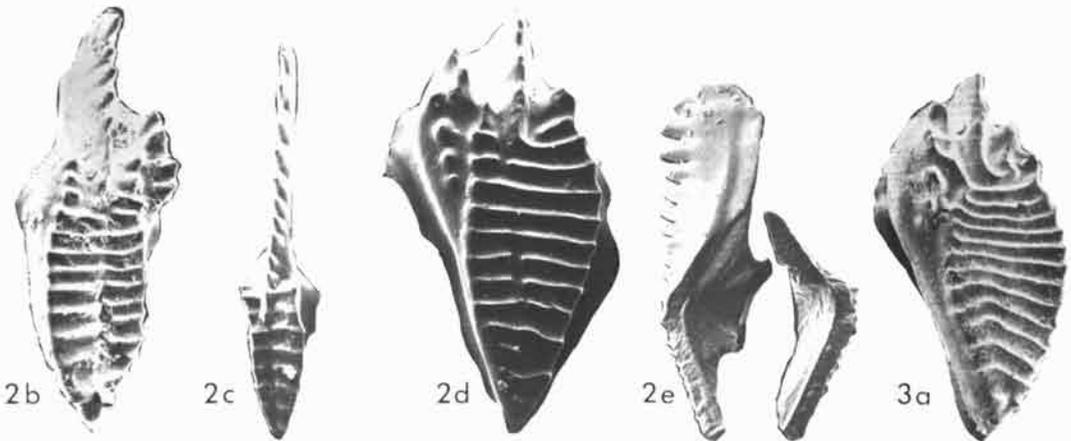
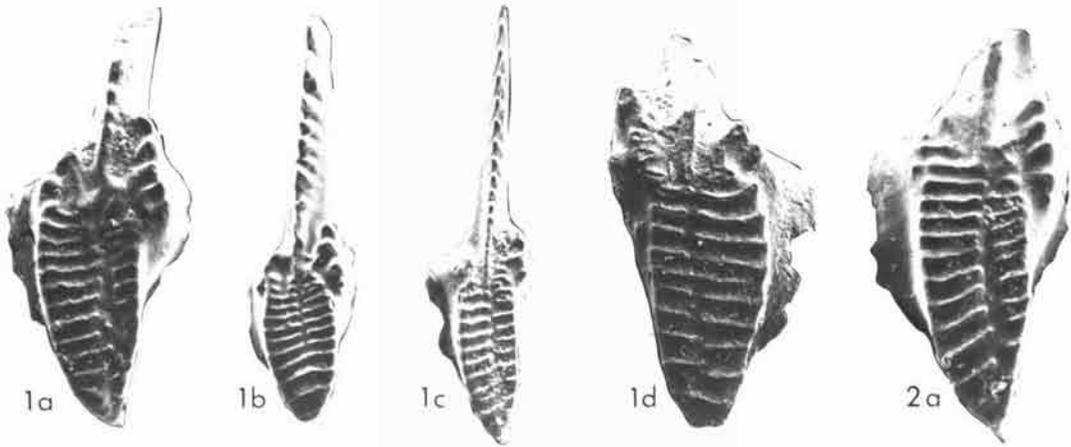


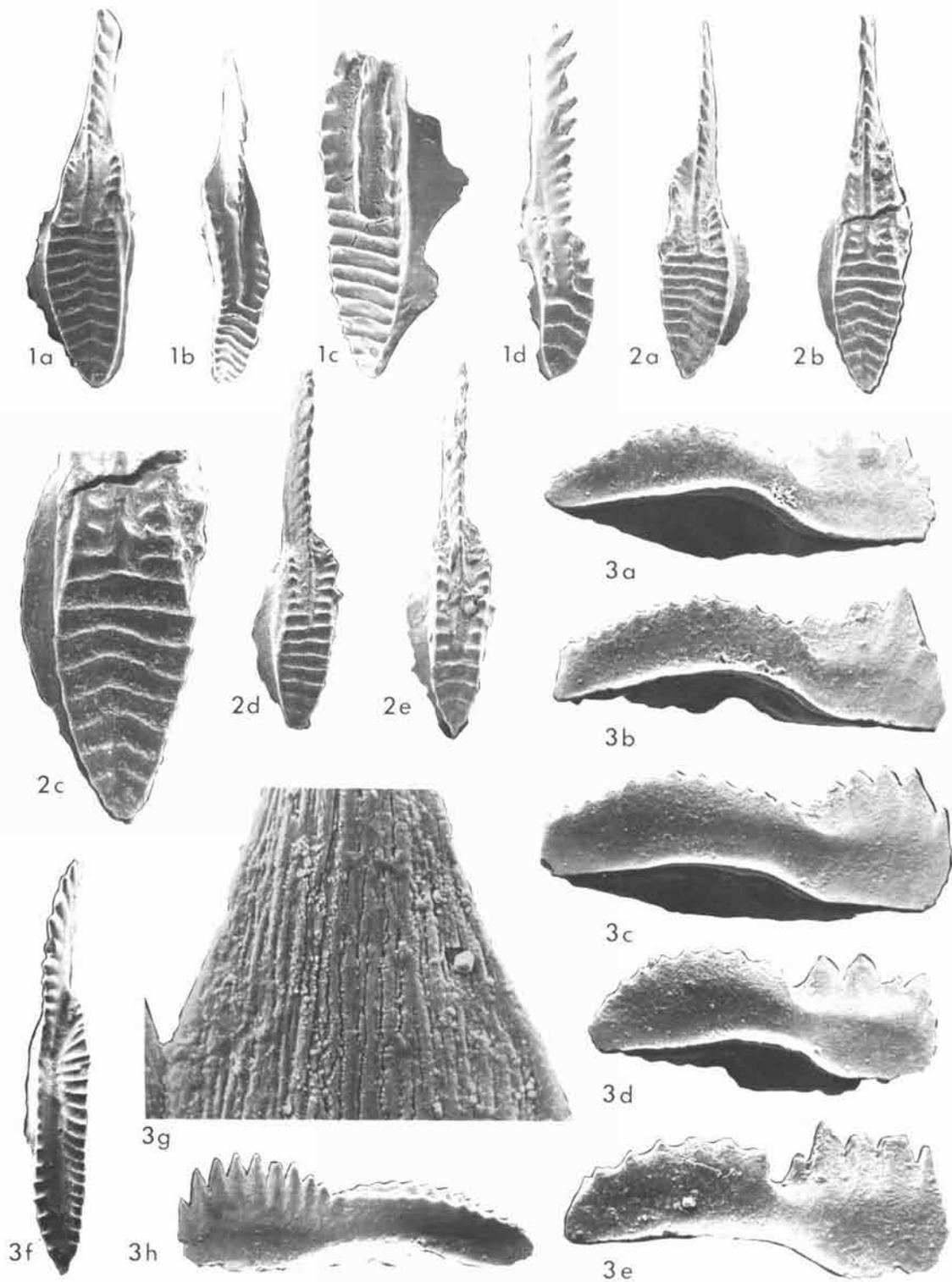


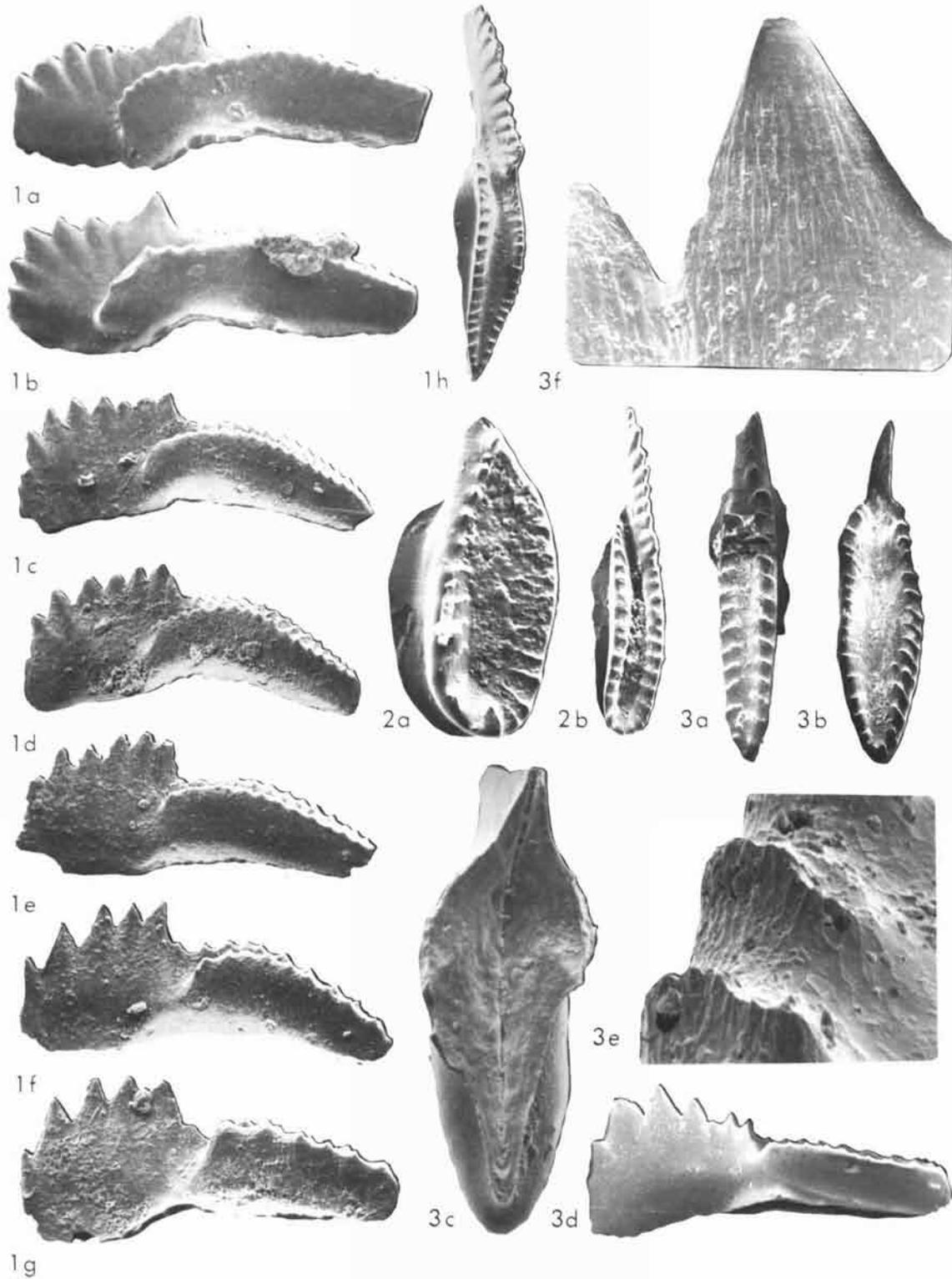


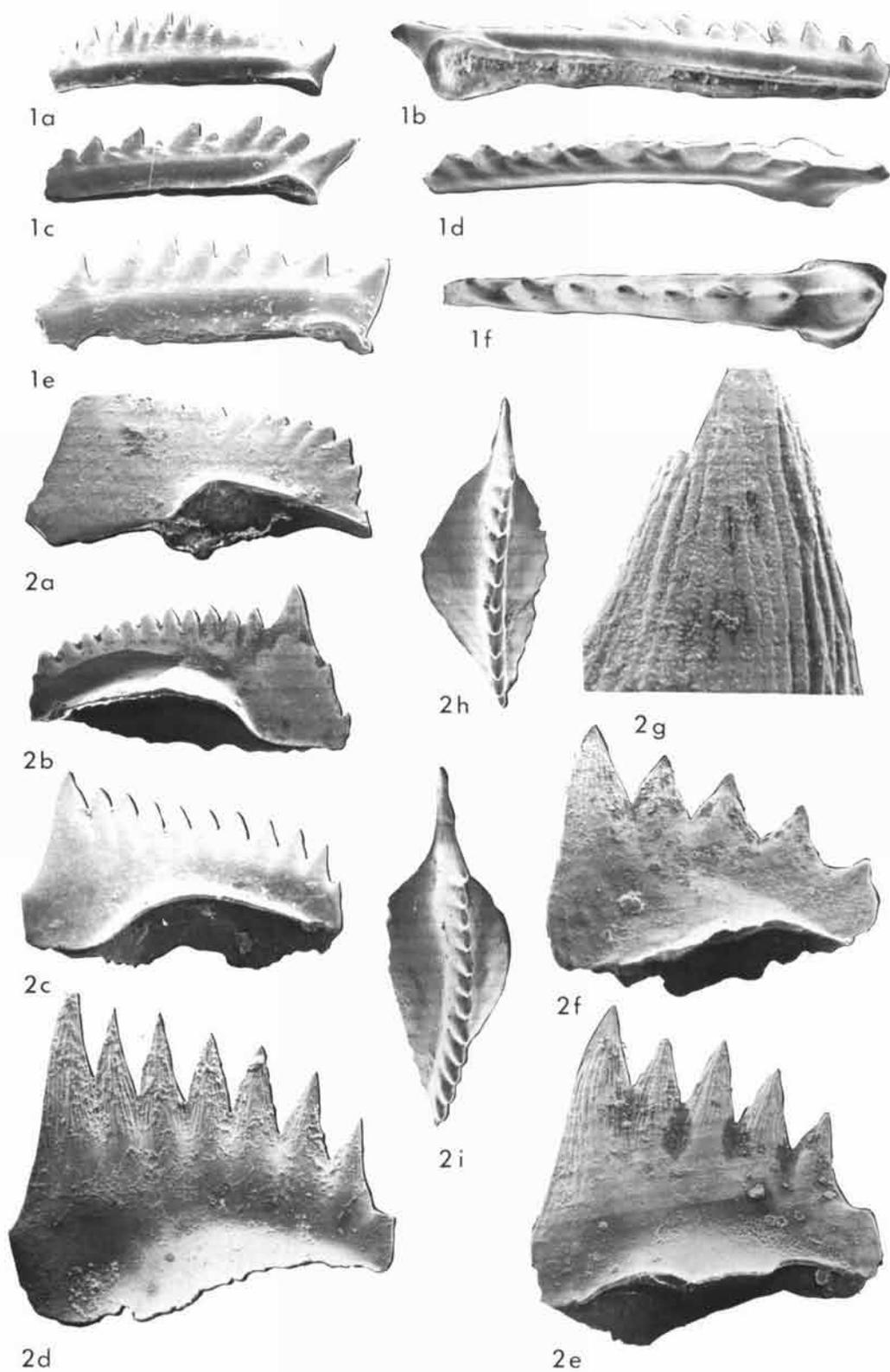


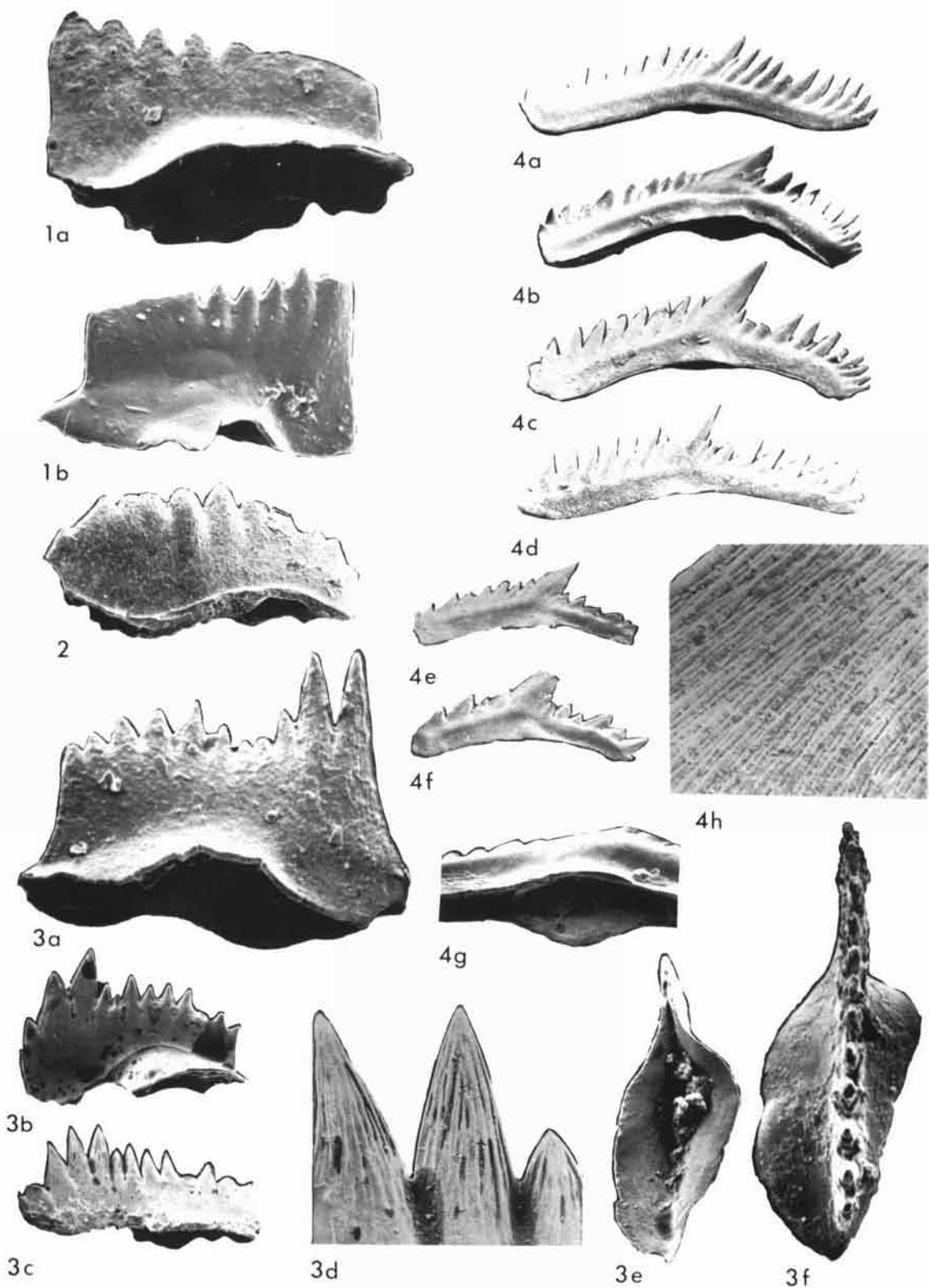














1a



1b



1c



1d



1e



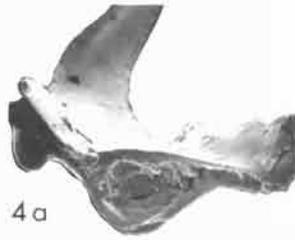
2a



2b



3a



4a



4b



5a



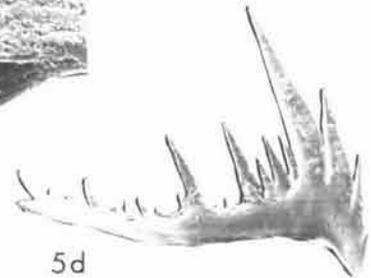
3b



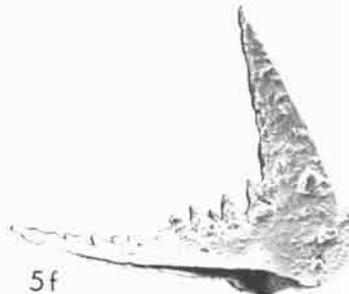
5b



5c



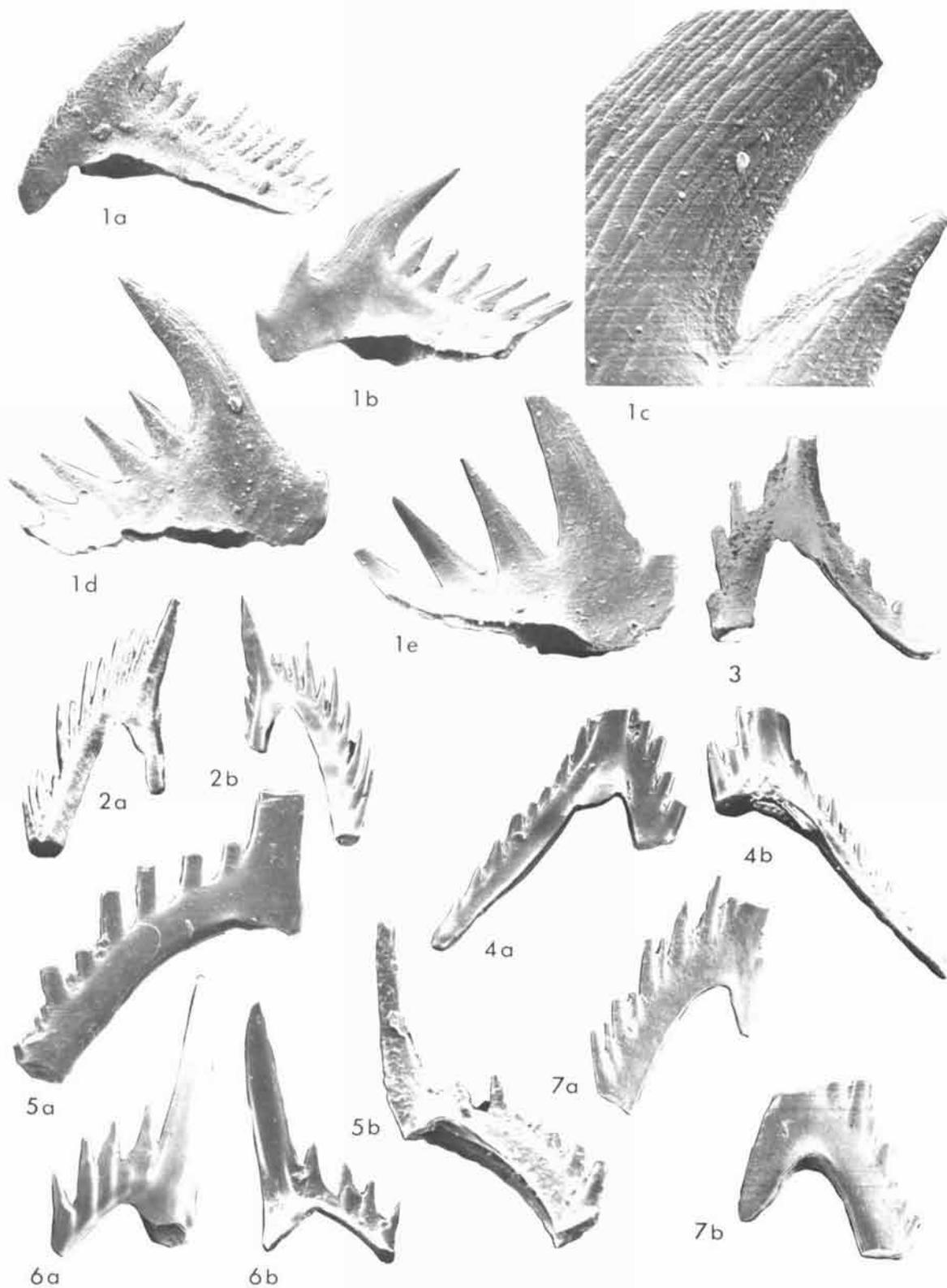
5d

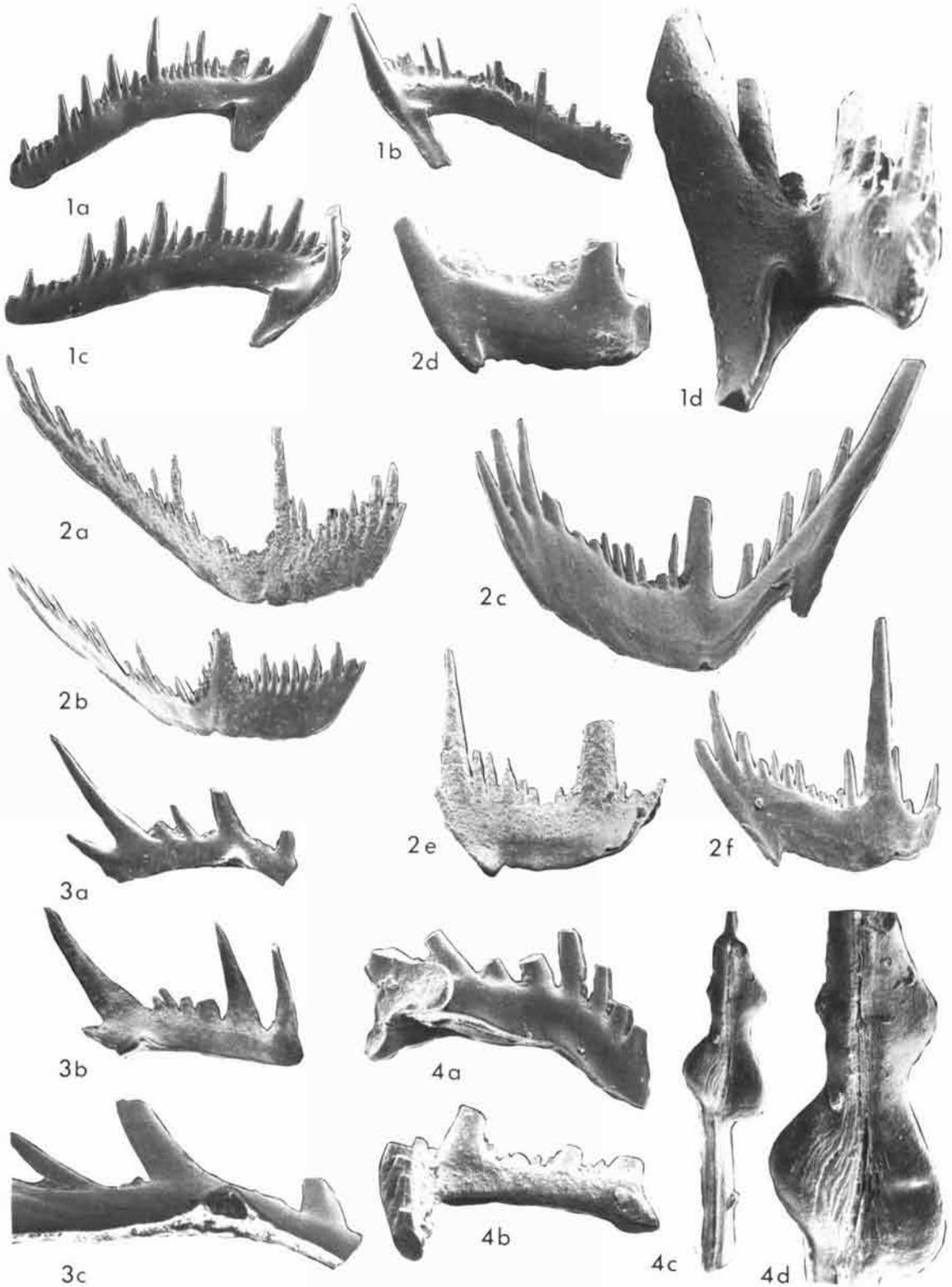


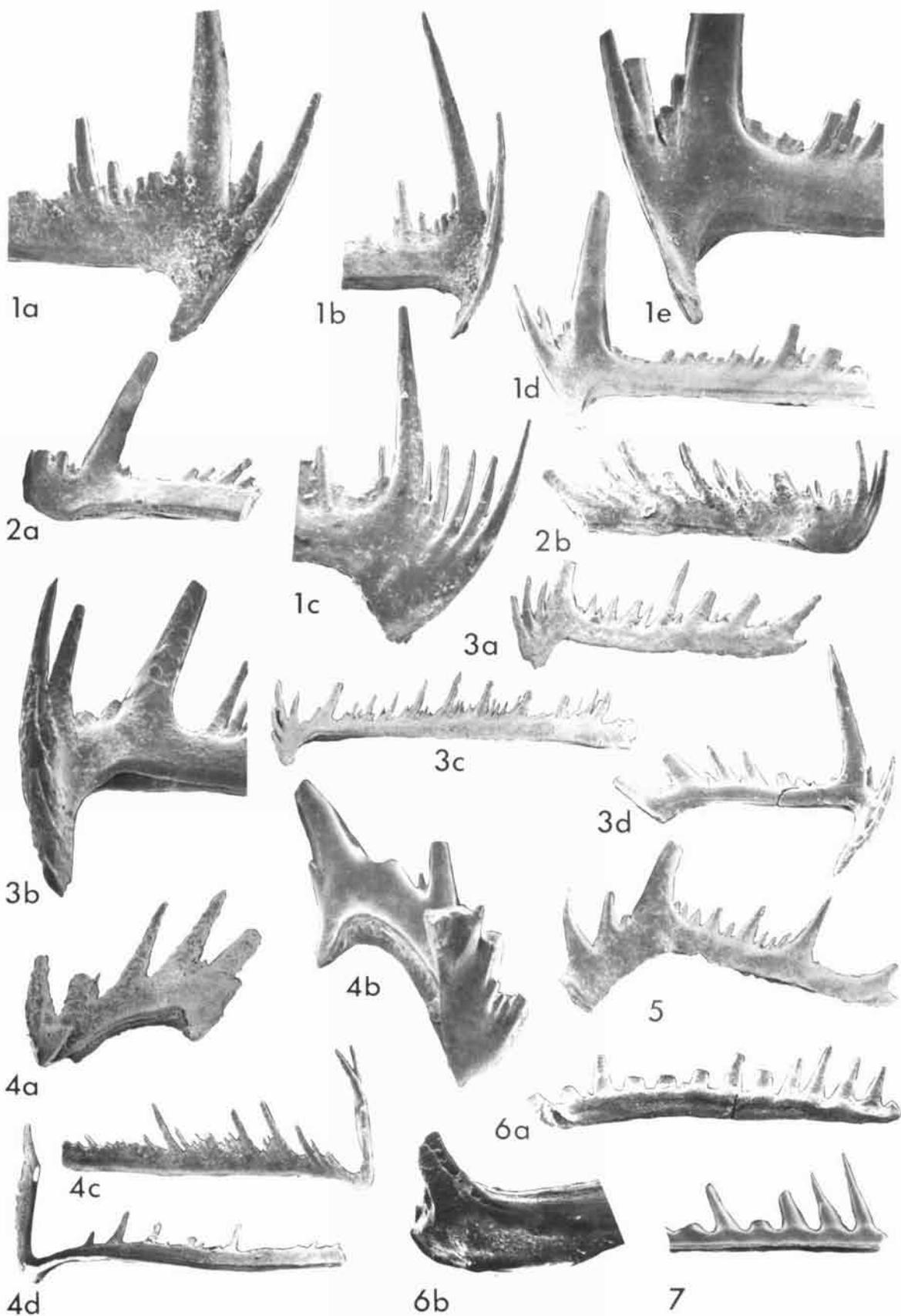
5e



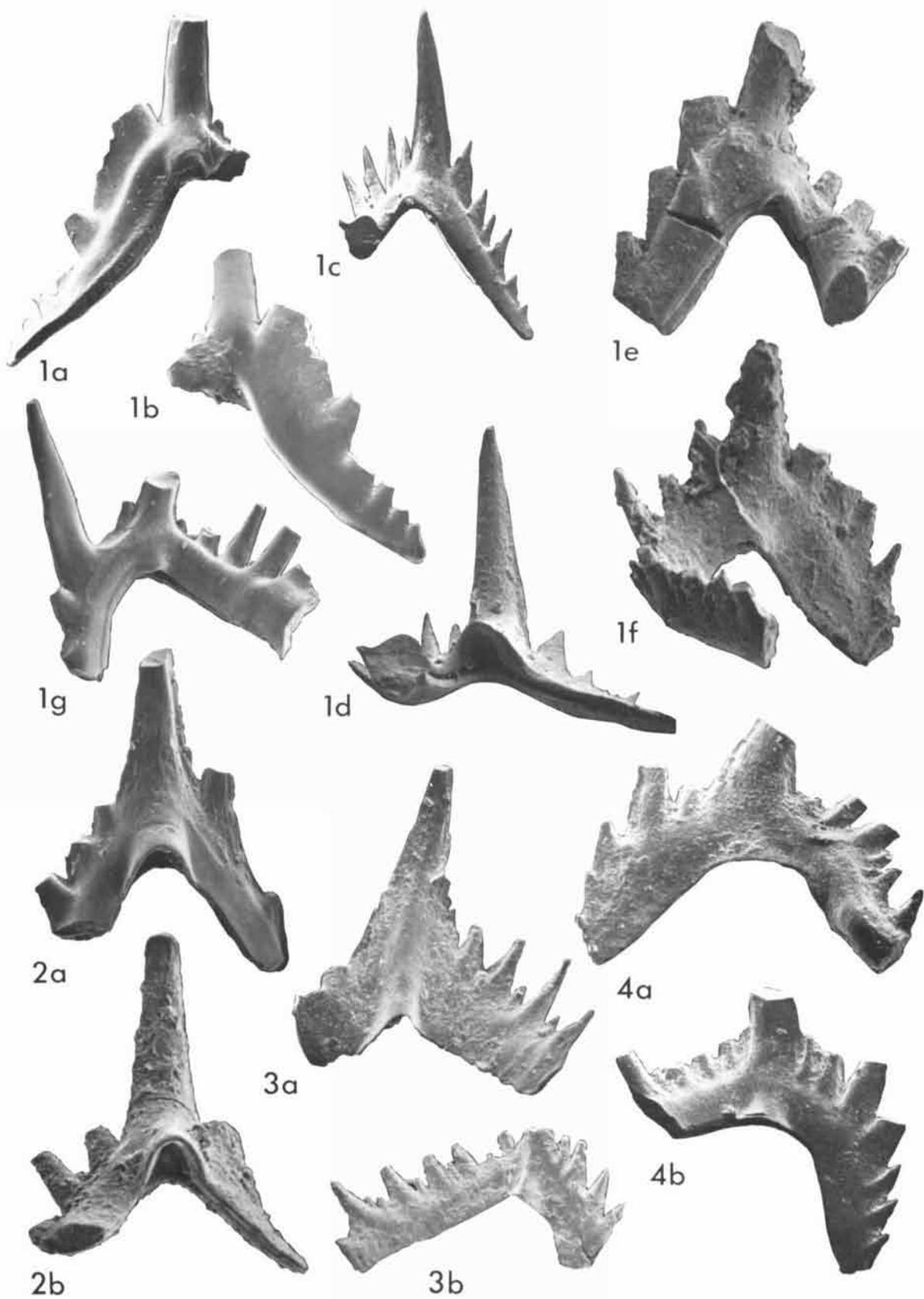
5f







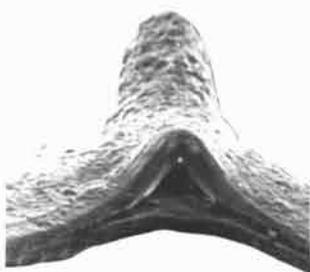




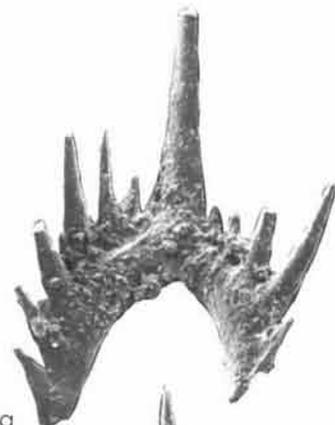




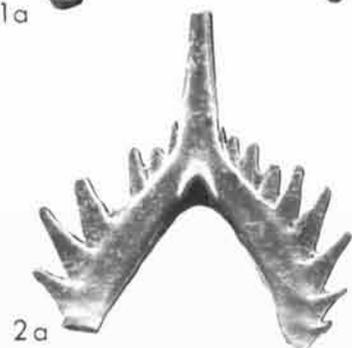
1a



1b



3a



2a



2b



3b



2c



3c



5



4a



4b

