MINNESOTA GEOLOGICAL SURVEY

**SP-4** *Special Publication Series*

# The Middle and Upper Ordovician Conodont Faunas of Minnesota

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MINNEAPOLIS • 1966

# THE MIDDLE AND UPPER ORDOVICIAN CONODONT FAUNAS OF MINNESOTA

by

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# THE MIDDLE AND UPPER ORDOVICIAN CONODONT FAUNAS OF MINNESOTA

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## ABSTRACT

About thirty-five thousand identifiable conodonts were recovered from samples of Middle and Upper Ordovician sedimentary rocks of Minnesota. One section was sampled in detail for each formation except the Glenwood, which was sampled at three localities in east-central and southeastern Minnesota.

Thirty-three form species or groups of form species are described as biological or natural species. Form species comprising a natural species are associated by similarities in stratigraphic range, abundance ratios, size, and secondary characteristics.

Problems stemming from the presently used invalid dual nomenclature can be solved by applying the name of the earliest described form species to the natural species according to the rules of zoological nomenclature.

The Middle and Upper Ordovician strata of Minnesota can be subdivided into ten biostratigraphic zones on the basis of the stratigraphic distribution of conodonts. An increase in European elements at the expense of American mid-continent elements in the Galena and Dubuque Formations represents a major shift in conodonts with respect to pre-Galena faunas.

## INTRODUCTION

This study of conodonts in Middle and Upper Ordovician rocks of Minnesota contributes to stratigraphic correlation, and grouping of forms into natural or biological species. Conodont species, as presently defined, are based entirely on structural complexities of individual elements. Rarely-preserved natural assemblages of conodonts represent biological species showing that the conodont-bearing animal consists of from 14 to 22 disjunct paired conodonts referred to three, four, or five form species. These natural assemblages and component form genera and species have been given formal names. Thus we have a dual nomenclature which is both improper, according to the rules of zoological

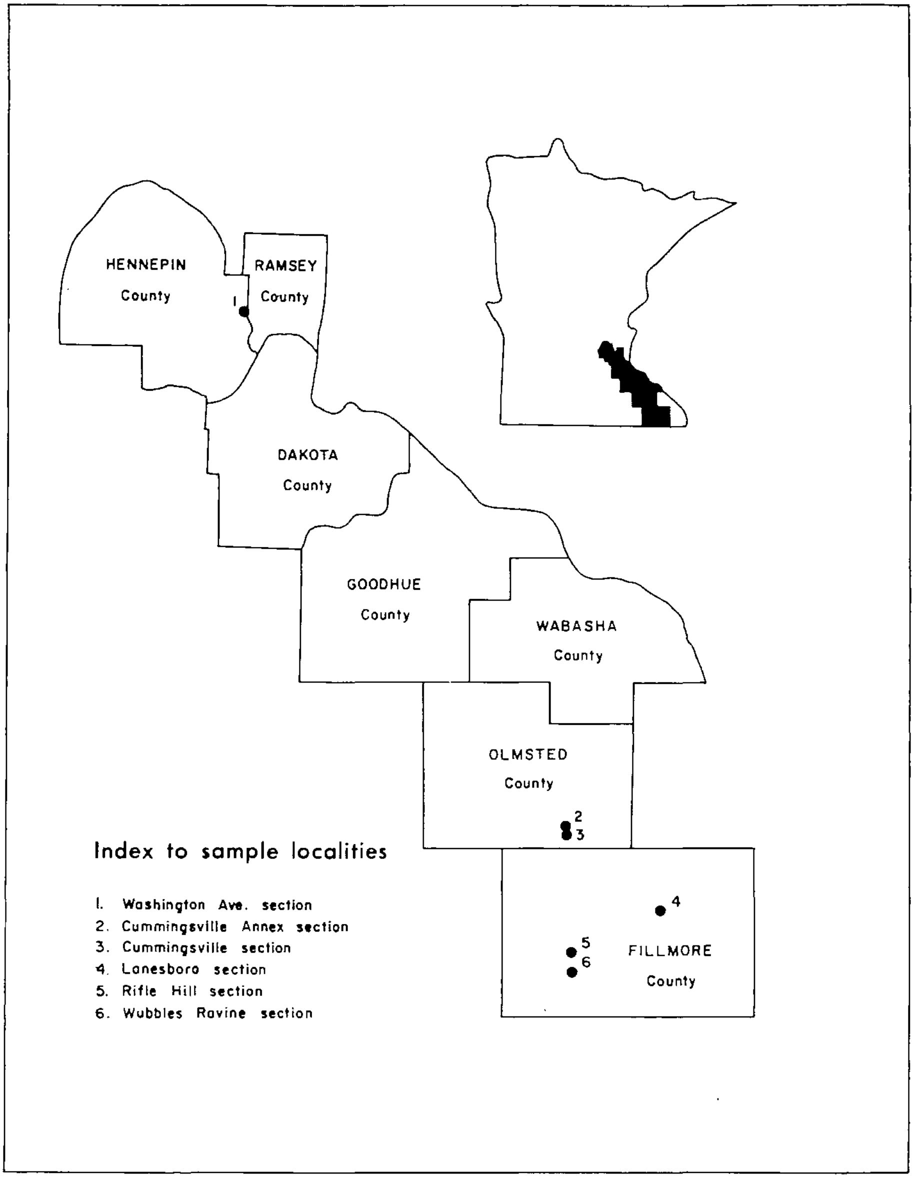



Figure 1 — Map showing locations of stratigraphic sections.

nomenclature, and unstable. The stratigraphic value of form species and the extreme rarity of naturally preserved assemblages have led many authors to defend dual nomenclature because of its usefulness.

If all conodonts could be grouped into natural assemblages, form species nomenclature would be superfluous. I believe that assemblages representing biological species can be defined by detailed study of stratigraphic distribution and relative abundances of disjunct conodont elements. To test this hypothesis, conodonts were concentrated from samples collected from each bed of the Middle and Upper Ordovician rocks of Minnesota. About thirty-five thousand conodonts were collected for study.

Because the name given to an assemblage of form species is the name of the earliest described component, confusion could arise in the following pages as to whether a given name refers to the assemblage or to a particular form species. Where necessary to avoid confusion, quotation marks are used to set off form species in the manner of Rhodes (1962). Thus, *"Pravognathus idonea"* and *"Pravognathus simplex"* are the two form species which comprise *Pravognathus idonea.*

Field and laboratory work continued from the fall of 1959 to the fall of 1964.

I am grateful to Robert E. Sloan of the Department of Geology and Geophysics, University of Minnesota, for suggesting the problem and helping in all phases of the study. Walter C. Sweet and Thomas J. Schopf of The Ohio State University, and Stig Bergstrom of Lund University provided important reference collections and offered many suggestions. Frederick M. Swain and P. K. Sims critically read the manuscript.

## PROCEDURES

### Sampling Method

Samples were collected at selected localities from the following formations from oldest to youngest: Glenwood, Platteville, Decorah, Galena, and Dubuque. The first section chosen for sampling, the Glenwood Formation (Cummingsville section), yielded so few conodonts that two other localities were included. The unpublished reports of Thompson (1959) and Anderson (1959) provided lateral coverage for the Platteville and the lower Decorah. A single stratigraphic section of the Elgin Member of the Maquoketa Formation was sampled at one-foot intervals. Conodonts are very scarce in this unit and those collected have not been included in the statistical treatment of form species.

Two types of samples were collected from the measured sections; most were collected for both detailed stratigraphic and statistical studies. The samples for statistical analysis were channel samples taken from each bed. In the Decorah Shale, channel samples represent one stratigraphic foot with no vertical gap between samples. One hundred grams of each sample was processed for conodonts.

The average statistical sample yielded 150 identifiable conodonts; however, samples from some stratigraphic intervals yielded poorly preserved or abraded conodonts, a fact which complicated the separation of the conodonts into species and limited accurate morphological description of conodont species unique to those intervals. To overcome this problem, large samples (up to 40 lbs.) were collected from the best stratigraphic intervals within the zones containing poorly preserved conodonts. These samples are labeled "Bulk" samples on the chart showing stratigraphic distribution (pl. 1). They were carefully picked for the best preserved of the problematic conodonts; the presence or absence of conodont elements from these samples has no statistical importance.

### Concentration and Separation Techniques

Shale samples were oven dried at 200°F overnight, saturated with unleaded gasoline, and then immersed in water. Shale fragments 1/4 inch in diameter became saturated in four hours, whereas fragments 3 inches in diameter required 24 hours. Limestone samples were digested in 4N formic acid.

The resulting disaggregated material was washed through a 100-mesh screen. Further concentration of conodonts from the material retained on the screen required one or more steps, depending on the mineralogy. Limonite was removed with a Franz Isodynamic Separator. Quartz and calcite were removed by flotation in bromoform. Diiodomethane was used to separate the conodonts from pyrite.

Initially the first 100 specimens from each sample were selected, but the residues became size-sorted while stored in glass vials resulting in a sampling bias. To avoid this bias, all conodonts were hand-picked from each sample and mounted for study.

Adhering matrix was cleaned from well-preserved specimens with an ultrasonic vibrator.

### Conodont Photography

All conodonts illustrated in this report were photographed in an uncoated condition using a combination of transmitted and reflected light. Although restricted depth of field poses a problem in photographing some conodonts with high relief, I think that this method is considerably more accurate than sketching. If necessary, photographs can be retouched slightly. These photographs of uncoated conodonts, while they do not show some surface detail obtainable with coatings, do show the internal characteristics, and look much like the view under the binocular microscope. For some platform conodonts, where surface details are critical, light coatings may be advantageous. Specimens were oriented on a petrographic universal stage.

## NATURAL ASSEMBLAGES OF CONODONTS

### General Discussion

Conodonts have been known for more than a hundred years and have long been described as though the conodont-bearing animal possessed only one kind of conodont.

Schmidt (1934) first described what has come to be called a "natural assemblage" of conodonts. Scott (1942), DuBois (1943), and Rhodes (1952) have described additional assemblages. Most students of conodonts have now concluded that each natural assemblage represents a single biological species. Earlier reports of natural assemblages by Hinde (1879) and Eichenberg (1930) are considered to be fortuitous associations of conodont elements (Rhodes, 1962).

Taxonomy at present is based entirely on structural complexities of individual disjunct conodonts. Each separate structural type is described as a separate form species. Natural assemblages, preserved intact, contain from 14 to 22 conodonts representing three to five form species. Each form species is present in equal numbers of right and left handed elements, the mirror image of each other. Right and left handed elements occur with denticles in opposition, and each form species is restricted to a definite part of the assemblage. The constituent form species of any natural assemblage are also present in simple ratios to each other. In the assemblages thus far described, this ratio has not exceeded 6:1.

Known natural assemblages are rare: they are recognized only from strata of Carboniferous age and, with the possible exception of those from the Mississippian Heath Shale of Montana, have all been found in black shales.

### Statistical Determination of Natural Assemblages

Scott (1942) pointed out that isolated conodont form species from the same stratigraphic interval as the natural assemblages he recognized were present in approximately the same ratios as those in the natural assemblages. DuBois (1943) found that form species in the natural assemblages he worked with occurred in a ratio of 1:1:4 whereas those found as isolated units were in a ratio of 1.6:1:4.5. He explained the difference in ratios as resulting from differential fragmentation. Müller (1956) has suggested that natural conodont assemblages could be separated from form genera by a statistical study of an abundant population composed of a small number of form genera and species. These suggestions led me to undertake this study.

Ideally, taking the assemblages of Carboniferous age as a model, forms belonging to a single biological species should have identical stratigraphic ranges and occur in simple uniform ratios to each other.

Form species in the present study were associated by similarity in stratigraphic ranges and similarity in ratios of abundance throughout the stratigraphic range. Departures from the ideal of exact stratigraphic ranges and completely uniform ratios of abundance could be expected because of the following:

1. Currents could effectively and selectively size-sort different structural types among the form species greatly modifying abundance ratios and, in an extreme case, affecting stratigraphic distribution.
2. Conodonts vary greatly in durability and, if subjected to strong current or wave action, or passage through the digestive tract of a predator, some will fragment into many identifiable pieces. For example, the form species *"Polyplacognathus ramosa"* is a six-lobed structure which is more easily fragmented than its associated three-lobed form species.
3. In a stratigraphic section representing a large time interval, addition, subtraction, or evolutionary modification of conodont elements from a natural assemblage may occur.
4. A homeomorphic form species could conceivably be found in more than one natural assemblage, causing discrepancies in stratigraphic distribution and abundance ratios. Moore (1962) states this possibility, and it might be expected with respect to evolutionary trends.

### Present Problems in the Zoological Nomenclature of Conodonts

In most natural assemblages described to date, the entire assemblage has been given a formal generic and specific name. The constituent form species are also given generic and specific names. Such dual nomenclature is unstable and illegal within the framework of the rules of zoological nomenclature (Rhodes, 1962). In some cases the type species of a form genus occurred as a constituent of a natural assemblage. Equivalence of this form species with the earliest described constituent of the natural assemblage would leave other members of that particular form genus without valid names. This situation could greatly impair a system of nomenclature of proven value. The natural assemblage called *Duboisella typica,* for example, contains two form species which are the types for their respective form genera.

Approximately two thousand form species of conodonts have been described (Rhodes, 1962). A small number of these are associated into natural assemblages. Rarity of natural assemblages appears to be the prime reason that conodont workers feel compelled to disregard the established rules of zoological nomenclature.

Three solutions have been proposed for the conodont nomenclature problem. Rhodes (1962), Scott (1942), and DuBois (1943) advocate maintaining a dual classification. In a recent attempt to legalize this procedure, Moore and Sylvester-Bradley (1957) proposed a modification of the rules at a Colloquium of Zoological Nomenclature held in London in 1958 as part of the Fifteenth International Congress of Zoology. Their proposal, explained by its title: "Proposed insertion in the 'Regles' of provisions recognizing 'Parataxa' as a special category for the classification and nomenclature of discrete fragments or of lifestages of animals which are inadequate for identification of whole-animal taxa, with proposals of procedure for the nomenclature of 'Parataxa'", was not accepted.

Schmidt (1934), Eichenberg (1930), and Sinclair (1953) advocate following the rules as presently stated. The problems caused by synonymies in this approach have already been discussed.

Moore (1962) suggests that because all identifications of species are subjective and form species are valid in that they represent part of a once-living organism, the problem of dual nomenclature could be avoided if the conodont worker would not formally identify the form species within the assemblage. He could rather describe them informally as similar to previously described form species.

I think that careful stratigraphic work and statistical analysis will permit grouping of all conodont elements into natural assemblages. The method of assigning the name of the earliest described component would be completely within the scope and sense of the present rules. This solution would eliminate the problem of synonymy of a type species. The conodonts that are unnamed could be associated into other assemblages, and possibly the present form species nomenclature would eventually be replaced completely. This method would not destroy the stratigraphic value of form species thus far established, but would simplify the nomenclature immensely.

In the proposed system of nomenclature, the generic name of the individual form species would be downgraded to an adjective in the manner of Scott (1942). Thus *"Dichognathus typica"* would be described and referred to as the dichognathid element of a particular assemblage. In a case where there is more than one form species of a particular form genus, the species name would be downgraded to an adjective rather than the generic name.

## RESULTS OF INVESTIGATION

### Statistical Assemblages

By applying the criteria of stratigraphic distribution and relative abundance, most Middle and Upper Ordovician conodont form species can be treated as natural species that consist of one to five forms (pl. 1). Except for rare species and cases where several unique form species occur in a narrow stratigraphic interval as in the Glenwood Formation, nearly all conodonts could be grouped as natural species. In general, discounting evolutionary modifications, greater stratigraphic intervals give a better chance of defining natural or statistical assemblages. Fluctuation of environmental conditions within the interval serves to distinguish natural groupings.

The conodonts, grouped according to distribution and relative abundance, exhibit other similarities that might serve as additional criteria in defining natural assemblages.

Size differences of conodonts can be helpful in associating elements, particularly among conodonts with similar stratigraphic ranges. In the Platteville Formation the form species associated with *Phragmodus cognitus* are approximately the same size as those associated with *Ozarkodina obliqua*. In the Glenwood and Decorah Formations, however, the elements associated with *Ozarkodina obliqua* are relatively larger conodonts. Similarly, samples which contain robust forms of *"Drepanodus homocurvatus"* also contain robust forms of *"Oistodus inclinatus"* and *"Drepanodus suberectus"*.

Also, similarities in secondary characteristics commonly occur within associated groups, although primary structural differences may be quite marked. These secondary characteristics include color of apatite, unique types of denticulation, thickness and excavation of structural processes, and form and development of the basal cavities. Thus, forms associated with *Ligonodina delicata* have two, three, and four processes, and differ enough structurally to be placed in four form genera. The posterior processes of all these units, however, are strikingly similar, exhibit a unique type of "hindeodellid" denticulation, and are similarly excavated. All conodont elements associated with *Icriodella superba* contain apatite of similar color, and might be thought of as variations or modifications of a tricostate cone. The conodont elements associated informally with *"Periodon aculeatus"* have a unique type of denticulation, and are alike in size and bladelike processes. Thus, associated groups of conodonts commonly have similar secondary characteristics although some of the same characteristics can also be found in other non-associated forms.

Published studies of rocks of similar age from adjacent regions were reviewed, and reference conodont collections kindly provided by Walter C. Sweet and Stig Bergström were studied to confirm natural assemblages in this study. Conodont elements grouped as an assemblage may have lateral equivalents in rocks of similar age in other areas. If the assemblage was truly representative of a single biological species, all constituent elements should occur where one of them is present. This requirement is modified by the possibility that a similar natural assemblage in another geographical area, or from a slightly different time interval, may be isolated and evolve elements that could not be placed within the same form species. It is also possible that elements placed in the same form species may be parts of closely related separate natural species. Thus, the dichognathid element of *Phragmodus cognitus* is a relatively invariable unit occurring only as the "brevis" type described by Branson and Mehl (1933). The dichognathid element of *Phragmodus undatus* is, however, a highly variable unit originally described as four "trend species" by Branson and Mehl. The "brevis" type of dichognathid of *Phragmodus undatus* is thus far indistinguishable from the dichognathid element of *Phragmodus cognitus*.

It is also quite possible that some of the present statistical groups could actually be composed of two or more species with similar environmental tolerances. The informal group associated with *Periodon aculeatus* may be of this type.

Wherever there is some question of the validity of a particular statistical association, the group is described here informally. Where in my opinion the groups are considered valid, they are described as a single species in accord with the rules of zoological nomenclature.

To illustrate the procedure followed in grouping form species thought to represent natural species, the association of elements belonging to *Phragmodus undatus* will be discussed in detail.

A study of the stratigraphic distribution of conodonts (pl. 1) shows that the stratigraphic range of one form species is like that of few other form species. These few form species are then possible associates and others can be ignored. In the case of *"Phragmodus undatus"* only the two form species, *"Dichognathus typica"* and *"Oistodus abundans"*, have similar stratigraphic ranges. These three form species also have a similar stratigraphic distribution within this range: all three forms are abundant in sample Pl-17, absent or rare in samples Pl-18 to De-9, generally common to abundant in samples De-10 to Cu-38, absent in samples Cu-39 to Rh-50, and rare at the top of their local range in samples Rh-51 to Rh-53. Their ratios of abundance are also generally similar. In any given sample phragmodids are more abundant than either dichognathids or oistodids, and the abundances of the last two are commonly similar. At this stage we can consider them probable associates. A search of published conodont studies from other areas tests the mutual occurrence of all members where one member is present. The association of all three elements is confirmed except for areas where these form species are rare. Thus I consider it valid to treat this association of form species as one "natural" species of conodont-bearing animal.

Natural species of conodonts consist of from one to five component form species. Some form species of conodonts have no associated elements. The stratigraphic ranges of *Scyphiodus primus, Cordylodus flexuosus, Ozarkodina concinna, Scolopodus insculptus,* and others, are individually different from other conodont form species. Thus, these form species are probably also natural species.

## Faunal List

### Natural Species

| Constituent Form Species | Formal Name |
|---|---|
| 1. *Acodus mutatus* (Branson and Mehl) | *Acodus mutatus* (Branson and Mehl) |
| *Distacodus procerus* Ethington | |
| 2. *Acontiodus aveolaris* Stauffer | *Acontiodus aveolaris* Stauffer |
| 3. *Amorphognathus ordovicica* Branson and Mehl | *Amorphognathus ordovicica* Branson and Mehl |
| *Ambalodus triangularis* Branson and Mehl | |
| 4. *Belodina compressa* (Branson and Mehl) | *Belodina compressa* (Branson and Mehl) |
| *Eobelodina fornicala* (Stauffer) | |
| 5. *Coelocerodontus trigonius* Ethington | *Coelocerodontus trigonius* Ethington |
| *Coelocerodontus tetragonius* Ethington | |
| 6. *Cordylodus flexuosus* Branson and Mehl | *Cordylodus flexuosus* Branson and Mehl |
| 7. *Cordylodus serratus* (Stauffer) | *Cordylodus serratus* (Stauffer) |
| *Oulodus primus* (Stauffer) | |
| 8. *Cordylodus grandis* (Stauffer) | *Cordylodus grandis* (Stauffer) |
| *Zygognathus gyroides* (Stauffer) | |
| 9. *Distacodus falcatus* Stauffer | *Distacodus falcatus* Stauffer |
| 10. *Distacodus variabilis* n.sp. | *Distacodus variabilis* n.sp. |
| 11. *Drepanodus excavatus* n.sp. | *Drepanodus excavatus* n.sp. |
| 12. *Drepanodus suberectus* (Branson and Mehl) | *Drepanodus suberectus* (Branson and Mehl) |
| *Drepanodus homocurvatus* Lindstrom | |
| *Oistodus inclinatus* Branson and Mehl | |

| | |
|---|---|
| 13. *Icriodella superba* Rhodes<br>*Rhyncognathodus typicus* (Ethington)<br>*Rhyncognathodus divaricatus* (Ethington)<br>*Sagittodontus dentatus* Ethington<br>*Sagittodontus robustus* Rhodes | *Icriodella superba* Rhodes |
| 14. *Ligonodina delicata* (Branson and Mehl)<br>*Hibbardella diminutiva* (Rhodes)<br>*Keislognathus gracilis* Rhodes<br>*Tetraprioniodus superbus* (Rhodes) | *Ligonodina delicata* (Branson and Mehl) |
| 15. *Oistodus pseudoabundans* Schopf ms. | *Oistodus pseudoabundans* Schopf ms. |
| 16. *Oistodus venustus* Stauffer | *Oistodus venustus* Stauffer |
| 17. *Ozarkodina concinna* Stauffer | *Ozarkodina concinna* Stauffer |
| 18. *Ozarkodina obliqua* (Stauffer)<br>*Prioniodina robusta* (Stauffer)<br>dichognathid element | *Ozarkodina obliqua* (Stauffer) |
| 19. *Panderodus arcuatus* (Stauffer) | *Panderodus arcuatus* (Stauffer) |
| 20. *Panderodus compressus* (Branson and Mehl) | *Panderodus compressus* (Branson and Mehl) |
| 21. *Panderodus feulneri* (Glenister) | *Panderodus feulneri* (Glenister) |
| 22. *Panderodus gracilis* (Branson and Mehl) | *Panderodus gracilis* (Branson and Mehl) |
| 23. *Panderodus panderi* (Stauffer) | *Panderodus panderi* (Stauffer) |
| 24. *Phragmodus cognitus* Stauffer<br>*Dichognathus brevis* Branson and Mehl | *Phragmodus cognitus* Stauffer |

| | |
|---|---|
| 25. *Phragmodus inflexus* Stauffer<br>*Dichognathus peculiaris* Stauffer<br>*Cordylodus elongatus* (Stauffer) | *Phragmodus inflexus* Stauffer |
| 26. *Phragmodus undatus* Branson and Mehl<br>*Dichognathus typica* Branson and Mehl<br>*Oistodus abundans* Branson and Mehl | *Phragmodus undatus* Branson and Mehl |
| 27. *Polyplacognathus ramosa* Stauffer<br>bifurcatid element | *Polyplacognathus ramosa* Stauffer |
| 28. *Pravognathus idonea* (Stauffer)<br>*Pravognathus simplex* (Stauffer) | *Pravognathus idonea* (Stauffer) |
| 29. *Scolopodus insculptus* (Branson and Mehl) | *Scolopodus insculptus* (Branson and Mehl) |
| 30. *Scyphiodus primus* Stauffer | *Scyphiodus primus* Stauffer |
| 31. tetraprioniodid element<br>hibbardellid element | *Tetraprioniodus breviconus* n.sp. |
| 32. *Trichonodella flexa* Rhodes<br>*Trichonodella exacta* Ethington | *Trichonodella flexa* Rhodes |
| 33. *Trichonodella recurva* (Branson and Mehl)<br>*Trichonodella barbara* (Stauffer) | *Trichonodella recurva* (Branson and Mehl) |

**Possible Natural Species**

| Constituent Form Species | Informal Name |
|---|---|
| 1. *Bryantodina typicalis* Stauffer<br>*Phragmodus inversus* n.sp.<br>*Hibbardella variabilis* (Stauffer)<br>*Hibbardella varians* (Stauffer) | *Bryantodina typicalis* Informal Group |

| | |
|---|---|
| *Prioniodina polita* (Stauffer) | |
| 2. *Chirognathus monodactyla* Branson and Mehl<br>*Chirognathus admiranda* Stauffer<br>*Chirognathus delicatula* Stauffer<br>*Chirognathus multidens* Branson and Mehl | *Chirognathus monodactyla* Informal Group |
| 3. *Periodon aculeatus* Hadding<br>*Periodon grandis* (Ethington)<br>*Falodus prodentatus* (Graves and Ellison)<br>*Hibbardella insolita* (Ethington)<br>*Ligonodina tortilis* Sweet and Bergström<br>4. *Prioniodina araea* n.sp. | *Periodon aculeatus* Informal Group |
| 4. *Zygognathus elongata* (Rhodes)<br>*Prioniodina pulcherimma* Rhodes<br>*Cordylodus delicatus?* (Branson and Mehl) | *Zygognathus elongata* Informal Group |
| 5. *Zygognathus illustris* (Stauffer)<br>*Cordylodus aculeatus* (Stauffer) | *Zygognathus illustris* Informal Group |

**Residual Form Species**

1. *Chirognathus invictus* Stauffer
2. *Chirognathus quadridactylus* Stauffer
3. *Chirognathus symmetrica* n.sp.
4. *Coleodus simplex* Branson and Mehl
5. *Curtognathus chatfieldensis* (Stauffer)
6. *Curtognathus limitaris* Branson and Mehl
7. *Distacodus trigonius* Schopf ms.
8. *Ligonodina fairmontensis?* (Pulse and Sweet)
9. *Erismodus symmetricus* Branson and Mehl
10. *Goniodontus superbus* Ethington
11. *Icriodella symmetrica* n.sp.
12. *Ligonodina* sp.
13. *Microcoelodus asymmetricus* Branson and Mehl

14. *Microcoelodus brevibraciatus* Branson and Mehl
15. *Microcoelodus expansus* Branson and Mehl
16. *Microcoelodus unicornis?* Branson and Mehl
17. *Microcoelodus* n.sp. A
18. *Microcoelodus* n.sp. B
19. *Microcoelodus* n.sp. C
20. *Mixoconus primus* Sweet
21. *Neocoelodus spicatus* Branson and Mehl
22. *Oneotodus ovatus* (Stauffer)
23. *Ozarkodina maxima* (Stauffer)
24. *Phragmodus? arcus* n.sp.
25. *Polycaulodus bidentatus* Branson and Mehl
26. *Polycaulodus* n.sp. A
27. *Polycaulodus* n.sp. B
28. *Polycaulodus* n.sp. C
29. *Prioniodina* n.sp. A
30. *Prioniodina* n.sp. B
31. *Ptiloconus compressus* (Branson and Mehl)
32. *Ptiloconus gracilis* (Branson and Mehl)
33. *Stereoconus robustus* Branson and Mehl

## Facies Concepts

Conodonts are considered to be independent of lithofacies, a fact which is supported by the ubiquitous nature of some conodont species. Other conodonts, however, show evidence of facies control of their distribution, whether direct or indirect.

The abrupt disappearance of *Cordylodus serratus, Cordylodus grandis, Trichonodella recurva, Ozarkodina obliqua* and the informal group associated with *Zygognathus illustris* at the top of the Decorah Formation, possibly indicates a direct or indirect dependence of these species on a shaly environment. A similar sharp faunal change occurs in the transition from the Glenwood to the Platteville Formation. In this example several lamellar and almost all fibrous conodonts disappear at the top of the Glenwood Formation. An alternate explanation for these marked faunal changes could be a time gap in sedimentation, although there is at present no evidence for a hiatus.

Differences in range and abundance of conodont species in Middle and Upper Ordovician strata of Minnesota appear to be related to the general shape of forms within a natural species, and might indicate variations in environmental tolerance. For the sake of discussion, conodont species may be lumped into general categories as simple cones, platforms, and bladelike forms. The platforms appear to be most limited in distribution. Only three species were identified in the present study. Two of these, *Polyplacognathus ramosa,* and *Scyphiodus primus,* were found abundant only in the lower part of the Platteville Formation; they occur less commonly in the Glenwood and the upper part of the

Decorah Formation. A third species, *Amorphognathus ordovicica,* is abundant only in the Dubuque Formation.

Conodont species with a predominance of bladelike forms have a somewhat longer range and are considerably more abundant than the platforms. *Ozarkodina concinna, Cordylodus flexuosus,* and *Phragmodus undatus* are three of the longer ranging species.

The simple cones have the longest range and usually are the most abundant conodont species. *Panderodus arcuatus* and *P. compressus* range from the upper beds of the Glenwood to the top of the Dubuque Formation; *P. panderi* and *P. gracilis* range throughout the stratigraphic interval studied. *Drepanodus suberectus* is an especially widespread, long ranging species, and is common in both American midcontinent and European faunas.

Thus, I believe that a relationship exists between the general shape of conodonts and their environmental tolerances. Environmental tolerances may be directly or indirectly influenced by bottom conditions.

## Stratigraphic Distribution of Conodonts

Several conodont zones can be recognized by the appearance and the disappearance of specific types (see fig. 2). The abruptness of these changes in fauna is accentuated by the fact that the natural species of conodonts involved commonly consist of three or four form species. What appears to be a major faunal change may be only the replacement of one natural species by another.

Ten biostratigraphic zones are defined here, in ascending order. The lateral continuity of these zones in Minnesota and northern Iowa is confirmed by study of the published papers of Ethington (1959), Glenister (1957), and the unpublished theses of Anderson (1959), Thompson (1959), and Webers (1961). However, many of the zones are based on assumed migrations of species from other areas and are considered valid only for these two areas.

1. *Chirognathus monodactyla—Bryantodina typicalis* Assemblage Zone

This zone comprises the upper beds of the Glenwood Formation, and is named for two of its' most common conodont species. The conodont fauna is unique, differing markedly from faunas above it. The lower beds of the Glenwood Formation and the underlying St. Peter Sandstone have thus far yielded no conodonts in Minnesota. Conodonts found abundant within this zone include the informal groups associated with *Chirognathus monodactyla* and *Bryantodina typicalis*. *Phragmodus inflexus,* and a variety of rare fibrous forms are unique to this interval.

2. *Polyplacognathus ramosa—Scyphiodus primus* Assemblage Zone

This zone was originally defined by Thompson (1959) on the basis of a collection of roughly nine thousand identifiable conodonts from the Platteville Formation of Minnesota. Ten stratigraphic sections provided lateral coverage. My work confirms the presence of this zone, which extends from the upper Glenwood through approximately the lower two-

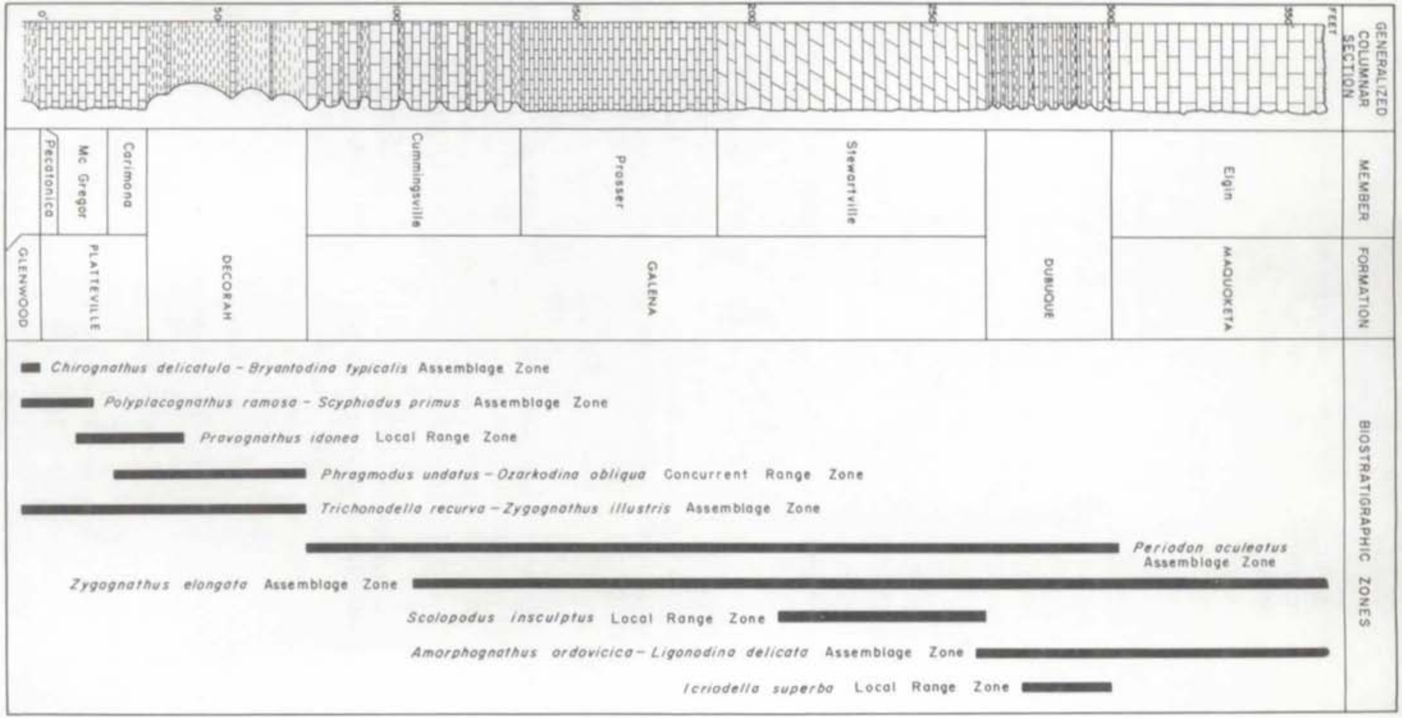



Figure 2 — Biostratigraphic zonation of conodonts.

thirds of the Platteville Formation. *Polyplacognathus ramosa* occurs in almost every sample from this interval, but *Scyphiodus primus* was abundant only in the upper part of the zone. Rare, strongly abraded, and broken specimens of these two species in the upper part of the Decorah Shale may be reworked fossils. *Distacodus variabilis* is also common in this zone and ranges slightly above it.

3. *Pravognathus idonea* Range Zone in Minnesota

The *Pravognathus idonea* zone includes the upper three-fourths of the Platteville Formation and the lower one-fourth of the Decorah Shale. The papers of Thompson (1959) and Anderson (1959) confirm the lateral continuity of this zone in Minnesota.

4. *Phragmodus undatus – Ozarkodina obliqua* Concurrent Range Zone

This zone is defined on the basis of overlapping ranges of the two species for which it is named. The zone includes the upper 8 feet of the Platteville Formation and most of the Decorah Shale. Both species are especially abundant 8 to 38 feet above the base of the Decorah Shale. These two species commonly dominate the conodont fauna within their concurrent ranges, accentuated by the fact that the two species comprise a total of six form species.

5. *Trichonodella recurva – Zygognathus illustris* Assemblage Zone

This zone is named for *Trichonodella recurva* and *Zygognathus illustris* and is defined by their local ranges. It includes the upper Glenwood, the Platteville and Decorah Formations. Conodont elements from these species are abundant through most of this interval although rare to absent in the lower part of the Platteville.

6. *Zygognathus elongata* Assemblage Zone

The mutual local ranges of the informal group associated with *Zygognathus elongata* and *Trichonodella flexa* form the basis for defining this zone. The zone ranges in Minnesota from the upper half of the Cummingsville Member of the Galena Formation at least to the top of the Elgin Member of the Maquoketa Formation. It is interesting to note that this zone is not present in the Elgin Member of the Maquoketa Formation in Iowa, but ranges only through the Depauperate Member (Glenister, 1957).

7. *Periodon aculeatus* Assemblage Zone

This zone is defined on the basis of the mutual ranges of the informal group associated with *Periodon aculeatus*. The zone includes the Galena and Dubuque Formations and the lower third of the Elgin Member of the Maquoketa Formation. The elements are generally rare throughout their range and are abundant only in a few samples. Where abundant, all members are found.

8. *Scolopodus insculptus* Range Zone in Minnesota

Although *Scolopodus insculptus* is never abundant, it defines a zone that is quite useful because it is restricted to the Stewartville Member of the Galena Formation. *Scolopodus insculptus* commonly forms 10 percent of the meager fauna within the zone.

9. *Amorphognathus ordovicica – Ligonodina delicata*
Assemblage Zone

The local ranges of *Amorphognathus ordovicica* and *Ligonodina delicata* in Minnesota are almost identical and define the zone including the uppermost beds of the Stewartville Member of the Galena Formation, the Dubuque Formation, and the Elgin Member of the Maquoketa Formation. *Amorphognathus ordovicica* is considerably more abundant than *Ligonodina delicata,* and is found in nearly every sample within its range.

10. *Icriodella superba* Range Zone in Minnesota

Conodont elements from *Icriodella superba* are confined to the upper two-thirds of the Dubuque Formation and disappear near the top. The five constituent form species are especially abundant in the upper 15 feet of their range. Ethington (1959) indicates a similar, though somewhat narrower, range for the constituent form species in exposures of the Dubuque Formation in Iowa.

## Faunal Migrations

Sweet and others (1959) suggested that conodont-bearing animals characteristic of the eastern United States, England, and Sweden migrated into the central United States during Edenian time. The two areas were referred to respectively as the Anglo-Scandinavian-Appalachian and the North American midcontinent faunal provinces. For simplicity, the two provinces and their faunas will here be referred to as European and midcontinent. Ethington (1959) also noted the presence of European forms in the Stewartville and Dubuque Members of the Galena Formation.

Evidence for these faunal migrations also was found in my work (pl. 1). Faunal migrations began during deposition of the uppermost beds of the Decorah Shale in Minnesota. Within the lowest beds of the Cummingsville Member of the Galena Formation, several abundant midcontinent species, including *Cordylodus serratus, Cordylodus grandis, Trichonodella recurva, Ozarkodina obliqua,* and the informal group associated with *Zygognathus illustris,* abruptly disappear. In this same stratigraphic zone the European elements in the informal group associated with *Periodon aculeatus* appear for the first time. *Phragmodus undatus,* a common midcontinent form, decreases in numbers but is present nearly to the top of the Cummingsville Member, where it disappears except for rare occurrences near the base of the Dubuque Formation. With the disappearance of *Phragmodus undatus,* the group informally associated with *Periodon aculeatus* becomes abundant and, in the upper part of the Stewartville Member, two new European species, *Ligonodina delicata* and *Amorphognathus ordovicica,* appear. Within the upper two-thirds of the Dubuque Formation *Icriodella superba* appears, becomes abundant, and then disappears. Disappearance of the informal group associated with *Periodon aculeatus* follows in the lower third of the Elgin Member of the Maquoketa Formation in Minnesota. *Ligonodina delicata* and *Amorphognathus ordovicica* continue at least to the top of the Elgin Member of the Maquoketa Formation in Minnesota. Glenister (1957) illustrates the return of *Phragmodus undatus* and other midcontinent forms in the Maquoketa of Iowa.

These changes are interpreted as one major faunal invasion beginning at the time of deposition of the Galena Formation, reaching a maximum during deposition of the Dubuque Formation, and reversing itself sometime during deposition of the Maquoketa Formation.

Probably the faunal invasion marks a major change in environmental conditions. Spjeldnaes (1958), on the basis of marine faunal province studies, postulated a climatic zonation in Ordovician time with fluctuation of zones. Swain (1957) notes that uncommon ostracodes of the *Monoceratella teres* zone in the northern Appalachian province show "definite European affinities and may be compared with suites of Sweden ...., Norway...., and Estonia...." Conodonts from this zone in an undescribed collection of mine from the Edinburg Formation of Virginia are nearly identical with those of the Ludibundus Limestone of Sweden (Bergström, 1961).

### Comments on Correlation

The formations studied have been correlated on the basis of conodonts at some time in the past. For a discussion of these correlations the reader is referred to the published reports of Branson and others (1951), Carlson (1960), Ethington (1959), Furnish and others (1936), Stauffer (1935a; 1935b), Pulse and Sweet (1960), Stone and Furnish (1959), Sweet (1955), Sweet and Bergstrom (1962), and Sweet and others (1959). No major revisions of previous correlations is proposed here although some comments and changes in detail are suggested.

The conodont fauna of the Glenwood Formation is unique both in containing an uncommonly large number of species and in having abundant lamellar and fibrous forms. As noted by Stauffer (1935a), Sweet (1955), and others the Glenwood fauna most nearly resembles that of the Harding Sandstone of Colorado. The present study strengthens this correlation. Of the 24 genera reported by Sweet (1955) from the Harding, 22 have been identified from the Glenwood Formation and 25 species are common to both formations. Most lamellar conodonts of the Glenwood Formation range to the top of the Decorah Shale, whereas few fibrous conodonts occur above the Glenwood.

The Platteville and the Decorah Formations contain conodont faunas which are so similar in gross aspects that they might be considered a single fauna differing primarily in abundance of the separate species. The Platteville-Decorah fauna is a close correlative of that from the Plattin Formation of Missouri.

Furnish and others (1936) illustrate conodonts from the Winnipeg Formation (Whitewood Shale and Whitewood Siltstone), which they correlate with the Glenwood, Platteville, and Decorah Formations.

The lower shale unit of the Winnipeg Formation, as described by Bayer (1959) from the subsurface in northeastern Minnesota, has yielded conodonts which were identified by W. M. Furnish. Conodonts from the lower part of the shale were correlated by Furnish with those from the

Harding Sandstone of Colorado (equivalent to the Glenwood Formation of this report). Conodonts from the upper part of the shale were considered equivalent to those of the Platteville and Decorah Formations of southeastern Minnesota. Conodont species, reported by Bayer (1959), with restricted ranges in strata I have studied, include *Chirognathus delicatula, Polyplacognathus ramosa,* and *Phragmodus cognitus;* they confirm the above correlations. No conodonts were reported from the overlying 73-foot sandstone unit of the Winnipeg Formation. Carlson (1960) in a study of the stratigraphy of the Winnipeg and Deadwood Formations in North Dakota lists Winnipeg conodonts from the subsurface of North Dakota and from surface exposures in the Black Hills region of South Dakota. Several of these conodonts have restricted distributions in the sections I studied. Included in these species are: *Chirognathus multidens, C. monodactyla, Bryantodina typicalis, Oneotodus ovatus, Scyphiodus primus, Eoligonodina magna (=Periodon aculeatus), Falodus prodentatus* and *Scolopodus insculptus*. These species show the equivalence of the Winnipeg Formation to a stratigraphic interval in Minnesota from the base of the Glenwood Formation to the top of the Galena Formation.

The conodont fauna of the Elgin Member of the Maquoketa Formation in Minnesota differs markedly from that illustrated by Glenister (1957) from this unit in Iowa and, in fact, is equivalent to the fauna from the one-foot thick Depauperate Member. Conodont species that are found throughout the 60-foot Elgin Member in Minnesota and in and below the Depauperate Member in Iowa include forms presently referred to as *Amorphognathus ordovicica, Cordylodus flexuosus, Goniodontus superbus, Ligonodina delicata, Ozarkodina concinna, Prioniodina pulcherrima,* and *Trichonodella flexa.* Glenister (1957) also points out that the three form species of *Phragmodus undatus* are common throughout the Elgin Member of Iowa. In my study only two poorly preserved specimens, possibly referable to *Phragmodus undatus,* were recovered. In fact there are only four conodont species common to the Elgin Members of Minnesota and Iowa and three of these are simple cones which range throughout the Middle and Upper Ordovician strata of Minnesota.

The Depauperate Member of the Maquoketa Formation has not been recognized in Minnesota, possibly because deposition was continuous through Dubuque time to the end of the interval represented by the exposed Elgin Member of the Maquoketa Formation. An abrupt faunal change, pointed out by Glenister (1957) between the Phosphatic and Elgin Members in Iowa, possibly indicates a time gap in sedimentation. Thus, I think that the Elgin Members of Minnesota and Iowa represent different time intervals and that the Depauperate Member of Iowa possibly represents a period of slow deposition, the time equivalent of the much thicker Elgin Member of Minnesota.

## Conclusions

1. In large populations, natural species of conodonts can be delineated from form species.
2. Criteria used for distinguishing natural species include: (1) approximate equivalence of stratigraphic range for all constituents, (2) relative uniformity of ratios of abundance to other constituents, (3) uniformity of size fluctuations, (4) similarity in "secondary characteristics," and (5) mutual occurrence of constituent form species in rocks of like age where one member is present.
3. The current dual nomenclature as applied to conodonts is unstable, invalid, and unnecessary.
4. A major faunal migration of conodont elements characteristic of eastern United States, England, and Sweden into the midcontinent regions of the United States occurred in Middle and Late Ordovician time.
5. All classifications of conodonts should be based on studies of natural species.

# SYSTEMATIC DESCRIPTIONS

The section on Systematic Descriptions is subdivided as follows: (1) natural conodont species, (2) possible natural conodont species, (3) residual form species, and (4) other phosphatic microfossils. The report by Fay (1952) was used for synonymies prior to 1949. All illustrated specimens may be found in the University of Minnesota Paleontological Collection (U.M.P.C.), Minneapolis, Minnesota.

## Natural Conodont Species

### Genus Acodus Pander, 1856

### Type Species A. erectus Pander, 1856

### Acodus mutatus (Branson and Mehl)

Plate 3 – Figures 5, 6

acodid element:

*Belodus? mutatus* Branson and Mehl, 1933, p. 126, pl. 10, fig. 11; Fay, 1952, p. 126; Bergstrom, 1964, p. 9-10, text-fig. 2.

*Acodus inornatus* Ethington, 1959, p. 268, pl. 39, fig. 11.

**Remarks**: The cotype illustrated by Branson and Mehl (1933) as *Belodus? mutatus,* and designated by Bergström (1964) as the lectotype, appears identical to Galena and Dubuque forms in my work. In their description, Branson and Mehl also mention that some specimens show a tendency to develop one or two minute denticles on the posterior of the oral surface. This tendency was not observed in my specimens.

distacodid element:

*Distacodus procerus* Ethington, 1959, p. 275, pl. 39, fig. 11.

**Remarks on the assemblage:** As noted below, these two form species show striking similarities to some variations of *Distacodus variabilis* n.sp.

The form species "*D. procerus*" and "*Acodus mutatus*" have the same stratigraphic distribution and are always found together in samples where one or the other is common. *Acodus mutatus* is rare in the Galena Formation but ranges to the top of the Dubuque Formation where it is common.

I recovered 46 acodid and 149 distacodid specimens giving a ratio of 1:3.2 and suggesting a 1:3 ratio of the form species in the conodont-bearing animal.

### Genus Acontiodus Pander, 1856

### Type Species A. latus Pander, 1856

### Acontiodus aveolaris Stauffer

Plate 3 – Figure 3

*Acontiodus aveolaris* Stauffer, 1935a, p. 601-602, pl. 74, fig. 44; Fay, 1952, p. 62; Ethington, 1959, pl. 39, figs. 23, 24.

**Remarks:** Only 12 specimens of this species were found, ranging from the upper beds of the Glenwood Formation to the upper Dubuque Formation.

### Genus Amorphognathus Branson and Mehl, 1933

### Type Species A. ordovicica Branson and Mehl, 1933

*Amorphognathus ordovicica* includes the type species of *Ambalodus* Branson and Mehl (*Ambalodus triangularis* Branson and Mehl). The genus *Ambalodus* Branson and Mehl is thus considered a junior synonym of *Amorphognathus* Branson and Mehl.

### Amorphognathus ordovicica Branson and Mehl

Plate 13 – Figure 16, 17

The description of *Amorphognathus ordovicica* Branson and Mehl, 1933, is here emended to include the form species "*Ambalodus triangularis*" Branson and Mehl, 1933.

amorphognathid element:

*Amorphognathus ordovicica* Branson and Mehl, 1933, p. 127, pl. 10, fig. 38; Fay, 1952, p. 63; Rhodes, 1955, p. 123, pl. 9, fig. 4; Stone and Furnish, 1959, p. 220, pl. 32, fig. 12; Pulse and Sweet, 1960, p. 248-249, pl. 37, figs. 13,15; Bergström, 1964, p. 12-16,50, tabs. III, IV,V, text-fig. 5.

?*Amorphognathus ordovicicus* Rhodes, 1953, p. 283, pl. 20, figs. 47-49.

*Amorphognathus adunca* Glenister, 1957, p. 723, pl. 88, figs. 23,24.

*Amorphognathus complicata* Glenister, 1957, p. 723, pl. 88, fig. 26.

*Amorphognathus ramosa* Glenister, 1957, p. 724, pl. 88, fig. 27.

?*Amorphognathus tridigitata* Glenister, 1957, p. 724, pl. 88, fig. 22.

*Amorphognathus* aff. *A. duftona* Ethington, 1959, p. 270, pl. 40, fig. 11.

**Remarks**: Both "blade" and "non-blade" specimens, as described by Bergström (1964), occur in the Minnesota representative of "*Amorphognathus ordovicica.*"

ambalodid element:

*Ambalodus triangularis* Branson and Mehl, 1933, p. 127-128, pl. 10, figs. 35-37; Fay, 1952, p. 26; Rhodes, 1953, p. 280, pl. 20, figs. 28-31; Rhodes, 1955, p. 122-123, pl. 7, figs. 9-14; Glenister, 1957, p. 722, pl. 88, figs. 20,21; Stone and Furnish, 1959, p. 219, pl. 32, fig. 3; Ethington, 1959, p. 269, pl. 40, fig. 12; Sweet and others, 1959, p. 1040, pl. 133, fig. 4; Pulse and Sweet, 1960, p. 248, pl. 35, fig. 16; Bergström, 1964, p. 48-50,52, tabs. I, III, IV, V.

*Dichognathus protexus* Stauffer, 1940, p. 422, pl. 59, figs. 45,46; Fay, 1952, p. 86.

**Remarks on the assemblage**: The two form species, *Ambalodus triangularis* and *Amorphognathus ordovicica,* are common constituents of conodont faunas from the Middle and Upper Ordovician of Europe and the U.S. midcontinent region. In the present study they have identical ranges, and samples yielding one will invariably yield the other, excepting samples with few conodonts. A search of the literature confirms the widespread association of the two.

Recovery of 425 specimens of the amorphognathid element and 105 of the ambalodid element might suggest a 4:1 ratio of the two in the conodont-bearing animal. However the amorphognathid element commonly fragments into three or four identifiable pieces while the ambalodid element can be distinguished only when it is fairly complete. Thus a ratio of 1:1 appears more probable.

*Amorphognathus ordovicica* was found to range in Minnesota from the uppermost beds of the Stewartville Member of the Galena Formation at least to the top of the Elgin Member of the Maquoketa Formation.

### Genus Belodina Ethington, 1959
### Type Species Belodus grandis Stauffer

*Belodina compressa* (Branson and Mehl) (=*Belodus grandis* Stauffer) includes the genotype of *Eobelodina* Sweet (*Oistodus fornicalis* Stauffer). *Eobelodina* Sweet is thus considered a junior synomyn of *Belodina* Ethington.

### Belodina compressa (Branson and Mehl)

Plate 6 – Figures 2, 6, 7, 13, 15

The description of *Belodina compressa* (Branson and Mehl) is here emended to include the form species *Eobelodina fornicala* (Stauffer).

belodinid element:

*Belodus compressus* Branson and Mehl, 1933, p. 114, pl. 9, figs. 15,16; Fay, 1952, p. 67.

*Belodus grandis* Stauffer, 1935b, p. 603-604, pl. 73, figs. 46,47,49,53,54, 57; Fay, 1952, p. 67.

*Belodus wykoffensis* Stauffer, 1935b, p. 604, pl. 72, figs. 51,52,55,58, 59; Fay, 1952, p. 67.

*Belodus dispansa* Glenister, 1957, p. 729-730, pl. 88, figs. 14,15.

*Belodina dispansa* Stone and Furnish, 1959, p. 220, pl. 31, fig. 11; Ethington and Furnish, 1959, p. 542, pl. 73, figs. 12,13.

*Belodina* aff. *B. dispansa* Ethington, 1959, p. 272, pl. 40, fig. 15.

*Belodina grandis* Ethington, 1959, p. 272, pl. 40, fig. 14; Carlson, 1960, tab. II; Sweet and Bergstrom, 1962, p. 1224, pl. 170, figs. 16,17.

*Belodina wycoffensis* Ethington, 1959, p. 272, pl. 40, fig. 16.

*Belodina compressa* Sweet and others, 1959, p. 1042-1044, pl. 133, figs. 12,15; Carlson, 1960, p. 71, pl. 2, fig. 19.

**Remarks**: Sweet and Bergström, 1962, noted the similarities between *Belodina wycoffensis* and *B. grandis* and concluded that they represented a single variable species. Their conclusion is confirmed in my study of over eleven hundred specimens of this form species. "*B. compressa*" Branson and Mehl is within the range of variation of the specimens in my study and is considered conspecific. *B. dispansa* Glenister is considered to be a juvenile form of this variable form species. Very well preserved mature specimens of the more elongate variety of "*B. compressa*" show that the earliest growth stages bore small denticles inclined exactly like those of *B. dispansa*. The stratigraphic range of these juvenile forms is the same as for the mature specimens.

eobelodinid element:

*Oistodus fornicalus* Stauffer, 1935b, p. 610, pl. 75, figs. 3-6; Fay, 1952, p. 135; Lindström, 1954, p. 573; Ethington, 1959, p. 282, pl. 39, fig. 19; Carlson, 1960, p. 77, pl. 2, fig. 18.

(non) *Oistodus fornicalus* Graves and Ellison, 1941, p. 4, 7, pl. 1, figs. 15,17.

*Eobelodina fornicala* Sweet and others, 1959, p. 1050-1051, pl. 133, fig. 11.

**Remarks:** *Eobelodina fornicala* (Stauffer) has the same range and stratigraphic variation as "*Belodina compressa*." With the exception of samples containing few of either form, they are always found together. A total of 1153 belodinid and 266 eobelodinid elements were recovered suggesting a ratio of 4:1 or 5:1 in the conodont-bearing animal.

### Genus Coelocerodontus Ethington, 1959
### Type Species C. trigonius Ethington, 1959
### Coelocerodontus trigonius Ethington
#### Plate 2 – Figures 12, 13a, b, 14

The description of the form species *Coelocerodontus trigonius* Ethington, is here emended to include the form species *C. tetragonius* Ethington.

trigonid element:

*Coelocerodontus trigonius* Ethington, 1959, p. 273, pl. 39, fig. 14.

tetragonid element:

*Coelocerodontus tetragonius* Ethington, 1959, p. 273, pl. 39, fig. 15.

**Remarks:** "*Coelocerodontus trigonius*" and *C. tetragonius* are rare throughout their range from the base of the Prosser Member of the Galena Formation to the top of the Dubuque Formation, but show a remarkable correlation in stratigraphic distribution. Only 18 specimens of "*C. trigonius*" and 13 specimens of "*C. tetragonius*" were recovered.

### Genus Cordylodus Pander, 1856
### Type Species C. angulatus Pander, 1856
### Cordylodus flexuosus (Branson and Mehl)
#### Plate 8 – Figure 8

*Prioniodus? flexuosus* Branson and Mehl, 1933, p. 130, pl. 10, fig. 16; Fay, 1952, p. 171.

*Cyrtoniodus complicatus* Stauffer, 1935a, p. 140,158, pl. 11, figs. 44,46, 48-51; Fay, 1952, p. 85; Rhodes, 1953, p. 302, pl. 22, figs. 193-196; Sweet, 1955, p. 254, pl. 28, fig. 3; Glenister, 1957, p. 732, pl. 88, fig. 16; Ethington, 1959, p. 274, pl. 40, fig. 7.

*Plectodina glenwoodensis* Stauffer, 1935a, p. 152, pl. 11, figs. 38,39; Fay, 1952, p. 147.

*Subcordylodus paratus* Stauffer, 1935a, p. 154, pl. 10, fig. 48; Fay, 1952, p. 147.

*Cyrtoniodus apicalis* Stauffer, 1935b, p. 604, pl. 73, figs. 1,10,43,45; Fay, 1952, p. 85.

*Cordylodus flexuosus* Sweet and others, 1959, p. 1045, pl. 132, fig. 13.

**Remarks**: *Cordylodus flexuosus* is abundant in most samples from the upper beds of the Glenwood Formation through the Elgin Member of the Maquoketa Formation, with the exception of the lower Platteville and the upper Decorah Formations. As previously noted by Sweet and others (1959) the description and illustration of *Prioniodus? flexuosus* in Branson and Mehl appear to be identical to those of Stauffer's *Cyrtoniodus complicatus*. I find *C. apicalis* conspecific with *C. complicatus*. *C. flexuosus* is also a natural species since it has no associated form species.

### Cordylodus grandis (Stauffer)

Plate 8 – Figure 11, 12, 16

The description of *Cordylodus grandis* (Stauffer), 1935, is here emended to include the form species *Zygognathus gyroides* (Stauffer).

cordylodid element:

*Barbarodina grandis* Stauffer, 1935b, p. 603, pl. 73, figs. 6,8; Fay, 1952, p. 66.

*Barbarodina typicala* Stauffer, 1935b, p. 603, pl. 73, figs. 4,5; Fay, 1952, p. 66.

*Subcordylodus* sp. Stauffer, 1935b, p. 618, pl. 73, fig. 21; Fay, 1952, p. 194.

zygognathid element:

*Trichognathus gyroides* Stauffer, 1935b, p. 619, pl. 71, figs. 28,43; Fay, 1952, p. 198.

*Trichognathus deformis* Stauffer, 1935b, p. 619, pl. 71, fig. 46.

*Gyrognathus planus* Stauffer, 1935b, p. 606, pl. 71, figs. 36,48; Fay, 1952, p. 99.

**Remarks**: The earliest immature stages of *"Cordylodus grandis"* appear to be quite similar to early growth stages of *Zygognathus elongata* Rhodes.

**Remarks on the assemblage**: Recovery of 141 cordylodids and 103 zygognathids in statistical samples possibly indicates a 3:2 ratio of the elements in the conodont-bearing animal. The assemblage is rare in the upper beds of the Glenwood and the lower Platteville Formation and becomes abundant in the upper Platteville and Decorah Formations. This range is essentially identical to that of *Cordylodus serratus* and the two assemblages have been kept separate on the basis of Ordovician reference collections kindly provided by Walter C. Sweet of The Ohio State University.

### Cordylodus serratus Stauffer, 1930

Plate 9 – Figures 1, 2, 3, 5

The description of "*Cordylodus serratus*" Stauffer, 1930, is here emended to include the form species *Oulodus primus* (Stauffer).

cordylodid element:

*Cordylodus serratus* Stauffer, 1930, p. 124, pl. 10, fig. 7; Fay, 1952, p. 83.

*Prioniodus cristulus* Stauffer, 1935b, p. 616, pl. 73, figs. 48,57,58 (not fig. 49); Fay, 1952, p. 170.

*Subcordylodus? inaequalis* Stauffer, 1935b, p. 618, pl. 73, figs. 2,3,17, 22,26; Fay, 1952, p. 194.

*Subcordylodus rectilineatus* Stauffer, 1935b, p. 618, pl. 73, figs. 7,23, 28,29,33,39; Fay, 1952, p. 194.

**Remarks**: Many of Stauffer's specimens of "*Lonchodus spinuliferous*" probably belong to "*Cordylodus serratus*".

oulodid element:

*Gyrognathus primus* Stauffer, 1935a, p. 144, pl. 12, figs. 8,9; Fay, 1952, p. 99.

**Remarks**: *Gyrognathus primus* appears to be quite similar to *Oulodus mediocris* Branson and Mehl, and may be conspecific. However I have not seen the type of the latter and hesitate to consider them equivalents on the basis of the Branson and Mehl illustration.

**Remarks on the assemblage**: The recovery of 490 cordylodids and 284 oulodids from statistical samples gives a ratio of 1.73:1. A 2:1 ratio of the elements in the conodont-bearing animal seems possible.

The assemblage is rare in the upper beds of the Glenwood and the lower Platteville Formations and becomes abundant in the upper Platteville and Decorah Formations. No constituents of the assemblage were found above the Decorah.

### Genus Distacodus Hinde, 1879

### Type Species Machairodus incurvus Pander, 1856

### Distacodus falcatus Stauffer

Plate 3 – Figure 4

*Distacodus falcatus* Stauffer, 1935a, p. 142, pl. 12, fig. 16; Fay, 1952, p. 87; Ethington, 1959, p. 275, pl. 39, fig. 9.

**Remarks**: *Distacodus falcatus* although rare is found from the upper beds of the Glenwood to the top of the Dubuque Formation. I recovered 69 specimens of this form which has no associated form species.

### Distacodus variabilis new species

Plate 2 – Figures 15, 16, 17

Holotype: U.M.P.C. 8934, from P1-15, Cummingsville Annex Section

Base laterally compressed and roughly triangular; aboral edge flat except near anterior and posterior terminations where curved upward. A small knoblike keel usually present at posterior terminations of base where upcurving aboral edge intersected by a continuation of posterior cusp heel. Basal excavation deep, laterally compressed, triangular, and usually reaching to mid-cusp height, where cusp strongly curved to posterior.

Cusp laterally compressed, set with sharp anterior and posterior keels continuous to the aboral margin. Lateral cusp surfaces set with a costa extending from distal tip, along cusp, occupying a position near posterior keel, to base, there occupying a median position and reaching almost to aboral margin.

A complete gradation from bilaterally symmetrical forms to markedly asymmetrical ones. With increasing asymmetry: posterior inclination of cusp changing from approximately 45° to nearly 90°; base expanding outward to form triangular cross-section; outer lateral carina becoming very prominent and inner lateral surface often becoming slightly concave near base with a very weak carina.

**Remarks:** Variations of *Distacodus variabilis* are strikingly similar to the distinct form species *"Distacodus procerus"* and *"Acodus mutatus"* found higher in the section. Platteville forms can be distinguished by the presence of a carina on both lateral surfaces, an outwardly flaring base, or the presence of a knoblike posterior termination of the base. Platteville forms also commonly taper more rapidly to mid-height, and are less compressed laterally.

This species is found only in the Platteville Formation, being common in the lower and rare in the upper Platteville. There are no associated form species.

### Genus Drepanodus Pander, 1856

### Type Species D. arcuatus Pander, 1856

### Drepanodus cavus new species

Plate 2 – Figures 4, 5

Holotype: U.M.P.C. 8924, from P1-15, Cummingsville Annex Section.

A nearly symmetrical simple cone recurved posteriorly. Strongest curvature in side view near mid-height; anterior and posterior sharply keeled. Lateral surfaces convex in cross-section with strongest curvature near anterior margin. Unit deeply excavated to mid-height.

**Remarks:** *Drepanodus cavus* is long ranging but nowhere abundant, occurring from the base of the Platteville to the top of the Dubuque Formation. The trivial name is derived from the Latin word "cavus" meaning "hollow". The deep basal excavation is unique among species of *Drepanodus*. Twenty-three specimens were recovered and there are apparently no associated form species.

### Drepanodus suberectus (Branson and Mehl)

Plate 6 – Figures 9, 11, 14, 16

The description of *Drepanodus suberectus* (Branson and Mehl) is here emended to include the form species *Drepanodus homocurvatus* Lindstrom and *Oistodus inclinatus* Branson and Mehl.

suberectid element:

*Oistodus suberectus* Branson and Mehl, 1933, p. 111, pl. 9, fig. 7; Fay, 1952, p. 136; Rhodes, 1953, p. 295, pl. 21, figs. 93, 94; pl. 22, figs. 166, 167; Glenister, 1957, p. 726, pl. 86, figs. 12, 14.

*Oistodus curvatus* (part) Stauffer, 1935b, p. 609, pl. 74, figs. 38, 39 (not figs. 5, 10, 12, 17, 20-29, 31, 33-37, 40, 47-49).

*Oistodus erectus* Stauffer, 1935b, p. 609, pl. 74, fig. 50; Fay, 1952, p. 135.

*Oistodus giganteus* Stauffer, 1935b, p. 610, pl. 74, fig. 45; Fay, 1952, p. 135.

*Drepanodus suberectus* Lindström, 1954, p. 568, pl. 2, figs. 21, 22; Sannemann, 1955, p. 27, pl. 1, fig. 22; pl. 2, fig. 1; Lindstrom, 1957, p. 164; Ethington, 1959, p. 276, pl. 39, fig. 17; Stone and Furnish, 1959, p. 222, pl. 31, fig. 7; Sweet and others, 1959, p. 1049, pl. 130, fig. 4; Pulse and Sweet, 1960, p. 253, pl. 35, figs. 2, 7; Bergström, 1961, p. 41, pl. 5, fig. 7, text-figs. 3k, 4b; Wolska, 1961, p. 349, pl. 1, figs. 8a, b; Sweet and Bergström, 1962, p. 1226, pl. 169, fig. 8; Bergström, 1964, p. 24, 50, 52, tabs. III, IV, V.

homocurvatid element:

*Oistodus curvatus* Branson and Mehl, 1933, p. 113, pl. 9, figs. 24-26; (part) Stauffer, 1935b, p. 609, pl. 75, figs. 5, 10, 17, 20-23, 25-29, 31, 33-37, 40, 47-49 (not figs. 12, 38, 39); Fay, 1952, p. 86; Rhodes, 1953, p. 295, pl. 21, figs. 82, 89, 90, pl. 22, figs. 157-161; Sweet, 1955, p. 251, pl. 28, fig. 7.

*Stereoconus gracilis* Stauffer, 1935a, p. 153, pl. 12, figs. 25, 32.

*Oistodus brevis* Stauffer, 1935b, p. 609, pl. 74, fig. 32; Fay, 1952, p. 134.

*Drepanodus homocurvatus* Lindström, 1955, p. 563, pl. 2, figs. 23, 24, 39, text-fig. 4d; Sannemann, 1955, p. 26, pl. 2, fig. 4, pl. 1, fig. 14; Lindström, 1957, p. 164; Glenister, 1957, p. 725, pl. 86, fig. 13; pl. 87, figs. 1-6, 8; Stone and Furnish, 1959, p. 222, pl. 31, fig. 8; Ethington, 1959, p. 276, pl. 36, fig. 16; Sweet and others, 1959, p. 1049, pl. 130, fig. 7; Carlson, 1960, tab. II; Bergström, 1961, p. 39-

41, pl. 2, figs. 13, 14; pl. 5, fig. 19, text-fig. 3e, 4a; Wolska, 1961, p. 348, pl. 2, figs. 7a, b; Sweet and Bergström, 1962, p. 1226, pl. 169, fig. 9; Bergström, 1964, p. 23, 24, 48-50, 52, tabs. I, III, IV, V.

oistodid element:

*Oistodus inclinatus* Branson and Mehl, 1933, p. 110, pl. 9, fig. 8; Fay, 1952, p. 135; Branson, Mehl, and Branson, 1951, p. 3, pl. 2, figs. 5, 6; Glenister, 1957, p. 726, pl. 86, fig. 11; Stone and Furnish, 1959, p. 224, pl. 31, fig. 6; Sweet and others, 1959, p. 1053, pl. 131, fig. 6.

*Oistodus acuminatus* Stauffer, 1935a, p. 146, pl. 12, fig. 33; Fay, 1952, p. 134.

*Oistodus abundans* (part) Stauffer, 1935b, pl. 75, figs. 7, 11-13, 19 (not fig. 2).

*Oistodus curvatus* (part) Stauffer, 1935b, pl. 74, fig. 12 (not figs. 5, 10, 17, 20-29, 31, 33-40, 47-49).

*Oistodus excelsus* Stauffer, 1935b, p. 610, pl. 74, fig. 43; Fay, 1952, p. 135; Glenister, 1957, p. 725, 726, pl. 86, figs. 4, 7; Ethington, 1959, p. 282, pl. 39, fig. 20; Bergström, 1964, p. 43, text-fig. 21, tabs. I, V.

*?Oistodus forceps?* Sweet and Bergström, 1962, p. 1231-1232, text-fig. 2, pl. 168, figs. 14, 15.

*Oistodus* cf. *inclinatus* Bergström, 1964, p. 45, 51, 52, tabs. IV, V.

**Remarks**: I find no differences in description or illustration between the two form species *Oistodus inclinatus* Branson and Mehl and *Oistodus excelsus* Stauffer and thus consider them conspecific.

**Remarks on the assemblage**: All three forms of *Drepanodus suberectus* and especially the homocurvatid element, are quite variable with respect to degree of inclination of the cusp and details of the basal excavation. *D. suberectus* is a ubiquitous and long-ranging species in both North American and European conodont faunas. In Minnesota it ranges at least from the upper beds of the Glenwood Formation through the Elgin Member of the Maquoketa Formation.

Statistical samples yielded 2364 homocurvatid, 364 suberectid, and 509 oistodid specimens, the ratio being 6.5:1:1.3. These results might suggest a 6:1:1 ratio of the elements in the conodont-bearing animal.

## Genus Icriodella Rhodes, 1953

### Type Species I. superba Rhodes, 1953

*Icriodella superba* Rhodes includes the type species of *Rhyncognathodus* Ethington *(R. typica* Ethington) and *Sagittodontus* Rhodes *(S. robusta* Rhodes). *Rhyncognathodus* Ethington and *Sagittodontus* Rhodes are thus considered junior synomyns of *Icriodella* Rhodes.

### Icriodella superba Rhodes

Plate 13 – Figures 3-9

The description of *Icriodella superba* Rhodes is here emended to include the form species *Sagittodontus robustus* Rhodes, *Sagittodontus dentatus* Ethington, *Rhyncognathodus typica* (Ethington), and *Rhyncognathodus divaricata* (Rhodes).

icriodellid element:

*Icriodella deforma* Rhodes, 1953, p. 286, pl. 20, figs. 68-70.

*Icriodella elongata* Rhodes, 1953, p. 287, pl. 20, figs. 79-81.

*Icriodella plana* Rhodes, 1953, p. 287, pl. 20, figs. 67, 74, 76.

*Icriodella superba* Rhodes, 1953, p. 288, pl. 20, figs. 54, 58, 62, 63, 65, 78; Bergström, 1964, p. 51, tabs. III, IV, V.

*Icriodella superba* var. *acuta,* 1953, p. 288, pl. 20, figs. 59, 60, 64, 66, 71-73, 77.

*Icriodella acuta* Ethington, 1959, p. 279, 280, pl. 41, fig. 5.

**Remarks**: Bergström, 1964, points out the identity of *Icriodella superba, I. deforma, I. elongata, I. plana,* and *I. superba* var. *acuta.* I completely concur with this equivalence after studying the descriptions and illustrations of Rhodes (1953) and reference collections kindly provided by Stig Bergström.

robustid element:

*Sagittodontus robustus* Rhodes, 1953, p. 311, pl. 21, figs. 141, 142; Ethington, 1959, p. 287, pl. 39, fig. 12; Bergström, 1964, p. 51, 53, tabs. III, IV, V.

*Sagittodontus robustus* var. *erectus* Rhodes, 1953, p. 311, pl. 21, figs. 143, 151, 152.

*Sagittodontus robustus* var. *distaflexus* Rhodes, 1953, p. 312, pl. 21, figs. 137, 138.

**Remarks**: I agree with Bergström (1964) in considering *S. robustus* a variable form species without further subdivision into *S. robustus* var. *erectus* and *S. robustus* var. *distaflexus.*

dentatid element:

*Sagittodontus dentatus* Ethington, 1959, p. 287, pl. 39, fig. 13; Sweet and others, 1959, p. 1062, 1063, pl. 131, figs. 7, 8; Bergström, 1964, p. 45, 51, tabs. III, V.

typicid element:

*Rhyncognathus typica* Ethington, 1959, p. 286, pl. 41, figs. 3, 4; Bergström, 1964, p. 51, tabs. III, V.

divaricatid element:

*Trichonodella divaricata* Rhodes, 1953, p. 313, pl. 21, figs. 145, 146, 124?, 140?.

*Rhyncognathus aborodentata* Ethington, 1959, p. 286, 287, pl. 41, figs. 1, 2.

**Remarks on the assemblage:** All five elements of *Icriodella superba* have been reported from the Gelli-grin and Pen-y-garnedd Limestones of England (Bergström, 1964) and from the Dubuque Formation of Iowa (Ethington, 1959). The form species *Sagittodontus dentatus* has also been reported from the Eden Formation of Ohio.

Elements of this species are abundant in the middle and upper Dubuque Formation of Minnesota and form a useful local range zone. Recovery of 227 icriodellid, 172 robustid, 37 dentatid, 56 typicid and 60 divaricatid elements in statistical samples yields a ratio of 4.05:3.07:0.66:1:1.07 respectively. Recognizing the fact that the icriodellid element commonly fragments into more than one identifiable part, a ratio of 3:3:1?:1:1 of the elements might be possible in the conodont-bearing animal.

## Genus Ligonodina Ulrich and Bassler, 1926

### Type Species L. pectinata Ulrich and Bassler, 1926

*Ligonodina delicata* (Branson and Mehl) includes the type species of *Keislognathus* Rhodes (*K. gracilis* Rhodes). The genus *Keislognathus* Rhodes is thus considered a junior synomyn of *Ligonodina* Ulrich and Bassler.

### Ligonodina delicata (Branson and Mehl)

Plate 13 – Figures 10, 11, 13-15

The description of *Ligonodina delicata* (Branson and Mehl) is here emended to include the form species *Keislognathus gracilis* Rhodes, *Tetraprioniodus superbus* Rhodes and *Hibbardella diminutiva* (Rhodes).

ligonodinid element:

*Phragmodus delicatus* Branson and Mehl, 1933, p. 123, pl. 10, fig. 22.

(non) *Ligonodina delicata* Branson and Mehl, 1934, (dated July 1, 1933) p. 199, pl. 14, figs. 22, 23.

(non) *Phragmodus delicatus* Graves and Ellison, 1941, p. 6, pl. 3, figs. 22, 23.

*Ligonodina elongata* Rhodes, 1953, p. 305-306, pl. 21, figs. 130, 131; Lindstrom, 1959, p. 440, pl. 3, fig. 26, 27; Bergström, 1962, p. 43, 44, pl. 5, figs. 14, 15, 17, 18.

*Ligonodina extensa* Rhodes, 1953, p. 306, pl. 21, figs. 128, 129.

*Cordylodus primus* Glenister, 1957, p. 732, pl. 88, fig. 18.

*Eoligonodina elongata* Ethington, 1959, p. 277, pl. 40, fig. 5; Sweet and others, 1959, p. 1051, pl. 32, fig. 4.

*Ligonodina delicata* Bergström, 1964, p. 28, 29, 51, 52, text-fig. 12, tabs. III, IV, V.

**Remarks**: As Bergström (1964) notes, *Ligonodina delicata* Branson and Mehl, 1934, is a junior homonym; and the forms referred to *Phragmodus delicatus* by Graves and Ellison, (1941), pl. 14, figs. 22, 23, belong to *Tetraprioniodus superbus* and *Keislognathus* sp. respectively.

keislognathid element:

*Keislognathus gracilis* Rhodes, 1955, p. 131, pl. 7, figs. 7, 8; Sweet and others, 1959, p. 1051, 1052, pl. 132, fig. 11; Pulse and Sweet, 1960, p. 254, pl. 36, fig. 3.

*Keislognathus simplex* Ethington, 1959, p. 280, pl. 40, figs. 9, 10.

**Remarks**: Ethington (1959) erected *Keislognathus simplex* for specimens which differed from *K. gracilis* primarily by the presence of a prominent denticle on both sides of the cusp. The prominence of these denticles is accentuated in mature specimens and is a variable feature in forms referred to this form species in the present study. Examination of European reference collections kindly provided by Stig Bergström reveals no significant difference between the Minnesota and European forms.

tetraprioniodid element:

*Phragmodus delicatus* (part) Graves and Ellison, 1941, p. 6, pl. 3, fig. 22 (not fig. 23).

*Rosagnathus superbus* Rhodes, 1955, p. 129, pl. 7, figs. 1-4.

*Tetraprioniodus parvus* Ethington, 1959, p. 288, 289, pl. 40, fig. 8.

*Tetraprioniodus superbus* Pulse and Sweet, 1960, p. 260, pl. 36, fig. 2.

**Remarks**: *Tetraprioniodus parvus* Ethington (1959) was erected to include specimens differing from *T. superbus* in having a greater length of the anterior aboral process and a smaller number of denticles on the lateral bars. Both characteristics were found to be variable features in specimens from the present study and I consider the two species to be conspecific.

hibbardellid element:

*Roundya diminutiva* Rhodes, p. 137, pl. 8, figs. 9, 12.

*Roundya inclinata* Glenister, 1959, p. 733, 734, pl. 88, fig. 19.

*Trichonodella inclinata* Ethington, 1959, p. 290, pl. 41, fig. 6.

*Hibbardella diminutiva* Bergström, 1964, p. 26, 51, tab. V.

**Remarks**: As indicated by a study of European reference collections, kindly provided by Stig Bergström, Minnesota forms from the Dubuque

Formation seem to belong to *Hibbardella diminutiva* rather than to *H. inclinata,* a similar form species.

**Remarks on the assemblage**: All elements of this assemblage possess similar "secondary characteristics," although the number of processes varies considerably. The unique "hindeodellid" denticulation of the posterior bars is especially uniform on all elements.

*Lingonodina delicata* ranges from the base of the Dubuque Formation through at least the Elgin Member of the Maquoketa Formation, although it is never common. Statistical samples yielded 17 keislognathid, 19 ligonodinid, 9 tetraprioniodid and 14 hibbardellid elements. Although few specimens were recovered, perhaps a 2:2:1:2? ratio of the elements existed in the conodont-bearing animal.

### Genus Oistodus Pander, 1856

### Type Species O. lanceolatus Pander, 1856

### Oistodus pseudoabundans Schopf ms.

Plate 2 – Figures 20, 21

**Remarks**: *Oistodus pseudoabundans* is common in the Platteville Formation and ranges to the lower beds of the Decorah Formation. One hundred eighty six specimens were recovered. This form is apparently not associated with any other form species: its range is generally similar to *Phragmodus cognitus* but differs considerably in relative abundance of the forms within its range. The species will be defined in a paper on the conodonts of the type Trenton in preparation by Thomas Schopf of The Ohio State University.

### Oistodus venustus Stauffer

Plate 2 – Figures 18, 19

*Oistodus venustus* Stauffer, 1935a, p. 147, pl. 12, fig. 12; Fay, 1952, p. 136; Rhodes, 1953, p. 195-196, pl. 22, figs. 168-170; Ethington, 1959, p. 282, pl. 39, fig. 22; Bergström, 1964, p. 48, 51, tabs. I, III.

(non) *Oistodus venustus* Glenister, 1957, p. 727, pl. 86, fig. 6.

*Oistodus fornicalus* Graves and Ellison, 1941, p. 4, pl. 2, fig. 18.

*Oistodus* sp. Lindstrom, 1957, p. 174, pl. 1, fig. 8.

*Oistodus* cf. O. *venustus* Bergström, 1961, p. 46-47, pl. 5, figs. 8, 9.

**Remarks**: *Oistodus venustus* is quite variable, especially in its growth stages. Earliest growth stages show a well developed lateral costa on both sides of a strongly laterally compressed cusp, giving a cross-shaped cross-section to the cusp. Anterior margins are generally well rounded in side view on these early stages.

With increasing maturity first the outer lateral and finally the inner lateral costa is lost as the cusp becomes more and more peglike, with a rhombic, triangular, or sub-circular cross-section. The anterior margin generally becomes more pointed with increasing maturity, although this is quite a variable feature.

This species is long-ranging in Minnesota, being found from the upper beds of the Glenwood Formation to the top of the Dubuque Formation although it never becomes common. Eighty-one specimens were recovered.

### Genus Ozarkodina Branson and Mehl, 1933

### Ozarkodina concinna Stauffer

Plate 9 – Figures 9-12

*Ozarkodina concinna* (part) Stauffer, 1935a, p. 148, pl. 10, figs. 41, 46 (not fig. 45); Fay, 1952, p. 137; Sweet, 1955, p. 260, pl. 29, fig. 18; Carlson, 1960, p. 69, pl. 2, figs. 7, 12.

*Ozarkodina amorphina* Stauffer, 1935a, p. 148, pl. 10, fig. 50; Fay, 1952, p. 137.

*Ozarkodina reperta* Stauffer, 1935a, p. 149, pl. 10, fig. 37; Fay, 1952, p. 138.

*Ozarkodina robusta* Stauffer, 1935b, n. 7, p. 612, pl. 71, figs. 1, 3, 6, 9-13, 15, 21; Fay, 1952, p. 138; Sweet and others, 1959, p. 1055, pl. 133, fig. 14; Pulse and Sweet, 1960, p. 256, pl. 35, figs. 18, 19.

*Ozarkodina pauperata* Stauffer, 1935b, p. 611, pl. 71, figs. 16, 24; Fay, 1952, p. 138.

*Ozarkodina inclinata* Glenister, 1957, p. 735, pl. 88, figs. 3, 7.

Unit laterally compressed, flaring inward and slightly outward beneath main cusp. Basal excavation a subconical pit beneath main cusp, continuing beneath anterior and posterior processes as a shallow notch uniformly decreasing in depth towards the tips.

Main cusp approximately twice as high as next largest denticle and located just posterior to center of unit. Main cusp and all denticles short, laterally compressed, basally confluent, and keeled anteriorly and posteriorly with broadly convex lateral surfaces.

Anterior process straight, longer than posterior, and set with eight or more denticles on mature specimens.

Posterior process twisted slightly outward, set with four or more denticles on mature specimens, and forming an angle of approximately 132° with the anterior process. Variations in this angle up to 10° in either direction noted.

**Remarks:** *Ozarkodina concinna* is quite a variable species, both within a single bed and also stratigraphically. Platteville and Decorah specimens commonly exhibit a small basal furrow, directed downward and posteriorly, on the inward flaring surface beneath the main cusp. This furrow is not present in population samples from the Galena, Dubuque, and Maquoketa Formations. Specimens from these formations are also more compressed laterally, and exhibit a slightly greater inclination of the anterior process. Platteville specimens average 134° between processes compared with an average of 130° for Dubuque specimens.

Glenister, 1957, chose to distinguish Maquoketa forms as a separate species described as *Ozarkodina inclinata*. Although there is some justification for differentiation, I feel that these variations can well be referred to a single species.

*Ozarkodina concinna* was abundant in all samples except those from the lower Platteville and the upper Decorah Formation. Its stratigraphic distribution is different from that of any other conodont form species and it is apparently not associated with any other form.

### Ozarkodina obliqua (Stauffer)

Plate 10 – Figures 1-7, 9

The description of the form species *Ozarkodina obliqua* (Stauffer), 1930, is here emended to include the form species of *Ptiloconus robustus* (Stauffer), 1930, and a previously undescribed form species of *Dichognathus*.

ozarkodinid element:

*Prioniodus? obliquus* Stauffer, 1930, p. 123, pl. 10, figs. 3, 4.

*Prioniodus cornutus* Stauffer, 1930, p. 127, pl. 10, fig. 15.

*Euprioniodina futilis* Stauffer, 1930, p. 126, pl. 10, fig. 10.

*Ozarkodina concinna* (part) Stauffer, 1935a, p. 148, pl. 10, fig. 45 (not figs. 41, 46).

*Euprioniodina dubia* Stauffer, 1935b, p. 605, 606, pl. 72, fig. 23.

*Microcoelodus obliquus* Stauffer, 1935b, p. 608, pl. 73, figs. 53, 56.

Base deeply excavated and flaring beneath main denticle, with a broad, very shallow excavation extending beneath posterior bar and a deep excavation uniformly becoming shallower toward tip of anterior process. Main cusp short and laterally compressed, with anterior and posterior keels. Anterior process straight or curving slightly inward, shorter than posterior, and bearing at least seven laterally compressed denticles on mature specimens. Posterior process twisted downward and outward, and bearing at least eight denticles on mature specimens. Denticles on posterior process bladelike on immature specimens, becoming peglike at maturity. Asymmetry of the unit increasing with maturity.

**Remarks**: The unit is commonly found with a broken posterior bar. *Ozarkodina obliqua* can easily be distinguished from *O. concinna* by the twisted posterior process, which is longer than the anterior process.

ptiloconid element:

*Euprioniodina robusta* Stauffer, 1930, p. 123, pl. 10, fig. 1; Fay, 1952, p. 93.

*Pteroconus tortus* Branson and Mehl, 1933, p. 112, fig. 33; Fay, 1952, p. 179.

*Pteroconus robustus* Stauffer, 1935b, p. 617, pl. 75, figs. 15-17, 20, 21; Fay, 1952, p. 179.

*Ptiloconus tortus* Sweet, 1955, p. 246, pl. 28, fig. 11.

Base deeply excavated beneath main denticle as a semiconical pit, flattened on outer lateral face, prominently flaring inward. Excavation continuing as a moderate notch decreasing toward tip of both processes. Main cusp long, laterally compressed, and twisted slightly inward; lateral faces convex, anterior and posterior keels sharp and continuous with denticulated processes. Anterior and posterior processes straight, forming an angle of 80° to 90°. Anterior process with at least four, and posterior process at least eight, laterally compressed, discrete denticles on mature specimens.

dichognathid element:

*Prioniodus cultellatus* Stauffer, 1930, p. 126, pl. 10, fig. 11; Fay, 1952, p. 170.

*Dichognathus variabilis* (part) Stauffer, 1935b, p. 604, 605, pl. 74, fig. 8 (not pl. 73, figs. 14, 24, 30, 31, 34-37, 40, 44, 50, 59).

?*Dichognathus* sp. Stauffer, 1935b, p. 605, pl. 75, fig. 10; Fay, 1952, p. 86.

Base deeply excavated forming semiconical pit beneath main denticle; excavation continuing as a shallow groove beneath lateral and posterior processes; outer lateral surface convex, inner surface flaring inward to junction with inner lateral process. Main cusp long, erect, laterally compressed and twisted slightly inward; lateral faces convex, inner lateral face with small costa near anterior margin continuous from lateral process to cusp tip. Anterior keel sharp and continuous into well developed anticusp. Posterior keel sharp and continuous with posterior process. Posterior process straight, inclined slightly outward, with five or more laterally compressed, discrete, posteriorly inclined denticles. Lateral process inclined downward and inward, with four or more laterally compressed, discrete denticles. Lateral and posterior processes approximately of equal length and forming an angle of about 90°.

**Remarks:** In most specimens the anterior process was broken off at its junction with the main cusp. The posterior process is also commonly broken.

**Remarks on assemblage:** *Ozarkodina obliqua* (Stauffer) is common in the upper beds of the Glenwood Formation, rare in the Platteville Formation, and abundant in the Decorah Formation. None of the constituent form species occurred above the latter formation.

Recovery of 218 ozarkodinid, 253 ptiloconid, and 282 dichognathid specimens gives a ratio of 0.86:1:1.1 suggesting a ratio of 1:1:1 of constituent form species in the conodont-bearing animal.

### Genus Panderodus Ethington, 1959

### Type Species Paltodus unicostatus Branson and Mehl, 1933

### Panderodus arcuatus (Stauffer)

Plate 2 – Figures 8a, b, 9a, b

*Paltodus arcuatus* Stauffer, 1935b, p. 612, pl. 74, figs. 6, 8, 9; Fay, 1952, p. 143.

*Panderodus arcuatus* Carlson, 1960, p. 69, pl. 2, fig. 8.

**Remarks**: *Panderodus arcuatus* is abundant in the Platteville and the Decorah Formations, and is not uncommon in the Glenwood, Galena, and Dubuque Formations. The stratigraphic range of this species is not greatly different than that of *Panderodus compressus* (Branson and Mehl), but the evidence from the relative abundance of the two is not sufficiently compelling to associate them.

### Panderodus compressus (Branson and Mehl)

Plate 2 – Figures 10, 11

*Paltodus compressus* Branson and Mehl, 1933, p. 109, pl. 8, fig. 19; Fay, 1952, p. 143; Amsden, 1957, p. 35.

*Paltodus cornutus* Stauffer, 1935b, p. 612, pl. 74, figs. 1, 2, 11, 13-15 (not fig. 19); Fay, 1952, p. 143.

**Remarks**: *Panderodus compressus* is common from the upper beds of the Glenwood Formation to the top of the Decorah Formation and is rare above the latter to the top of the Dubuque Formation.

### Panderodus feulneri (Glenister)

Plate 3 – Figures 1a, b, 2a, b

*Paltodus feulneri* Glenister, 1957, p. 728, pl. 85, fig. 11.

*Panderodus feulneri* Ethington, 1959, p. 284, 285, pl. 39, fig. 2.

**Remarks**: Forms referred to *Panderodus feulneri* compare closely with those figured by Glenister (1957) and were found to range in Minnesota from the top of the Decorah Formation at least to the top of the Elgin Member of the Maquoketa Formation.

**Panderodus gracilis (Branson and Mehl)**

Plate 3 – Figures 10a, b, 11a, b, 12a, b

*Paltodus gracilis* Branson and Mehl, 1933, p. 108, pl. 8, figs. 20, 21; Fay, 1952, p. 144; Amsden, 1957, p. 35.

*Paltodus cornutus* (part) Stauffer, 1935b, p. 612, pl. 74, fig. 19 (not figs. 1, 2, 11, 13-15).

*Paltodus elegans* Stauffer, 1935b, p. 612, 613, pl. 74, figs. 4, 7; Fay, 1952, p. 143, 144.

*Paltodus striatus* Stauffer, 1935b, p. 613, pl. 74, figs. 3, 16; Fay, 1952, p. 144.

?*Paltodus intermedius* Glenister, 1957, p. 728, pl. 85, fig. 10; Ethington, 1959, p. 285, pl. 39, fig. 3.

*Panderodus gracilis* Ethington, 1959, p. 285, pl. 39, fig. 1; Pulse and Sweet, 1960, p. 256, pl. 35, figs. 3, 6; Carlson, 1960, tab. II; Wolska, 1961, p. 353, pl. 4, figs. 2a, b; Sweet and Bergström, 1962, p. 1233, text-fig. 1H; Bergström, 1964, p. 33, 51, text-fig. 16, tabs. I, III, V.

?*Panderodus intermedius* Ethington, 1959, p. 285, pl. 39, fig. 3.

**Remarks**: *Panderodus gracilis* is quite variable in width and appears to be completely gradational with forms illustrated by Ethington (1959) and Glenister (1957) as *Panderodus intermedius* and *Paltodus intermedius* respectively. This species does not appear to be associated with any other forms. It's range in Minnesota includes the interval from the upper beds of the Glenwood Formation at least to the top of the Elgin Member of the Maquoketa Formation.

**Panderodus panderi (Stauffer)**

Plate 2 – Figures 1a, b, 2a, b, 3a, b, 6a, b

*Paltodus panderi* Stauffer, 1940, p. 427, pl. 60, figs. 8, 9; Fay, 1952, p. 144; Glenister, 1957, p. 728, 729, pl. 85, figs. 8, 9.

*Panderodus panderi* Ethington, 1959, p. 285, pl. 35, fig. 5; Stone and Furnish, 1959, p. 226, pl. 31, fig. 4.

**Remarks**: *Panderodus panderi* is quite variable in width of base and degree of posterior inclination of the cusp. Specimens with nearly erect cusps tend to be slender with a relatively narrow base. A complete gradation is present from these to forms which have a posteriorly elongate base, taper rapidly to mid-cusp height, and exhibit a posterior inclination of the distal portion of the cusp which is nearly parallel to the base. Stauffer's types and almost all specimens in the present study exhibit a strong carina which is either anterior or slightly deflected from this position toward the convex inner lateral surface.

*Panderodus panderi* (Stauffer) is long ranging in Minnesota. The observed range is from the upper beds of the Glenwood Formation at least to the top of the Elgin Member of the Maquoketa Formation. I recovered 1341 specimens.

### Phragmodus inflexus Stauffer

Plate 3 – Figure 8

Plate 8 – Figures 1, 2, 4

The description of *Phragmodus inflexus* Stauffer is here emended to include the form species *Cordylodus elongatus* (Stauffer) and *Dichognathus peculiaris* Stauffer.

phragmodid element:

*Phragmodus inflexus* (part) Stauffer, 1935a, p. 151, pl. 11, figs. 9, 16, 20, 25, 26 (not figs. 15, 17, 19, 21, 22, 34); Fay, 1952, p. 146.

*Subcordylodus elongatus* Stauffer, 1935a, p. 153, 154, pl. 11, fig. 33; Fay, 1952, p. 194.

*Subcordylodus sinuatus* Stauffer, 1935a, p. 154, pl. 11, figs. 28, 37, 42, 45; Fay, 1952, p. 194.

*Phragmodus singularis* Stauffer, 1935a, p. 151, pl. 11, figs. 23, 24, 35, 36; Fay, 1952, p. 146.

**Remarks**: Sweet (1959) describes three distinct cusp types of *"Phragmodus undatus"*. The same three cusp types are present in my collection of *"Phragmodus cognitus"* and *"Phragmodus undatus"*. In *"Phragmodus inflexus"*, however, only two cusp types are present: the bicostate type is absent. *"Cordylodus elongatus"* exhibits a bicostate cusp and, except for the arching of the posterior process, is identical to *"Phragmodus inflexus"*. *"Cordylodus elongatus"* and *"Phragmodus inflexus"* have sinuous posterior processes which exhibit a "hindeodellid" denticulation similar to *"Phragmodus undatus"* and both are restricted to a narrow stratigraphic interval, the upper beds of the Glenwood Formation. Thus I consider the phragmodid element of *Phragmodus inflexus* to consist of the two form species *"Phragmodus inflexus"* and *"Cordylodus elongatus"*.

dichognathid element:

*Dichognathus peculiaris* Stauffer, 1935a, p. 141, pl. 11, figs. 1, 4, 6, 11; Fay, 1952, p. 86.

*Dichognathus typicus* (part) Stauffer, 1935a, p. 141, pl. 11, figs. 2, 3, 5, 8 (not fig. 10); Fay, 1952, p. 86.

**Remarks**: The dichognathid element of *Phragmodus inflexus* is distinguished from similar forms by the presence of a small denticle anterior to the main cusp. Nearly all specimens exhibit some trace of anterior denticulation. The population variation includes forms ranging from those with a well defined anterior denticle to those in which the denticle is completely lacking, or present as an unerupted germ denticle.

**Remarks on the assemblage**: The association of these forms, which occur only in the upper beds of the Glenwood Formation, was suspected because of the association of a dichognathid and phragmodid element in both *Phragmodus cognitus* and *Phragmodus undatus*. *"Phragmodus inflexus"* and *"Dichognathus peculiaris"* were also found associated in reference collections from the Castell Limestone of Wales kindly provided by Stig Bergström.

A bulk sample yielded 142 phragmodid and 74 dichognathid elements from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Phragmodus cognitus Stauffer

Plate 11 – Figures 1-3, 5, 6

The description of *Phragmodus cognitus* Stauffer is here emended to include a dichognathid element similar if not identical to the "trend" species, *Dichognathus brevis* Branson and Mehl.

phragmodid element:

*Phragmodus cognitus* (part) Stauffer, 1935a, p. 150, 151, pl. 11, figs. 13, 14 (not figs. 12, 18, 31, 41); Fay, 1952, p. 146.

**Remarks**: Stauffer figured three cotypes and three paratypes for *Phragmodus cognitus*. Two form species are represented in these cotypes necessitating a new name for one species and the designation of a lectotype for the other. The cotype B4379, plate 11, figure 14, is here designated as a lectotype for *"Phragmodus cognitus"*.

dichognathid element:

**Remarks**: *Dichognathus brevis* Branson and Mehl was originally described as one of four "trend" species about which the authors noted (1933) that "...little difficulty is encountered in arranging completely gradational series." This variable dichognathid is associated with the form species *"Phragmodus undatus"*. The dichognathid element associated with *"Phragmodus cognitus"* shows no such variability, but is presently indistinguishable from the "brevis" variation in the dichognathid element associated with *"Phragmodus undatus"*.

**Remarks on the assemblage**: A total of 820 specimens were recovered in statistical samples of which 611 were phragmodids and 209 dichognathids. The resulting phragmodid-dichognathid ratio of 2.92:1 suggests a ratio of 3:1 in the conodont-bearing animal. *Phragmodus cognitus* was found in the upper beds of the Glenwood Formation at Minneapolis, Minnesota, throughout the Platteville Formation, and as high as the lower third of the Decorah Formation.

### Phragmodus undatus Branson and Mehl

Plate 10 – Figures 10, 11, 13, 15

The description of *Phragmodus undatus* Branson and Mehl is here emended to include the form species *Dichognathus typica* Branson and

Mehl, and *Oistodus abundans* Branson and Mehl.

phragmodid element:

*Phragmodus undatus* Branson and Mehl, 1933, p. 115, 116, pl. 8, figs. 22-26; Fay, 1952, p. 146; Glenister, 1957, p. 733, pl. 88, figs. 1, 2; Ethington, 1959, p. 285, pl. 41, fig. 12; Sweet and others, 1959, p. 1058, pl. 133, figs. 7, 10, 13.

**Remarks**: *Phragmodus undatus* is present in my collection in three distinct forms. These forms, as described by Sweet and others (1959), are distinguished by differences in costa on the main cusp, and are present in approximately equal numbers.

dichognathid element:

*Dichognathus brevis* Branson and Mehl, 1933, p. 113, pl. 9, figs. 24-26; Fay, 1952, p. 86; Sweet, 1955, p. 258, pl. 28, fig. 14; Glenister, 1957, p. 734, pl. 88, figs. 10, 12; Sweet and others, 1959, p. 1047, pl. 132, fig. 7.

*Dichognathus typica* Branson and Mehl, 1933, p. 113, 114, pl. 9, figs. 27-29; Fay, 1952, p. 96; Glenister, 1957, p. 735, pl. 88, figs. 4, 6; Ethington, 1959, p. 274, pl. 40, fig. 17; Sweet and others, p. 1048, pl. 132, fig. 6.

?*Dichognathus* cf. *D. typica* Rhodes, 1953, p. 317, pl. 22, figs. 178-180; Sannemann, 1955, p. 25, pl. 2, fig. 13.

*Dichognathus extensa* Branson and Mehl, 1933, p. 114, pl. 9, fig. 2; Fay, 1952, p. 86; Glenister, 1957, p. 734, pl. 88, figs. 11, 17.

*Dichognathus* cf. *extensa* Sannemann, 1955, p. 25, pl. 2, fig. 12.

*Dichognathus attenuata* Branson and Mehl, 1933, p. 113, 114, pl. 9, figs. 22, 23.

**Remarks**: Branson and Mehl (1933, p. 112-114) describe four species of *Dichognathus: D. typica, D. brevis, D. attenuata,* and *D. extensa*. They mention in their descriptions, however, that these species are "trend" species:

> "Markedly different forms are evident in almost every sample studied, but little difficulty is encountered in arranging completely gradational series. For convenience we have selected a few distinctive forms as 'trends' which we here record as species regardless of the fact that we sometimes find it difficult to decide to which species a given specimen should be referred."

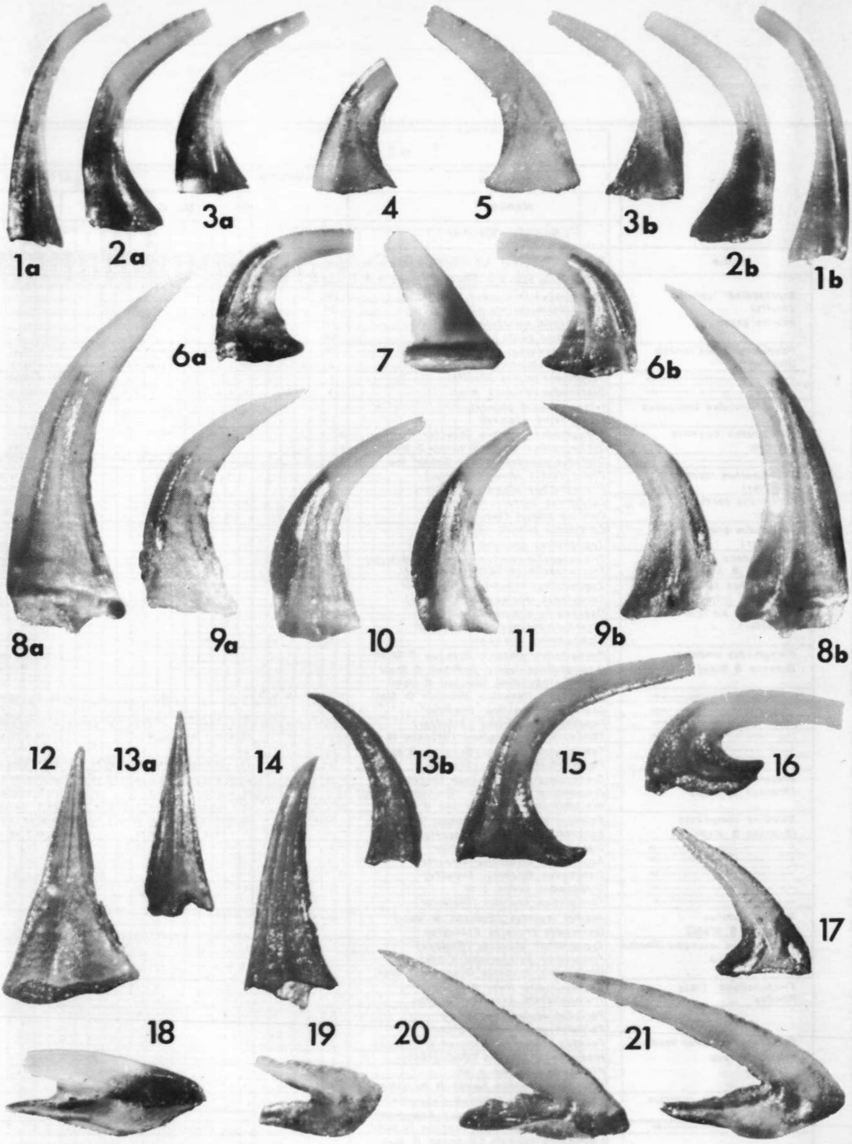
Other students of conodonts have had similar difficulty with this group, generally recognizing two or three of the variations as valid species. These variations occur in the specimens referred to *Dichognathus typica* and, although preservation is far from ideal, appear to be completely gradational. The dichognathid element associated with *Phragmodus cognitus* Stauffer is very similar to the *"Dichognathus brevis"* variation of *"D. typica"*, but does not show the continuous var-

# STRATIGRAPHIC DISTRIBUTION OF CONODONTS

Plate 1

Formations: GLENWOOD; PLATTEVILLE (Members: P., Mc Gregor, Carimona); DECORAH; GALENA (Members: Cummingsville, Prosser, Stewartville); overlap; DUBUQUE

| Name | Form Species or Element | WG Bulk | LG Bulk | Gl-4 | Gl-7 | Gl-8 | Gl-9 | Gl-10 | Platteville, Decorah, Galena, Dubuque samples (Pl-1 … Wr-76) |
|---|---|---|---|---|---|---|---|---|---|
| Bryantodina typicalis Stauffer informal group | Bryantodina typicalis Stauffer | 1 | 373 | | | | | 1 | [illegible] |
| | Phragmodus inversus n. sp. | | 148 | | | | | | [illegible] |
| | Hibbardella varians (Stauffer) | | 228 | | | | | | [illegible] |
| | Hibbardella variabilis (Stauffer) | | 42 | | | | | | [illegible] |
| | Prioniodina polita (Stauffer) | | 134 | | | | | | [illegible] |
| Polyplacognathus ramosa Stauffer | Polyplacognathus ramosa Stauffer | | 28 | | 1 | | | | [illegible] |
| | bifurcatid element | | 6 | | 2 | | | | [illegible] |
| → | Scyphiodus primus Stauffer | | 1 | | | | | | [illegible] |
| → | Distacodus variabilis n. sp. | | 3 | | | | | | [illegible] |
| Tetraprioniodus breviconus n. sp. | tetraprioniodid element | | | | | | | | [illegible] |
| | hibbardellid element | | | | | | | | [illegible] |
| Phragmodus cognitus Stauffer | Phragmodus cognitus Stauffer | 18 | | | | | | | [illegible] |
| | Dichognathus brevis Branson & Mehl | 6 | | | | | | | [illegible] |
| → | Oistodus pseudoabundans Schopf ms. | | | | | | | | [illegible] |
| Pravognathus idonea (Stauffer) | Pravognathus idonea (Stauffer) | | | | | | | | [illegible] |
| | Pravognathus simplex (Stauffer) | | | | | | | | [illegible] |
| Cordylodus serratus Stauffer | Cordylodus serratus Stauffer | | | | | | | | [illegible] |
| | Oulodus primus (Stauffer) | | | | | | | | [illegible] |
| Cordylodus grandis (Stauffer) | Cordylodus grandis (Stauffer) | | | | | | | | [illegible] |
| | Zygognathus gyroides (Stauffer) | | | | | | | | [illegible] |
| Trichonodella recurva (Branson & Mehl) | Trichonodella recurva (Branson & Mehl) | 13 | 46 | | | | | | [illegible] |
| | Trichonodella barbara (Stauffer) | 17 | 63 | | | | | | [illegible] |
| Zygognathus illustris (Stauffer) informal group | Zygognathus illustris (Stauffer) | 34 | 24 | | | | | | [illegible] |
| | Cordylodus aculeatus (Stauffer) | 45 | 62 | | | | | | [illegible] |
| Ozarkodina obliqua (Stauffer) | Ozarkodina obliqua (Stauffer) | 36 | 148 | | | | | 1 | [illegible] |
| | Prioniodina robusta (Stauffer) | 37 | 48 | | 1 | | | 1 | [illegible] |
| | dichognathid element | 34 | 40 | | | | 1 | | [illegible] |
| Phragmodus undatus Branson & Mehl | Phragmodus undatus Branson & Mehl | | | | | | | | [illegible] |
| | Dichognathus typica Branson & Mehl | | | | | | | | [illegible] |
| | Oistodus abundans Branson & Mehl | | | | | | | | [illegible] |
| → | Cordylodus flexuosus Branson & Mehl | 62 | 105 | | | 5 | 6 | 3 | [illegible] |
| → | Ozarkodina concinna Stauffer | | 1 | | | | | | [illegible] |
| → | Panderodus arcuatus (Stauffer) | 12 | 15 | | | 1 | | 1 | [illegible] |
| → | Panderodus compressus (Branson & Mehl) | 13 | 24 | | | 1 | | | [illegible] |
| → | Panderodus gracilis (Branson & Mehl) | | 4 | | | | 1 | | [illegible] |
| → | Panderodus panderi (Stauffer) | | 24 | | | | | | [illegible] |
| Drepanodus suberectus (Branson & Mehl) | Drepanodus homocurvatus Lindstrom | 94 | 10 | 1 | 1 | 2 | 1 | 1 | [illegible] |
| | Drepanodus suberectus (Branson & Mehl) | 24 | 5 | | | | | 1 | [illegible] |
| | Oistodus inclinatus Branson & Mehl | 20 | 9 | | | 1 | | | [illegible] |
| Belodina compressa (Branson & Mehl) | Belodina compressa (Branson & Mehl) | | 35 | 1 | | | | | [illegible] |
| | Eobelodina fornicala (Stauffer) | | 6 | | | | | | [illegible] |
| → | Oistodus venustus Stauffer | | 24 | | | | | | [illegible] |
| → | Acontiodus alveolaris Stauffer | 1 | 1 | | | | | | [illegible] |
| → | Distacodus falcatus Stauffer | 12 | 7 | | | | | | [illegible] |
| → | Drepanodus cavus n. sp. | | | | | | | | [illegible] |
| → | Panderodus feulneri (Glenister) | | | | | | | | [illegible] |
| Acodus mutatus (Branson & Mehl) | Acodus mutatus (Branson & Mehl) | | | | | | | | [illegible] |
| | Distacodus procerus Ethington | | | | | | | | [illegible] |
| Zygognathus elongata (Rhodes) informal group | Zygognathus elongata (Rhodes) | | | | | | | | [illegible] |
| | Prioniodina pulcherrima Lindstrom | | | | | | | | [illegible] |
| | Cordylodus delicatus Branson & Mehl | | | | | | | | [illegible] |
| Trichonodella flexa Rhodes | Trichonodella flexa Rhodes | | | | | | | | [illegible] |
| | Trichonodella exacta Ethington | | | | | | | | [illegible] |
| Periodon aculeatus Hadding informal group | Periodon aculeatus Hadding | | | | | | | | [illegible] |
| | Periodon grandis (Ethington) | | | | | | | | [illegible] |
| | Falodus prodentatus (Graves & Ellison) | | | | | | | | [illegible] |
| | Hibbardella insolita (Ethington) | | | | | | | | [illegible] |
| | Prioniodina araea n. sp. | | | | | | | | [illegible] |
| | Ligonodina tortilis Sweet & Bergstrom | | | | | | | | [illegible] |
| Coelocerodontus trigonius Ethington | Coelocerodontus trigonius Ethington | | | | | | | | [illegible] |
| | Coelocerodontus tetragonius Ethington | | | | | | | | [illegible] |
| → | Scolopodus insculptus (Branson & Mehl) | | | | | | | | [illegible] |
| Ligonodina delicata (Branson & Mehl) | Ligonodina delicata (Branson & Mehl) | | | | | | | | [illegible] |
| | Hibbardella diminutiva (Rhodes) | | | | | | | | [illegible] |
| | Tetraprioniodus superbus Rhodes | | | | | | | | [illegible] |
| | Keislognathus gracilis Rhodes | | | | | | | | [illegible] |
| Amorphognathus ordovicica Branson & Mehl | Amorphognathus ordovicica Branson & Mehl | | | | | | | | [illegible] |
| | Ambalodus triangularis Branson & Mehl | | | | | | | | [illegible] |
| Icriodella superba Rhodes | Icriodella superba Rhodes | | | | | | | | [illegible] |
| | Rhyncognathodus typicus (Ethington) | | | | | | | | [illegible] |
| | Rhyncognathodus divaricatus (Rhodes) | | | | | | | | [illegible] |
| | Sagittodontus robustus Rhodes | | | | | | | | [illegible] |
| | Sagittodontus dentatus Ethington | | | | | | | | [illegible] |



1a
2a
3a
4
5
3b
2b
1b
6a
7
6b
8a
9a
10
11
9b
8b
12
13a
14
13b
15
16
17
18
19
20
21

semiconical pit; excavation continuing anteriorly as a deep notch and posteriorly as a shallow groove. Main cusp short, commonly only slightly higher than denticles immediately posterior to it. Main cusp, two small denticles immediately anterior to it, and denticles on posterior process laterally compressed, basally confluent, and sharply keeled anteriorly and posteriorly. Denticles on anterior process, except two just anterior to main denticle, short, stubby, and arranged in transverse triads. Denticles in a triad partially fused. At least seven triads present on mature specimens. Anterior process straight, platform-like and slightly longer than posterior process. Posterior process laterally compressed, set with seven more denticles, and curved outward and slightly downward.

**Remarks**: All specimens figured in Stauffer (1935b) lack the posterior process. *Scyphiodus primus* Stauffer probably originated from an ozarkodinid form species since the earliest growth stages recovered are typical ozarkodinids, except that the third denticle anterior to the main cusp exhibits a denticle on either side.

*Scyphiodus primus* ranges in Minnesota from the upper beds of the Glenwood Formation to the top of the Decorah Formation. It is most common in the lower Platteville, absent in the upper Platteville and lower Decorah and extremely rare in the upper Decorah. One hundred seven specimens were recovered. No other form species is associated with it.

### Genus Scolopodus Pander, 1856

### Type Species S. sublaevis Pander, 1856

### Scolopodus insculptus (Branson and Mehl)

Plate 12 — Figures 14, 15

*Phragmodus insculptus* Branson and Mehl, 1933, p. 124, pl. 10, figs. 32-34; Fay, 1952, p. 146; Rhodes, 1953, p. 310, pl. 21, figs. 136, 153, 154; Rhodes, 1955, p. 136, pl. 10, fig. 17.

*Distacodus insculptus* Ethington, 1959, p. 275, pl. 39, fig. 10.

*Scolopodus insculptus* Sweet and others, 1959, p. 1063, pl. 130, fig. 6; Bergström, 1964, p. 53, tabs. III, V.

**Remarks**: The stratigraphic distribution of *Scolopodus insculptus* forms a useful local range zone in Minnesota. It is found in the Stewartville Member of the Galena Formation and in the lowermost beds of the Dubuque Formation. Although only 48 specimens were recovered, conodonts are not abundant in this interval and this species makes up a significant percentage of the conodont fauna.

*Bryantodina.* I think, however, that the twisted and arched central region in specimens of this genus is unique and distinct from *Bryantodina.* Broken fragments of form species in this genus closely resemble the posterior bar of *"Phragmodus undatus"* and for this reason several conodont workers have incorrectly considered the genus invalid.

### Pravognathus idonea (Stauffer)

Plate 10 – Figure 8

Plate 11 – Figures 4, 9

The description of *Pravognathus idonea* (Stauffer) is here emended to include the form species *P. simplex* (Stauffer).

idoneid element:

*Heterognathus brevis* Stauffer, 1935b, p. 607, pl. 72, figs. 17, 30; Fay, 1952, p. 100.

*Heterognathus idoneus* Stauffer, 1935b, p. 607, pl. 72, figs. 9, 14, 15, 18?, 20, 26, 29, 32; Fay, 1952, p. 99, 100.

*Pravognathus brevis* Stauffer, 1936, p. 79; Fay, 1952, p. 163.

*Pravognathus idoneus* Stauffer, 1936, p. 79; Fay, 1952, p. 163.

simplid element:

*Heterognathus simplex* Stauffer, 1935b, p. 607, pl. 72, figs. 21, 22, 31; Fay, 1952, p. 100.

*Prioniodus liratus* Stauffer, 1935b, p. 616, pl. 72, fig. 38; Fay, 1952, p. 172.

*Pravognathus simplex* Stauffer, 1936, p. 79; Fay, 1952, p. 163.

**Remarks:** *Pravognathus brevis* was found to be composed of immature or broken specimens of *"P. idonea"*. Samples yielded 317 idoneid and 250 simplid elements. The idoneid element is, however, somewhat easier to identify on broken specimens and a 1:1 ratio is suggested. The species is common in the upper half of the Platteville and the lower beds of the Decorah Formations.

### Genus Scyphiodus Stauffer, 1935

### Type Species Scyphiodus primus Stauffer, 1935

### Scyphiodus primus Stauffer

Plate 8 – Figures 15a, b

*Scyphiodus primus* Stauffer, 1935b, p. 617, 618, pl. 75, figs. 34, 40, 41, 45, 46, 50, 51, 57, 58; Fay, 1952, p. 181; Thompson, 1959, p. 137-139, pl. 8, figs. 1-7.

Base narrow on posterior process, wide on anterior process, flaring slightly beneath main cusp. Base excavated beneath main cusp as a

### Genus Tetraprioniodus Lindstrom, 1955
### Type Species T. robustus Lindström, 1955
### Tetraprioniodus breviconus new species

Plate 3 — Figures 13, 14

**Holotype:** U.M.P.C. 8954 from P1-15B, Cummingsville Annex Section.

tetraprioniodid element:

Unit bilaterally symmetrical. Main cusp tapering rapidly to a point, rhombic in cross-section, and set with four costa continuous with denticulated processes. Basal excavation a shallow pit beneath main cusp and continuous beneath all four processes as shallow groove along aboral margin. All processes strongly compressed laterally with a costa at mid-height on lateral surfaces. Anterior process straight, inclined strongly downward and slightly to the anterior, and set with at least four small, erect, keeled denticles fused nearly to their full height along their posterior keel. Lateral processes curved strongly downward, slightly laterally, and set with six or more small unerupted or low denticles. Posterior process horizontal, straight, and set with at least three small erect denticles.

hibbardellid element:

Main cusp triangular in cross-section and set with three costae continuous with denticulated processes. Basal excavation forming very small pit beneath main cusp continuous beneath all processes as a shallow groove along aboral margin. All processes strongly compressed laterally, with weak costa at mid-height on lateral surfaces and bearing five or more small erect denticles varying from germ denticles to denticles fused to two-thirds their height. Inner lateral process inclined strongly downward and slightly to the posterior. Posterior process straight and horizontal.

**Remarks:** Only Bulk Sample P1-15 yielded well preserved specimens for study. Morphological description was helped by study of specimens collected from the Platteville Formation by Thompson (1959). Fragments of the processes of the two constituent forms were recovered from the lower Platteville Formation, but could not be assigned definitely to one or the other species. Eleven specimens were recovered.

### Genus Trichonodella Branson and Mehl, 1948
### Type Species Trichognathus primus Branson and Mehl, 1933
### Trichonodella flexa Rhodes

Plate 12 — Figures 2-5

The description of *Trichonodella flexa* Rhodes is here emended to include the form species *T. exacta* Ethington.

flexid element:

*Trichonodella flexa* Rhodes, 1953, p. 313, 314, 'pl. 22, figs. 181-183, 188, 189, 191, 192; Glenister, 1957, p. 734, pl. 88, fig. 13; Ethington, 1959, p. 290, pl. 41, figs. 7, 8.

**Remarks**: Bergstrom (1964) has figured the previously unillustrated holotype of *Trichonodella superba* (Rhodes) from the Crug and Gelli-grin Limestones of Wales, and considers it conspecific with "*T. flexa*" Rhodes. The two form species are certainly similar. The holotype of *T. superba*, however, is somewhat fragmentary and I hesitate to consider "*T. flexa*" a junior synomyn of "*T. superba*" on the basis of the illustration. As Bergström (1964) notes, "*T. flexa*" is also close to *T. angulata Sweet*.

exactid element:

*Trichonodella exacta* Ethington, 1959, p. 290, pl. 41, figs. 10, 11.

**Remarks**: Bergström (1964) notes symmetrical specimens of *Trichonodella* with a denticulated posterior associated with *T. superba*. He referred these specimens, which differed slightly in the angle of the posterior process, to *T.* sp. cf. "*T. exacta*". *T. subundulata* Sweet is similar to Bergström's Welch material and also to my specimens of "*T. exacta*".

**Remarks on the assemblage**: Forms very similar to or conspecific with the two form species of *Trichonodella flexa* are known from Middle and Upper Ordovician conodont faunas of Wales, England and the midcontinent region of the United States. In the present study the two constituent form species were found to have identical stratigraphic ranges and to be present in approximately equal numbers within this range. I recovered 218 flexid and 175 exactid elements suggesting a possible 1:1 ratio of the elements in the conodont-bearing animal. The species ranges in Minnesota from the upper half of the Cummingsville Member of the Galena Formation at least to the top of the Elgin Member of the Maquoketa Formation.

### Trichonodella recurva (Branson and Mehl)

Plate 8 – Figures 3, 5-7

The form species *Trichonodella recurva* (Branson and Mehl) is here emended to include the form species *Trichonodella barbara* Stauffer.

recurvid element:

*Trichognathus recurva* Branson and Mehl, 1933, p. 119, pl. 10, fig. 6; (part) Stauffer, 1935a, p. 156, pl. 12, fig. 1 (not fig. 2); (part) Stauffer, 1935b, p. 619-620, pl. 71, figs. 20, 27, 39, 41, 47, pl. 72, fig. 48 (not fig. 56), pl. 75, fig. 22; Fay, 1952, p. 199.

*Trichognathus inopinatus* (part) Stauffer, 1935a, p. 156, pl. 12, fig. 5 (not fig. 6).

barbarid element:

*Trichognathus barbarus* ~~Stauffer~~, 1935a, p. 155, pl. 12, fig. 11; Fay 1952, p. 198.

*Trichognathus inopinatus* (part) Stauffer, 1935a, p. 156, pl. 12, fig. 6 (not fig. 5); Fay, 1952, p. 198.

*Trichognathus recurva* (part) Stauffer, 1935a, p. 156, pl. 12, fig. 2 (not fig. 1); (part) Stauffer, 1935, p. 619, 620, pl. 72, fig. 56 (not fig. 48; pl. 71, figs. 20, 27, 39, 41, 47, pl. 75, fig. 22).

*Dichognathus variabilis* (part) Stauffer, 1935b, p. 604, 605, pl. 73, fig. 59 (not pl. 73, figs. 14, 24, 30, 31, 34-37, 40, 44, 50, pl. 75, fig. 8).

*Trichognathus minnesotensis* Stauffer, 1935b, p. 619, pl. 71, figs. 45, 50; Fay, 1952, p. 198.

*Trichognathus symmetricus* Stauffer, 1935b, p. 620, pl. 75, figs. 25,26; Fay, 1952, p. 199.

**Remarks:** Both elements of *Trichonodella recurva* Branson and Mehl show immature growth stages which exhibit a posterior process with a sharp oral surface. This surface becomes rounded with increasing maturity and mature specimens actually exhibit a furrow in place of the original sharp carina. This species ranges in Minnesota from the upper beds of the Glenwood to the top of the Decorah Formation, and excepting the lower half of the Platteville Formation, is common to abundant throughout. Samples yielded 267 recurvid and 266 barbarid elements suggesting a 1:1 ratio of the elements in the conodont-bearing animal.

## Possible Natural Conodont Species (Informal Groups)

### Bryantodina typicalis Informal Group

The *Bryantodina typicalis* group includes the form species *Bryantodina typicalis* Stauffer, *Hibbardella varians* (Stauffer), *Hibbardella variabilis* (Stauffer), *Phragmodus inversus* new species, and *Prioniodina polita* (Stauffer). These form species have been associated on the basis of similar stratigraphic range, a marked tendency toward inversion of the aboral surfaces, and general similarities produced by the great range of lateral compression in all. The group is abundant in the upper beds of the Glenwood Formation at Lanesboro, Minnesota and also rarely found in the upper beds of the Decorah Formation. Nine hundred twenty five specimens were recovered.

### Genus Bryantodina Stauffer, 1935

### Type Species B. typicalis Stauffer, 1935

### Bryantodina typicalis Stauffer

Plate 7 – Figures 4-7

*Bryantodina typicalis* Stauffer, 1935a, p. 134, 135, pl. 10, figs. 16, 18, 19, 23-25, 29; Fay, 1952, p. 68.

*Bryantodina digna* Stauffer, 1935a, p. 132, pl. 10, fig. 34; Fay, 1952, p. 68.

*Bryantodina dissimilis* Stauffer, 1935a, p. 132, pl. 10, fig. 17; Fay, 1952, p. 68.

*Bryantodina compacta* Stauffer, 1935a, p. 131, 132, pl. 10, figs. 15, 22, 31; Fay, 1952, p. 68; Carlson, 1960, p. 71, pl. 2, fig. 6.

*Bryantodina excellsa* (part) Stauffer, 1935a, p. 132, pl. 10, fig. 35 (not fig. 33); Fay, 1952, p. 68.

*Bryantodina limata* Stauffer, 1935a, p. 133, pl. 10, fig. 49; Fay, 1952, p. 68.

*Ozarkodina crenulata* Stauffer, 1935a, p. 148, pl. 10, fig. 43; Fay, 1952, p. 137.

*Ozarkodina* sp. *a* Stauffer, 1935a, p. 149, pl. 10, fig. 32; Fay, 1952, p. 138.

Main denticle short, somewhat anterior to center of unit, and only slightly larger than the denticle immediately posterior to it. Base of main cusp flared inward and slightly outward. Basal excavation beneath anterior and posterior processes as shallow groove becoming flat or inverted near tips of processes. Anterior process straight, shorter than posterior, and commonly with four to seven denticles. Posterior process curved slightly downward, on some specimens slightly inward, with 12 or more denticles on mature specimens. Denticles decreasing uniformly in size posteriorly. Denticle immediately anterior to main denticle usually only one-half as high, and denticles increasing uniformly in size anteriorly.

Lateral compression from strong to weak. Strongly compressed specimens with thin keeled denticles fused to approximately two-thirds their height. Weakly compressed specimens with discrete peglike denticles with no keels.

**Remarks:** *Bryantodina typicalis* Stauffer exhibited more variation than any other species in this study. I recovered 373 well preserved, nearly complete specimens.

### Genus Hibbardella Bassler, 1925
### Type Species Prioniodus angulatus Hinde, 1879
### Hibbardella variabilis (Stauffer)

Plate 7 – Figures 3, 9

*Dichognathus variabilis* Stauffer, 1935a, p. 141, pl. 11, fig. 7.

Unit bilaterally symmetrical. Main cusp slightly recurved posteriorly, set with anterior and posterior keels, with a costa on both lateral surfaces. Anticusp tapering rapidly to a point. Basal excavation as very small pit at base of main cusp. Lateral processes curving outward and posteriorly, variably set with from one to four small denticles; aboral surface flat or slightly inverted.

Posterior process straight and set with four or more denticles inclined posteriorly. One denticle near center of process somewhat larger than others giving process a phragmodid appearance. Aboral surface inverted. Junction of lateral and aboral surfaces forming a costa with convex upward outline in side view.

Lateral compression continuous from strong to weak. Strongly compressed specimens with well developed costa and thin keeled denticles fused to nearly their full height. Weakly compressed specimens with poorly developed or no costa on main cusp; and discrete, peglike denticles sub-circular in cross-section.

**Remarks:** The holotype of *Dichognathus variabilis* Stauffer has a second lateral process broken off near its junction with the base of the main cusp. Samples yielded 42 specimens.

### Hibbardella varians (Stauffer)

Plate 7 – Figures 14-16

*Phragmodus varians* Stauffer, 1935a, p. 151, pl. 11, fig. 27.

Main cusp erect and triangular in cross-section. Basal excavation a small pit beneath main cusp extending a short distance beneath both lateral processes. Anterior of main cusp flat with costate edges continuous with lateral processes; posterior keel continuous with posterior process. Inner lateral process curved posteriorly with three or more small denticles. Outer lateral process straight, directed laterally and slightly posteriorly, with a single denticle nearly as high as main cusp and wider at base. Posterior process nearly straight and set with four or more denticles inclined posteriorly, generally increasing in size posteriorly to near posterior tip. In some specimens, a tendency to develop a phragmodid type of posterior bar with one denticle considerably larger than the others. Aboral surface inverted with v-shaped cross-section. A convex upward costa in the central part of the posterior process produced at junction of lateral and aboral surfaces in side view.

Lateral compression continuous from strong to weak. Strongly compressed specimens with well developed costae and thin keeled denticles fused to approximately two-thirds their height. Weakly compressed specimens with poorly developed costae on the main cusp and peglike discrete denticles.

**Remarks:** The holotype of *Phragmodus varians* Stauffer is strongly compressed laterally, with two lateral processes broken off near the base of the main cusp. I recovered 228 specimens.

### Genus Phragmodus Branson and Mehl, 1933

### Type Species P. primus Branson and Mehl, 1933

### Pragmodus inversus new species

Plate 7 – Figures 1, 2, 11, 13

**Holotype:** U.M.P.C. 8995 from the Glenwood Formation, Lanesboro Section.

*Pragmodus cognitus* (part) Stauffer, 1935, p. 150, 151, pl. 11, figs. 12, 18, 31, 41 (not figs. 13, 14).

*Phragmodus inflexus* (part) Stauffer, 1935, p. 151, pl. 11, figs. 17, 19, 21, 22, 34 (not figs. 9, 15, 16, 20, 25, 26).

Main cusp moderately recurved posteriorly. Anti cusp tapering rapidly to a point. Basal excavation a semiconical, laterally compressed pit at base of main cusp. Posterior process moderately arched with a large denticle, second in size only to main cusp, surmounting top of arch. Denticles and posterior process twisted somewhat inwardly in vicinity of the arch. At least 12 denticles posterior to and 3 to 5 anterior to the large "arch" denticle, decreasing in size in both directions. Aboral surface of posterior process "inverted" in the sense of Lindström (1955) with a flat v-shaped cross-section.

Lateral compression of specimens continuous from strong to weak. Strongly compressed specimens with bladelike denticles fused to two-thirds their height, sharp anterior and posterior keels, and slight inward twisting of posterior process in arched area. Weakly compressed specimens with discrete, peglike denticles having subcircular cross-sections and strong inward twisting of arch area on posterior process.

**Remarks:** One cotype and all paratypes of *"Phragmodus cognitus"* Stauffer belong to *P. inversus*. A lectotype has been designated for *"Phragmodus cognitus"* from the remaining two cotypes requiring a new name for this species. The latinized form of "inverse" was chosen as a species name because of inversion of the basal cavity on the posterior process, which is unique among species of *Phragmodus*. I collected 148 specimens.

### Genus Prioniodina Bassler, 1925

### Type Species P. subcurvata Ulrich and Bassler

### Prioniodina polita (Stauffer)

Plate 7 – Figures 8, 10, 17

*Tortoniodus politus* Stauffer, 1935a, p. 155, pl. 10, figs. 38, 42; Fay, 1952, p. 197.

*Bryantodina excellsa* Stauffer, 1935a, p. 132, pl. 10, fig. 33 (not fig. 35); Fay, 1952, p. 68.

*Bryantodina inaequalis* Stauffer, 1935a, p. 133, pl. 10, fig. 40; Fay, 1952, p. 68.

*Bryantodina informis* Stauffer, 1935a, p. 133, pl. 10, fig. 49; Fay, 1952, p. 68.

*Bryantodina levicula* Stauffer, 1935a, p. 133, pl. 10, fig. 20; Fay, 1952, p. 68.

*Euprioniodina insigna* Stauffer, 1935a, p. 143, pl. 10, fig. 26; Fay, 1952, p. 93.

*Ozarkodina delecta* Stauffer, 1935a, p. 148, pl. 10, fig. 40; Fay, 1952, p. 137.

*Ozarkodina insolita* Stauffer, 1935a, p. 149, pl. 10, figs. 44, 47; Fay, 1952, p. 138.

Main cusp erect and approximately twice as high as next largest denticle. Basal excavation a subconical pit flattened on outer side. Excavation continuing anteriorly and posteriorly to approximately half the process lengths, either flattened or inverted toward the extremities. Anterior process shorter than posterior, set with five or more denticles, and inclined slightly downward, tending to curve more strongly downward near anterior tip. Posterior process set with seven or more denticles and inclined slightly downward, tending to curve more sharply downward near posterior tip. Denticles generally larger in either direction from main cusp to a point near process tips.

Lateral compression of specimens from strong to weak. Strongly compressed specimens with thin keeled denticles fused to approximately two-thirds their height; weakly compressed specimens with discrete peglike denticles, tending to curve inward toward their tips.

**Remarks**: The holotype of *Ozarkodina delecta* is a strongly laterally compressed specimen and the holotype of *Tortoniodus politus* is a weakly compressed specimen of the variable form species, *Prioniodina polita*. *Polita* was chosen as the trivial name because of earlier confusion of *Ozarkodina delecta* Stauffer with *Prioniodina pulcherrima* Lindström. *Prioniodina polita* is thought to best fit in the form genus *Prioniodina*. I recovered 134 specimens.

### Chirognathus monodactyla Informal Group

The *Chirognathus monodactyla* informal group consists of *C. admiranda* Stauffer, *C. delicatula* Stauffer, *C. monodactyla* Branson and Mehl, and *C. multidens* Branson and Mehl. The group has been associated on the basis of similarity in color, denticulation, "fibrous" nature, and stratigraphic distribution. Similar or identical forms are present in the Harding Sandstone of Colorado and the lower shales of the Winnipeg Formation of North and South Dakota. In Minnesota the group was found only in the upper beds of the Glenwood Formation.

### Genus Chirognathus Branson and Mehl, 1933

### Type Species C. duodactylus Branson and Mehl, 1933

### Chirognathus admiranda Stauffer

Plate 5 – Figure 3

*Chirognathus admiranda* Stauffer, 1935a, p. 135, pl. 9, figs. 6, 16, 22; Fay, 1952, p. 79; Sweet, 1955, p. 235, 236, pl. 27, fig. 15.

?*Chirognathus duodactylus* Stauffer, 1935a, p. 136, 158, pl. 9, fig. 29.

*Chirognathus expatiatus* Stauffer, 1935a, p. 137, 158, pl. 9, fig. 4; Fay, 1952, p. 80.

*Chirognathus magnificus* Stauffer, 1935a, p. 138, 158, pl. 9, fig. 25; Fay, 1952, p. 80.

*Chirognathus radiatus* Stauffer, 1935a, p. 139, 158, pl. 9, fig. 15; Fay, 1952, p. 80.

*Chirognathus unguliformis* Stauffer, 1935a, p. 139, 158, pl. 9, fig. 41; Fay, 1952, p. 81; Sweet, 1955, p. 242, pl. 27, fig. 21.

Base short, somewhat compressed laterally, aborally flattened, and concave inward forming a palm shaped unit. Shallow pitlike excavation near center of unit often filled with basal material on mature specimens. Denticles laterally compressed tending to become flared, with sharp keels, in an antero-posterior direction on mature specimens.

Largest denticle near anterior tip with only one or two small denticles anterior to it. Denticle immediately posterior to largest denticle often two-thirds as large followed by six or more smaller denticles decreasing in size posteriorly.

**Remarks:** *Chirognathus admiranda* is fairly common in the upper beds of the Glenwood Formation at Lanesboro, Minnesota. All of the 85 specimens recovered came from this locality.

### Chirognathus delicatula Stauffer

Plate 5 – Figures 1, 4

*Chirognathus alternatus* Stauffer, 1935a, p. 135, 158, pl. 9, fig. 31.

*Chirognathus delicatulus* (part) Stauffer, 1935a, p. 136, 158, pl. 9, figs. 1, 3, 5, 8-10, 12, 17, 19, 21 (not figs. 2, 7, 11, 13, 18); Fay, 1952, p. 79; Sweet, 1955, p. 237, pl. 27, figs. 14, 22.

*Chirognathus eucharis* Stauffer, 1935a, p. 136, 158, pl. 9, figs. 23, 27, 28, 34; Fay, p. 80; Sweet, 1955, p. 238, pl. 27, fig. 17.

*Chirognathus hamatus* Stauffer, 1935a, p. 137, 158, pl. 9, fig. 33; Fay, 1952, p. 80.

*Chirognathus idoneus* Stauffer, 1935a, p. 137, 158, pl. 9, fig. 24; Fay, 1952, p. 80; Sweet, 1955, p. 238, 239, pl. 27, figs. 8, 16.

*Chirognathus irregularis* Stauffer, 1935a, p. 137-138, 158, pl. 9, fig. 32; Fay, 1952, p. 80.

*Chirognathus lanesboroensis* Stauffer, 1935a, p. 138, 158, pl. 9, fig. 14; Fay, 1952, p. 80.

?*Chirognathus scalenus* Stauffer, 1935a, p. 139, 158, pl. 9, figs. 20, 26; Fay, 1952, p. 80.

?*Cyrtoniodus erectus* Stauffer, 1935a, p. 140, 158, pl. 9, figs. 30, 37, 38; Fay, 1952, p. 85.

Base short, laterally compressed, flattened aborally, concave inward. Entire unit palm-shaped. Shallow basal pit often filled with basal material on mature specimens. Largest denticle near center of unit usually followed by three or four slightly smaller denticles decreasing uniformly in size anteriorly. All denticles sharply keeled, tending to flare on mature specimens. Posterior process with seven or more smaller denticles approximately one-half the height of largest denticle and decreasing in size posteriorly.

**Remarks:** This species is extremely variable as to size and number of denticles. Smaller denticles are often present between larger on both processes, especially on immature specimens. The smaller denticles tend to be lost by incorporation into adjacent denticles on mature specimens.

*Chirognathus delicatula* was found only in the upper beds of the Glenwood Formation. It is abundant at Lanesboro, Minnesota and 310 specimens were recovered.

### Chirognathus monodactyla Branson and Mehl

Plate 5 – Figure 5

*Chirognathus monodactyla* Branson and Mehl, 1933, p. 29, 31, pl. 2, figs. 11-13; Fay, 1952, p. 80; Sweet, 1955, p. 239, pl. 27, fig. 20.

*Chirognathus delicatula* (part) Stauffer, 1935a, p. 136, 158, pl. 9, figs. 2, 7, 11, 13, 18 (not figs. 1, 3, 5, 8-10, 12, 17, 19, 21).

Entire unit palm-shaped. Base short, laterally compressed and aborally flat. Shallow basal pit in center of unit often filled with basal material in mature specimens.

Main denticle in center of unit commonly twice as high as next largest denticle. All denticles slightly compressed laterally, basally confluent and sharply keeled, tending to flare in antero-posterior direction on mature specimens.

Anterior process twisted outward and set with four or more denticles. Posterior process small, straight or slightly incurving, set with four or more denticles.

**Remarks**: *Chirognathus monodactyla* was found only in the upper beds of the Glenwood Formation at Lanesboro, Minnesota where it is common. Eighty-seven specimens were recovered.

### Chirognathus multidens Branson and Mehl

Plate 5 – Figure 2

*Chirognathus multidens* Branson and Mehl, 1933, p. 34, pl. 2, fig. 43; Fay, 1952, p. 80; Sweet, 1955, p. 239, pl. 27, fig. 1.

**Remarks**: *Chirognathus multidens* was found only in the upper beds of the Glenwood Formation at Lanesboro, Minnesota, where it is fairly common. Sixty-five specimens were recovered.

### Periodon aculeatus Informal Group

The *Periodon aculeatus* informal group consists of *Falodus prodentatus* (Graves and Ellison), *Ligonodina tortilis* Sweet and Bergström, *Periodon aculeatus* Hadding, *P. grandis* (Ethington), *Prioniodina araea* n. sp., and *Hibbardella insolita* (Ethington). These form species are associated on the basis of almost identical stratigraphic distribution and similarity in size, denticulation, lateral compression, and color. Members of this group are known from the Middle and Upper Ordovician conodont faunas of the United States, Sweden and England. I believe this group may represent two or more natural species with similar environmental tolerances because not all members occur together in other faunas thus far reported.

### Genus Falodus Lindström, 1954

#### Type Species Oistodus prodentatus Graves and Ellison, 1941

### Falodus prodentatus (Graves and Ellison)

Plate 12 – Figures 6, 7

*Oistodus prodentatus* Graves and Ellison, 1941, p. 13, 14, pl. 2, figs. 6, 22, 23, 28; Fay, 1952, p. 136.

*Falodus prodentatus* Lindström, 1955, p. 164; Ethington, 1959, p. 277, 278, pl. 39, fig. 18; Carlson, 1960, p. 71, tab. 2; Sweet and Bergström, 1962, p. 1227-1229, pl. 170, figs. 2, 3, text-fig. 2B.

*Falodus* n. sp. Lindström, 1957, p. 173, pl. 1, figs. 25, 26, text-figs. 2-25, 26.

?*Falodus* sp. Lamont and Lindström, 1957, p. 63, 64, 65; Wolska, 1961, p. 350, pl. 2, figs. 1a, b, 5.

**Remarks:** Immature specimens of *Falodus prodentatus* show no anterior denticulation of the cusp. I recovered 297 specimens from the Galena, Dubuque, and Maquoketa (Elgin Member) Formations.

### Genus Hibbardella Bassler, 1925

### Type Species Prioniodus angulatus Hinde, 1879

### Hibbardella insolita Ethington

Plate 12 – Figure 12

*Trichonodella insolita* Ethington, 1959, p. 289, 290, pl. 41, fig. 9.

**Remarks:** *Hibbardella insolita* is rare throughout its range from the lower Galena Formation to the top of the Dubuque Formation in Minnesota. Only 28 specimens were recovered.

### Genus Ligonodina Bassler, 1925

### Type Species L. pectinata Ulrich and Bassler, 1926

### Ligonodina tortilis Sweet and Bergström

Plate 12 – Figure 10

*Ligonodina tortilis* Sweet and Bergstrom, 1962, p. 1230, 1231, pl. 170, figs. 13, 14.

**Remarks:** *Ligonodina tortilis* ranges in Minnesota from the lower Galena Formation to the top of the Dubuque Formation. It is rare throughout this interval and only 31 specimens were recovered.

### Genus Periodon Hadding, 1913

### Type Species P. aculeatus Hadding, 1913

### Periodon aculeatus Hadding

Plate 12 – Figure 16

*Periodon aculeatus* Hadding, 1913, p. 33, pl. 1, fig. 14; Lindström, 1955, p. 110, pl. 22, figs. 10, 11, 14-16, 35; Lindström, 1960, p. 89; Lamont and Lindström, 1957, p. 61, 63, 64, 65, 67, pl. 5, fig. 15; Sweet and others, 1959, p. 1057-1058; Sweet and Bergström, 1962, p. 1235, pl. 171, figs. 3, 9.

?*Loxognathus flabellata* (part) Graves and Ellison, 1941, p. 12, pl. 2, figs. 29, 32 (not pl. 2, fig. 31).

?*Subcordylodus* n. sp. Mehl and Strothman in Branson, 1944, pl. 13, fig. 19.

*Periodon* n. sp. aff. *aculeatus* Lindström, 1957, p. 174-175, pl. 1, figs. 15-19.

*Phragmodus* spp. Ethington, Furnish and Markewicz, 1958, p. 673-674, text-fig. A-D.

*Eoligonodina magna* Ethington, 1959, p. 227, pl. 40, figs. 3, 4; ? Carlson, 1960, tab. II.

**Remarks:** *Periodon aculeatus* ranges from the base of the Galena Formation to the top of the Dubuque Formation. It is usually rare throughout this interval although 163 specimens were recovered.

### Periodon grandis (Ethington)

Plate 12 – Figure 8

*Loxognathus grandis* Ethington, 1959, p. 281, pl. 40, fig. 6; Sweet and Bergström, 1962, p. 1235.

**Remarks:** *Periodon grandis* is similar to *Periodon aculeatus* and is certainly in *Periodon* as emended by Sweet and Bergström (1962). *P. grandis* ranges from the base of the Galena Formation to the top of the Dubuque Formation. I recovered 64 specimens.

### Genus Prioniodina Bassler, 1925

### Type Species P. subcurvata Ulrich and Bassler, 1926

### Prioniodina araea new species

Plate 12 – Figure 13

**Holotype:** U.M.P.C. 9075 from Rh-24, Rifle Hill Section.

*Ozarkodina macrodentata* Ethington, 1959, p. 284, pl. 41, fig. 14; (not *Prioniodina macrodentata* (Graves and Ellison), 1941, pl. 2, figs. 33, 35, 36; Fay, 1952, p. 138).

Unit strongly compressed laterally; prominent flaring downward and posteriorly beneath main cusp. Base excavated to form semiconical pit beneath main cusp, continuous anteriorly and posteriorly as a shallow groove becoming inverted approximately two-thirds the process length from the main cusp. Anterior and posterior processes curved inward and set with at least seven and five denticles, respectively, on mature specimens. Denticles strongly compressed laterally, confluent basally, sharply keeled anteriorly and posteriorly, with broadly convex lateral surfaces. Main cusp approximately twice the height of next largest denticle and like other denticles except for a faint costa on distal half of lateral surfaces of some specimens.

**Remarks:** *Prioniodina araea* is similar to *P. pulcherrima,* but is smaller, more compressed laterally, and has a relatively larger basal cavity. The species ranges from the lower Galena Formation to the top of the Dubuque Formation. I recovered 94 specimens.

### Zygognathus elongata Informal Group

The *Zygognathus elongata* informal group consists of *Zygognathus elongata* Rhodes, *Cordylodus delicatus?* Branson and Mehl, and *Prioniodina pulcherrima* Rhodes. These form species have identical stratigraphic ranges in Minnesota, from the upper half of the Cummingsville Member of the Galena Formation at least to the top of the Elgin Member of the Maquoketa Formation. This group is known from both European and United States midcontinent faunas of the Middle and Upper Ordovician.

### Genus Zygognathus Branson, Mehl, and Branson, 1951

### Type Species Z. pyramidalis Branson, Mehl, and Branson, 1951

### Zygognathus elongata (Rhodes)

Plate 12 – Figure 1

*Gyrognathus elongata* Rhodes, 1953, p. 318, 319, pl. 22, figs. 201, 202, 205, 206; Ethington, 1959, p. 279, pl. 40, fig. 13; Ethington and Furnish, 1959, p. 543, pl. 73, fig. 14; Stone and Furnish, 1959, p. 223, pl. 32, fig. 9.

*Zygognathus deformis* Sweet, 1959, p. 1066, 1067, pl. 132, figs. 1, 5; Pulse and Sweet, 1960, p. 261, 262, pl. 37, figs. 1, 5.

**Remarks:** Immature specimens of *Zygognathus illustris* and *Z. gyroides* resemble immature specimens of *Z. elongata*. *Z. elongata* ranges in Minnesota from the upper half of the Cummingsville Member of the Galena Formation at least to the top of the Elgin Member of the Maquoketa Formation. Samples yielded 350 specimens.

### Genus Cordylodus Pander, 1856

### Type Species C. angulatus Pander, 1856

### Cordylodus delicatus? Branson and Mehl

Plate 10 – Figure 16

*Cordylodus? delicatus* Branson and Mehl, 1933, p. 129, pl. 10, figs. 14, 15; Fay, 1952, p. 82; Glenister, 1957, p. 731, 732, pl. 88, fig. 5.

*Subcordylodus delicatus* Branson, 1944, p. 89, 90, pl. 13, figs. 17, 18; Fay, 1952, p. 194; Ethington, 1959, p. 288, pl. 41, fig. 13.

*Cordylodus elongatus* Rhodes, 1953, p. 299, pl. 21, figs. 114-118.

*Cordylodus rectilineatus* Rhodes, 1953, p. 300, 301, pl. 22, figs. 172-175.

*Cordylodus delicatus* Sweet and others, 1959, p. 1044, 1045, pl. 132, figs. 12, 14, 17; Pulse and Sweet, 1960, p. 251, pl. 36, figs. 4, 7.

**Remarks:** Bergström (1964) has suggested that the types of Stauffer's *Plectodina dilata (=Cordylodus aculeatus)* and Branson and Mehl's *Cordylodus? delicatus* might well represent mature and immature specimens of the same form species. All specimens referred to *C. aculeatus* in this report came from strata below the top of the Decorah Formation and almost all were robust mature individuals. All specimens referred to *C. delicatus?* were recovered from strata above the top of the Decorah Formation and are immature individuals. Thus I do not have adequate growth series available to evaluate Bergström's suggestion.

Although it is difficult to quantify differences between these two species the writer thinks that *C. aculeatus* has a more erect cusp, a less bowed posterior process, a greater curvature of the outer sheath lamellae, and a more pronounced downward recurve of the anticusp, than *C. delicatus*. Since these differences may be due to maturity or to slight evolutionary modification the specific reference is questioned. Additional evidence tending to maintain separate species can be found in the fact that these two species of *Cordylodus* appear to be associated with slightly different forms of *Zygognathus*.

*Cordylodus delicatus?* ranges from the upper half of the Cummingsville Member of the Galena Formation at least to the top of the Elgin Member of the Maquoketa Formation in Minnesota. I collected 1152 specimens.

### Genus Prioniodina Bassler, 1925

### Type Species P. subcurvata Ulrich and Bassler, 1926

### Prioniodina pulcherrima Lindström

**Plate 12 – Figures 9, 11**

*Ozarkodina* n. sp. Mehl and Strothmann, 1940, in Branson, 1944, pl. 12, figs. 16-17.

*Ozarkodina delecta* Glenister, 1957, p. 735, pl. 88, figs. 8, 9; Ethington, 1959, p. 283, pl. 41, fig. 17.

*Prioniodina?* n. sp. 2, Lindström, 1957, No. 2, p. 175, pl. 1, fig. 22, text-fig. 2.

*Ozarkodina? delecta* Stone and Furnish, 1959, p. 225, pl. 32, figs. 1, 2.

*Prioniodina delecta* Sweet and others, 1959, p. 1060, pl. 131, fig. 11; Pulse and Sweet, 1960, p. 258, 259, pl. 36, figs. 10, 11.

*Prioniodina pulcherrima* Lindström, 1959, p. 442, 444, pl. 3, figs. 28-30.

**Remarks**: Specimens of *Prioniodina pulcherrima* have often been incorrectly referred to *Ozarkodina delecta* Stauffer. The holotype of *O. delecta* is fragmentary but quite distinct. *O. delecta* is more laterally compressed, exhibits differences in denticulation and has a considerably greater angle between the anterior and posterior processes. *Prioniodina pulcherrima* ranges in Minnesota from the upper half of the Cummingsville Member of the Galena Formation at least to the top of the Elgin Member of the Maquoketa Formation. Samples yielded 642 specimens.

### Zygognathus illustris Informal Group

The *Zygognathus illustris* informal group consists of the form species *Zygognathus illustris* (Stauffer) and *Cordylodus aculeatus* (Stauffer).

Both species are abundant in the Glenwood Formation, rare in the Platteville Formation and abundant in the Decorah Formation.

**Genus Zygognathus Branson, Mehl, and Branson, 1951**

**Type Species Z. pyramidalis Branson, Mehl, and Branson, 1951**

**Zygognathus illustris (Stauffer)**

Plate 9 – Figures 7, 8

*Trichognathus illustris* Stauffer, 1935a, p. 156, pl. 12, fig. 4; Fay, 1952, p. 198.

*Trichognathus deformis* Stauffer, 1935a, p. 155, 156, pl. 12, fig. 3; Fay, 1952, p. 198.

**Remarks**: Immature specimens of *Zygognathus illustris* tend to have a relatively large denticle adjacent to the main cusp on the inner lateral process. This denticle becomes less prominent with increasing maturity. The holotype of *Zygognathus deformis* Stauffer is an immature specimen of *Z. illustris* Stauffer with the peglike main denticle broken off at the base.

**Genus Cordylodus Pander, 1856**

**Type Species C. angulatus Pander, 1856**

**Cordylodus aculeatus (Stauffer)**

Plate 8 – Figures 13, 14
Plate 9 – Figures 4, 6

*Prioniodus aculeatus* Stauffer, 1930, p. 126, pl. 10, fig. 12; Fay, 1952, p. 167.

*Prioniodus cultellatus* Stauffer, 1930, p. 126, pl. 10, fig. 11; Fay, 1952, p. 170.

*Prioniodus calcaratus* Stauffer, 1930, p. 126, 127, pl. 10, fig. 13; Fay, 1952, p. 169.

*Prioniodus cristulus* Stauffer, 1930, p. 128, pl. 10, fig. 19; Fay, 1952, p. 170; Stauffer, 1935, p. 616, pl. 73, fig. 49 (not figs. 48, 57, 58).

*Cordylodus plattinensis* Branson and Mehl, 1933, p. 116, 117, pl. 8, figs. 34, 36; Sweet, 1955, p. 253, pl. 29, fig. 15; Carlson, 1960, p. 69, 70, pl. 2, figs. 1, 9.

*Belodus lineatus* Stauffer, 1935a, p. 131, pl. 12, fig. 13; Fay, 1952, p. 67.

*Plectodina dilata* Stauffer, 1935a, p. 152, pl. 11, figs. 43, 47; Stauffer, 1935, p. 613, pl. 73, fig. 51; Fay, 1952, p. 147.

*Subcordylodus rectilineatus* Stauffer, 1935a, p. 154, pl. 11, figs. 30, 32; Fay, 1952, p. 194.

*Subprioniodus hamatus* Stauffer, 1935b, p. 618, pl. 73, fig. 55; Fay, 1952, p. 195.

**Remarks**: As noted previously *Cordylodus aculeatus* is similar to *C. delicatus?* Branson and Mehl.

Approximately 25 percent of the specimens of *C. aculeatus* from the upper beds of the Glenwood Formation at Minneapolis, Minnesota bear one, and rarely two small denticles on the anticusp. *C. aculeatus* ranges from the upper beds of the Glenwood Formation to the top of the Decorah Formation. I recovered 676 specimens.

## Residual Form Species

### Genus Chirognathus Branson and Mehl, 1933
### Type Species C. duodactyla Branson and Mehl, 1933
### Chirognathus invictus Stauffer

Plate 4 – Figure 9

*Chirognathus invictus* Stauffer, 1935a, p. 137, pl. 9, fig. 43; Fay, 1952, p. 80.

**Remarks**: *Chirognathus invictus* is a rare species found only in the upper beds of the Glenwood Formation at Lanesboro, Minnesota. Only four specimens were recovered.

### Chirognathus quadridactylus Stauffer

Plate 6 – Figure 1

*Chirognathus quadridactylus* Stauffer, 1935a, p. 138, pl. 9, fig. 35; Fay, 1952, p. 80.

**Remarks**: *Chirognathus quadridactylus* was found only in the upper beds of the Glenwood Formation at Lanesboro, Minnesota where 15 specimens were recovered.

### Chirognathus symmetrica new species

Plate 5 – Figure 7

**Holotype**: U.M.P.C. 8971, from the Glenwood Shale, Lanesboro Section.

A bilaterally symmetrical, arched, "fibrous" unit. Base prominantly arched and set with at least seven peglike, marginally keeled, slightly curved denticles. Denticles confluent somewhat above base of unit, larger toward center of unit. Base excavated to form a small pit beneath largest denticle. Aboral surface slightly concave and commonly filled with basal material.

**Remarks**: I collected 12 specimens from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Genus Coleodus Branson and Mehl, 1933

### Type Species C. simplex Branson and Mehl, 1933

### Coleodus simplex Branson and Mehl

Plate 4 – Figure 5

*Coleodus simplex* Branson and Mehl, 1933, p. 24, pl. 1, figs. 22-25; Fay, 1952, p. 81; Sweet, 1955, p. 233, pl. 29, fig. 27; Carlson, 1960, pl. 1, fig. 1.

**Remarks:** Two specimens were recovered from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Genus Curtognathus Branson and Mehl, 1933

### Type Species C. typa Branson and Mehl, 1933

### Curtognathus chatfieldensis (Stauffer)

Plate 4 – Figure 4

*Polycaulodus chatfieldensis* Stauffer, 1935b, p. 613, 614, pl. 71, fig. 44; Fay, 1952, p. 147.

**Remarks:** *Curtognathus* and *Polycaulodus* are closely related genera differing primarily in that the former has an arched base while the latter is flat. *C. chatfieldensis* has a strongly arched base and therefore correctly belongs in *Curtognathus*. Seven specimens were recovered from the upper beds of the Glenwood Formation at Minneapolis, Minnesota, and three specimens from the Decorah Formation at Cummingsville, Minnesota.

### Curtognathus limitaris Branson and Mehl

Plate 4 – Figure 3

*Curtognathus limitaris* Branson and Mehl, 1933, p. 88, pl. 5, figs. 17, 23, 25; Fay, 1952, p. 85; Sweet, 1955, p. 249, pl. 29, fig. 16.

**Remarks:** Five specimens were recovered from the upper beds of the Glenwood Formation at Minneapolis, Minnesota and two specimens from the upper beds of the Decorah Formation at Cummingsville, Minnesota.

### Genus Erismodus Branson and Mehl, 1933

### Type Species E. typus Branson and Mehl, 1933

### Erismodus symmetricus Branson and Mehl

Plate 4 – Figure 7

*Erismodus symmetricus* Branson and Mehl, 1933, p. 104, pl. 10, fig. 10.

**Remarks:** Six specimens were recovered from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Genus Goniodontus Ethington, 1959

### Type Species G. superbus Ethington, 1959

### Goniodontus superbus Ethington

Plate 13 – Figure 12

*?Ligonodina* sp. Glenister, 1957, p. 732, pl. 88, fig. 25.

*Goniodontus superbus* Ethington, 1959, p. 278, pl. 40, figs. 1, 2.

**Remarks:** *Goniodontus superbus* Ethington is quite rare. Only four specimens were recovered from the Elgin Member of the Maquoketa Formation. The form figured by Glenister (1957) from the Phosphatic Member of the Maquoketa Formation in Iowa appears very similar to, if not conspecific with, my specimens.

### Genus Icriodella Rhodes, 1953

### Type Species I. superba Rhodes, 1953

### Icriodella symmetrica new species

Plate 13 – Figures 1, 2

**Holotype:** U.M.P.C. 9097 from Wr-63, Wubbles Ravine Section.

Unit triangular, barblike, approaching bilateral symmetry. Entire unit an anteriorly inclined, stout denticle divided by three nearly flat surfaces meeting to form sharp costa. The smallest surface, here designated "anterior", slightly concave, inclined upward and slightly to the anterior. Inner lateral surface slightly concave and outer lateral surface slightly convex. Posterior costa set with at least two small anteriorly inclined secondary denticles. Base deeply excavated to mid-height as a triangular pit.

**Remarks:** *Icriodella superba* is rare and was found in only two samples from the middle portion of the Dubuque Formation where nine specimens were recovered.

### Genus Ligonodina Bassler, 1925

### Type Species L. pectinata Ulrich and Bassler, 1926

### Ligonodina fairmontensis? (Pulse and Sweet)

Plate 10 – Figure 12

**Remarks:** A single specimen of *Ligonodina fairmontensis?* was recovered from the Prosser Member of the Galena Formation. It closely fits the description of *Eoligonodina fairmontensis* Pulse and Sweet except that the inner lateral process is inclined slightly more to the posterior than in the specimen figured by Pulse and Sweet (1960).

**Ligonodina sp.**

Plate 10 — Figure 14

**Remarks:** A single specimen of this unique form was recovered from the Stewartville Member of the Galena Formation.

**Genus Microcoelodus Branson and Mehl, 1933**

**Type Species M. typus Branson and Mehl, 1933**

**Microcoelodus asymmetricus Branson and Mehl**

Plate 4 — Figure 10

*Microcoelodus asymmetricus* Branson and Mehl, 1933, p. 91, pl. 7, figs. 5, 10, 11, 14, 15; Fay, 1952, p. 130; Sweet, 1955, p. 243, pl. 28, fig. 4.

**Remarks:** I collected seven specimens of *Microcoelodus asymmetricus* from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

**Microcoelodus brevibrachiatus Branson and Mehl, 1933**

Plate 5 — Figure 10

*Microcoelodus brevibrachiatus* Branson and Mehl, 1933, p. 91-92, pl. 7, figs. 3, 27; Branson, 1944, p. 69, 71, pl. 10, fig. 6.

**Remarks:** A single specimen of *Microcoelodus brevibrachiatus* was recovered from the upper beds of the Glenwood Formation.

**Microcoelodus expansus Branson and Mehl**

Plate 5 — Figure 6

*Microcoelodus expansus* Branson and Mehl, 1933, p. 93, pl. 6, fig. 7; (part) Stauffer, 1935a, p. 145, 146, pl. 12, fig. 10 (not fig. 15); Fay, 1952, p. 130; Sweet, 1955, p. 243, 244, pl. 27, figs. 3, 19.

**Remarks:** Only three specimens of this rare species were recovered from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

**Microcoelodus unicornis? Branson and Mehl**

Plate 4 — Figure 6

*Microcoelodus unicornis?* Branson and Mehl, 1933, p. 160, pl. 7, figs. 20, 24, 25; Sweet, 1955, p. 244, pl. 28, fig. 21.

**Remarks:** Sweet (1955), in a study of the conodonts from the Harding Formation, noted the identity of one of his form species with the form from the Joachim illustrated by Branson and Mehl as *Microcoelodus unicornis?*.Sweet questioned its specific reference and I am also unsure of it. The form is certainly identical to those found in the Harding Formation of Colorado and the Joachim Formation of Missouri.

Six specimens were recovered from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Microcoelodus new species A

Plate 4 – Figure 2

Main cusp large, peglike, slightly recurved posteriorly and set with a costa on each lateral surface continuous with the denticulated processes. Basal excavation a conical pit at base of main cusp nearly reaching anterior margin. Inner lateral process with at least one, and outer lateral process at least three, peglike keeled denticles somewhat smaller than the main denticle. Inner lateral process directed laterally and outer lateral process curved strongly to the posterior. Aboral surface of processes flat or slightly concave.

**Remarks:** I recovered five specimens from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Microcoelodus new species B

Plate 4 – Figure 1

Main cusp large, twisted slightly inward, slightly compressed laterally, and set with antero-lateral and postero-lateral costae continuous with the denticulated processes. Inner lateral process directed laterally, strongly downward, and set with at least four slightly compressed keeled denticles. Outer lateral process directed laterally, strongly to the posterior, with at least five slightly compressed keeled denticles. Denticles smaller away from main cusp, except for the small immediately adjacent denticles. Basal excavation a small pit at the base of the main cusp. Aboral surface of processes flat or slightly concave. Unit commonly filled with basal material.

**Remarks:** Samples yielded 12 specimens from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Microcoelodus new species C

Plate 4 – Figure 8

Unit slightly asymmetric. Main cusp long, and twisted slightly toward outer lateral process set with sharp lateral costa and a prominent posterior carina. Base excavated to form a small conical pit at base of main cusp. Inner and outer lateral processes with flat aboral surfaces, set with three peglike basally confluent denticles. Middle denticle on inner lateral process nearly twice the size of adjacent denticles.

**Remarks:** A single specimen was recovered from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Genus Mixoconus Sweet, 1955
### Type Species M. primus Sweet, 1955
### Mixoconus primus Sweet
Plate 6 – Figure 5

*Mixoconus primus* Sweet, 1955, p. 245, pl. 28, figs. 27, 28.

**Remarks**: Only two specimens of *Mixoconus primus* Sweet were recovered from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Genus Neocoleodus Branson and Mehl, 1933
### Type Species N. spicatus Branson and Mehl, 1933
### Neocoleodus spicatus Branson and Mehl
Plate 5 – Figure 11

*Neocoleodus spicatus* Branson and Mehl, 1933, p. 24, pl. 1, fig. 37; Fay, 1952, p. 132.

**Remarks**: Only four specimens of *Neocoleodus spicatus* Branson and Mehl were found in the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Genus Oneotodus Lindstrom, 1954
### Type Species Distacodus simplex Furnish, 1938
### Oneotodus ovatus (Stauffer)
Plate 2 – Figure 7

*Oistodus ovatus* Stauffer, 1935a, p. 147, pl. 12, fig. 34; Fay, 1952, p. 136.

Base flat or slightly excavated, cusp slightly recurved and circular to subcircular in cross-section. Height of cusp three to six times diameter of base.

**Remarks**: A minor percentage of *Oneotodus ovatus* exhibited a flattened truncation of the cusp tip inclined downward and anteriorly. This species was found only in the upper beds of the Glenwood Formation at Lanesboro, Minnesota where 60 specimens were recovered.

### Genus Ozarkodina Branson and Mehl, 1933
### Type Species O. typica Branson and Mehl, 1933
### Ozarkodina maxima (Stauffer)
Plate 7 – Figures 12a, b

*Bryantodina maxima* Stauffer, 1935a, p. 134, pl. 10, fig. 28; Fay, 1952, p. 68.

Unit laterally compressed, flaring laterally beneath main denticle. Basal excavation deep beneath main denticle as a semiconical pit continuing beneath anterior process as a deep, and beneath posterior process as a shallow, excavation. Main cusp laterally compressed, set with sharp anterior and posterior keels continuous with the denticulated processes, and exhibiting an outer lateral costa continuous from tip to aboral margin. Posterior process curved downward and outward, set with at least nine laterally compressed denticles commonly fused to mid-height and sharply keeled anteriorly and posteriorly. Anterior process slightly longer than posterior and set with at least eight laterally compressed, sharply keeled, basally confluent denticles generally increasing in size anteriorly to near anterior margin.

**Remarks**: Stauffer's holotype of *Bryantodina maxima* is fragmentary, but is clearly conspecific with specimens collected from the upper beds of the Glenwood Formation at Minneapolis, Minnesota (Washington Avenue Section). The species was found only at this location. The prominence of the outer lateral carina in some mature specimens produces a dichognathid-like appearance. Samples yielded 51 specimens.

### Genus Phragmodus Branson and Mehl, 1933
### Type Species P. primus Branson and Mehl, 1933
### Phragmodus? arcus new species
Plate 3 – Figures 7, 9

**Holotype**: U.M.P.C. 8948, from P1-15B, Cummingsville Annex Section.

Unit strongly arched. Anterior denticle triangular in cross-section and set with three sharp costae; all other denticles laterally compressed, keeled anteriorly and posteriorly, and basally confluent. A large denticle, approximately equal in size to the anterior denticle, on top of the arch. Two small denticles anterior, and at least six small denticles posterior, to the large "arch" denticle. Unit very slightly excavated beneath anterior and "arch" denticle, becoming flat or inverted along remainder of aboral surface.

**Remarks**: Sample P1-15 Bulk yielded 12 specimens from near the middle of the Platteville Formation.

### Genus Polycaulodus Branson and Mehl, 1933
### Type Species P. inclinatus Branson and Mehl, 1933
### Polycaulodus bidentatus Branson and Mehl
Plate 6 – Figure 10

*Polycaulodus bidentatus* Branson and Mehl, 1933, p. 106, pl. 8, figs. 9, 12; Fay, 1952, p. 147; Sweet, 1955, p. 250, pl. 28, fig. 5.

**Remarks**: I found four specimens of *Polycaulodus bidentatus* Branson and Mehl in the upper beds of the Glenwood Formation and one in the upper Decorah Formation.

### Polycaulodus new species A

Plate 6 – Figure 4

Unit oval in plan view. Oral surface set with three peglike, keeled denticles along one edge. Center denticle erect and slightly smaller than others. Other two denticles inclined away from center. Aboral surface slightly inverted.

**Remarks:** A single specimen was recovered from the upper beds of the Glenwood Formation at Minneapolis, Minnesota.

### Polycaulodus new species B

Plate 6 – Figure 8

Unit triangular in plan view. Aboral surface flat or slightly inverted. Oral surface set with one large keeled denticle inclined at approximately 40° to base, and flanked on one side by one, and on the opposite side by two, small, nodose, slightly keeled denticles.

**Remarks:** I collected four specimens, of which three were fragmentary, from the upper beds of the Glenwood Formation at Minneapolis, Minnesota.

### Polycaulodus new species C

Plate 6 – Figure 3

Base barlike, nearly straight, and tapering in either direction from center. Oral surface set with six small, marginally keeled denticles increasing in size toward the center and tending to be flattened on one side and convex on the opposite. Aboral surface convex and inverted.

## Genus Prioniodina Bassler, 1925

### Type Species P. subcurvata Ulrich and Bassler, 1926

### Prioniodina new species A

Plate 8 – Figure 9

Main cusp large, erect, and keeled anteriorly and posteriorly, with convex lateral surfaces. Main cusp broken on all specimens, but on preserved portion, no upward decrease in width. Base of main cusp prominently flared and deeply excavated as a subconical pit. Excavation continuing beneath both processes as shallow groove. Anterior process straight and inclined downward and anteriorly. Posterior process curved downward and posteriorly. Both processes set with at least five somewhat laterally compressed, keeled denticles increasing slightly in size away from main cusp.

**Remarks:** Six specimens of *Prioniodina* n. sp. A were recovered from the upper beds of the Glenwood Formation at Minneapolis, Minnesota.

### Prioniodina new species B

Plate 8 – Figure 10

Main cusp large, slightly recurved, keeled anteriorly and posteriorly and twisted slightly inward. Base of main cusp prominently flared and deeply excavated as a semiconical pit. Excavation continuous under both processes as a prominent groove. Anterior process set with at least four, and posterior process at least three, discrete peglike denticles. Anterior process inclined nearly horizontal, posterior process nearly vertical to form an interprocess angle of approximately $100^{\circ}$.

**Remarks**: The upper beds of the Glenwood Formation at Minneapolis, Minnesota yielded 10 fragmentary specimens of *Prioniodina* n. sp. B.

## Genus Ptiloconus Sweet, 1955

## Type Species P. gracilis (Branson and Mehl) 1933

### Ptiloconus compressus (Branson and Mehl)

Plate 5 – Figure 9

*Pteroconus compressus* Branson and Mehl, 1933, p. 111-112, pl. 8, fig. 31; Fay, 1952, p. 179.

*Ptiloconus compressus* Sweet, 1955, p. 246, pl. 28, fig. 1.

**Remarks**: I collected 28 specimens of *Ptiloconus compressus* from the upper beds of the Glenwood Formation at Lanesboro, Minnesota.

### Ptiloconus gracilis (Branson and Mehl)

Plate 5 – Figure 8

*Pteroconus gracilis* Branson and Mehl, 1933, p. 111, pl. 8, figs. 28, 30, 32, 35; Fay, 1952, p. 179.

*Ptiloconus gracilis* Sweet, 1955, p. 246, pl. 28, figs. 6, 20.

**Remarks**: *Ptiloconus gracilis* is fairly common in the upper beds of the Glenwood Formation and is also occasionally found in the upper part of the Decorah Formation. I recovered 42 specimens.

## Genus Stereoconus Branson and Mehl, 1933

## Type Species S. gracilis Branson and Mehl, 1933

### Stereoconus robustus Branson and Mehl

Plate 6 – Figure 12

*Stereoconus robustus* Branson and Mehl, 1933, p. 27, pl. 1, figs. 28, 29; Fay, 1952, p. 190; Sweet, 1955, p. 247, 248, pl. 28, fig. 25.

**Remarks**: Samples from the upper beds of the Glenwood Formation at Lanesboro, Minnesota yielded four specimens of *Stereoconus robustus*.

## Other Phosphatic Microfossils

### Phylum Colenterata
### Order Conulariida Miller and Gurvey, 1896
### Family Conulariidae Walcott, 1886
### Genus Conularia Sowerby, 1821
### Type Species C. quadrisulcata Sowerby, 1821
### Conularia cf. C. trentonensis Hall

Plate 15 – Figures 1-3

*?Conularia trentonensis* Hall, 1847, p. 224, pl. 59, figs. 4c, d.

Form Beta, Furnish and others, 1936, p. 1134, tab. 1, pl. 1, fig. 4, pl. 2, fig. 2.

*Lonchodus distans* Rhodes, 1953, p. 309, pl. 21, figs. 119, 120, 123.

*Lonchodus dentatus* Rhodes, 1953, p. 309, pl. 21, fig. 122.

Many periderm fragments were recovered from my samples. A typical fragment consists of a narrow, straight or slightly wavelike bar, with unique tubercles occupying the crests of undulations (Pl. 15, Figs. 2, 3). The tubercles are prominent, bilaterally symmetrical, hollow units with one flattened side or face set with from three to six costa which parallel the length of the bar. Several barlike fragments exhibit short lateral projections. Tabular periderm fragments are also common and exhibit longitudinal ribs corresponding to the previously described bars and short transverse ribs corresponding to the lateral projections of the bars (Pl. 15, Fig. 1). An inverse relationship exists between the thickness of the tabular fragments and the development of the tubercles: on the thickest fragments the tubercles are reduced to low unornamented nodose projections.

Fragments of *Conularia* cf. *C. trentonensis* Hall occur from the top of the Decorah to the top of the Dubuque Formations.

## Incertae Sedis

### Genus Lepodus Branson and Mehl, 1933
### Type Species L. minutus Branson and Mehl, 1933

Original description: "Comparatively broad, low cones with thin walls and deeply excavated base." Although commonly associated with conodonts, *Lepodus* is considered to be a scale of unknown affinity.

### Lepodus sp.

Plate 14 – Figure 4

These low, simple lamellar, symmetrical cones are ornamented with concentric lines paralleling the outer margin. All gradations from an elliptical to a roundly triangular outline are produced by flexures of conic wall.

**Remarks**: *Lepodus* sp. differs from *L. minutus* Branson and Mehl as it does not exhibit any of the four knotty ridges extending from the tip of the cone to the base. This species was found common throughout the section studied.

### Form A

Plate 14 – Figures 1, 2

Form A consists of phosphatic, lamellar, bar-like fragments with an upper surface set with low nodose projections elongated at right angles to the length of the bars. The highest point of the projections occurs near one edge, with uniform thinning toward the opposite edge generally forming a slight lateral projection. The underside of the bars is flat.

**Remarks**: These fragments bear some resemblance to conularid periderm fragments referred to *Conularia* cf. *C. trentonensis*.

Form A fragments range from the upper beds of the Glenwood Formation at least to the top of the Dubuque Formation. They are very abundant in the lower Decorah Formation.

### Form B

Plate 14 – Figures 3, 6

Many small lamellar, phosphatic, circular forms were recovered in the residues. Although rare, they range throughout the section studied.

### Form C

Plate 14 – Figure 5

Many phosphatic, elongate, hollow, thin-walled tubes were recovered in the residues. The tubes are generally found singly but in several cases the tubes occurred in groups of four or five attached to a thin, slightly convex surface. Form C ranges in Minnesota from the upper half of the Cummingsville Member of the Galena Formation to the top of the Dubuque Formation.

### Form D

Plate 14 – Figure 7

Unornamented, lamellar, phosphatic, bar-like fragments were found common throughout the section studied. Most of these fragments are hemi-cylindrical although some exhibit a triangular cross-section.

### Form E

Plate 14 – Figures 8a, b, 9

Fragmentary plates, Stauffer, 1935a, p. 157, pl. 12, figs. 39, 40, 43, 44.

Most specimens referred to this form were short lamellar, phosphatic, bar-like structures with flange-like terminations at both ends of the bars (Plate 14, Figure 9). During growth lamellae were added to the lateral and lower surfaces of the bars. In several cases the bars occurred in longitudinally arranged parallel rows on a thin phosphatic surface. The largest of the latter (Pl. 14, Figs. 8a, b) has a relatively flat undersurface with small depressions elongated at right angles to the length of the bars. The depressions occur only at the junction of two bars. The upper surface is marked by elongate ridges corresponding to the depressions of the undersurface.

### Form F

Plate 15 – Figure 4

Form F occurs as tabular, lamellar, phosphatic fragments. The upper surface is marked by irregularily curving longitudinal ridges which exhibit short prominent transverse ridges. The under surface is marked by longitudinal excavations corresponding to the longitudinal ridges of the upper surface. Form F ranges from the top of the Decorah Formation to the top of the Dubuque Formation.

### Form G

Plate 15 – Figure 5

Form G consists of tabular, lamellar, phosphatic fragments. The upper surface is marked by numerous small nodelike projections producing a linear braided appearance and the underside is flat. This form ranges from the upper beds of the Glenwood Formation to the top of the Decorah Formation, and is abundant in the Decorah Formation.

### Form H

Plate 15 – Figure 6

Form H also occurs as tabular, lamellar, phosphatic fragments. The upper surface is marked by orthogonal rows of low nodes and the under surface is flat. Form H was found only in the Prosser and Stewartville Members of the Galena Formation.

### Form I

Plate 15 – Figure 7

In Form I the simple, unornamented, thin-walled, gently recurved, high cones show a gently to strongly elliptical cross-section. The height of cone is approximately 1 to 1½ times basal diameter. The base is deeply excavated to a point just below the tip. This form is quite rare although it is found throughout the section studied.

## Form J

### Plate 15 – Figure 8

Fragmentary plates, Stauffer, 1935a, p. 157, pl. 12, figs. 37, 38, 41, 42, 47, 48.

Form J consists of tabular, lamellar, phosphatic fragments with an upper surface set with irregular broad, longitudinal ridges resembling a mold of a ripple-marked surface. The underside is flat. Cross-sections of the fragments at right angles to the ridges commonly exhibit laminations, truncated at the upper surface, which curve to parallel the underside producing a "cross-bedded" appearance. Form J ranges from the upper beds of the Glenwood Formation to the top of the Decorah Formation.

## Form K

### Plate 15 – Figure 9

Form K occurs as small, phosphatic units having a figure-eight shape in plan view. The upper surface is convex upward with a slight depression near the center of the unit. The surface is crowded with small nodelike projections and the underside is excavated paralleling the convexity of the upper surface. Most of the units are complete and without broken edges. These forms range throughout the section studied, but are common only in the Galena and the Dubuque Formations.

## Explanation of Plate I

### Gaps and overlaps:

A 4.5 ft. covered interval exists in the Decorah Formation between samples De-39 and De-45.

An estimated 30 ft. of rock of the Prosser Member of the Galena Formation is covered between samples Cu-38 and Rh-1.

The Rifle Hill and Wubbles Ravine sections overlap; sample Rh-52 is approximately equivalent to sample Wr-6.

### Stratigraphic distribution of conodont species:

Broken processes of the two form species of *Tetraprioniodus breviconus* n. sp. are so alike in structure that they could not be distinguished. These fragments have been recorded on the line separating the two form species in order to show stratigraphic distribution.

The conodont species recorded on the faunal list (p. 20-25) and not listed on Plate 1 were restricted to the upper beds of the Glenwood Formation with the exception of the following:

*Curtognathus chatfieldensis* (Stauffer), samples WG-Bulk, De-19, De-34.

*Icriodella symmetrica* n. sp., samples Wr-60, Wr-62.

*Ligonodina fairmontensis* (Pulse and Sweet), sample Rh-24

*Ligonodina* sp., sample Rh-6

*Phragmodus arcus* n. sp., sample Pl-15 Bulk

*Ptiloconus compressus* (Branson and Mehl), samples WG-Bulk, LG-Bulk, De-19, De-39

*Ptiloconus gracilis* (Branson and Mehl), samples WG-Bulk, LG-Bulk, De-15, De-39

### Stratigraphic section represented by sample letters:

Gl and Pl – Cummingsville Annex Section, p. 114
De and Cu – Cummingsville Section, p. 116
LG – Lanesboro Section, p. 113
Rh – Rifle Hill Section, p. 118
WG – Washington Avenue Section, p. 113
Wr – Wubbles Ravine Section, p. 120

iation found in *"D. typica"*. These "trends" then may exist both as separate form species and as a single form species with a wide range of variability including all the "trends."

oistodid element:

*Oistodus abundans* Branson and Mehl, 1933, p. 109, pl. 9, figs. 11, 17; Fay, 1952, p. 134; Lindstrom, 1954, p. 572; Amsden, 1957, p. 35; Glenister, 1957, p. 725, pl. 86, fig. 5; Sannemann, 1957, p. 4, 28; Ethington, 1959, p. 282, pl. 39, fig. 21; Sweet and others, 1959, p. 1052, pl. 130, fig. 3; Pulse and Sweet, 1960, p. 254, 255, pl. 35, figs. 1, 8.

**Remarks on the assemblage:** A total of 882 dichognathid, 773 oistodid, and 1410 phragmodid elements were recovered. The ratios of these forms are then 1.14:1:1.83, suggesting a simple ratio in the conodont-bearing animal of 1:1:2. The three phragmodid costa types occur in approximately equal numbers, requiring two of each type to fulfill the above ratio. Bilateral symmetry doubles this number, and the result is a total of 12 phragmodid elements. Our total requires three oistodids and three dichognathids on either side, resulting in a conodont assemblage with 24 units.

*Phragmodus undatus* is abundant from near the base of the Decorah Formation to the top of the Cummingsville Member of the Galena Formation. It is also present, but rare, in the Dubuque Formation.

### Genus Polyplacognathus Stauffer, 1935

### Type Species P. ramosa Stauffer, 1935

### Polyplacognathus ramosa Stauffer

Plate 11 – Figures 7, 8, 10

The form species *Polyplacognathus ramosa* Stauffer is here emended to include the manuscript form species *Polyplacognathus bifurcatus* (Thompson) (1959).

ramosid element:

*Polyplacognathus ramosa* Stauffer, 1935b, p. 615, pl. 75, figs. 23, 28-31, 37; Fay, 1952, p. 163, Sweet and Bergstrom, 1962, p. 1235, 1240.

*?Ancyrognathus?* sp. *a* Stauffer, 1935b, p. 602, pl. 75, fig. 24; Fay, 1952, p. 64.

*Polyplacognathus expansus* Stauffer, 1935b, p. 615, pl. 75, figs. 27, 33; Fay, 1952, p. 163.

*?Polyplacognathus* sp. *a* Stauffer, 1935b, p. 615, 616, pl. 75, figs. 32, 36, 38, 43, 49, 62, 63; Fay, 1952, p. 163.

*?Polygnathus?* sp. Stauffer, 1935b, p. 615, pl. 75, fig. 53; Fay, 1952, p. 162.

*Amorphognathus ramosa* Branson and Mehl, 1944, in Shimer and Shrock, Index Fossils of North America, p. 237, pl. 93, figs. 5, 6; Fay, 1952, p. 63, Sweet, 1955, p. 248, pl. 29, figs. 9-11, 17, 23, 25.

(non) *Amorphognathus ramosa* Glenister, 1957, p. 724, pl. 88, fig. 27.

bifurcatid element:

*Ancyrognathus?* sp. *b* Stauffer, 1935b, p. 602, pl. 75, figs. 60, 61; Fay, 1952, p. 64.

*?Polyplacognathus* sp. *b* Stauffer, 1935b, p. 616, pl. 72, figs. 8, 11, 12, 16, pl. 75, figs. 39, 42, 44, 47; Fay, 1952, p. 163.

*Amorphognathus bifurcatus* Thompson ms., 1959, p. 63, pl. 1, fig. 11.

**Original description of bifurcatid element Thompson (1959):**

"Elongate, bilobate, denticulated platforms. Anterior lobe long and broad surmounted with six or more sharp transverse ridges which occupy the center of the lobe. Margins of the anterior lobe faintly nodose. The postero-lateral lobe is bifid and nodose with a prominent line of low denticles or nodes running the length of each portion of the lobe. At the junction of the two lobes a large transversely elongate ridge or "denticle" is set parallel to those on the anterior lobe. Aborally the typical development of keels is observed forming a knot beneath the central ridge."

**Remarks:** The earliest immature specimens of this form species show a relatively undeveloped anterior lobe and are reminiscent of some species of *Ambalodus*. Development of the large "denticle" at the junction of the anterior and posterior lobes is quite variable, and is absent in some mature specimens. Most mature specimens develop a bladelike anterior termination.

**Remarks on the assemblage:** Thompson (1959) notes that these two form species are always found together in the Platteville. My work confirms Thompson's statement. Generally more ramosid than bifurcatid elements are found, probably the result of the ramosids breaking into more identifiable parts. I recovered 316 ramosid and 277 bifurcatid elements and suggest a 1:1 ratio of elements in the conodont-bearing animal. *Polyplacognathus ramosa* is probably closely related to *Amorphognathus ordovicica* Branson and Mehl. *Polyplacognathus ramosa* is abundant in the lower Platteville Formation, then rare to the top of its range in the upper Decorah Formation.

### Genus Pravognathus Stauffer, 1936

### Type Species Pravognathus idoneus (Stauffer), 1935

Stauffer (1936) proposed the name *Pravognathus* to replace *Heterognathus* Stauffer, 1935b, which was preoccupied by *Heterognathus* Girard (1854).

Ellison (1962) considers *Pravognathus* a junior synonym of

## Explanation of Plate 2

## All Figures X60

Figs. 1a, b, 2a, b, 3a, b, 6a, b *Panderodus panderi* (Stauffer), inner and outer lateral views of four specimens, U.M.P.C. 8920, 8921, 8922, 8923, Platteville Formation, p. 39.

Figs. 4, 5 *Drepanodus cavus* n. sp., Platteville Formation, p. 28.
Fig. 4 Lateral view of holotype U.M.P.C. 8924.
Fig. 5 Lateral view of specimen U.M.P.C. 8925.

Fig. 7 *Oneotodus ovatus* (Stauffer), lateral view of specimen U.M.P.C. 8926, Glenwood Formation, p. 67.

Figs. 8a, b, 9a, b *Panderodus arcuatus* (Stauffer), outer and inner lateral views of two specimens U.M.P.C. 8927, 8928, Platteville Formation, p. 38.

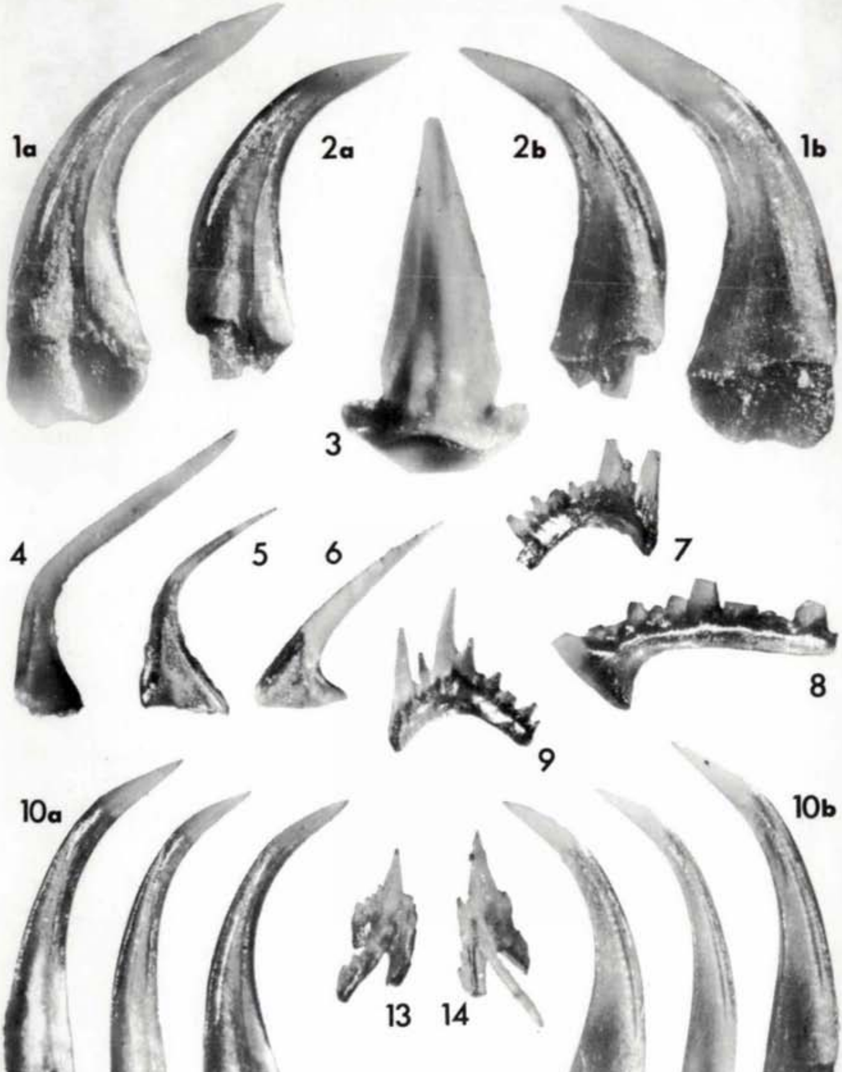
Figs. 10, 11 *Panderodus compressus* (Stauffer), outer and inner lateral views of two specimens U.M.P.C. 8929, 8930, Platteville Formation, p. 38.

Figs. 12, 13a, b, 14 *Coelocerodontus trigonius* Ethington, Dubuque Formation, p. 25.
Fig. 12 Trigonid element?, posterior view of specimen U.M.P.C. 8931.
Fig. 13a, b Trigonid element, posterior and lateral views of specimen U.M.P.C. 8932.
Fig. 14 Tetragonid element, postero-lateral view of specimen U.M.P.C. 8933.

Figs. 15, 16, 17 *Distacodus variabilis* n. sp., Platteville Formation, p. 28.
Fig. 15 Inner lateral view of holotype U.M.P.C. 8934.
Figs. 16, 17 Inner and outer lateral views of two specimens U.M.P.C. 8935, 8936.

Figs. 18, 19 *Oistodus venustus* Stauffer, inner lateral views of two specimens U.M.P.C. 8937, 8938, Glenwood Formation, p. 34.

Figs. 20, 21 *Oistodus pseudoabundans* Schopf ms., inner-lateral views of two specimens U.M.P.C. 8939, 8940, Platteville Formation, p. 34.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## Explanation of Plate 3
## All Figures X60

Figs. 1a, b, 2a, b *Panderodus feulneri* (Glenister), inner and outer lateral views of two specimens U.M.P.C. 8941, 8942, Galena Formation, p. 38.

Fig. 3 *Acontiodus aveolaris* Stauffer, posterior view of specimen U.M.P.C. 8943, Platteville Formation, p. 22.

Fig. 4 *Distacodus falcatus* Stauffer, inner lateral view of specimen U.M.P.C. 8944, Platteville Formation, p. 27.

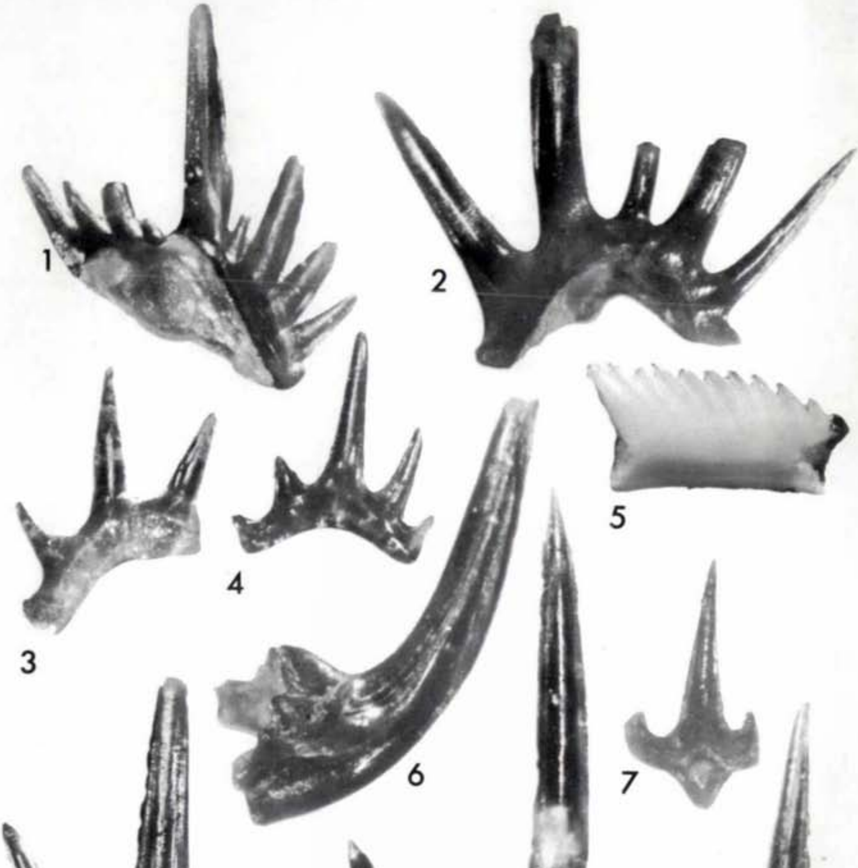
Figs. 5, 6 *Acodus mutatus* (Branson and Mehl), Dubuque Formation, p. 21.
Fig. 5 Distacodid element, lateral view of specimen U.M.P.C. 8945.
Fig. 6 Acodid element, inner lateral view of specimen U.M.P.C. 8946.

Figs. 7, 9 *Phragmodus arcus* n. sp., Platteville Formation, p. 68.
Fig. 7 Inner lateral view of specimen U.M.P.C. 8947.
Fig. 9 Inner lateral view of holotype U.M.P.C. 8948.

Fig. 8 *Phragmodus inflexus* Stauffer, phragmodid element, inner lateral view of specimen U.M.P.C. 8949, Glenwood Formation, p. 40.

Figs. 10a, b, 11a, b, 12a, b *Panderodus gracilis* (Branson and Mehl), inner and outer lateral views of three specimens U.M.P.C. 8950, 8951, 8952, Dubuque Formation, p. 39.

Figs. 13, 14 *Tetraprioniodus breviconus* n. sp., Platteville Formation, p. 47.
Fig. 13 Hibbardellid element, antero-lateral view of specimen U.M.P.C. 8953.
Fig. 14 Tetraprioniodid element, postero-lateral view of holotype U.M.P.C. 8954.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## Explanation of Plate 4
### All Figures X60

Fig. 1 *Microcoelodus* n. sp. B, postero-inner-lateral view of specimen U.M.P.C. 8955, Glenwood Formation, p. 66.

Fig. 2 *Microcoelodus* n. sp. A, postero-inner-lateral view of specimen U.M.P.C. 8956, Glenwood Formation, p. 66.

Fig. 3 *Curtognathus limitaris* Branson and Mehl, lateral view of specimen U.M.P.C. 8957, Glenwood Formation, p. 63.

Fig. 4 *Curtognathus chatfieldensis* (Stauffer), lateral view of specimen U.M.P.C. 8958, Glenwood Formation, p. 63.

Fig. 5 *Coleodus simplex* Branson and Mehl, lateral view of specimen U.M.P.C. 8959, Glenwood Formation, p.63.

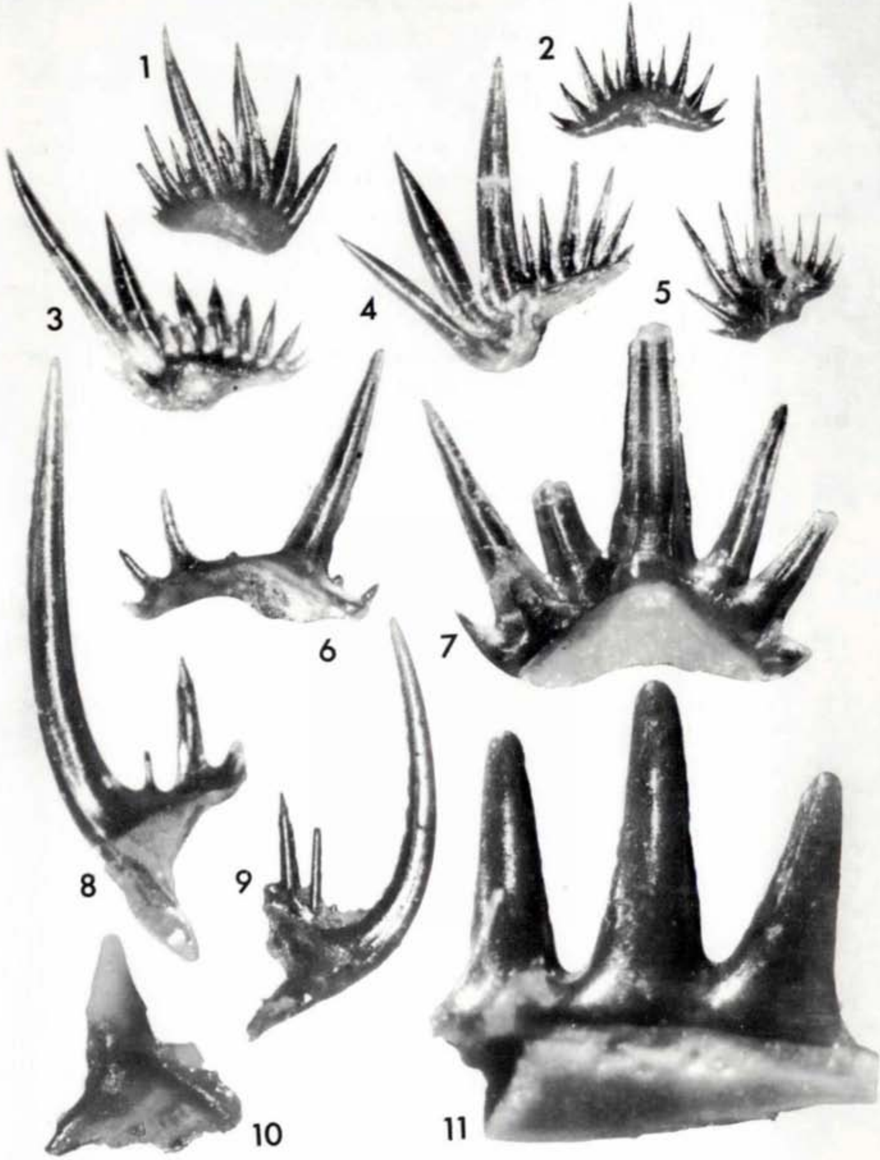
Fig. 6 *Microcoelodus unicornis?* Branson and Mehl, lateral view of specimen U.M.P.C. 8960, Glenwood Formation, p.65.

Fig. 7 *Erismodus symmetricus* Branson and Mehl, lateral view of specimen U.M.P.C. 8961, Glenwood Formation, p.63.

Fig. 8 *Microcoelodus* n. sp. C, posterior view of specimen U.M.P.C. 8962, Glenwood Formation, p. 66.

Fig. 9 *Chirognathus invictus* Stauffer, posterior view of specimen U.M.P.C. 8963, Glenwood Formation, p. 62.

Fig. 10 *Microcoelodus asymmetricus* Branson and Mehl, inner lateral view of specimen U.M.P.C. 8964, Glenwood Formation, p.65.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## Explanation of Plate 5

### All Figures X60

Figs. 1, 4 *Chirognathus delicatula* Stauffer, inner lateral views of two specimens U.M.P.C. 8965, 8966, Glenwood Formation, p. 54.

Fig. 2 *Chirognathus multidens* Branson and Mehl, posterior view of specimen U.M.P.C. 8967, Glenwood Formation, p. 56.

Fig. 3 *Chirognathus admiranda* Stauffer, inner lateral view of specimen U.M.P.C. 8968, Glenwood Formation, p. 54.

Fig. 5 *Chirognathus monodactyla* Branson and Mehl, inner lateral view of specimen U.M.P.C. 8969, Glenwood Formation, p. 55.

Fig. 6 *Microcoelodus expansus* Branson and Mehl, postero-inner lateral view of specimen U.M.P.C. 8970, Glenwood Formation, p. 65.

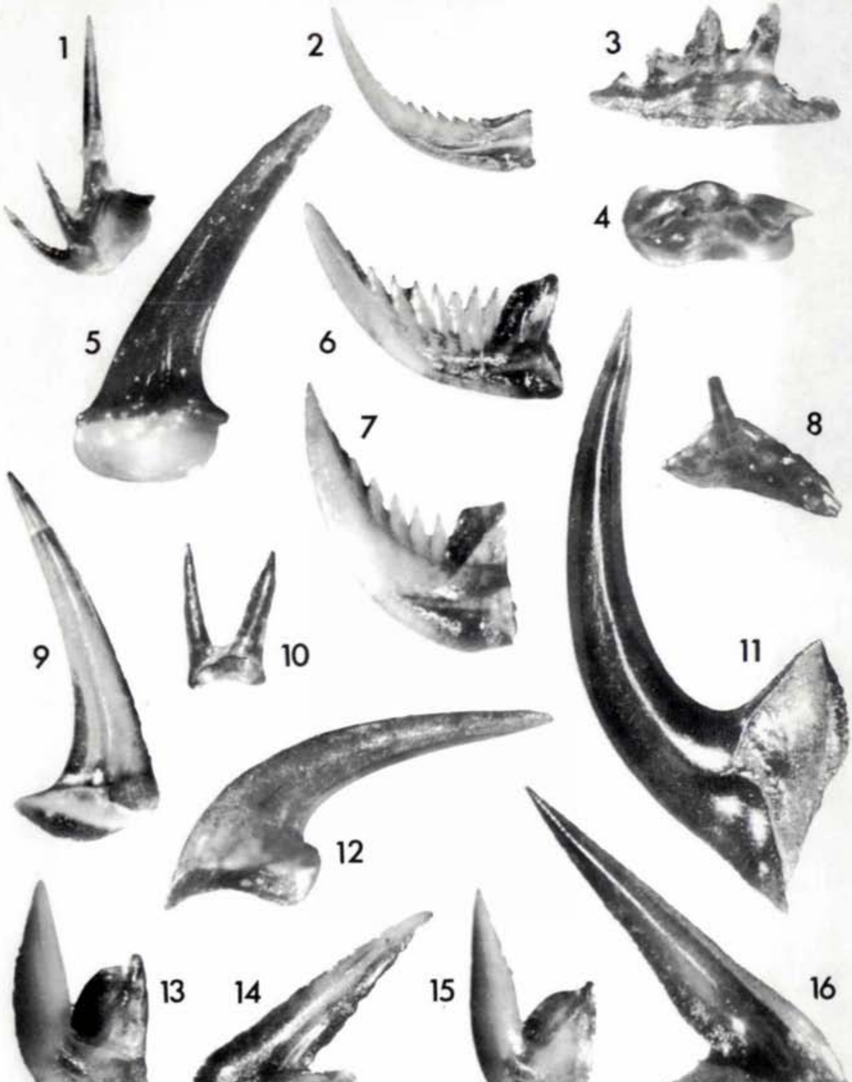
Fig. 7 *Chirognathus symmetrica* n. sp., posterior view of holotype U.M.P.C. 8971, Glenwood Formation, p. 62.

Fig. 8 *Ptiloconus gracilis* Branson and Mehl, inner lateral view of specimen U.M.P.C. 8972, Glenwood Formation, p. 70.

Fig. 9 *Ptiloconus compressus* (Branson and Mehl), inner lateral view of specimen U.M.P.C. 8973, Glenwood Formation, p. 70.

Fig. 10 *Microcoelodus brevibrachiatus* Branson and Mehl, posterior view of specimen U.M.P.C. 8974, Glenwood Formation, p. 65.

Fig. 11 *Neocoleodus spicatus* Branson and Mehl, lateral view of specimen U.M.P.C. 8975, Glenwood Formation, p. 67.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## Explanation of Plate 6

### All Figures X60

Fig. 1 *Chirognathus quadridactylus* Stauffer, postero-inner lateral view of specimen U.M.P.C. 8976, Glenwood Formation, p. 62.

Figs. 2, 6, 7, 13, 15 *Belodina compressa* (Branson and Mehl), Platteville Formation, p. 24.

Figs. 2, 6, 7 Belodinid element, inner lateral views of three specimens U.M.P.C. 8977, 8978, 8979.

Figs. 13, 15 Oistodid element, inner and outer lateral views of two specimens U.M.P.C. 8980, 8981.

Fig. 3 *Polycaulodus* n.sp. C, lateral view of specimen U.M.P.C. 8982, Glenwood Formation, p. 69.

Fig. 4 *Polycaulodus* n. sp. A, superior view of specimen U.M.P.C. 8983, Glenwood Formation, p. 69.

Fig. 5 *Mixoconus primus* Sweet, inner lateral view of specimen U.M.P.C. 8984, Glenwood Formation, p. 67.

Fig. 8 *Polycaulodus* n. sp. B, superior view of specimen U.M.P.C. 8985, Glenwood Formation, p. 69.

Figs. 9, 11, 14, 16 *Drepanodus suberectus* Branson and Mehl, Platteville Formation, p. 29.

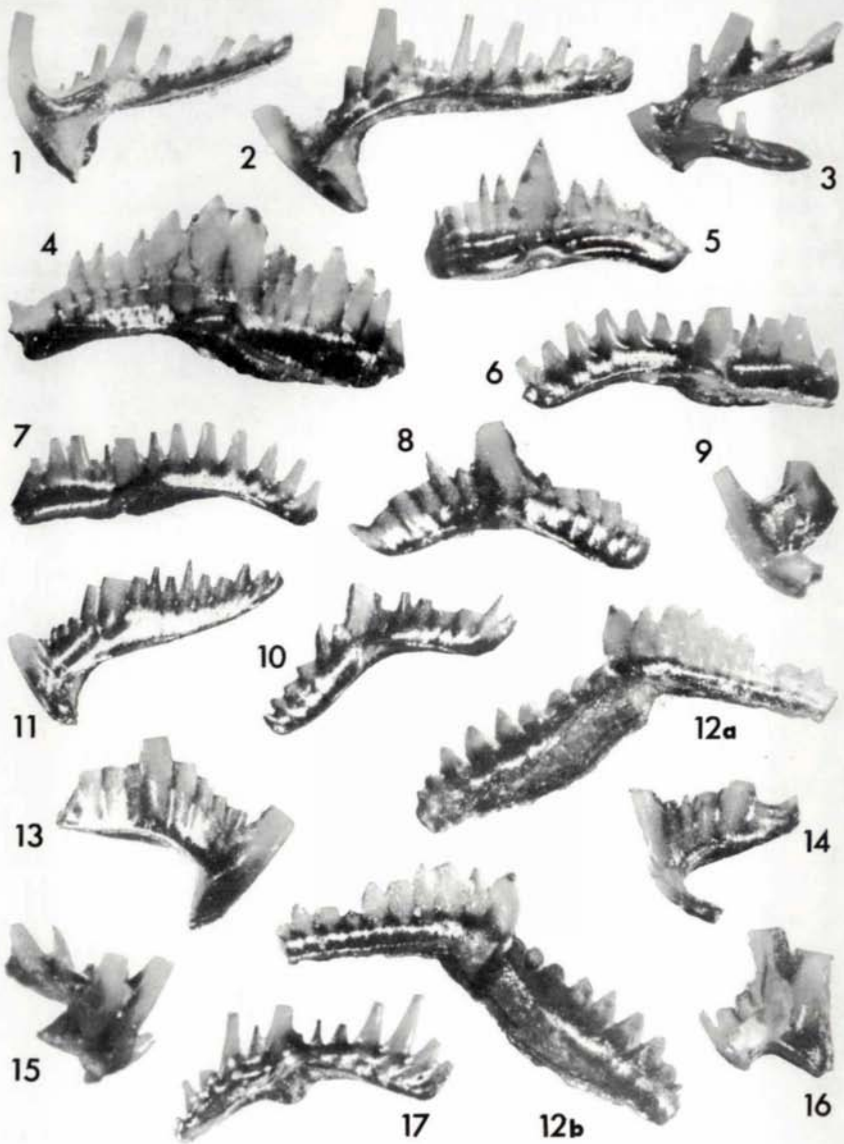
Fig. 9 Suberectid element, inner lateral view of specimen U.M.P.C. 8986.

Fig. 11 Homocurvatid element, outer lateral view of specimen U.M.P.C. 8987.

Figs. 14, 16 Oistodid element, inner lateral views of two specimens U.M.P.C. 8988, 8989.

Fig. 10 *Polycaulodus bidentatus* Branson and Mehl, lateral view of specimen U.M.P.C. 9105, Decorah Formation, p. 68.

Fig. 12 *Stereoconus robustus* Branson and Mehl, lateral view of specimen U.M.P.C. 8991, Glenwood Formation, p. 70.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## Explanation of Plate 7
## All Figures X60

Figs. 1, 2, 11, 13 *Phragmodus inversus* n. sp., Glenwood Formation, p. 52.

Figs. 1, 11, 13 Lateral view of three specimens U.M.P.C. 8992, 8993, 8994.

Fig. 2 Lateral view of holotype, U.M.P.C. 8995.

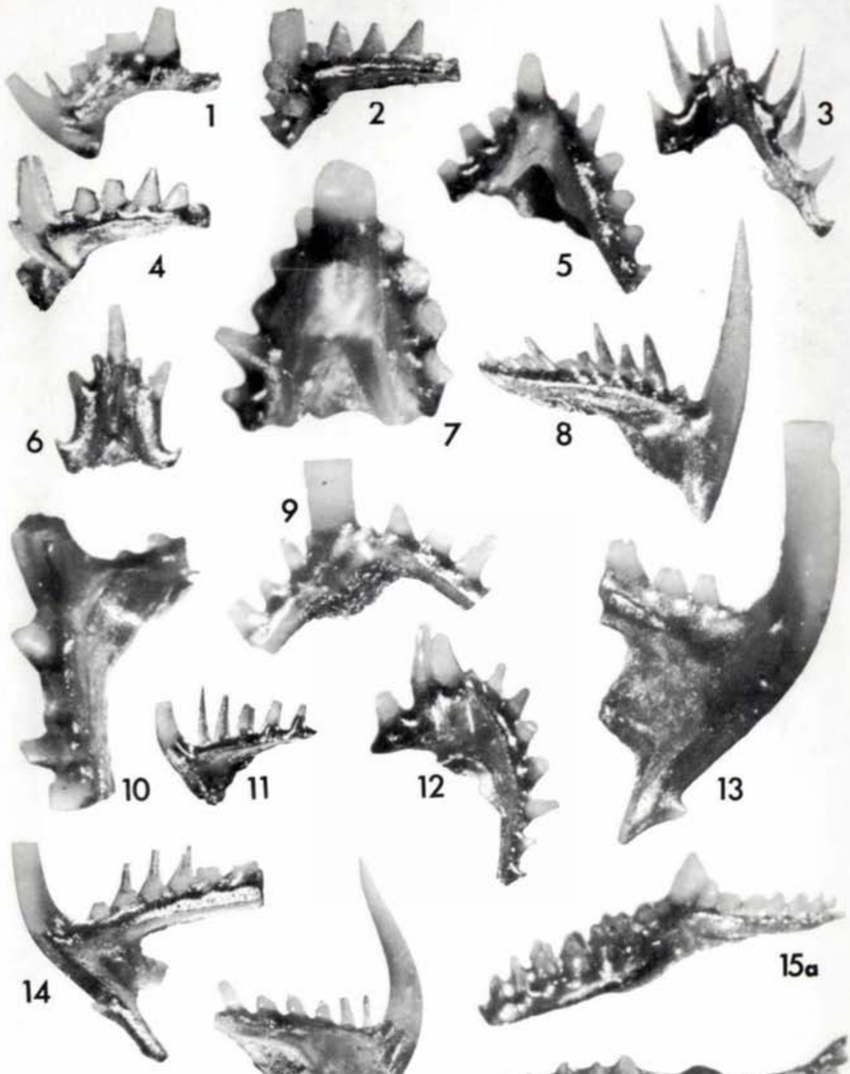
Figs. 3, 9 *Hibbardella variabilis* (Stauffer), lateral views of two specimens U.M.P.C. 8996, 8997, Glenwood Formation, p. 51.

Figs. 4-7 *Bryantodina typicalis* Stauffer, inner lateral views of four specimens U.M.P.C. 8998, 8999, 9000, 9001, Glenwood Formation, p. 50.

Figs. 8, 10, 17 *Prioniodina polita* (Stauffer), inner lateral views of three specimens U.M.P.C. 9002, 9003, 9004, Glenwood Formation, p. 53.

Figs. 12a, b *Ozarkodina maxima* (Stauffer), inner and outer lateral views of specimen U.M.P.C. 9005, Glenwood Formation, p. 67.

Figs. 14, 15, 16 *Hibbardella varians* (Stauffer), outer, inner, and posterior views of three specimens U.M.P.C. 9006, 9007, 9008, Glenwood Formation, p. 51.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## Explanation of Plate 8

All Figures X60

Figs. 1, 2, 4 *Phragmodus inflexus* Stauffer, Glenwood Formation, p. 40.

Fig. 1 Phragmodid element, inner lateral view of specimen U.M.P.C. 9009.

Figs. 2, 4 Dichognathid element, inner and outer lateral views of two specimens U.M.P.C. 9010, 9011.

Figs. 3, 5-7 *Trichonodella recurva* (Branson and Mehl), Platteville Formation, p. 48.

Figs. 3, 5 Recurvid element, postero-superior view of two specimens U.M.P.C. 9012, 9013.

Figs. 6, 7 Barbarid element, postero-superior views of two specimens U.M.P.C. 9014, 9015.

Fig. 8 *Cordylodus flexuosus* (Branson and Mehl), inner lateral view of specimen U.M.P.C. 9016, Dubuque Formation, p. 25.

Fig. 9 *Prioniodina* n. sp. A, inner lateral view of specimen U.M.P.C. 9017, Glenwood Formation, p. 69.

Fig. 10 *Prioniodina* n. sp. B, inner lateral view of specimen U.M.P.C. 9018, Glenwood Formation, p. 70.

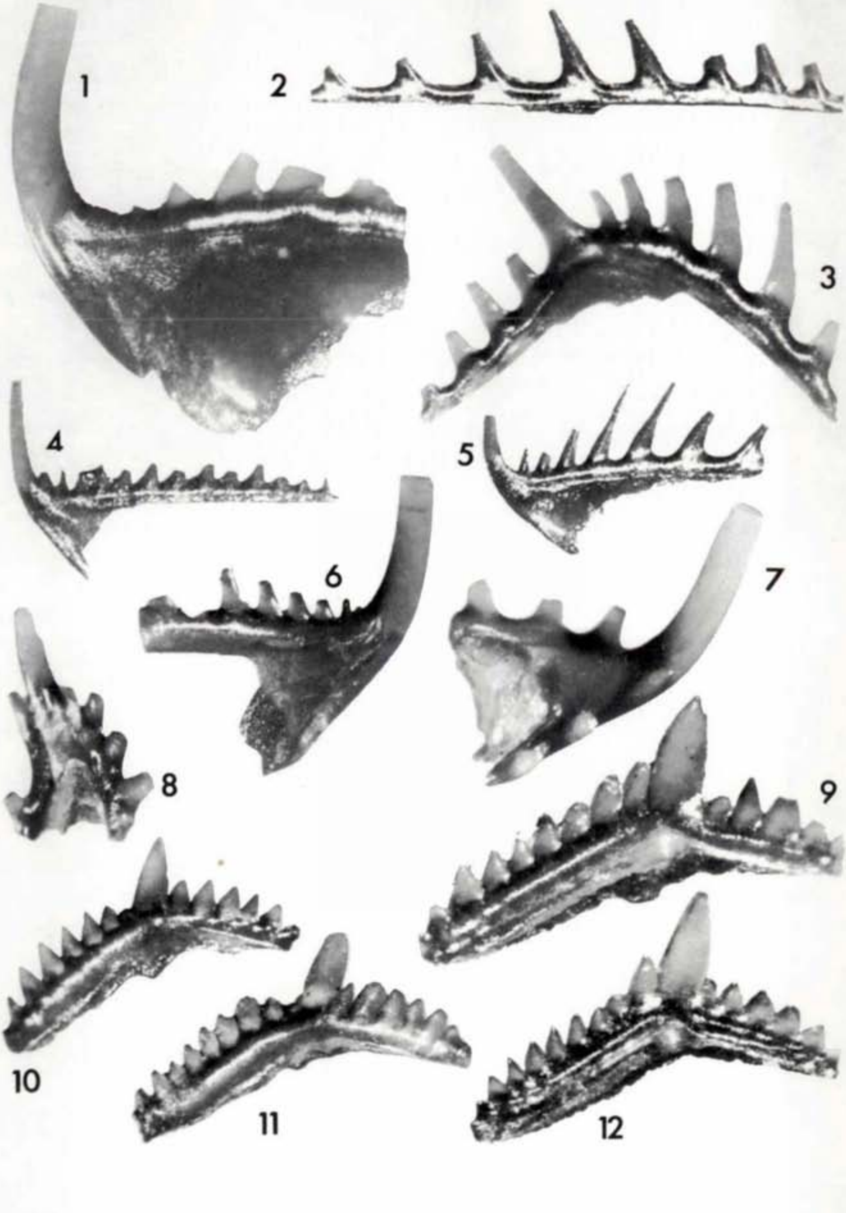
Figs. 11, 12, 16 *Cordylodus grandis* Stauffer, Platteville Formation, p. 26.

Figs. 11, 16 Cordylodid element, inner lateral views of two specimens U.M.P.C. 9019, 9020.

Fig. 12 Zygognathid element, superior view of specimen U.M.P.C. 9021.

Figs. 13, 14 *Cordylodus aculeatus* (Stauffer), inner lateral views of two specimens U.M.P.C. 9022, 9023, Glenwood Formation, p. 61.

Figs. 15a, b *Scyphiodus primus* Stauffer, inner lateral and superior views of specimen U.M.P.C. 9024, Platteville Formation, p. 45.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## Explanation of Plate 9
### All Figures X60

Figs. 1, 2, 3, 5 *Cordylodus serratus* Stauffer, Platteville Formation, p. 27.

Figs. 1, 5 Cordylodid element, inner lateral views of two specimens U.M.P.C. 9025, 9026.

Fig. 2 Cordylodid element, lateral view of posterior process, specimen U.M.P.C. 9027.

Fig. 3 Oulodid element, posterior view of specimen U.M.P.C. 9028.

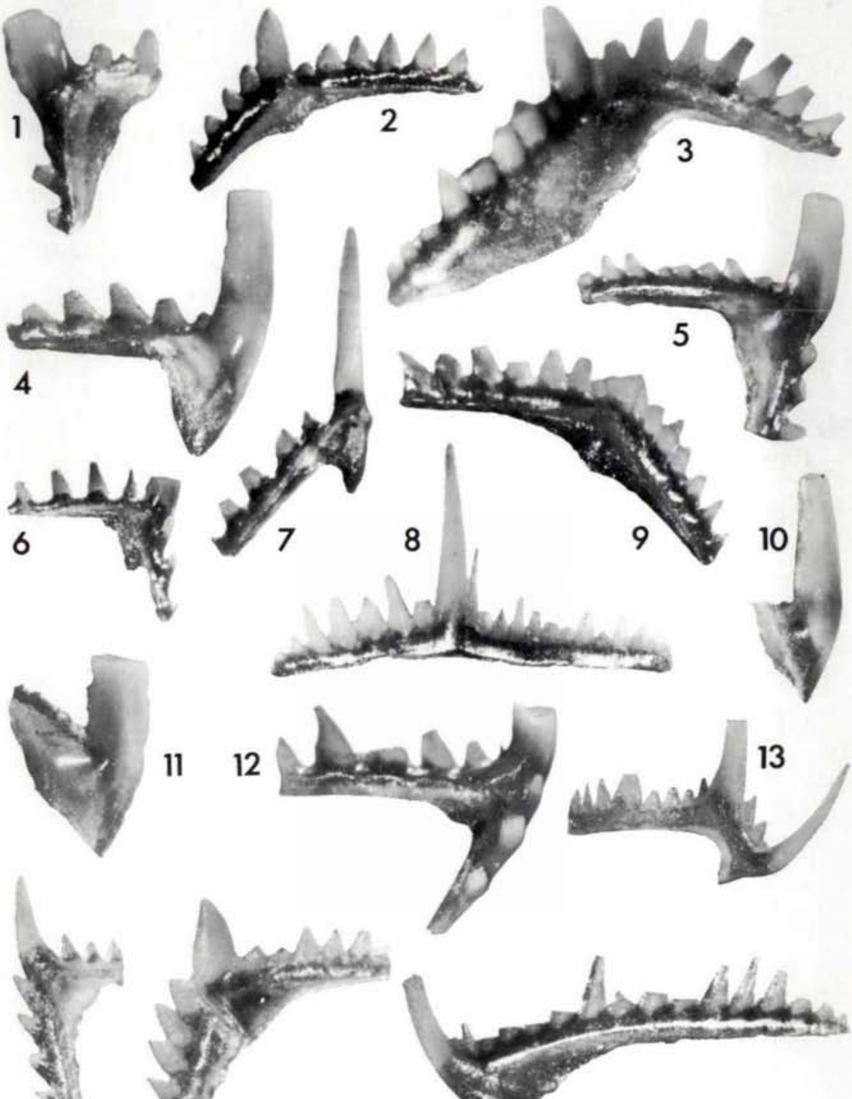
Figs. 4, 6 *Cordylodus aculeatus* (Stauffer), inner lateral views of two specimens U.M.P.C. 9029, 9030, Platteville Formation, p. 61.

Figs. 7, 8 *Zygognathus illustris* (Stauffer), oblique views of two specimens U.M.P.C. 9031, 9032, Platteville Formation, p. 61.

Figs. 9-12 *Ozarkodina concinna* Stauffer p. 35.

Figs. 9, 12 Inner lateral views of two specimens U.M.P.C. 9033, 9034, Dubuque Formation.

Figs. 10, 11 Inner lateral views of two specimens U.M.P.C. 9035, 9036, Platteville Formation.



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## Explanation of Plate 10

### All Figures X60

Figs. 1-7, 9 *Ozarkodina obliqua* (Stauffer), Glenwood Formation, p. 36.

Figs. 1, 5 Ptiloconid element, inner lateral views of two specimens U.M.P.C. 9037, 9038.

Figs. 2, 3, 9 Ozarkodinid element, inner lateral views of three specimens U.M.P.C. 9039, 9040, 9041.

Figs. 4, 6, 7 Dichognathid element, inner lateral views of two specimens U.M.P.C. 9042, 9043, and posterior view of specimen with broken posterior process, U.M.P.C. 9044.

Fig. 8 *Pravognathus idonea* (Stauffer), simplid element, inner lateral view of specimen U.M.P.C. 9045, Platteville Formation, p. 45.

Figs. 10, 11, 13, 15 *Phragmodus undatus* Branson and Mehl, Galena Formation, p. 41.

Figs. 10, 11 Oïstodid element, inner lateral views of two specimens, U.M.P.C. 9046, 9047.

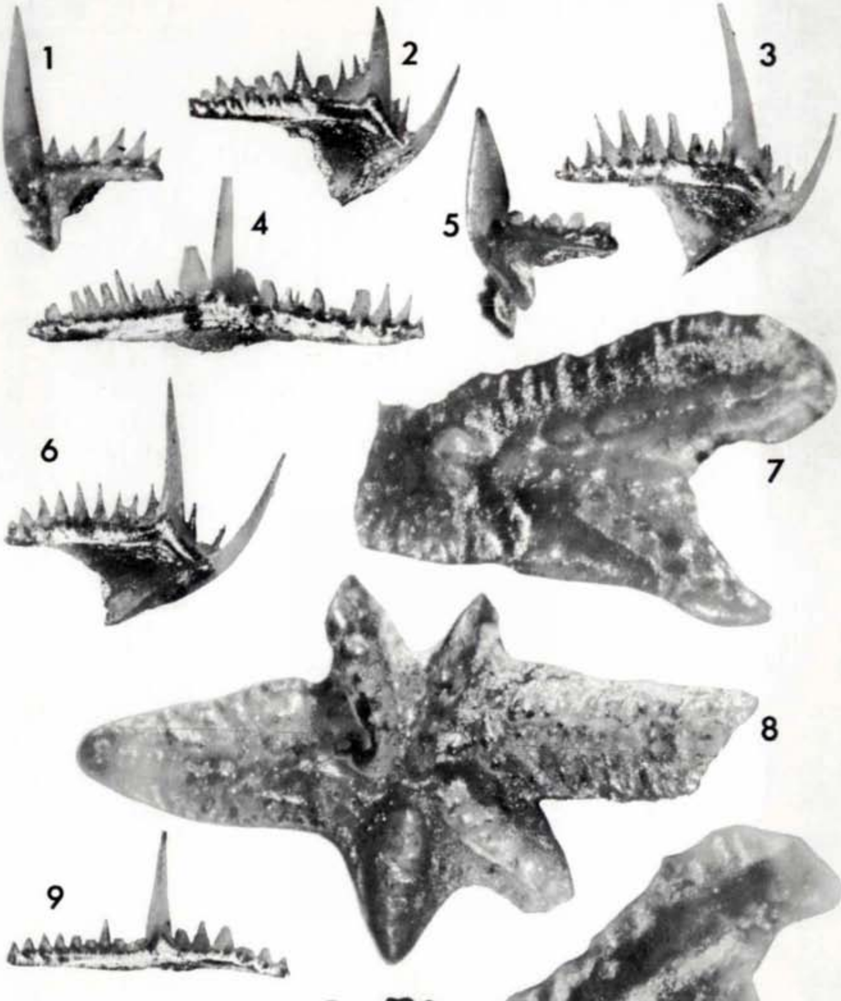
Fig. 13 Phragmodid element, inner lateral view of specimen, U.M.P.C. 9048.

Fig. 15 Dichognathid element, outer lateral view of specimen, U.M.P.C. 9049.

Fig. 12 *Ligonodina fairmontensis?* (Pulse and Sweet), inner lateral view of specimen, U.M.P.C. 9050, Galena Formation, p. 64.

Fig. 14 *Ligonodina* sp., lateral view of specimen U.M.P.C. 9051, Galena Formation, p. 65.

Fig. 16 *Cordylodus delicatus?* Branson and Mehl, inner lateral view of specimen U.M.P.C. 9052, Galena Formation, p. 59.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## Explanation of Plate II
## All Figures X60

Figs. 1, 2, 3, 5, 6 *Phragmodus cognitus* Stauffer, Platteville Formation, p. 41.

Figs. 1, 5 Dichognathid element, inner and outer lateral views of two specimens U.M.P.C. 9053, 9054.

Figs. 2, 3, 6 Phragmodid element, inner lateral views of three specimens U.M.P.C. 9055, 9056, 9057.

Figs. 4, 9, *Pravognathus idonea* (Stauffer), Platteville Formation, p. 45.

Fig. 4 Idoneid element, inner lateral view of specimen U.M.P.C. 9058.

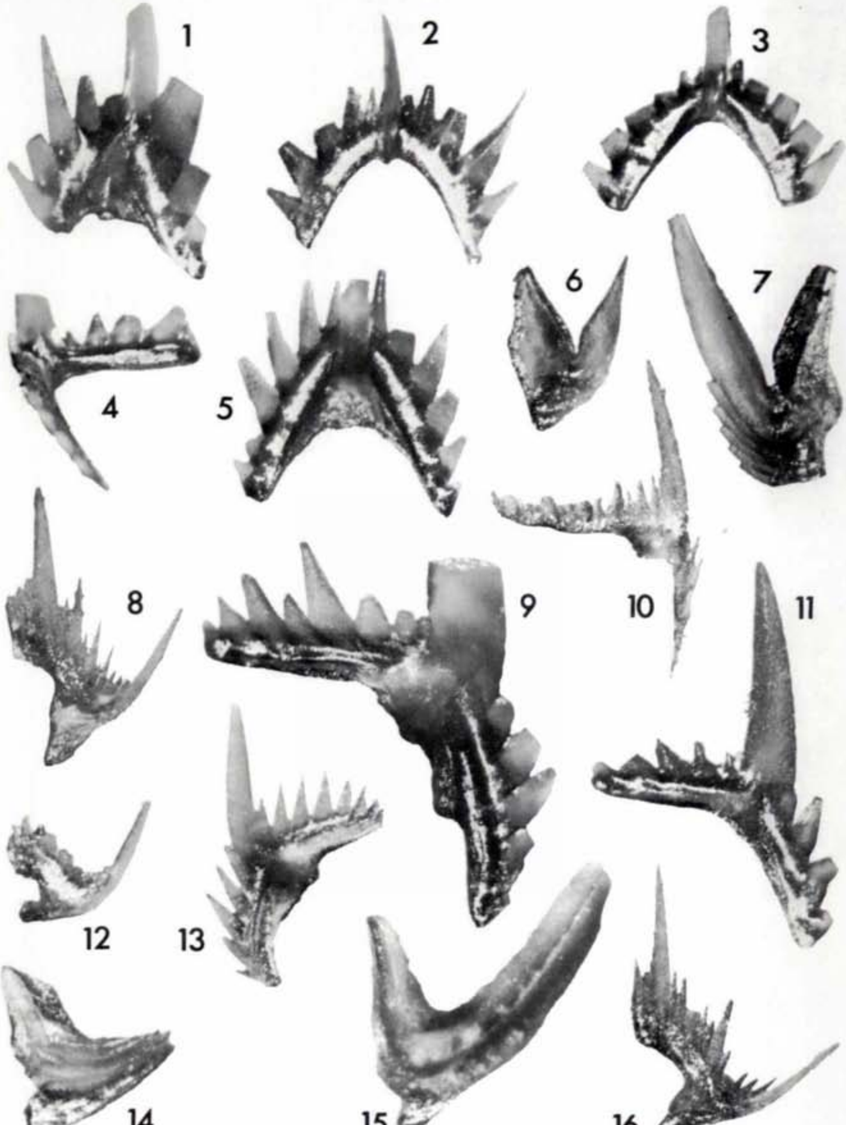
Fig. 9 Simplid element, inner lateral view of specimen U.M.P.C. 9059.

Figs. 7, 8, 10 *Polyplacognathus ramosa* Stauffer, Platteville Formation, p. 43.

Fig. 7 Bifurcatid element, superior view of incomplete specimen U.M.P.C. 9060.

Fig. 10 Bifurcatid element, superior view of complete specimen U.M.P.C. 9061.

Fig. 8 Ramosid element, superior view of specimen U.M.P.C. 9062.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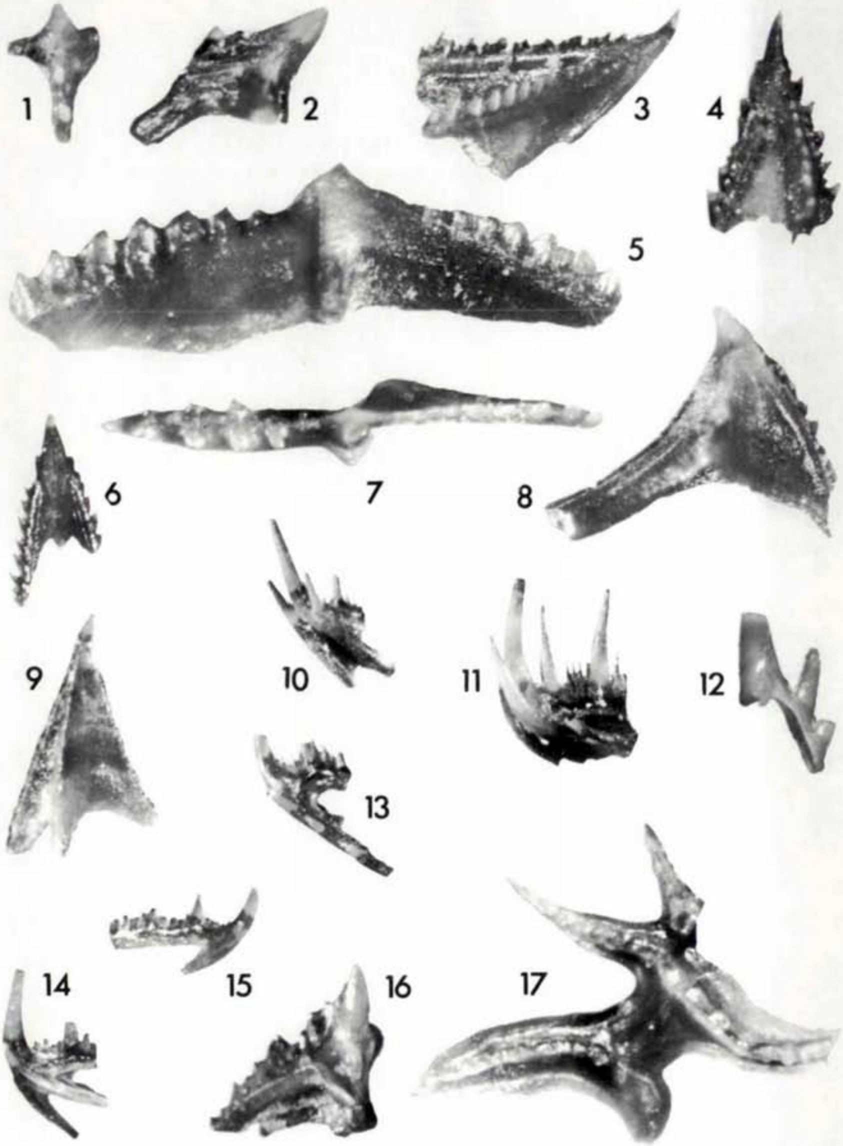
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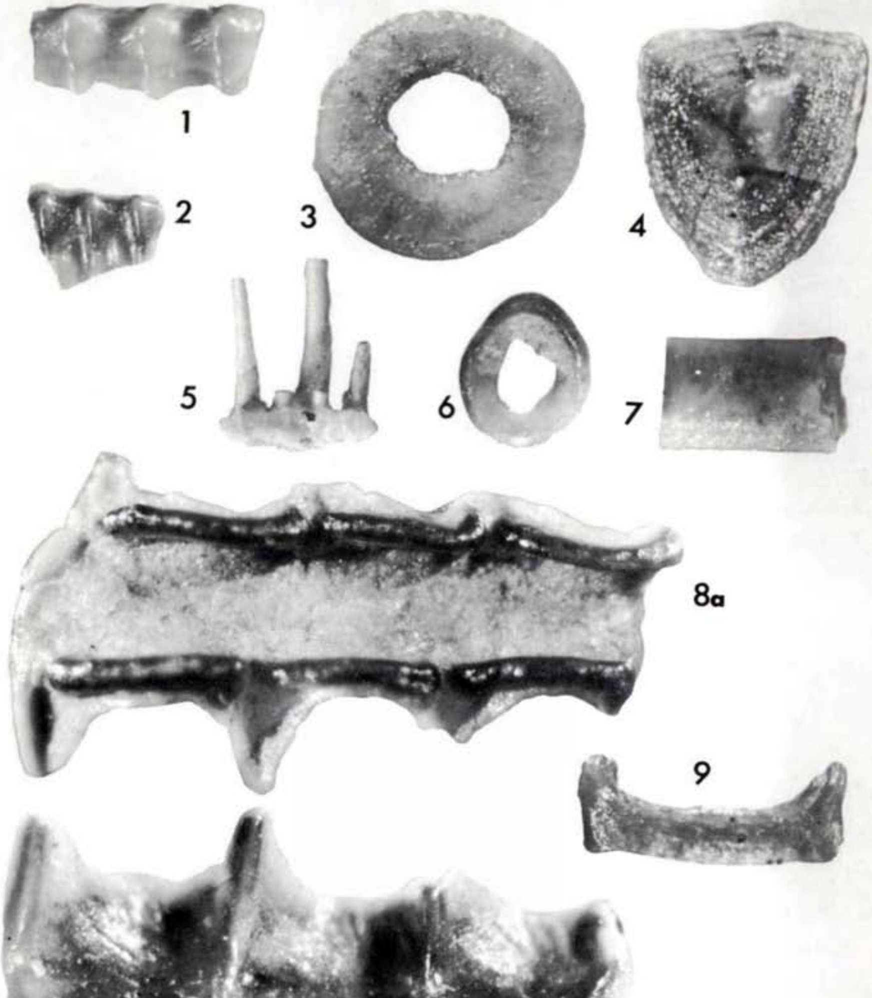
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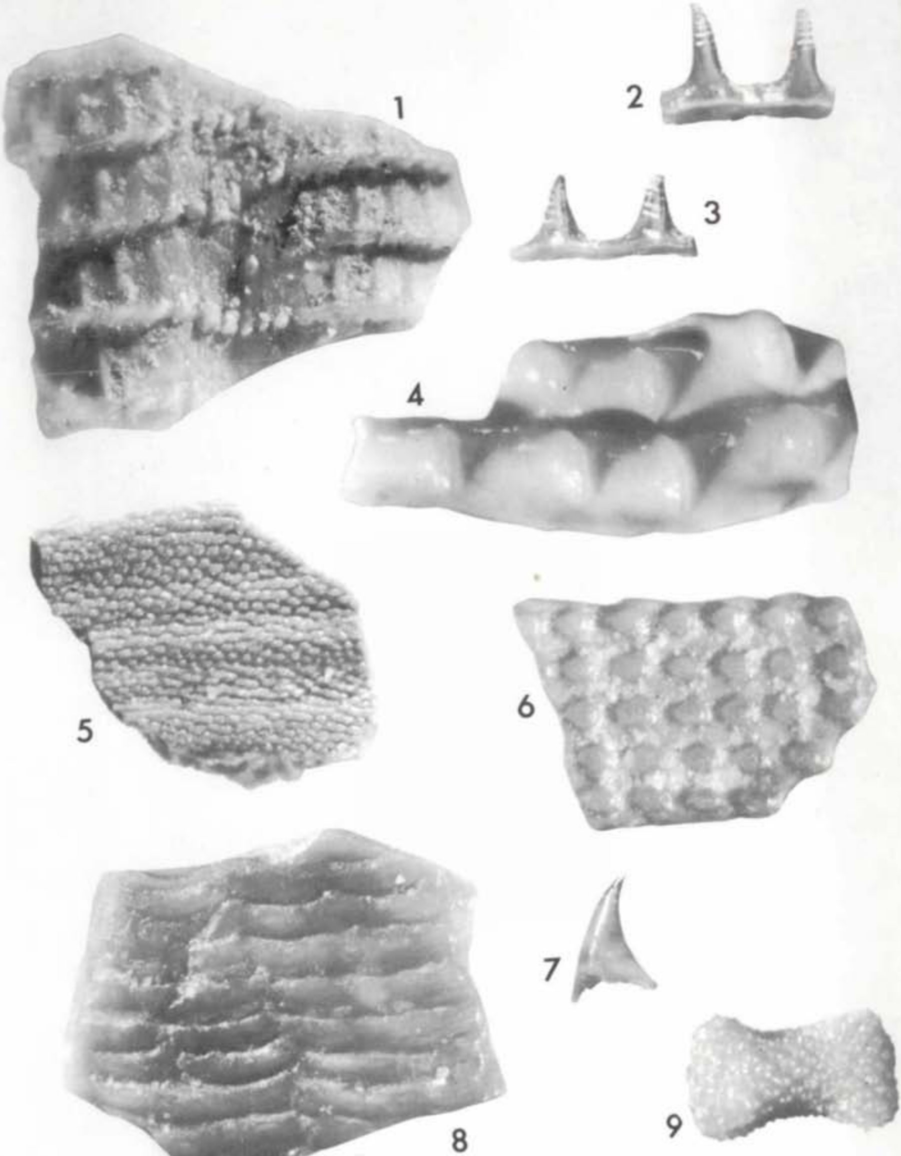
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# APPENDIX

## Stratigraphic Sections

### Lanesboro Section

Location: Road cut on north side of U. S. Highway 16 approximately 2 miles southwest of Lanesboro, Minnesota. Section located in State Roadside Park, SE 1/4 Sec. 26, T103N, R10W, Fillmore County.

| Height above base | | Thickness and Description |
|---|---|---|
| | (Section continues above) | |
| 1' 9.5" | | 6.5" Sandy limestone |
| 1' 3.0" | | 6.5" Calcareous sandstone |
| | Platteville Formation | |
| | Glenwood Formation | |
| 8.5" | | 5.0" Buff sandstone, partially cemented with calcite |
| 3.0" | Bulk Sample | 5.5" Green shale with 1" bed of limonite - cemented sandstone |
| 0' 00" | | 3.0" Dark brown limonitic sandstone |
| | Glenwood Formation | |
| | St. Peter Sandstone | |
| | (Section continues below) | |

### Washington Avenue Section

Location: Base of low bluff on the east bank of the Mississippi River, below the Washington Avenue Bridge (U. S. Highway 12), on the campus of the University of Minnesota at Minneapolis, Minnesota.

| Height above base | | Thickness and Description |
|---|---|---|
| | (Section continues above) | |
| | Platteville Formation / Glenwood Formation | |
| 4' 2.5" | | 3" Gray-green hard shale |
| 3' 9.5" | Bulk | 5" Gray-green soft shale |
| 3' 00" | Sample | 9½" Brown shale and punky dark-gray weathered limestone |
| 2' 4.0" | | 8" Chocolate brown-gray soft shale with limonite stringers |
| 2' 00" | | 4" Calcite-cemented green shaly sandstone with white mottles |
| 1' 2.0" | | 10" Green shaly sand with white mottles |
| 0' 00" | | 14" Greenish-yellow and buff sand |
| | Glenwood Formation / St. Peter Sandstone | |
| | (Section continues below) | |

## Cummingsville Annex Section

Location: Road cut along town road in the SW 1/4 of NW 1/4, Sec. 28, Orion Twp. (105N, 12W), Olmsted County.

| Height (in feet) above base | Sample Number | Thickness (in feet) and Description |
|---|---|---|
| | | Top of Platteville Formation |
| | | Carimona Member |
| 30.15 | Pl 26 | 0.4 Limestone |
| 29.95 | Pl 25 | 0.2 Shale |
| 29.45 | Pl 24 | 0.5 Limestone |
| 28.95 | Pl 23 | 0.4 Shale |
| 28.55 | Pl 22 | 0.4 Limestone |

| | | |
|---|---|---|
| 28.25 | Pl 21 | 0.3 Limestone |
| 28.05 | Pl 20 | 0.2 Shale and Limestone |
| 27.25 | Pl 19 | 0.8 Purplish cast limestone |
| 26.85 | Pl 18 | 0.4 Purplish cast limestone |
| 25.85 | Pl 17 | 1.0 Purplish cast limestone, 0.4' coquina 0.3' from base |
| 25.6 | Pl 16 | 0.25 Bentonite and shale |
| 25.0 | Pl 15 | 0.6 Limestone |
| 24.8 | Pl 14 | 0.2 Shaly limestone |
| | | Carimona Member, Platteville Formation |
| | | McGregor Member, Platteville Formation |
| 24.2 | Pl 13 | 0.6 Limestone, fine-grained, glassy textured |
| 22.7 | Pl 12 | 1.5 Limestone, some shale |
| 21.2 | Pl 11 | 1.5 Limestone, some shale |
| 19.7 | Pl 10 | 1.5 Limestone, slightly shaly |
| 18.2 | Pl 9 | 1.5 Limestone, slightly shaly |
| 17.7 | Pl 8 | 0.5 Limestone, massive |
| 17.5 | Pl 7 | 0.2 Limestone, coarsely-crystalline, purplish |
| 16.3 | Pl 6 | 1.2 Limestone, conch blue crinkly-bedded |
| 15.3 | Pl 5 | 1.0 Limestone, massive |
| 14.3 | Pl 4 | 1.0 Limestone, massive, blue, crinkly-bedded |
| 13.4 | Pl 3 | 0.9 Limestone, massive, crinkly-bedded |
| 12.2 | Pl 2 | 1.2 Limestone, mottled blue and buff |
| | | McGregor Member, Platteville Formation |
| | | Pecatonica Member, Platteville Formation |
| 11.2 | Pl 1 | 1.0 Limestone, mottled blue and buff, collophane nodules |
| | | Pecatonica Member, Platteville Formation |
| | | Glenwood Formation |
| 10.7 | Gl 11 | 0.5 Shale, sandy, blue with 0.1' calcareous shale in center |
| 9.6 | Gl 10 | 1.1 Sandstone, massive, calcite-cemented |
| 8.5 | Gl 9 | 1.1 Sandstone, massive, calcite-cemented |
| 7.4 | Gl 8 | 1.1 Sandstone, massive, calcite-cemented |
| 7.0 | Gl 7 | 0.4 Sandstone, massive, calcite-cemented |

| | | |
|---|---|---|
| 6.0 | Gl 6 | 1.0 Sandstone, shaly, iron-stained |
| 5.0 | Gl 5 | 1.0 Clay, blue, iron-stained bands at base |
| 4.0 | Gl 4 | 1.0 Clay, yellow and blue |
| 3.0 | Gl 3 | 1.0 Clay, yellow and blue |
| 2.0 | Gl 2 | 1.0 Clay, blue |
| 1.4 | Gl 1 | 0.6 Clay, yellow |
| | | Glenwood Formation |
| | | St. Peter Sandstone |
| 1.0 | Sp 2 | 0.4 Sandstone, reddish, friable |
| 0.0 | Sp 1 | 1.0 Sandstone, buff, friable |

Section measured and sampled by R. E. Sloan.

Cummingsville Section

Location: Road cut and quarries on State Aid Road 7, from 0.2 to 0.7 miles north of Cummingsville, Olmsted County, Minnesota. (Cummingsville is a settlement of two buildings at the junction of State Aid Road 7 and Minnesota State Highway 30.) Section on line between SE 1/4 Sec. 21, and SW 1/4 Sec. 22, Orion Twp. (105N, 12W), Olmsted County.

Approximate top of Cummingsville Member of Galena Formation

| | | |
|---|---|---|
| 105.6 | Cu 38 | 1.0 Massive limestone |
| 104.1 | Cu 37 | 1.5 Massive limestone |
| 100.6 | Cu 36 | 3.5 Shaly limestone |
| 100.4 | Cu 35 | 0.1-0.2 Coquinoid limestone |
| 98.5 | Cu 34 | 1.9 Shaly limestone |
| 96.4 | Cu 33 | 2.1 Massive limestone with minor shaly limestone |
| 91.7 | Cu 32 | 4.7 Shaly limestone |
| 90.8 | Cu 31 | 0.9 Shale |
| 87.8 | Cu 30 | 3.0 Massive limestone with minor shaly limestone |
| 86.7 | Cu 29 | 1.0 Shale |
| 86.1 | Cu 28 | 0.7 Massive limestone |

| Height (in feet) above base | Sample Number | Thickness (in feet) and Description |
|---|---|---|
| 84.1 | Cu 27 | 2.0 Shaly limestone |
| 83.1 | Cu 26 | 1.0 Massive limestone |
| 82.1 | Cu 25 | 1.0 Shaly limestone |
| 79.1 | Cu 24 | 3.0 Massive limestone with shale partings |
| 78.1 | Cu 23 | 1.0 Green shale |
| 76.3 | Cu 22 | 1.8 Massive limestone |
| 74.3 | Cu 21 | 2.0 Shaly limestone |
| 73.6 | Cu 20 | 0.7 Massive limestone |
| 72.9 | Cu 19 | 0.7 Limy shale |
| 72.0 | Cu 18 | 0.9 Massive limestone |
| 71.1 | Cu 17 | 0.9 Shaly limestone |
| 69.8 | Cu 16 | 1.3 Massive crinkly-bedded limestone |
| 68.3 | Cu 15 | 1.5 Shaly nodular limestone |
| 65.8 | Cu 14 | 2.5 Massive crinkly-bedded limestone |
| 63.9 | Cu 13 | 1.9 Massive calcarenite with 0.2' cross-bedded calcarenite |
| 63.2 | Cu 12 | 0.7 Shaly limestone |
| 60.7 | Cu 11 | 2.5 Massive calcarenite |
| 59.3 | Cu 10 | 1.4 Shaly nodular limestone |
| 57.5 | Cu 9 | 1.8 Massive crinkly-bedded limestone |
| 55.6 | Cu 8 | 1.9 Shaly nodular limestone |
| 53.9 | Cu 7 | 1.7 Massive crinkly-bedded limestone |
| 52.4 | Cu 6 | 1.5 Shaly crinkly-bedded limestone |
| 51.1 | Cu 5 | 1.3 } Massive, coquinoid, crinkly-bedded calcarenite |
| 49.0 | Cu 4 | 2.1 } |
| 47.1 | Cu 3 | 1.9 } |
| 45.5 | Cu 2 | 1.6 } |
| 45.0 | Cu 1 | 0.5 Limestone |

Cummingsville Member, Galena Formation

Decorah Formation

De 1-45 45' Green Shale with occasional thin coquinoid limestone beds, sampled at 1' intervals. 4.5' covered from 40.0' to 44.5' above the base of the Decorah Formation

Decorah Formation

Platteville Formation

(Continues below, poorly exposed)

Section measured and sampled by R. E. Sloan and R. Bleifuss.

Rifle Hill Section

Location: Group of large quarries and the road cut in Rifle Hill on State Aid Road 11 just west of Canfield Creek, NW 1/4 Sec. 35, Forestville Twp. (102N, 12W), Fillmore County.

| | | |
|---|---|---|
| 103.7 | Rh 55 | 1.6 Thin-bedded limestone |
| 102.0 | Rh 54 | 1.7 Thin-bedded limestone |
| 100.0 | Rh 53 | 2.0 Crinkly-bedded limestone |

Dubuque Formation

Galena Formation, Stewartville Member

| | | |
|---|---|---|
| 98.4 | Rh 52 | 1.6 Massive limestone |
| 96.4 | Rh 51 | 2.0 Massive limestone |
| 92.9 | Rh 50 | 3.5 Badly weathered, crinoidal, massive limestone |
| 91.5 | Rh 49 | 1.4 Massive, mottled limestone |
| 89.7 | Rh 48 | 1.8 Massive limestone |
| 88.4 | Rh 47 | 1.3 Massive limestone |
| 86.1 | Rh 46 | 2.3 Massive limestone |
| 83.8 | Rh 45 | 2.3 Massive limestone |
| 81.8 | Rh 44 | 2.0 Massive limestone |
| 78.5 | Rh 43 | 3.3 Massive limestone |
| 74.6 | Rh 42 | 3.9 Massive limestone |
| 72.6 | Rh 41 | 2.0 Massive limestone |
| 70.6 | Rh 40 | 2.0 Massive limestone |
| 67.3 | Rh 39 | 3.3 Massive limestone |
| 65.0 | Rh 38 | 2.3 Massive limestone |

| Height (in feet) above base | Sample Number | Thickness (in feet) and Description |
|---|---|---|
| 61.8 | Rh 37 | 3.2 Massive limestone |
| 59.8 | Rh 36 | 2.0 Massive limestone |
| 56.3 | Rh 35 | 3.5 Massive limestone |
| 53.9 | Rh 34 | 2.4 Massive limestone |
| 51.1 | Rh 33 | 2.8 Massive limestone |
| 48.3 | Rh 32 | 2.8 Massive limestone, includes 0.1' corrosion zone |
| 46.5 | Rh 31 | 1.8 Massive limestone, weathered |
| 44.1 | Rh 30 | 2.4 Massive limestone |
| 41.6 | Rh 29 | 2.5 Massive limestone, includes 1/4" shale at top |
| 39.2 | Rh 28 | 2.4 Massive limestone |
| 37.7 | Rh 27 | 1.5 Massive limestone |
| 35.9 | Rh 26 | 1.8 Lithographic limestone, minor coarsely crystalline limestone |
| 35.3 | Rh 25 | 0.6 Coarsely crystalline limestone |
| 34.6 | Rh 24 | 0.7 Lithographic limestone |
| 33.6 | Rh 23 | 1.0 Coarsely crystalline limestone |
| 32.5 | Rh 22 | 1.1 Lithographic limestone, includes 0.1' shale at base |
| 31.4 | Rh 21 | 1.1 Massive limestone |
| 30.5 | Rh 20 | 0.9 Limestone with 6 thin corrosion zones |
| | | Galena Formation, Stewartville Member |
| | | Galena Formation, Prosser Member |
| 28.7 | Rh 19 | 1.8 Massive limestone with 0.2' limonite-stained chert at base |
| 27.4 | Rh 18 | 1.3 Massive limestone |
| 26.6 | Rh 17 | 0.8 Coarsely crystalline limestone with shale parting at top |
| 25.4 | Rh 16 | 1.2 Massive limestone |
| 22.9 | Rh 15 | 2.5 Massive limestone with two chert zones near top |
| 20.3 | Rh 14 | 2.6 Massive limestone with limonite-stained chert zone near center |
| 19.3 | Rh 13 | 1.0 Shale |

| Height (in feet) above base | Sample Number | Thickness (in feet) and Description |
|---|---|---|
| 16.8 | Rh 12 | 2.5 Massive limestone |
| 15.4 | Rh 11 | 1.4 Massive limestone |
| 14.2 | Rh 10 | 1.2 Massive limestone with thin corrosion zone |
| 11.5 | Rh 9 | 2.7 Massive limestone |
| 11.4 | Rh 8 | 0.1 Shale |
| 7.4 | Rh 7 | 4.0 Massive limestone |
| 6.3 | Rh 6 | 1.1 Massive limestone with two chert zones |
| 5.5 | Rh 5 | 0.8 Massive limestone |
| 4.5 | Rh 4 | 1.0 Massive limestone |
| 3.7 | Rh 3 | 0.8 Massive limestone with minor coarsely crystalline limestone |
| 2.8 | Rh 2 | 0.9 Massive limestone |
| 0.0 | Rh 1 | 2.8 Massive limestone |

Quarry Floor – base of Prosser Member not exposed.

Section measured and sampled by R. E. Sloan and R. Bleifuss.

## Wubbles Ravine Section

Location: Road cut along township road in ravine in the N 1/2 of Sec. 2, York Twp. (101N, 12W), Fillmore County. Section near the township line.

| Height above base | Sample Number | Thickness and Description |
|---|---|---|
| 35' 0.25" | | Slumped and covered limestone beds |
| 34' 3.25" | WR 76 | 9" buff, medium-grained limestone |
| 34' 0.25" | WR 75 | 3" buff shale |
| 33' 4.75" | WR 74 | 7.5" buff, medium-grained limestone |
| 33' 2.25" | WR 73 | 2.5" buff shale |
| 32' 6.75" | WR 72 | 7.5" gray-buff, medium-grained limestone |
| 32' 1.25" | WR 71 | 5.5" gray shale |
| 31' 5.75" | WR 70 | 7.5" gray-buff, medium-grained limestone |
| 31' 0.25" | WR 69 | 5.5" gray shale |
| 30' 3.00" | WR 68 | 9.25" gray-buff, medium-grained limestone |
| 30' 0.00" | WR 67 | 3" gray shale |

| Height (in feet) above base | Sample Number | Thickness (in feet) and Description |
|---|---|---|
| 29' 2.50" | WR 66 | 9.5" gray, medium-grained limestone, irregular clay partings |
| 29' 1.00" | WR 65 | 1.5" gray shale |
| 28' 4.00" | WR 64 | 9" gray-buff, medium-grained limestone, irregular clay partings |
| 27' 9.50" | WR 63 | 5.5" gray shale |
| 27' 0.50" | WR 62 | 9.5" gray-buff, medium-grained limestone |
| 26' 8.50" | WR 61 | 4" gray shale |
| 26' 5.50" | WR 60 | 3" gray-buff, medium-grained limestone |
| 26' 2.50" | WR 59 | 3" buff-brown shale |
| 25' 4.00" | WR 58 | 10.5" gray, medium-grained limestone |
| 24' 2.50" | WR 57<br>WR 56 | 13.5" shale, 1" (interbedded) pink felspathic shale and 12.5" brown shale |
| 23' 6.50" | WR 55 | 8" gray-buff, medium-grained limestone |
| 23' 3.50" | WR 54 | 3" brown shale |
| 23' 0.50" | WR 53 | 3" gray, medium-grained limestone |
| 22' 10.50" | WR 52 | 2" buff shale |
| 22' 3.50" | WR 51 | 7" gray, medium-to fine-grained limestone |
| | WR 50<br>WR 49<br>WR 48 | 21.5" gray and brown shale |
| 19' 8.50" | WR 47 | 7.5" gray, medium-grained limestone |
| 19' 4.00" | WR 46 | 4.5" buff shale |
| 18' 9.00" | WR 45 | 7" gray-buff, medium-grained limestone |
| 18' 6.50" | WR 44 | 2.5" soft, buff shale |
| 18' 0.50" | WR 43 | 6" buff, medium-grained limestone |
| 17' 7.50" | WR 42 | 5" brown shale |
| 17' 1.00" | WR 41 | 5.5" gray, fine-grained limestone |
| 16' 7.50" | WR 40 | 6.5" buff, fine-grained limestone and buff shale |
| 16' 1.50" | WR 39 | 6" shaly, medium-grained, buff limestone |
| 15' 9.00" | WR 38 | 4.5" buff shale |
| 15' 6.00" | WR 37 | 3.0" gray-buff, medium-grained limestone |
| 15' 0.50" | WR 36 | 5.5" buff shale |

| Height (in feet) above base | Sample Number | Thickness (in feet) and Description |
|---|---|---|
| 14' 6.50" | WR 35 | 6" buff, medium-grained limestone, irregular clay partings |
| 14' 3.50" | WR 34 | 3" gray shale |
| 13' 8.50" | WR 33 | 6.5" buff, fine-grained limestone |
| 13' 4.50" | WR 32 | 4" buff shale |
| 12' 9.00" | WR 31 | 7.5" gray-buff, medium-grained limestone |
| 12' 7.50" | WR 30 | 1.5" gray-buff shale |
| 12' 1.00" | WR 29 | 6.5" gray-buff, medium-grained limestone |
| 11' 11.50" | WR 28 | 1.5" gray shale |
| 10' 5.75" | WR 27 | 17.5" gray-buff, medium-grained limestone, irregular clay partings |
| 10' 4.75" | WR 26 | 1" gray shale |
| 10' 1.75" | WR 25 | 3" gray-buff, medium-grained limestone |
| 10' 1.50" | WR 24 | 0.25" buff shale |
| 9' 9.75" | WR 23 | 3.75" buff, medium-grained limestone |
| 9' 7.75" | WR 22 | 2.00" buff shale |
| 9' 3.75" | WR 21 | 4" gray-buff limestone, irregular thickness |
| 9' 3.25" | WR 20 | 0.5" gray shale |
| 9' 0.25" | WR 19 | 3" gray-buff, medium-grained limestone |
| 8' 11.75" | WR 18 | 0.5" buff shale |
| 7' 2.75" | WR 17<br>WR 16<br>WR 15 | 21" gray-buff, medium-grained limestone, lower 6" shaly |
| 7' 0.25" | WR 14 | 2" gray-buff shale |
| 6' 3.25" | WR 13 | 9.5" buff, medium-grained limestone |
| 6' 3.00" | —— | 0.25" buff shale |
| 5' 5.50" | WR 12 | 9.50" buff, medium-grained limestone, small calcite vugs |
| 5' 3.50" | WR 11 | 2" buff, fine-grained shaly limestone |
| 4' 10.00" | WR 10 | 5.5" buff, medium-grained limestone |
| 4' 9.50" | | 0.5" gray-buff shale |
| 4' 0.00" | WR 9 | 9.5" buff, medium-grained limestone |
| 3' 11.50" | WR 8 | 0.5" gray shale |

| | | |
|---|---|---|
| 3' 10.00" | WR 7 | 1.5" buff, medium-grained limestone |
| 3' 9.00" | | 1" gray shale, irregular thickness |
| | Dubuque Formation | |
| | Galena Formation, Stewartville Member | |
| 3' 6.00" | WR 6 | |
| 2' 6.00" | WR 5 | 42" massive buff, dolomitic limestone with several partings |
| 2' 0.00" | WR 4 | |
| 1' 6.00" | WR 3 | |
| 1' 0.00" | WR 2 | |
| 0' 6.00" | WR 1 | |

----- (covered)------