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Conodont biostratigraphy of the Middle and Upper Ordovician of the Central Basin, Tennessee

Kim, Yoo Bong, Ph.D.
The Ohio State University, 1988

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CONODONT BIOSTRATIGRAPHY OF THE MIDDLE AND UPPER ORDOVICIAN OF THE CENTRAL BASIN, TENNESSEE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Yoo Bong Kim, B.S., M.S.

* * * * *

The Ohio State University
1988

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Professor Walter C. Sweet
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1988
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Major Field: Geology

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Studies in Stratigraphy. Dr. Walter C. Sweet, Dr. Stig M. Bergström.

Studies in Paleoecology. Dr. William I. Ausich.

Studies in Sedimentary Petrology. Dr. James W. Collinson, Dr. Lawrence A. Krissek.
# TABLE OF CONTENTS

ACKNOWLEDGMENTS ................................................................................................. ii
VITA ......................................................................................................................... iv
FIELD OF STUDY ................................................................................................... v
TABLE OF CONTENTS ............................................................................................. vi
LIST OF TABLES ....................................................................................................... viii
LIST OF FIGURES .................................................................................................... ix
INTRODUCTION ....................................................................................................... 1
MATERIALS AND METHODS ................................................................................... 5

**CHAPERS**

I. LITHOSTRATIGRAPHY ......................................................................................... 11
   Previous Studies ................................................................................................. 11
   Description of Stratigraphic Units ..................................................................... 16

II. BIOSTRATIGRAPHY ............................................................................................ 32
   Previous Studies ................................................................................................. 32
   Previous Conodont Studies .............................................................................. 34
   Conodont Fauna ................................................................................................ 35
   Conodont Succession ......................................................................................... 44
   Discussion ........................................................................................................... 67
   Biostratigraphy by Nontraditional Methods ................................................... 69

III. PALEOENVIRONMENTAL INTERPRETATION ................................................. 102

IV. SUMMARY AND CONCLUSIONS ...................................................................... 112
V. SYSTEMATIC PALEONTOLOGY..............................115
LIST OF REFERENCES............................................169

APPENDICES

A. Description of Sections.................................186
B. Conodont Distribution and Frequency...............203
C. Ranges of species in the lower and upper
sections.......................................................210
D. Ranges of species in Tennessee Composite
section in terms of Cincinnati Composite
Section.........................................................213
E. Percentages of Phragmodus, Plectodina,
Aphelognathus + Oulodus, and Rhipidognathus in
Sections for Relative-abundance analysis........215
F. Conodont Plates...........................................218
   Plate I......................................................219
   Plate II.....................................................221
   Plate III...................................................223
   Plate IV....................................................226
   Plate V......................................................229
### LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lithostratigraphic Classification Scheme in the Central Basin, Tennessee</td>
<td>14</td>
</tr>
<tr>
<td>2. Conodont Species Represented in studied sections of central Tennessee</td>
<td>36</td>
</tr>
<tr>
<td>3. Conodont Bioprovince of Central Tennessee</td>
<td>39</td>
</tr>
<tr>
<td>4. Correlation of the Central Tennessee Sections with Middle and Late Ordovician Chronostratigraphic Units</td>
<td>97</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Outline Map of Tennessee Showing Major Physiographic Provinces</td>
<td>2</td>
</tr>
<tr>
<td>2. Index Map of Tennessee Showing Locations of Measured Sections</td>
<td>6</td>
</tr>
<tr>
<td>3. Coverage of Formations by Measured Sections</td>
<td>8</td>
</tr>
<tr>
<td>4. Lithologies of Western Sections</td>
<td>18</td>
</tr>
<tr>
<td>5. Lithologies of Eastern Sections</td>
<td>22</td>
</tr>
<tr>
<td>6. Local Ranges of Species in Western Sections</td>
<td>45</td>
</tr>
<tr>
<td>7. Local Ranges of Species in Eastern Sections</td>
<td>49</td>
</tr>
<tr>
<td>8. Correlation of sections of Central Tennessee by Relative-abundance Logs</td>
<td>75</td>
</tr>
<tr>
<td>9. Graphic Correlation of Lower Sections with Tennessee Composite Section</td>
<td>79</td>
</tr>
<tr>
<td>10. Ranges of conodont species in Tennessee Composite Section</td>
<td>82</td>
</tr>
<tr>
<td>11. Graphic Correlation of Upper Sections with Tennessee Composite Section</td>
<td>87</td>
</tr>
<tr>
<td>12. Relative-abundance Logs of Four Districts of the Cincinnati Region and Correlation of Tennessee Composite Section with the</td>
<td></td>
</tr>
</tbody>
</table>
Southeastern Cincinnati Region..................89

13. Graphic Correlation of Tennessee Composite Section with the Southeastern Cincinnati Region..............................91
INTRODUCTION

A Middle and Upper Ordovician carbonate sequence is widely exposed in central Tennessee. The sequence comprises the Hermitage, Bigby-Cannon, Catheys, and Leipers formations. The Ordovician rocks are exposed physiographically in the Central Basin, which is positioned in the geographic center of the state and is a nearly elliptical area enclosed by the eastern and western Highland Rims (Fig. 1). The basin was formed by erosion of the Nashville Dome.

Up to the present, most stratigraphic studies of the Middle and Upper Ordovician sequence in central Tennessee have dealt mainly with rocks (Bassler, 1932; Wilson, 1949, 1962). Although some paleontological studies listed numerous megafossils from the Ordovician formations, studies of the megafossils failed to determine the age of the Middle and Upper Ordovician formations with precision because the species represented are poorly preserved and have long ranges. However, a preliminary conodont study by Sweet and Bergström (1976) indicated that conodonts might be very useful in establishing a biostratigraphy for the Middle and Upper Ordovician strata of central Tennessee.
Figure 1.—Outline map of Tennessee showing major physiographic provinces (after Miller, 1974).
Figure 1
The purpose of this study is to establish a conodont-based biostratigraphy for a portion of the Middle and Upper Ordovician sequence of central Tennessee through correlation with sections in the Cincinnati Region (Sweet, 1979a, 1984), which include the reference standard for the North American Ordovician. In addition, conodont faunas of the Middle and Upper Ordovician rocks of central Tennessee are described systematically for the first time.
MATERIALS AND METHODS

Altogether, 174 samples were collected at 13 sections from a portion of the Middle and Upper Ordovician rocks in central Tennessee, in an interval between the Upper Hermitage Formation and the Leipers Formation. Among these samples, 58 were collected and processed by Drs. Sweet and Bergström at two localities. Figure 2 shows the localities of measured sections. Sections are grouped geographically into two areas: western and eastern sections, located on the western and eastern sides of the Central Basin, Tennessee, respectively. The western group includes sections from Davidson and Williamson counties; the eastern group includes sections from Macon, eastern Wilson, Smith, DeKalb, and Cannon counties. The subdivision was made to determine if there are differences in conodont faunas between the two areas, because previous lithologic studies have shown there to be differences in lithology between two areas.

None of sections studied includes all of the Middle and Upper Ordovician formations considered in this study (Fig. 3); however, the scattered short sections were compiled by graphic correlation and relative-abundance
Figure 2.—Index map of Tennessee showing locations of measured sections.
Figure 3.—Coverage of formations by measured sections (not scaled).
analysis.

Samples were collected at 3-to 5-foot intervals from each exposure. Weight of samples ranged from 4 to 5 kg. One kg of each crushed sample was placed in a bucket, to which were added 6 liters of water and 750 ml of glacial acetic acid. The acid was changed as many times as necessary to dissolve the sample completely. Three acid changes were enough to dissolve calcium carbonate material completely. Disaggregated samples were washed through 20- and 100-mesh sieves. Residue remaining on the sieves was collected and dried. Ferruginous material in residue was removed by magnetic separation.

All conodont specimens were picked from the residue and placed in microfossil slides. All sorted specimens are stored in the Micropaleontological Laboratories at The Ohio State University. Figured specimens have been deposited in the Orton Geological Museum at The Ohio State University.
CHAPTER I
LITHOSTRATIGRAPHY

Previous Studies

The Ordovician System in central Tennessee was first classified by Safford in 1851. In his classification, the central Tennessee Ordovician System was divided into two groups: the Stones River Group and the Nashville Group. The Nashville Group included, in ascending order, Siliceous or sandy limestone, Lower Nashville beds and Upper Nashville beds.

The Siliceous or sandy limestone was characterized by the abundance in it of *Orthis testudinaria*. The Lower and Upper Nashville beds were described as thick-bedded blue limestone interbedded with shale.

In 1869, Safford revised his original classification and proposed a new one for the Nashville Group. The lowest unit was named the *Orthis* Bed because it contains abundant *Orthis*. The next higher units were named the Middle Member and Upper Member. Safford further subdivided the Middle and Upper members of the Nashville Group into several beds according to detailed lithology and fossil content. The
Middle Member included the Capitol Limestone, the Dove Limestone, the Bed of Limestone and the Cyrtodonta Bed. The Upper Member included the College Hill Limestone.

Although Safford’s study might have provided a general stratigraphic framework for subsequent studies, most of his work was restricted to the city of Nashville. Therefore, the sedimentary pattern could not be recognized throughout the Central Basin. Also, his Upper Nashville Group has been considered to belong to the Maysville and Richmond Groups by Wilson (1949) because Wilson included all units of Maysvillian and Richmondian age in the Maysville and Richmond Group, respectively.

In 1892, Jones included the Carters Creek Limestone, Ward Limestone (= Safford’s "Bed of Limestone"), Cyrtodonta Bed and the newly recognized Sponge Bed in the Trenton Group, and assigned the College Hill Limestone to the Hudson River Group. His Trenton Group was different from Safford’s (1869) Trenton Group. In Safford’s classification, the Carter Creek Limestone was the top unit of the Trenton Group, whereas in Jones's classification, the Trenton Group included the Carters Creek Limestone and younger units.

In 1903, Hayes and Ulrich named the Hermitage, Bigby, Catheys and Leipers formations, and these names are the ones now used. The name Hermitage Formation was proposed for Safford’s Orthis Bed; the name Bigby Formation was
applied to the Capitol through Sponge beds; and the term Catheys Formation was proposed for Safford's College Hill Limestone. The Leipers Limestone was included in the Nashville Group. Ulrich in 1911 recognized the Cannon Limestone as an additional part of the Trenton Group in Cannon County. The Cannon was thought to represent the same stratigraphic interval as the Bigby and Catheys formations, but on the east flank of the Nashville Dome.

In 1932, Bassler thoroughly reviewed previous stratigraphic work and completed the stratigraphic succession of the Nashville, Tennessee. After correlating sections across the Nashville Dome, Bassler concluded that the Bigby Limestone in the western part of the Central Basin was equivalent to the Cannon Limestone in the eastern part of the Central Basin. He classified the Leipers Formation as a Maysvillian unit.

In 1949, Wilson provided definitions and descriptions of the Ordovician formations and the members into which they are subdivided in central Tennessee. He traced contacts between the formations or members and recognized lateral continuities and changes in thickness of the formations and members. He grouped the Hermitage Formation, Bigby-Cannon Limestone, and Catheys Formation into the Nashville Group; recognized the Inman Formation as an Edenian unit; and kept the Leipers Formation in the Maysville Group (Table 1).
Table 1.—Lithostratigraphic classification scheme in the Central Basin, Tennessee (modified from Wilson, 1949).
<table>
<thead>
<tr>
<th>Safford</th>
<th>Safford</th>
<th>Hayes, Ulrich</th>
<th>Ulrich</th>
<th>Bassler</th>
<th>Wilson</th>
<th>Present Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1851</td>
<td>1869</td>
<td>1903</td>
<td>1911</td>
<td>1932</td>
<td>1949, 1962</td>
<td>1988</td>
</tr>
<tr>
<td>Upper</td>
<td>Upper Nashville Group</td>
<td>Leipers</td>
<td>Leipers</td>
<td>Leipers</td>
<td>M. Leipers</td>
<td>Upper Catheys-Leipers</td>
</tr>
<tr>
<td>Nashville Beds</td>
<td>College Hill</td>
<td>not recognized</td>
<td>not recognized</td>
<td>E. Inman</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>Cyrtodonta bed</td>
<td>U. Catheys</td>
<td>Catheys</td>
<td>Catheys</td>
<td>Catheys</td>
<td>Lower Catheys-Leipers</td>
</tr>
<tr>
<td></td>
<td>Beds of Ls.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dove Ls.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capitol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siliceous or Sandy Ls</td>
<td>Orthis bed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Safford
- Ulrich
- Bassler
- Wilson
- Present Study

- Leipers
- M. Leipers
- E. Inman
- U. Catheys
- Catheys
- M. Catheys
- L. Catheys
- Catheys
- Bigby
- Cannon
- Hermitage
Description of Stratigraphic Units

Hermitage Formation.--The Hermitage Formation is the lowest unit of the Nashville Group in the Central Basin. This formation was named by Hayes and Ulrich in 1903, for exposures in the vicinity of Hermitage Station in the city of Nashville. The unit had previously been termed the "Orthis Bed" (Safford, 1869). Wilson (1949) subdivided the 60- to 70-foot thickness of the formation into 7 units (members). Later, in 1962, he regrouped them into 5.

In this study, only the upper Hermitage Formation was considered and the upper unit represents Wilson’s Dalmanella Coquina Member in most western sections (Fig. 4) and the Laminated Argillaceous Member in the one eastern section, 85KC (Fig. 5).

According to Wilson’s subdivision of the Hermitage Formation, the lowest member is the Curdsville Limestone Member, which was named and described in north-central Kentucky by Miller (1905). The member consists of thin beds of blue to gray limestone interbedded with partings of gray shale. This member overlies different parts of the upper Carters Formation, which indicates an unconformable contact. The Curdsville is overlain by the Laminated Argillaceous Member.

The Laminated Argillaceous Member has been considered a major unit of the Hermitage Formation and includes
Wilson's (1949) **Ctenodonta** and Blue Clay-Shale members. This member consists of thin-bedded, laminated, argillaceous limestone, interbedded with shale. It contains deformed boulder beds (Wilson, 1962). This member thickens toward the west from the Central Basin, and it represents the entire upper Middle and Upper Ordovician sequence in the western Highland Rim (Wilson, 1962). In section 85KC, the lower 8 feet represent this member. Rocks are light to medium gray, very fine-grained silty wackestone, interbedded with thin dark gray shale. Benthic fossils were not found.

Above the Laminated Argillaceous Member is the **Dalmanella** Coquina Member, which is the typical lithic type of the Hermitage Formation along with the underlying Laminated Argillaceous Member. This member comprises the top unit of the formation in the western area and is restricted to the western side of the Central Basin. The name of this member refers to the fact that shells of the brachiopod **Dalmanella fertilis** are abundant in it. The small brachiopods are not fragmented in spite of their fragile shells. Total thickness was measured up to 30 feet. Limestone of the member is massively bedded and gray in color, and contains disseminated silt. In section 86KP, ripple marks were found on a bedding surface, which indicates that wave energy was available to form the structure but was not strong enough to break shells of
Figure 4.—Lithologies of western sections: 61A, 61B, 86KP, 85KH, 85KA, 85KF, and 85KB.
<table>
<thead>
<tr>
<th>HERMITAGE</th>
<th>BIGBY-CANNON</th>
<th>L. CATHEYS-LEIPERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dalmanella</td>
<td>Bigby D. Bigby Facies</td>
<td>Nodular Member</td>
</tr>
</tbody>
</table>

**Figure 61A**

**Figure 61B**

**Figure 4**
### HERM. - BIGBY-CANNON

<table>
<thead>
<tr>
<th>Dalmanella</th>
<th>Big. Dove Facies</th>
<th>Bigby</th>
</tr>
</thead>
</table>

![Diagram](chart1.png)

### HERMITAGE - BIGBY-CANNON

<table>
<thead>
<tr>
<th>Dalmanella Coquina</th>
<th>Big. Dove</th>
<th>Bigby Facies</th>
</tr>
</thead>
</table>

![Diagram](chart2.png)

### HERMITAGE - BIGBY-CANNON - L.C.L.

<table>
<thead>
<tr>
<th>Dalmanella</th>
<th>Dove Facies</th>
<th>Bigby Facies</th>
<th>Nodul.</th>
</tr>
</thead>
</table>

![Diagram](chart3.png)
### U. CATH.-LEIP.  
| Nodular Member | U.C.L. | Nod. |

Figure 4 (cont'd)

Legend:
- Laminated Wackestone
- Nodularly bedded Wackestone
- Fine-grained Packstone
- Lime mudstone
- Glauconite
- Bioturbated Contra
- Massive-bedded Packstone
Figure 5.—Lithology of western sections: 85KC, 85KD, 85KS, 85KW, 85KT, and 85KL (rock symbols are same as in Fig. 4).
Figure 5

HERM.
AgIII. M.

BIGBY-CANNON
Cannon Facies

BIGBY-CANNON
Cannon Facies

BIGBY-CANNON
Dove Cannon Facies

85KC

85KD

85KS
Figure 5 (cont'd)

UPPER CATHEYS-LEIPERS
Nodular Member

UPPER CATHEYS-LEIPERS
Dove M. Nodular Member

UPPER CATHEYS-LEIPERS
Dove M. Nodular Member
brachiopods.

Wilson’s (1949, 1962) other two members are the Granular Phosphatic and Silty Nodular members, however those were not recognized in my field study. In his description, the Granular Phosphatic Member is a lentil composed of very coarse-grained gray limestone that is extensively cross-bedded and contains a great abundance of ground-up fossil fragments, many of which have been phosphatized. This member grades into the Dalmanella Coquina Member in the west and into the Silty Nodular Limestone Member to the east. The Silty Nodular Limestone Member consists of gray nodular limestone and is in many places interbedded with silt and shale. The most common fossil is Tetradium minus. This member thickens toward the east side of the Central Basin and intertongues with the Dalmanella Coquina Member and Laminated Argillaceous Limestone Member to the west. Wilson’s description of the Silty Nodular Limestone Member indicates that it is closely similar in lithology to the Catheys-Leipers Formation.

Bigby-Cannon Limestone.—The Bigby-Cannon Limestone overlies the Hermitage Formation conformably in the sections studied. The name "Bigby", derived from Big Bigby Creek in Maury County by Hayes and Ulrich (1903), was named Capitol Limestone by Safford in 1869. The name Cannon Limestone was first published by Ulrich in 1911 without
definition, but in 1932 Bassler suggested the section along
the Cannon-Rutherford County line as a type section. Wilson
(1949) believed that the Bigby and Cannon are
contemporaneous, and he considered them as different facies
of the same formation, the Bigby-Cannon, within which he
recognized a third facies, the Dove-colored facies.

The Bigby facies consists of coarse-grained,
extensively crossed-bedded, blue-gray grainstone. The
limestone is composed of fragments of the shells of diverse
benthic marine animals, and also contains many phosphatized
shell fragments, which are brown in color. Wilson's (1962)
isopach map shows that the facies thickens greatly to the
west side of the Central Basin. In most of the western
localities studied, the lower and upper parts of sections
are occupied by this facies, but it is not represented in
the eastern sections. Wilson (1949, 1962) reported that the
Bigby facies overlies the Silty Nodular Limestone Member of
the Hermitage Formation in the middle of, and on the
eastern side of the Central Basin.

The Dove-colored facies of the Bigby-Cannon Limestone
is composed of fine-grained, dense, brittle lime mudstone,
and mudcracks are present. The limestone breaks with a
conchoidal fracture. Fossils are rare, only ostracodes and
gastropods were observed. The name was derived from the
light gray and dove color of the rock. The most
characteristic features of the facies are vertical
stringers of calcite termed "birdseyes". The birdseyes were formed by the filling of voids that were previously bored by the worm, *Scolithus columbiana* (Bassler, 1932). This facies occurs in western sections as lentils that intertongue with the Bigby facies (Fig. 4), but it is not represented in the eastern sections (Fig. 5). This facies thins and ultimately disappears westward and eastward from the middle of the Central Basin (Wilson, 1962).

The Cannon facies, which is an eastern equivalent of the Bigby and Dove-colored facies, consists of fine-grained, uniformly bedded, dark gray wackestone and packstone. This facies is represented mostly in the eastern sections, 85KC, 85KD, where it makes up the entire Bigby-Cannon Limestone (Fig. 5). In the western area, on the other hand, the facies represents only the upper 5 feet of section 85KA (Fig. 4). Wilson (1949, 1962) showed that the facies thickens toward the east of the Central Basin.

Catheys-Leipers Formation.—The stratigraphic interval between the Bigby-Cannon Limestone and the Richmondian strata in the Central Basin has previously been divided into two formations: the Catheys Formation and the Leipers Formation (Bassler, 1932; Wilson, 1949, 1962), although Wilson (1949) described the Inman Formation of Edenian age from southernmost central Tennessee. Wilson (1949) included the Catheys Formation in the Nashville Group and the
Leipers Formation in the Maysville Group.

According to Wilson's (1949, 1962) description of the two formations, the Catheys and Leipers are lithologically closely similar in that rocks of both formations are fine- to coarse-grained, argillaceous, fossiliferous, thin- bedded, nodularly bedded limestone interbedded with shale. Members of the two formations, which were subdivided by Wilson (1949, 1962), are also identical. That is, Wilson (1962) recognized three facies within the Catheys Formation: the Granular facies on the western side of the Central Basin, the Dove-Colored facies in the middle of the Basin, and on the eastern side of the Basin the Normal Eastern facies, which Wilson had termed the Shaly, Laminated Siltstone, and Nodular facies in 1949. Wilson (1949, 1962) described three similar facies from the Leipers Formation. Those are the Argillaceous facies, the Granular facies, and the Pale-Colored facies. The Argillaceous, Granular, and Pale-Colored facies of the Leipers are similar to the Nodular or the Normal Eastern, Granular, and Dove-Colored facies of the Catheys in both lithology and distributional pattern.

Despite their lithologic similarity, Wilson (1949, 1962) differentiated the two formations on the basis of species of brachiopods. That is, the Catheys and the Leipers were differentiated by the presence of Platystrophia precursor in the Catheys and P. sublaticosta
in the Leipers.

Wilson's subdivision of rock units into formations in the above case was on the basis of fossils. According to the North American Commission on Stratigraphic Nomenclature (1983), however, a formation is defined as a body of rock identified by lithic characteristics. Therefore, Wilson's classification of the Catheys and Leipers does not meet the rule of stratigraphic nomenclature.

Another variance from rules of the North American Commission on Stratigraphic Nomenclature (1983) is Wilson's misuse of the name Maysville Group. He included the Leipers in the Maysville Group because the age of the Leipers had been determined to be Maysvillian. Therefore the Maysville Group implies a body of rock that was deposited during the middle Late Ordovician, or Maysvillian. However, the term "group" simply refers to a body of rock and the name for group does not necessarily contain any term that indicates time. Therefore, if the Maysville Group refers simply to a body of rocks, the name "Maysville" should be avoided.

Based on the discrepancy in stratigraphic nomenclature just described, Wilson's Catheys and Leipers formations are combined in this study and tentatively termed the "Catheys-Leipers Formation." The Catheys-Leipers is divided into lower and upper parts on the basis of the stratigraphic position of their units. The lower unit, which is tentatively termed "lower Catheys-Leipers", refers to
strata that conformably overlie the Bigby-Cannon, whereas
the designation "upper Catheys-Leipers" refers to the
Leipers and upper Catheys formations in Wilson's (1949)
sections, which are overlain by either the Fernvale
Limestone or the Chatanooga Shale and are not underlain by
the Bigby-Cannon Limestone. At none of sections studied,
are the lower and upper Catheys-Leipers continuously
represented. Therefore, a boundary between two units could
not be drawn.

The lower Catheys-Leipers is represented only in the
western sections, 86KP and 61A (Fig. 4). This formation is
easily distinguished from the underlying Bigby-Cannon
Limestone by an abrupt increase of silt and clay. Rocks of
the lower Catheys-Leipers are highly fossiliferous, knotty,
fine- to coarse-grained wackestone and packstone with shale
partings, which are thin-bedded and nodular.

The upper Catheys-Leipers is lithologically identical
to the lower Catheys-Leipers. However, medium gray to dark
gray lime mudstone, which is the lithic type of Wilson's
Dove-Colored or Pale-colored facies, is represented in the
eastern sections, 85KW and 85KT (Fig. 5).

Although Wilson described three major facies in the
Catheys and Leipers formations, which are similar in
lithology and distributional pattern to those of the Bigby-
Cannon, except for the Dove-Colored facies the facies are
far less distinct in their distribution in my field area
than are those of the Bigby-Cannon. That is, Wilson's Granular and Normal Eastern or Nodular facies are represented together in both western and eastern sections without discernible difference.
CHAPTER II

BIOSTRATIGRAPHY

Previous Studies.—Paleontological studies of Middle and Upper Ordovician strata in the Central Basin in Tennessee have dealt mainly with megafossils.

Bassler (1932) provided lists of benthic invertebrates from the exposed Middle to Upper Ordovician rocks in central Tennessee. The fauna included sponges, corals, bryozoans, stromatoporoids, brachiopods, gastropods, cephalopods, trilobites, and ostracodes.

In 1949, Wilson reported on fossils represented in the newly subdivided members of formations. According to his study, Orthis testudinaria (now -Dalmanella fertilis) is the most common fossil in the lower Hermitage Formation, which was originally named the "Orthis Bed" by Safford in 1869. No benthic fossils were reported from the Laminated Argillaceous Member and Ctenodonta hermitagensis is the most commonly represented species in the Ctenodonta Member. The coral (?) Tetradium minus is the most common fossil in the Silty Nodular Limestone Member.

The Bigby facies of the Bigby-Cannon Limestone is dominated by the branching bryozoans Prasopora,
Homotrypella, Homotrypa, Peronopora, Cyphotrypa, Dekayella, Heterotrypa, Eridotrypa, and Hallopora. The Dove-colored facies of the formation is characterized by presence of the ostracodes Leperditia and Isochilina; the high-spired gastropod, Hormotoma; the sponge, Saccospongia; and the bryozoan, Hallopora dumalis. The Cannon facies contains a fauna that is less specialized than that of the Bigby and Dove-colored facies and includes brachiopods, gastropods, and pelecypods.

Many fossils are found in the Shaly and Nodular facies of the Catheys Formation. Other facies of the Catheys have few well-preserved fossils. The bryozoans Constellaria emaciata and C. teres are typical organisms in the Shaly facies.

The brachiopod Platystrophia sublaticosta with seven lateral plications has been regarded as the most reliable guide fossil for distinguishing the Leipers Formation from the Catheys Formation (Wilson, 1949). P. ponderosa, which occurs in the upper part of the Leipers, has been considered to be the key species in distinguishing the Leipers Formation from overlying formations (Wilson, 1949).

Although Bassler's and Wilson's reports include long lists of fossils from each formation, those fossils do not provide the basis for determining precise ages for the formations. Based on lithology and fossils, Bassler and Wilson included the Hermitage, Bigby-Cannon, and Catheys in
the Nashville Group, which was equated with the Trenton. The Leipers Formation was included in the Maysvillian Stage. Also, although the fossils listed may be useful for local correlation, they are not good enough to correlate Middle to Upper Ordovician strata of the Central Basin with rocks outside of central Tennessee.

As is common with the use of benthic megafossils in biostratigraphic studies, many are confined to limited members of each formation. That is, few or no fossils have been reported from the Laminated Argillaceous Limestone, Pale-colored, or Dove-colored Lime Mudstone facies. In the Granular facies, most fossils are broken, so it is almost impossible to identify them.

Previous conodont studies.—Up to the present, no detailed studies of conodonts have been achieved from Middle and Upper Ordovician rocks of the Central Basin, Tennessee. Bergström and Sweet's (1966) paper, in which they described *Rhipidognathus discretus* Bergström and Sweet from the Catheys Formation, is the first one to mention conodonts from the area. In 1976, based on undescribed collections Sweet and Bergström suggested that the Hermitage belongs in the interval of Fauna 9; the Bigby-Cannon in that of Faunas 9-10; the Catheys in the interval of Fauna 10; and the Leipers in that of Fauna 11. They did not determine the age of the Arnheim and Fernvale because
they had no conodonts from the former and no diagnostic specimens from the latter.

Conodonts have been described from the strata in central Tennessee beneath the Nashville Group. Votaw (1971) described conodonts from the Stones River Group, which includes the Murfreesboro, Pierce, Ridley, Lebanon, and Carters formations. He suggested that the top of the Carters Limestone, the youngest formation of the Stones River Group, was the top of the *Phragmodus inflexus* "Zone," which might be equivalent to the upper part of the interval of Sweet et al.'s (1971) Fauna 7. He placed the top of the *P. inflexus* "Zone" at the level of first occurrence of *P. undatus*, which had been collected by Drs. W. C. Sweet and S. M. Bergström from the base of the Hermitage Formation. Votaw's study thus indicated that the Hermitage is no older than the base of Sweet's (1984) *P. undatus* Zone.

Conodont Fauna

Conodonts are abundantly represented at virtually every level in all the sections studied. A total of 31,633 identifiable conodont elements has been recovered from the 174 samples processed, which were derived from the upper Hermitage, the Bigby-Cannon, Catheys-Leipers, and lowermost Fernvale formations. The conodont elements are referable to 32 species of 16 genera (Table 2).
Table 2.—Conodont species represented in studied sections of central Tennessee.
## Table 2

<table>
<thead>
<tr>
<th>Species</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Amorphognathus sp.</td>
<td>77</td>
<td>0.24</td>
</tr>
<tr>
<td>2. Aphelognathus floweri?</td>
<td>52</td>
<td>0.16</td>
</tr>
<tr>
<td>3. Aphelognathus grandis</td>
<td>53</td>
<td>0.17</td>
</tr>
<tr>
<td>4. A. sp. aff. A. kimmischwickei</td>
<td>469</td>
<td>1.48</td>
</tr>
<tr>
<td>5. Aphelognathus politus</td>
<td>2414</td>
<td>7.63</td>
</tr>
<tr>
<td>6. Aphelognathus rhodesi</td>
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</tr>
<tr>
<td>7. Aphelognathus n. sp. A</td>
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</tr>
<tr>
<td>8. Aphelognathus n. sp. B</td>
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</tr>
<tr>
<td>9. Aphelognathus sp.</td>
<td>533</td>
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</tr>
<tr>
<td>10. Bryantodina staufferi</td>
<td>29</td>
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</tr>
<tr>
<td>11. Drepanoistodus suberectus</td>
<td>1055</td>
<td>3.34</td>
</tr>
<tr>
<td>12. Fibrous conodonts</td>
<td>199</td>
<td>0.63</td>
</tr>
<tr>
<td>13. Icriodella superba</td>
<td>549</td>
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</tr>
<tr>
<td>14. Oulodus oregonia</td>
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</tr>
<tr>
<td>15. Oulodus robustus</td>
<td>247</td>
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</tr>
<tr>
<td>16. Oulodus robustus?</td>
<td>9</td>
<td>0.03</td>
</tr>
<tr>
<td>17. Oulodus ulrichi</td>
<td>14</td>
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</tr>
<tr>
<td>18. Oulodus velicuspis</td>
<td>192</td>
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<tr>
<td>19. O. sp. aff. O. velicuspis</td>
<td>686</td>
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</tr>
<tr>
<td>20. Oulodus sp.</td>
<td>246</td>
<td>0.78</td>
</tr>
<tr>
<td>21. Panderodus feulneri</td>
<td>2915</td>
<td>9.22</td>
</tr>
<tr>
<td>22. Panderodus gracilis</td>
<td>846</td>
<td>2.67</td>
</tr>
<tr>
<td>23. Periodon grandis</td>
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<td>0.03</td>
</tr>
<tr>
<td>24. Phragmodus undatus</td>
<td>6977</td>
<td>22.07</td>
</tr>
<tr>
<td>25. Plectodina sp. aff. P. aculeata</td>
<td>4</td>
<td>0.01</td>
</tr>
<tr>
<td>26. Plectodina tenuis</td>
<td>9462</td>
<td>29.91</td>
</tr>
<tr>
<td>27. Pseudobelodina inclinata</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>28. P. vulgaris vulgaris</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>29. Rhipidognathus symmetricus</td>
<td>917</td>
<td>2.89</td>
</tr>
<tr>
<td>30. Rhodesognathus elegans</td>
<td>32</td>
<td>0.09</td>
</tr>
<tr>
<td>31. Walliserodus sp.</td>
<td>9</td>
<td>0.03</td>
</tr>
<tr>
<td>32. Yaoxianognathus abruptus</td>
<td>19</td>
<td>0.06</td>
</tr>
</tbody>
</table>
More than 72 percent of the conodonts recovered from Ordovician rocks in the Nashville Basin are characteristic of the fauna of the Ohio Valley Province in the warm-water realm (Sweet and Bergström, 1984) (Table 3).

Since 1959 when Sweet and others recognized two biogeographic realms based on conodonts in the Late Ordovician, two major provinces, the North American Midcontinent Province and the North Atlantic Province, exhibited by Ordovician conodont faunas have been delineated and discussed by Bergström and Sweet (1966), Bergström (1971, 1973), Barnes et al. (1973), Sweet and Bergström (1974, 1976), and Jaanusson and Bergström (1980), among others.

Water temperature, warm- and cold-water, has been regarded as a principal factor responsible for distribution of Ordovician conodonts (Sweet et al., 1959; Bergström, 1973; and Sweet and Bergström, 1974). Because the warm- and cold-water pelagic conodont faunas of the Ordovician are known best from the North American Midcontinent and from the North Atlantic Basin, respectively, the Ordovician conodont realms have been loosely termed the North American Midcontinent Province for the warm-water realm and the North Atlantic Province for the cold-water realm (Bergström, 1973; Sweet and Bergström, 1974).

Sweet and Bergström (1984) grouped early Late Ordovician conodonts into assemblages of species on the
Table 3.—Conodont bioprovince of central Tennessee (data of three columns from left are from Sweet and Bergström, 1984).
<table>
<thead>
<tr>
<th>Red River Province</th>
<th>Cincinnati Region</th>
<th>West Virginia</th>
<th>Central Tennessee</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amorphognathus sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walliserodus curvatus</td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Panderodus bergstroemi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. breviusculus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudobelodina quadra</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plegagnathus nelsoni</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belodina arca</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staufferella brevispinata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphelognathus shoshonensis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plectodina aculeatoides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudobelodina torta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plectodina florida</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Culumbodina pennia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudobelodina kirk</td>
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<td></td>
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</tr>
<tr>
<td>Culumbodina accidentalis</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pseudobelodina obtusa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oulodus ulrichi</td>
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<td></td>
<td>0.04</td>
</tr>
<tr>
<td>Panderodus feulneri</td>
<td></td>
<td></td>
<td>9.22</td>
</tr>
<tr>
<td>Pseudobelodina dispansa</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pseudobelodina vulgaris</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Aphelognathus floweri</td>
<td></td>
<td></td>
<td>0.16</td>
</tr>
<tr>
<td>Staufferella lindstroemi</td>
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<td></td>
</tr>
</tbody>
</table>

**Cosmopolitites**

<table>
<thead>
<tr>
<th>(Warm-water)</th>
<th>Cincinnati Region</th>
<th>West Virginia</th>
<th>Central Tennessee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belodina confluens</td>
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<td>3.34</td>
</tr>
<tr>
<td>Drepanoistodus suberectus</td>
<td>6.0</td>
<td>7.0</td>
<td>29.91</td>
</tr>
<tr>
<td>Panderodus panderi</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plectodina tenuis</td>
<td>32.0</td>
<td>24.0</td>
<td>22.07</td>
</tr>
<tr>
<td>Phragmodus undatus</td>
<td>44.0</td>
<td>44.0</td>
<td>0.03</td>
</tr>
<tr>
<td>Periodon grandis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudobelodina inclinata</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Cold-water)</th>
<th>Cincinnati Region</th>
<th>West Virginia</th>
<th>Central Tennessee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amorphognathus superbus</td>
<td>3.0</td>
<td></td>
<td>1.74</td>
</tr>
<tr>
<td>Icriodella superba</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panderodus gracilis</td>
<td>2.0</td>
<td>0.2</td>
<td>0.01</td>
</tr>
<tr>
<td>Dapsilodus mutatus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coelocerodontus sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhodesognathus elegans</td>
<td>0.1</td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>Amorphognathus ordovicicus</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protopanderodus liripipus</td>
<td>0.1</td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ohio Valley Province</th>
<th>Cincinnati Region</th>
<th>West Virginia</th>
<th>Central Tennessee</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphelognathus politus</td>
<td>2.0</td>
<td>11.0</td>
<td>7.63</td>
</tr>
<tr>
<td>Staufferella falcata</td>
<td>0.2</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Yaoxianognathus abruptus</td>
<td>0.1</td>
<td>0.1</td>
<td>0.06</td>
</tr>
<tr>
<td>Oulodus velicuapis</td>
<td>5.0</td>
<td>13.0</td>
<td>0.61</td>
</tr>
<tr>
<td>Oulodus oregonia</td>
<td>1.0</td>
<td></td>
<td>3.37</td>
</tr>
<tr>
<td>Rhipidognathus symmetricus</td>
<td>0.1</td>
<td></td>
<td>2.89</td>
</tr>
</tbody>
</table>
basis of the palaeogeographic positions of the sampling sites. One assemblage was cosmopolites; another includes conodonts that were confined in their distribution between the 15°N and 16°S paleolatitudes; and a third consists of the conodont species that were confined between 18°S and 23°S paleolatitudes. Sweet and Bergström (1984) coined the term Red River Province for the area between 15°N and 16°S paleolatitudes, and the term Ohio Valley Province for the region between 18°S and 23°S paleolatitudes.

Although Sweet and Bergström (1984) did not consider the entire Ordovician in their provincial analysis, their analysis serves to illustrate basic principles in Ordovician conodont biogeography.

According to the list of conodonts of each province provided by Sweet and Bergström (1984), the Nashville conodont fauna consists 60 percent of cosmopolites, 17 percent Ohio Valley Province species, 9 percent of species of the Red River Province, and 14 percent of species whose provincial affinity is not determinable because they are either newly described in this study or are older species whose ranges do not reach to the Velicuspis Zone (Table 3).

The Nashville fauna is similar to that of the Cincinnati Region and the part of the Martinsburg Formation in West Virginia that were included in the Ohio Valley Province (Sweet and Bergström, 1984). As in faunas of the Cincinnati Region and West Virginia, cosmopolites occupy
more than half of the total collections from the Central Basin, Tennessee and include all but *Staufferella falcata* of the endemic species listed in the Ohio Valley Province (Sweet and Bergström, 1984) (Table 3).

The Nashville fauna also includes several species typical of the Red River Province, such as *Oulodus ulrichi*, *Panderodus feulneri*, *Pseudobelodina vulgaris*, *Aphelognathus floweri?*, and *Walliserodus* sp. These species make up only 9 percent of the total collection, and they are only 5 out of 22 species known from the Red River Province (Sweet and Bergström, 1984) (Table 3).

Among the cosmopolites, cold-water stenothermal cosmopolites that have been regarded as characteristic of the North Atlantic Province are represented in the Nashville Basin by *Amorphognathus* sp., *Icriodella superba* Rhodes, *Rhodesognathus elegans* (Rhodes), and *Periodon grandis* (Ethington), but their contribution to the Ordovician conodont fauna of the Central Basin of Tennessee is minimal. The stenothermal cold-water species account for slightly more than 2 percent of the total fauna, and *I. superba* dominates (Table 3). Most of the specimens of *Amorphognathus*, the species of which have been regarded as zonal indicators and key species for correlation between the two traditional biogeographic realms, are broken and diagnostic elements were not recovered so it has not been possible to identify the species represented.
Therefore, although the Nashville fauna includes all of the species represented from the late Middle Ordovician to late Maysvillian in central Tennessee, the fauna belongs to the Ohio Valley Province.

Among the species represented in Middle and Upper Ordovician sections in the Central Basin, *Plectodina tenuis* (Branson and Mehl) is the most abundant. *P. tenuis* occupies almost 30 percent of the total fauna. The next most highly represented species is *Phragmodus undatus* Branson and Mehl, whose elements make up 22 percent (Table 2).

*Aphelognathus* is another major genus in the Central Basin. Representatives have been recovered of three previously described species and of four not previously reported species. *A. politus* (Hinde) and *A. grandis* Branson, Mehl, and Branson have been described from elsewhere in North America, but *A. rhodesi* (Lindström) has been reported previously only from Wales. *A. floweri*? Sweet, *A. sp. aff. A. kimmswickensis* Sweet, Thompson, and Satterfield, *A. new sp. A*, and *A. new sp. B* are newly described from the Nashville Basin. *Aphelognathus* makes up 19 percent of the total collection (Table 2).

Representatives of *Oulodus* make up 7.79 percent of the total collection. Species are referable to *O. oregonia*, *O. robustus*, *O. ulrichi*, *O. velicuspis*, and *O. sp. aff. O. velicuspis*. Except for *O. oregonia*, these are the most reliable species for biostratigraphic study of the Upper
Ordovician strata in the Central Basin because their stratigraphic ranges are relatively short. O. sp. aff. O. velicuspis is newly described.

**Drepanoistodus suberectus** (Branson and Mehl) and **Rhipidognathus symmetricus** Branson, Mehl, and Branson constitute 3.34 percent and 2.89 percent of the total collection, respectively and representatives of other genera, such as **Bryantodina**, **Pseudobelodina**, **Rhodesognathus**, **Walliserodus**, and **Yaoxianognathus** make up less than 1 percent of the total collection (Table 2).

**Conodont Succession**

Following is a description of the conodonts represented in the upper Hermitage through the lowermost Fernvale formations and a summary of their occurrences outside central Tennessee.

**Upper Hermitage Formation.**—The upper Hermitage Formation was sampled at localities 61A, 86KP, 85KH, 85KA, and 85KC. As shown in Figures 4 and 5, sections 61A, 86KP, 85KH, and 85KA are on the western side of the Central Basin and 85KC is on the eastern side.

Figure 6 and Figure 7 show the ranges of conodont species in sections that include the Hermitage Formation. **Drepanoistodus suberectus**, **Plectodina tenuis**, **Phragmodus undatus**, **Panderodus gracilis**, **Icriodella superba**, and
Figure 6.—Local ranges of species in western sections: 61A, 61B, 85KA, 85KB, 86KP, 85KH, and 85KF. Numbers on bars refer to species listed in table 2. Scales on columnar sections are in feet.
Figure 6
Figure 6 (cont'd)
Figure 6 (cont'd)
Figure 7.—Local ranges of species in eastern sections: 85KW, 85KT, 85KD, 85KL, 85KS, and 85KC. Numbers on bars refer to species listed in table 2. Scales on columnar sections are in feet.
Figure 7
Figure 7 (cont'd)
**Periodon grandis** are represented at the base of most of the western sections. **Yaoxianognathus abruptus** (Branson and Mehl) (=**Bryantodina? abrupta**) and **Bryantodina? staufferi** are represented at the base of section 86KP and 85KH respectively. Pastinate elements, which I tentatively identify as **Plectodina sp. aff. P. aculeata** (Stauffer), occur only at the base of section 61A.

Fibrous conodonts, **Rhodesognathus elegans**, and **Aphelognathus n. sp. B** occur first in western sections in the middle of the Hermitage Formation.

**Aphelognathus sp. aff. A. kimmswickensis** and **Oulodus oregonia** make their debut in the Central Basin at the top of the Hermitage Formation, and are represented in section 61A.

One broken specimen of **Amorphognathus** was recovered 9 feet above the base of section 85KA. Despite the biostratigraphic usefulness of **Amorphognathus**, the specimen at hand could not be identified specifically due to the lack of other well-preserved diagnostic elements.

The conodont fauna of the eastern section, 85KC, is different from that of western sections. Species in the Hermitage Formation abundantly represented in western sections, such as **Plectodina tenuis** and **Phragmodus undatus**, do not occur in eastern sections, which yielded only 11 fibrous conodonts, one element of **Panderodus gracilis** and one specimen of **Drepanoistodus suberectus**. This difference
in faunas may be interpreted to represent a difference in environment. That is, the eastern area may not have had optimum conditions for many conodont species, possibly oxygen and nutrients were not sufficient. Lack of a well-developed benthic fauna supports such an interpretation. Also, the lithology is different in the two areas. In the western area, rocks are wackestone, Dalmanella coquina, and ripple-marked fine-grained grainstone, whereas rock in the eastern section is micrite interbedded with shale. Thus lithology and the fossil record indicate that conditions on the eastern side of the Central Basin were more restricted than they were on the western side.

Species represented in the upper Hermitage Formation have long ranges. They have been reported from Middle Ordovician rocks elsewhere in the North American Midcontinent and in Europe, and many range upward into the Upper Ordovician. Therefore it is difficult to determine the precise age of the Hermitage Formation by faunal comparison alone.

Drepanoistodus suberectus has been reported from Middle and Upper Ordovician rocks in Iowa and Minnesota (Glenister, 1957; Ethington, 1959; Webers, 1966; Sweet, 1987). It ranges from as low as the base of the Glenwood Shale, of late Black Riveran age, to the top of the Maquoketa Formation, of Richmondian age. In New York, Schopf (1966) reported D. suberectus from the upper
Chaumont, of Black Riveran age, to the Cobourg of Edenian age. Sweet (1983) reported the species from the Viola Springs and Welling formations of Kirkfieldian to early Maysvillian age in Oklahoma. In the Cincinnati Region, the species ranges from the Chazyan to the top of the Richmondian (Sweet, 1984), and Sweet (1979b) reported it from the Upper Ordovician rocks of the western Midcontinent Province.

Fibrous conodonts, which may be components of several multielement species, first appear in Sweet et al.'s (1971) Fauna 5, which is Chazyan in age. In the Cincinnati Region, the fibrous conodonts range from nearly the base of the \textit{P. aculeata} Zone to the early \textit{P. tenuis} Zone (Sweet, 1984).

\textit{Panderodus gracilis} is commonly represented in Middle and Upper Ordovician rocks in the Midcontinent Province (Glenister, 1957; Webers, 1966, Schopf, 1966; Bergström and Sweet, 1966; Sweet, 1979a; Sweet, 1983; Sweet, 1984). In the Cincinnati Region, \textit{P. gracilis} ranges from the early Black Riveran to the late Richmondian (Sweet, 1984).

\textit{Icriodella superba}, \textit{Periodon grandis}, and \textit{Phragmodus undatus} occur first in the interval of Fauna 8 of Sweet et al. (1971), whose base is slightly higher than the base of the Rocklandian Stage.

\textit{Icriodella superba} occurs continuously as high as the Arnheim Formation of Richmondian age (McClish, 1964). In the Cincinnati Region, it ranges from the base of the
Lexington Limestone into early Richmondian strata (Sweet, 1984).

Periodon grandis has been reported from as low as the base of the Rockland Formation (Schopf, 1966), and Kennedy, Barnes, and Uyeno (1979) reported it from the rocks of the Amorphognathus ordovicicus Zone. In the Cincinnati Region, it is represented from the base of the Lexington Limestone into rocks of mid-Edenian (Sweet, 1984).

Phragmodus undatus defines the base of Fauna 8 of Sweet et al. (1971). In the interval of Fauna 8, P. undatus occurs with P. cognitus Stauffer, Plectodina aculeata (Stauffer), and Bryantodina typicalis Stauffer (Sweet et al. 1971). In the Cincinnati Region, the species ranges from the upper part of the Tyrone Limestone of early Rocklandian age nearly to the top of the Richmondian Stage (Sweet, 1984).

Yaoxianognathus abruptus (Branson and Mehl) (=Bryantodina? abrupta Bergström and Sweet, 1966) ranges from the Middle Ordovician of the Lake Champlain district, New York (Roscoe, 1973). In the Cincinnati Region, it ranges from the Rocklandian to the top of the Edenian (Sweet, 1984).

Bryantodina? staufferi ranges from the base of the Lexington Limestone into lower Edenian strata in the Cincinnati Region (Sweet, 1984). Rust (1968) reported the species from the lower middle Martinsburg Formation.
**Plectodina tenuis** is the zonal indicator of the P. **tenuis** Zone of Sweet (1984) and Fauna 9 of Sweet et al. (1971). It is one of the most abundantly represented species in the eastern North American Midcontinent. In the Cincinnati Region, it occurs from the base of the Lexington Limestone of early Shermanian age into rocks of Richmondian age. The P. **tenuis** Zone is divided into lower and upper subzones. In the lower **Tenuis** Zone, P. **tenuis** occurs with P. **aculeata** (Stauffer). P. **aculeata** disappears at the base of the upper **Tenuis** Zone.

**Oulodus oregonia** has been used to distinguish Fauna 11 from Fauna 10 (Sweet, et al. 1971; Sweet and Bergström, 1976). Fauna 11 appears in the Cincinnati Region in rocks of mid-Edenian age. However, the skeletal concept of O. **oregonia** was emended by Sweet (1979a). That is, the O. **oregonia** that was used in 1971 to distinguish between Fauna 10 and Fauna 11 is O. **velicuspis** in updated taxonomy. O. **subundulatus** (Sweet and others, 1959) of Sweet and Schönlaub (1975) is the species herein named O. **oregonia**.

Of all the species of **Oulodus**, O. **oregonia** has the least diagnostic elements in its skeletal apparatus. Therefore it is difficult to evaluate previous reports of its occurrence. In the southeastern Cincinnati Region, the species ranges from rocks of late Shermanian age into strata of mid-Edenian age (Sweet, 1979a).

The skeletal apparatus of **Aphelognathus** n. sp. B,
which I describe in open nomenclature in this study, is different from that of any previously known species of Aphelognathus. The skeletal apparatus is like that of other species in the A. grandis stock (Sweet, 1983) in having irregular denticulation. The species is similar to A. gigas Sweet in many respects but the pastinate Pa element is more closely similar to that of A. kimmswickensis than that of A. gigas.

**Aphelognathus gigas**, which is known only from the Fite Formation of Kirkfieldian age in Oklahoma, is the oldest species of the A. grandis stock. A. kimmswickensis, on the other hand, is the oldest species of the A. politus stock (Sweet, 1983), in which denticles are aligned regularly. A. kimmswickensis appears in rocks as old as Kirkfieldian. The next younger species of the A. grandis stock appears in mid-Edenian rocks, so there is a major break in the evolutionary lineage of the A. grandis stock. The A. politus stock, however, is represented continuously from A. kimmswickensis through A. politus to A. rhodesi.

I interpret Aphelognathus n. sp. B as an intermediate between the grandis and politus stocks. It partially fills the gap in the A. grandis stock by way of convergent evolution from A. gigas and A. kimmswickensis.

Four pastinate elements of Plectodina are represented at the base of section 61A. The pastinate elements are similar to those of P. aculeata, which is confined in its
range to the Middle Ordovician. However, I am not sure if
the pastinate elements I tentatively describe as P. sp.
aff. P. aculeata belong to P. aculeata because of poor
preservation and lack of other diagnostic elements.

The assemblage of conodonts in the upper Hermitage
Formation indicates that the upper Hermitage Formation is
no older than late Shermanian in age, but it may be younger
since O. oregonia, Yaoxianognathus abruptus, and
Bryantodina? staufferi are represented elsewhere to as high
as middle or late Edenian.

The late Shermanian-Edenian interval has been
subdivided into zones (Sweet, 1984) or numbered faunas
(Sweet, et al, 1971) based on the first occurrence of
Belodina confluens Sweet and Amorphognathus superbus
(Rhodes). That is, the base of the B. confluens Zone
(Sweet, 1984), in mid-Shermanian strata, is defined by the
first occurrence of B. confluens whereas the interval of
Fauna 10 (Sweet et al. 1971) is defined by the first
occurrence of the North Atlantic conodont A. superbus,
which is slightly higher than the base of the B. confluens
Zone.

The top of the Superbus Zone is in the lower third of
the Maysvillian Stage, but the tops of the interval of
Fauna 10 and the Confluens Zone are in middle Edenian
rocks. The Confluens Zone is succeeded by the Velicuspis
Zone (Sweet, 1984).
The key species for defining either the Confluens Zone or the interval of Fauna 10 are not represented in the Middle and Upper Ordovician rocks of the Central Basin, however. Therefore it is not possible to apply the previously established zones or faunas correctly to the Hermitage Formation.

Bigby-Cannon Limestone.—The Bigby-Cannon Limestone was sampled in the same sections that contain Hermitage strata, and in two more. Those are 85KS and 85KD. 85KD is located on the eastern side, and 85KS is on the central-eastern side of the Central Basin (Fig. 2).

In the Bigby-Cannon Formation, long-ranging species represented from the Hermitage Formation occur continuously. *Periodon grandis* is the only species not found above the formation.


*Aphelognathus* sp. aff. *A. kimmswickensis* appears at the base of the Bigby-Cannon in section 61A; in the middle of the formation in sections 85KA and 85KP (Fig. 6); and at the top of the formation in section 85KH. The species is
not represented in the eastern sections (85KC, 85KS, 85KD).

Sweet (1981) discussed the relationship between Aphelognathus kimmswickensis and its descendant, A. politus. A. kimmswickensis gave rise to A. politus by closure of the outer process angle of the Pa element and by shortening of the anterior process of the M element. Therefore, the Pa element of the former is pastinate whereas that of the latter is angulate.

The specimens at hand share the morphologic characteristics of Aphelognathus kimmswickensis and A. politus. That is, the Pa element is pastinate, as in A. kimmswickensis, but the angle between the anterior and lateral processes is smaller than that of the Pa element typical of A. kimmswickensis. The M element is dolabrulate, lacks denticles on the anterior process, and thus resembles that of A. politus. Therefore, I interpret the species as intermediate in skeletal morphology between A. kimmswickensis and A. politus.

Aphelognathus kimmswickensis has been reported from rocks of Kirkfieldian and Shermanian age since the species was described by Sweet and et al. (1975) from the Kimmswick Limestone in Missouri. A. politus is represented in the upper part of the Bigby-Cannon Formation in sections 61A, 85KA, 85KD, and 86KP. In section 61A, it appears slightly before the last occurrence of A. sp. aff. A. kimmswickensis.
Aphelognathus politus has been reported from the Cincinnati Region from rocks of late Shermanian to mid-Maysvillian age (Sweet, 1979a).

Rhipidognathus symmetricus is represented in the lower part of the Bigby-Cannon Formation in sections 85KD and 61A; in the middle part of the formation in section 86KP; and at the top of the formation in section 85KA. In these four sections, the species is most abundantly represented in section 85KD, which is located on the eastern side of the Central Basin. The difference in distribution and abundance may reflect different environments. That is, the species may have favored a shallower over a deeper water environment, since the eastern Central Basin has been considered to have been a somewhat restricted shallower water environment in the Ordovician (Alberstadt, 1973).

Rhipidognathus symmetricus includes the two subspecies, R. symmetricus discreetus and R. symmetricus symmetricus recognized by Kohut and Sweet (1968). However, the two subspecies have similar ranges, and their paleoecologic significance has not been worked out. Hence I do not subdivide R. symmetricus into subspecies although elements typical of these are recognized in samples prepared for this study.

Rhipidognathus symmetricus has been reported in the Cincinnati Region from rocks of latest Shermanian to latest Richmondian age. Hall (1986) reported R. symmetricus
discretus from the upper Chickamauga Limestone in Alabama, from the Hermitage, Cannon, and Catheys in the Sequatchie Valley in Tennessee, and from the Trenton Formation in Virginia. His study indicates that R. symmetricus appeared as early as the interval of Fauna 9 of Sweet et al. (1971).

Hall also described Rhipidognathus sp. aff. R. symmetricus from the lower Chickamauga Limestone, Alabama; and from the Pond Spring and Ridley formations in Georgia, which were deposited in the interval of Fauna 7.

Panderodus feulneri ranges upward from the lower part of the Bigby-Cannon in the eastern section and occurs in the middle and upper part of the formation in the western sections. The species also has a long stratigraphic range. The diagnostic falciform element has been reported from the Bad Cache Rapids Formation of Shermanian to Maysvillian age (Barnes, 1977); and from the upper Decorah to Dubuque (Webers, 1966); from the Maquoketa (Glenister, 1959). Sweet (1979b) established the skeletal apparatus of multielement P. feulneri from materials collected from Upper Ordovician rocks of the western Midcontinent.

M elements of Oulodus sp. aff. O. velicuspis appear at the top of the Bigby-Cannon in section 61A. These elements are closely similar to those of O. velicuspis, but differ in having a cusp that is less conspicuously sailshaped and loosely fused denticles on the posterior process. Since the M element is such a diagnostic component of the apparatus
of *O. velicuspis*, I tentatively identify the specimens at hand as *O. sp. aff. O. velicuspis*. This species may well be a forerunner of *O. velicuspis*, which appears in younger rocks in central Tennessee.

As for the underlying Hermitage Formation, it is difficult to determine the age and duration of the Bigby-Cannon Limestone based on qualitative study of the conodont data at hand. However the first occurrence of *Aphelognathus politus* indicates that the formation can be no older than late Shermanian.

**Lower Catheys-Leipers Formation.**—Two sections (86KP, 61A) include exposures of the lower Catheys-Leipers Formation. In these sections, the formation overlies the Bigby-Cannon Limestone. The tentatively named lower Catheys-Leipers may be equivalent to the Catheys Formation in Bassler’s (1932) and Wilson (1949)’s classification.

Long-ranging species such as *Plectodina tenuis*, *Drepanoistodus suberectus*, *Phragmodus undatus*, and *Icriodella superba* are represented throughout the lower Catheys-Leipers, and range upward into it from the underlying Hermitage and Bigby-Cannon. But, *Bryantodina? staufferi*, *Yaoxianognathus abruptus*, *Aphelognathus sp. aff. A. kimmswickensis*, and *A. n. sp. B* are not represented in the formation. *Rhipidognathus symmetricus* and *Panderodus feulneri* are also not represented in the formation, but
they reappear in the overlying upper Catheys-Leipers Formation.

Other than disappearance of the species noted, only one new species of *Aphelognathus* makes its first appearance in the formation. At nearly the top of the formation in section 61A, *A. n. sp. A* first appears, but is more abundantly represented in the upper Catheys-Leipers. *A. n. sp. A* belongs to *A. grandis* stock (Sweet, 1983) in that its elements have irregular denticulation. However, it is different from any other previously known species of the stock. All elements are small in size. The apparatus of this species is similar to that of *A. grandis* but differs in having laterally compressed ramiform elements.

Because *Bryantodina? staufferi* and *Yaoxianognathus abruptus* have not been recovered from the lower Catheys-Leipers, the formation was deposited no later than Edenian. The other long-ranging species do not help date the formation.

Upper Catheys-Leipers Formation.--Samples were collected from the upper Catheys-Leipers Formation in sections 61B, 85KB, and 85KF on the western side of the Central Basin, and from sections 85KW, 85KC, and 85KT in eastern portion of the Basin.

In most of the sections, *Plectodina tenuis*, *Phragmodus undatus*, *Drepanoistodus suberectus*, and *Rhipidognathus*
symmetricus occur from the base to the top of the formation. *P. undatus*, however, is represented in the middle of only one eastern section (85KW) (Fig. 7); and *R. symmetricus* is more abundantly represented in the eastern sections than in the western sections. *D. suberectus* is somewhat more abundantly represented in the western sections than in the eastern ones.

*Icriodella superba* disappears in the middle of the upper Catheys-Leipers Formation. *Panderodus gracilis* occurs only at base and top of the formation in the western sections whereas it appears in the middle of the formation in the eastern sections. *P. feulneri* occurs only in a short interval at base of the eastern sections (85KW, 85KT).

*Aphelognathus politus*, which occurs from a level in the upper Bigby-Cannon, is continuously represented up to the top of the upper Catheys-Leipers Formation. In sections 61A and 85KB, *A. politus* is succeeded by *A. rhodesi* (Lindström). But in sections 85KF and 85KW, *A. rhodesi* appears in a short interval before the appearance of *A. politus*. *A. rhodesi* has been reported only from the Crug Limestone of Wales of late Pusgillian to early Cautleyan age (Savage and Bassett, 1985). Sweet (1981) reported the age of the species to be Middle Ordovician.

*Aphelognathus n. sp. A*, which is represented in a thin interval at the top of the lower Catheys-Leipers, occurs in the middle of the upper Catheys-Leipers Formation in the
eastern sections (85KW, 85KT). It does not occur in the western sections.

In section 85KW, *Aphelognathus floweri* Sweet? appears slightly below the first appearance of *A. n. sp. A*. The specimens at hand are similar to *A. floweri*, but the Pa element is different in that the posterior and anterior processes are not completely joined. *A. floweri* ranges from the middle Maysvillian almost to the top of the Richmondian (Sweet, 1984).

*Aphelognathus grandis* (Branson, Mehl, and Branson), which is the zonal indicator of the *A. grandis* Zone (Sweet, 1984), occurs only in one short section, 85KL. In that section it occurs from base to top with other long-ranging species such as *Plectodina tenuis* and *Drepanoistodus suberectus*.

The most biostratigraphically useful species in the upper Catheys-Leipers are species of *Oulodus*. The oldest species of the genus in central Tennessee, *O. oregonia*, does not occur, but the next oldest species, *O. sp. aff. O. velicuspis* occurs continuously. In section 61B, *O. sp. aff. O. velicuspis* gives rise to *O. velicuspis* 86 feet above the base of the section. In the other sections, the change is not well recognized. *O. sp. aff. O. velicuspis* occurs after one brief appearance of *O. velicuspis* or it is directly replaced by *O. robustus*. At the top of the upper Catheys-Leipers Formation, *Oulodus ulrichi* (Stone and Furnish),
Pseudobelodina inclinata (Branson and Mehl), and P. vulgaris vulgaris Sweet appear in section 61A.

In the Cincinnati Region, Oulodus ulrichi occurs first in rocks of latest Maysvillian to late Richmondian age (Sweet, 1984). Pseudobelodina inclinata and P. vulgaris vulgaris range from the mid-Edenian to the late Richmondian (Sweet, 1981), but P. inclinata and P. vulgaris vulgaris are represented only in rocks of middle to late Richmondian age in the Cincinnati Region (Sweet, 1984).

The combination of Oulodus velicuspis, O. robustus, O. ulrichi, and Aphelognathus grandis along with Plectodina tenuis and Phragmodus undatus in the upper Catheys-Leipers indicates that the formation belongs somewhere in the interval between the upper O. velicuspis Zone and the lower A. grandis Zone. This interval is equivalent to the upper part of the Fauna 11 interval to the lower half of the interval of Fauna 12.

Discussion.—In the conodont biostratigraphic study of the Middle and Upper Ordovician rocks in the Central Basin, I have faced two major problems. The first problem is that most of the species have long stratigraphic ranges, especially those of the Hermitage, Bigby-Cannon, and lower Catheys-Leipers. In these formations, most species range from base to top of the sections. Although several species occur in a relatively short interval, the species also have
been reported from the lower Middle to Upper Ordovician rocks in other areas. Therefore it is difficult to determine the age of the formations precisely.

The combination of species represented in them indicates that the three formations I recognize in the Central Basin are Shermanian and early Edenian in age. Thus the formations were deposited during the interval of Fauna 9 and Fauna 10 or within the P. tenuis Zone and B. confluens Zone.

The boundary between the interval of Fauna 9 and Fauna 10 was defined by species of Amorphognathus. That is, the last occurrence of A. tvaerensis Bergström or the first occurrence of A. superbus (Rhodes) defines the boundary.

The boundary between the Plectodina tenuis Zone and Belodina confluens Zone is defined by the first occurrence of one western midcontinent species, B. confluens Sweet. Unfortunately, the key species of Faunas 9 and 10 and of the Tenuis and Confluens zones are not represented in the Middle and Upper Ordovician rocks of the Central Basin. Therefore, it is not possible to draw zonal boundaries or recognize faunal intervals in the formations.

In the upper Catheys-Leipers Formation, there are several key species to indicate Late Ordovician zones. But the key species are represented in the upper two thirds of the formation, so the problem of precisely correlating the lower third of the formation is similar to that with the
underlying formations.

The second problem is that long continuous sections are rare in central Tennessee. None of the sections studied includes all formations. Only parts of one to three formations are represented in the scattered sections. Furthermore, as mentioned above, the species represented have long ranges and there is no datum plane within the formations; thus it is difficult to compile the scattered short sections into a longer section in a chronostratigraphically meaningful way. Therefore, there are limits to qualitative biostratigraphy in situations in which the strata being correlated have the problems just discussed.

Biostratigraphy by Nontraditional Methods

As mentioned earlier, long continuous sections are rare in the area of Middle and Upper Ordovician outcrops in central Tennessee. Also most species represented in the area have long ranges and they are represented from base to top of the sections studied. Therefore it is difficult to compile scattered short sections into a long composite section by traditional biostratigraphic means, or to correlate the sections with the Middle and Upper Ordovician composite section established by Sweet (1984).

However, the biostratigraphic difficulties can be at
least partially solved by using nontraditional approaches to biostratigraphic correlation. These methods, graphic correlation and relative-abundance analysis, have been successfully utilized not only in the Cincinnati Region but also in the western North American Midcontinent for correlation of Middle and Upper Ordovician rocks.

Graphic correlation.—This method, as utilized in conodont studies, has been described and discussed in several papers (Shaw, 1964; Sweet, 1979b; Sweet, 1984). For utilizing the graphic correlation method, ranges of species are required in feet or meters above an arbitrary base in all sections to be compared.

Paired sections are compared by plotting range-bases and range-tops of species that occur in the two sections compared. After plotting all the bases and tops of species ranges on a graph, a straight line that best expresses the array of points is drawn only if the array appears visually to be rectilinear. The straight line is termed a Line Of Correlation (LOC) (Shaw, 1964).

The LOC is then expressed by an equation in terms of the X axis \( X = aY+b \) on which is plotted the longest, best-controlled section, the Standard Reference Section (SRS) of Shaw (1964). On the Y axis is plotted a section to be compared with the SRS. The range-bases and range-tops of the Y axis are converted by use of the LOC equation into terms of the SRS. By comparing the range-bases and range-
tops in the SRS with converted range-bases and range-tops of the Y-axis section, the lowest range-bases and highest range-tops of all species are chosen to make range-bases and range-tops in a Composite Standard Section.

Following the initial round of compilation, component sections, adjusted by subtracting values they control, are recorrelated with the Composite Section. Recorrelation rounds are continued until LOCs and ranges of species reach stability.

The ranges of species compiled by the graphic correlation method are maximum ranges within sections compiled, and the total ranges of species are plotted on the Composite Standard Section compiled by the graphic correlation.

Relative-abundance analysis.—Relative-abundance analysis has been widely used in palynology. This method was initiated for Ordovician conodont study in the Cincinnati Region by Bergström and Sweet (1966). In studying conodonts from the Lexington Limestone, they chose Phragmodus undatus and a combination of Panderodus gracilis and Belodina compressa for constructing a relative-abundance log for the Lexington Limestone, which they correlated with one for the Trenton Group of New York, and one for Middle Ordovician rocks in Minnesota. This method of correlation turned out to be the most reliable way to correlate these widely spaced sections.
Subsequently, Sweet (1979a,b) utilized relative-abundance logs of a different group of genera as a means of correlating the Middle and Upper Ordovician rocks of western North America with those in the Cincinnati Region.

In the initial utilization of the method in the Cincinnati Region by Bergström and Sweet (1966), it was recognized that the relative abundance of Phragmodus undatus varied vertically and that fluctuations in relative abundance were strikingly similar from section to section within the studied area. So, they concluded that a conodont biostratigraphy was effected by matching peaks on relative-abundance logs of sections to be compared.

In interpreting factors responsible for fluctuations in relative abundance, attention has focused on ecology of the selected genera or species. In the Cincinnati Region, detailed study of the relations between lithologic change and changes in the selected genera or species in a passage of time has been worked out (Bergström and Sweet, 1966, Kohut and Sweet, 1968; Seddon and Sweet, 1971; Sweet, 1979a).

From a study of the relationship between rock types and the relative abundance of various genera, it has been recognized that a particular species or genus favored life in certain environments. That is, certain genera or species may have inhabited different water depths. In the Cincinnati Region, Phragmodus undatus is more abundantly
represented in the northern half of the region, where the rocks are dominated by shale with thin limestone, than in the southern half of the area, where *Plectodina tenuis* is more abundant and siltstone and silty limestones dominate the sections.

By matching lithology and relative abundance of the two species, Seddon and Sweet (1971) concluded that *Phragmodus undatus* lived in a more deeply submerged part of the basin and *Plectodina tenuis* in shallower water.

In a relative-abundance log, lateral changes in the environment are also shown vertically. Within the Lexington Limestone, the lithology of members shows that water depth became shallower with time. That is, the Logana Member, lower unit in the Lexington Limestone, was deposited in the deepest water and the Tanglewood Member at the top was deposited in the shallowest environment. Thus, *Phragmodus undatus* increases in relative abundance toward the older members and *Plectodina tenuis* increases toward the younger members (Seddon and Sweet, 1971).

Along with *Phragmodus undatus* and *Plectodina tenuis*, the other genera also show a close relationship between abundance and rock types.

*Aphelognathus*, *Oulodus*, and *Rhipidognathus* are major faunal elements in the southern half of the Cincinnati Region. Sweet (1979a) concluded that water depth of *Aphelognathus* and *Oulodus* was shallower than that of
Plectodina and Phragmodus.

Rhipidognathus is abundantly represented in mudcracked and ripple-marked calcareous or dolomitic mudstone in the Cincinnati Region, so Rhipidognathus is considered to be the shallowest water indicator in the group Aphelognathus, Oulodus, and Rhipidognathus (Sweet, 1979a).

Based on biostratigraphic study by relative-abundance analysis in the Cincinnati Region, I selected five species or genera for similar analysis in central Tennessee. Those are Phragmodus undatus, Plectodina tenuis, and species of Oulodus and Aphelognathus, and Rhipidognathus symmetricus.

As in the Cincinnati Region, species of Oulodus and species of Aphelognathus were combined because their ecologic significance is apparently similar and it is often difficult to differentiate elements of the two genera.

Fig. 8 shows relative-abundance logs for the sections studied. Each genus is represented as a percentage (Appendix E), from the left, Phragmodus, Plectodina, Aphelognathus + Oulodus, and Rhipidognathus. The order of genera is the order of decreasing water depth. Sections 85KL, 85KC, 85KS, 85KT, and 85KF are not included because they are not long enough that major peaks may be identified with certainty and only one or two of the selected genera are represented.

After constructing relative-abundance logs for all sections, logs of the two longest sections (61A and 61B)
Figure 8.—Correlation of sections of central Tennessee by relative-abundance logs.
Figure 8
were preliminarily compared with relative-abundance logs of other sections of Middle and Upper Ordovician rocks in the North American Midcontinent made by Sweet (1979a, 1979b). When I made this comparison, I found a strikingly similar pattern of fluctuations in relative abundance not only within central Tennessee sections but also between sections in central Tennessee and the southeastern Cincinnati Region (Sweet, 1979a). The similarity is most striking in the upper Hermitage, Bigby-Cannon, and lower Catheys-Leipers formations, but decreases in the upper Catheys-Leipers, which could be matched without great difficulty, however.

From the preliminary comparison, I identified a gap between sections 61A and 61B, which were originally thought to represent a continuous sequence. This gap does not necessarily correspond to the stratigraphic break between the Catheys and Leipers recognized by Wilson (1949) because no physical break was found between the two sections. However, comparison of sections 61A and 61B with the long continuous section of the southeastern Cincinnati Region indicates that an unconformity exists somewhere within the Catheys-Leipers Formation.

Based on the observation just described, I treated the sections of the Hermitage to lower Catheys-Leipers (61A, 86KP, 85KH, 85KA, 85KD) and sections of the upper Catheys-Leipers (61B, 85KW, 85KB,) separately for correlation by relative-abundance analysis and graphic correlation. The
Catheys-Leipers Formation was divided into lower and upper parts on the basis of stratigraphic position. That is, the designation "lower Catheys-Leipers" refers to strata that conformably overlie the Bigby-Cannon and the expression "upper Catheys-Leipers" refers to the Leipers and upper Catheys formations in Wilson's (1949) sections, which are overlain by either the Fernvale or the Chatanooga and are not directly underlain by the Bigby-Cannon.

Sections of the upper Hermitage to lower Catheys-Leipers were compiled by graphic correlation to make a Tennessee Composite Section. Relative-abundance logs of the sections already indicate that all sections but 85KH correlate with some part of the longest section, 61A. But the correct rock-accumulation rates of the sections can not be calculated by relative-abundance analysis. Hence I used the graphic correlation method to compile a more accurate Tennessee composite section and to get the maximum ranges of species represented in the sections.

Section 61A was chosen as Standard Reference Section because it is not only the longest section that includes all three formations but it is also the one in which most of the species are represented. Sections 86KP, 85KH, 85KD, and 85KA were compiled in that order.

As shown in Fig. 9, the points of the first and last occurrences of species are widely dispersed on the graph. Although most of the bases are plotted on the upper left-
Figure 9.—Graphic correlation of lower sections with Tennessee Composite Section. Lower sections refer to sections that include the Hermitage, Bigby-Cannon, and Lower Catheys-Leipers. Numbers on graphs refer to species listed in Table 2.
Figure 9

TCS = 1.0KH - 12

TCS = 1.06 KA + 3.4

+ = range top
• = range base
*= inflection point
Figure 9 (cont'd)
Figure 10.—Ranges of conodont species in Tennessee Composite Section. Numbers on bars refer to species listed in Table 2. Numbers in parentheses are values of stratigraphic boundaries in Cincinnati Composite Section.
Figure 10
hand side and most of the tops are plotted on the lower right hand side of the graph, it is difficult to draw a LOC based solely on points representing first- and last- occurrence events. So, I plotted as many as possible of the inflection points, which are peaks of fluctuation in relative-abundance because those points may also represent chronologic events as discussed by Sweet (1979b). The inflection points are identifiable through nearly all the sections compared.

All the plotted points, including the inflection points, make it possible to draw a reasonable LOC on the graph to express the stratigraphic relationship between two sections being compared.

After the third recorrelation round, the LOC and ranges of species stabilized. Figure 10 shows composite ranges of conodonts in the Tennessee Composite Standard Section. The rock-accumulation rates between sections do not vary much. The rate ranges from 0.94 to 1.06, relative to section 61A. All sections but 85KH are fitted within the Standard Reference Section 61A, as was recognized from relative-abundance analysis.

Graphic correlation indicates that the base of 85 KH is equivalent to a point 12 feet below the Tennessee Composite Standard Section (TCSS). Since the rock-accumulation rates of TCSS and 85KH appear to be the same by graphic correlation, 12 feet was directly added below
the base of TCSS.

Sections of upper Catheys-Leipers were compiled in the same manner. Prior to compilation of these sections by the graphic correlation method, relative-abundance logs were constructed as for the underlying formations. Similarity in fluctuations of relative abundance logs between sections is less than that between Hermitage to lower Catheys-Leipers sections. However, there are several biostratigraphically important key species as discussed in the previous chapter. Therefore the three sections were compared first by matching major peaks of fluctuations in relative-abundance logs and minor adjustments were made by comparing the first occurrence of *Oulodus robustus*. *Oulodus robustus* is not abundantly represented in the Nashville Basin, but the species is the zonal indicator of the *O. robustus* Zone of Sweet (1984), which is limited to a position in the mid-Maysvillian Stage.

As shown in Fig. 8, relative abundances of *Phragmodus undatus* and *Rhipidognathus symmetricus* are different between sections 61B, 85KB and section 85KW. Sections 61B and 85KB are located in the western part of the Central Basin and section 85KW is in the eastern part of the Central Basin. *P. undatus* is more abundantly represented in sections 61B and 85KB, whereas *R. symmetricus* is more abundant in section 85KW.

The two sides of the Central Basin have been
considered to represent different depositional environments by Wilson (1949). That is, the eastern portion of the Nashville Basin was shallower than the western portion of the Basin. Thus differences in the relative abundance of the two species is considered to indicate a difference in depositional environment. Lithology also supports this interpretation. Sections 61B and 85KB consist of silty nodular limestone with shale, whereas section 85KW consists of carbonate mudstone and limestone with less shale.

From relative-abundance analysis, several inflection points were achieved for use in the graphic correlation.

Section 61B was chosen for SRS of the upper Catheys-Leipers Formation, and sections 85KW and 85KB were compiled. After the third recorrelation round, a TCSS for the upper Catheys Leipers Formation was achieved.

As shown in the relative-abundance analysis, all sections compared correlate with some part of the SRS. As in the lower sections, the rock-accumulation rates are similar between the sections compiled, they range from 1.03 to 1.14 compared to the SRS (Fig. 11).

Fig. 12 shows correlation of the Central Basin Ordovician strata studied with those in the southeastern Cincinnati Region by comparison of relative-abundance logs of the lower and upper TCSS and a log for the southeastern Cincinnati Region prepared by Sweet (1979a).
Figure 11.—Graphic correlation of upper sections with Tennessee Composite Section. Upper sections are those that include the Upper Catheys-Leipers. Numbers on graph refer to species listed in Table 2.
Figure 11
Figure 12.—Relative-abundance logs of four districts of the Cincinnati Region and correlation of Tennessee Composite Section with the southeastern Cincinnati Region. (Data of the Cincinnati Region have been provided by Dr. W. C. Sweet, who is revising the logs of his 1979a paper)
Figure 12
Figure 13.—Graphic correlation of Tennessee Composite Section with the Southeastern Cincinnati Region. Numbers on graph refer to species listed in Table 2.
Figure 13

**TENNESSEE CS**

\[
CCS = 1.06 \times TCS + 744
\]

**CINCINNATI COMPOSITE SECTION**

\[
CCS = 0.91 \times TCS + 1127
\]

+= range top
.- = range base
*= inflection point
Relative rock-accumulation rate of the two areas was calculated by the graphic correlation method (Fig. 13). As in the local correlation, as many inflection points as possible were also plotted on the graph. The rock-accumulation rate of the lower TCSS (includes Hermitage to lower Catheys-Leipers) is a little bit different from that of the upper TCSS.

The rock-accumulation rate of the lower TCSS is 1.06 by comparison with the southeastern Cincinnati Region, and the rate of the upper TCSS, compared with the same region, is 0.91. Thus, relative to strata of similar age in the Cincinnati Region, rock of the upper Catheys-Leipers Formation accumulated somewhat more rapidly than did that of underlying formations.

The log of Figure 12, at a vertical scale 1.06 and 0.91 times that of the lower and upper Tennessee sections, respectively, represents the relative abundance of selected conodonts in the Late Mohawkian and Cincinnati strata in central Tennessee and in the southeastern Cincinnati Region (Sweet, 1979a) and shows a closely similar pattern between two areas.

It is necessary to mention the divisions of the Cincinnati Region because correlation with the southeastern Cincinnati Region provides not only the biostratigraphic position of the Tennessee sections but also it serves as a guide to interpretation of the regional depositional
The Cincinnati Region has been divided into four smaller regions: SE Indiana, Cincinnati Area of SW Ohio, Maysville Area of Ohio-Kentucky border, and southeastern Cincinnati Region of Kentucky (Sweet, 1979a).

Relative-abundance logs of the four areas in the Cincinnati Region indicate that Phragmodus undatus increases in dominance from the southeastern Cincinnati Region to SE Indiana and Rhipidognathus symmetricus is more abundantly represented in the southeastern Cincinnati Region than in the SE Indiana and SW Ohio areas. In SE Indiana and SW Ohio, R. symmetricus appears in the middle to late Richmondian Stage, whereas the species appears in the middle Shermanian in the southeastern Cincinnati Region. So the relative-abundance logs imply that water depth increased from south to north in the Cincinnati Region (Fig. 12).

The Central Basin is located geographically to the south of the Cincinnati Region, so the Central Basin can be roughly considered as the southern extension of the Cincinnati Region although several faults are known to have interrupted the Cincinnati Arch around the border between Kentucky and Tennessee (Borella and Osborne, 1978).

The late Middle and Late Ordovician conodont fauna of central Tennessee is similar to that of the southeastern Cincinnati Region not only at the generic but also at the
specific level.

*Aphelognathus rhodesi, A. floweri?, and Panderodus feulneri* are represented only in the Nashville Basin, whereas species of *Amorphognathus, Belodina compressa, B. monitorensis, B. profunda, Polyplacognathus ramosus, Staufferella falcata*, and *Synprioniodina? forsentata* are not represented in the Nashville Basin.

Comparison of the composite relative-abundance log for central Tennessee with that for the southeastern Cincinnati Region indicates that the base of the lower TCSS is equivalent to a point 744 feet above the base of the Southeastern Cincinnati CSS.

The base of the Bigby-Cannon Limestone is equivalent to a point 786 feet above the base of the Southeastern Cincinnati CSS. The top of the Bigby-Cannon or the base of the lower Catheys-Leipers corresponds to a level 861 feet above the base of the southeastern Cincinnati CSS, which is 9 feet below the boundary between the Middle and Upper Ordovician or the boundary between the Shermanian and Edenian stages.

The top of the lower Catheys-Leipers Formation in the studied sections is equivalent to a point 914 feet above the base of the Southeastern Cincinnati CSS.

Thus, upper Hermitage, the Bigby-Cannon, and the lower 9 feet of the lower Catheys-Leipers formations are Shermanian in age and the upper 44 feet of the lower
Catheys-Leipers was deposited in Edenian time (Table 4).

In the Cincinnati Region, the base of the Belodina confluens Zone (Sweet, 1984) is 737 feet above the base of the CSS, and the top of the zone is 967 feet above the base of the CSS. Therefore the Hermitage to lower Catheys-Leipers are within the B. confluens Zone.

The base of the upper Catheys-Leipers is 1127 feet above the base of the southeastern Cincinnati Region Composite Section. The upper Catheys-Leipers thus belongs in the Maysvillian Stage. The top of the upper TCSS is equivalent to a point 1301 feet above the base of the Southeastern Cincinnati CSS. However, the upper TCSS includes 16 feet of lower Fernvale Limestone, so the top of the upper Catheys-Leipers is 1286 feet above the base of the Southeastern Cincinnati Region section. Therefore, the entire upper Catheys-Leipers belongs within the Maysvillian Stage, and in the upper Oulodus velicuspis Zone, the O. robustus Zone, and the lower Aphelognathus grandis Zone (Table 4).

Based on my conodont data, the age of the overlying Fernvale Limestone is probably latest Maysvillian to earliest Richmondian, but only if the section is continuous.

Up to the present, the Hermitage, Bigby-Cannon, and Catheys of Wilson’s (1949) classification have been regarded as Middle Ordovician in age, and Wilson’s Leipers
Table 4.--Correlation of the Central Tennessee sections with Middle and Late Ordovician chronostratigraphic units. Columns A and B represent Middle and Upper Ordovician chronostratigraphic units. Column C represents conodont faunal units of Sweet et al. (1971). Column D represents conodont-based chronozones of Sweet (1984), which are revised by Sweet (1986). Column E represents North Atlantic conodont zones of Bergström (1971). Column F represents ages of formations by Wilson (1949). Column G represents correlation of formations by Sweet and Bergström (1976). Column H represents correlation of formations in this study.
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Table 4
Formation has been regarded as Maysvillian. Edenian rocks, represented by the Inman Formation, were described only in the southern end of the Nashville Basin (Wilson, 1949). The Inman Formation has not been described from any other area in the Nashville Basin. Therefore, Wilson (1949, 1962) presumed an unconformity existed between his Catheys and Leipers formations.

But my conodont data indicate that most of Wilson's Catheys, which may correspond to at least the lower Catheys-Leipers of this study, was deposited in Edenian time rather than in Middle Ordovician. There is thus a gap between the lower and upper Catheys-Leipers.

Figure 12 seems to indicate that a stratigraphic break exists between the lower and upper Catheys-Leipers Formation. But it is also possible that the unconformity is located either within the lower Catheys-Leipers or in the lower part of the upper Catheys-Leipers.

The reason is that although the upper and lower TCSS are composite sections compiled from all sections studied, all sections but 85KH fit within the SRSs (61A, 61B). That is, only section 85KH extends 12 feet below the SRS, so 61A and 61B are the maximum sections.

Unfortunately, sections 61A and 61B are not at the same location, but are 8 to 10 miles apart. Therefore, the gap between the lower and upper TCSS or between 61A and 61B may be partly due to a sampling problem.
The possibility of locating an unconformity within the lower Catheys-Leipers or in the lower part of the upper Catheys-Leipers also can not be answered. First, I was not able to recognize any physical break in the two units. All rocks are wackestone interbedded with shale, so it would be difficult to recognize an unconformity in such rocks. Second, most of the species represented in the interval have long ranges, and none indicates a specific time, so the graphic correlation method does not help to determine a time gap.

Therefore, the most reliable way of recognizing unconformity is by relative-abundance logs. As briefly mentioned in the first part of this chapter, an abundance log is useful in situations in which the sections being compared are reasonably long. Short sections can not be correlated with certainty unless key species or conspicuous peaks in relative abundance can be recognized. Even though an unconformity is assumed to exist either within the lower or upper Catheys-Leipers, short sections of the lower Catheys-Leipers and of the lower portion of the upper Catheys-Leipers alone can not be certainly correlated with the southeastern Cincinnati Region section by relative-abundance analysis to find the unconformity.

In conclusion, based on the conodont data of this study, an unconformity exists somewhere in the Edenian part of the central Tennessee section. However, the exact
position of the unconformity or duration of time it represents can not be determined unless a long continuous section that includes at least the interval from the upper Bigby-Cannon to the lower Fernvale becomes available.
CHAPTER III
PALEOENVIRONMENTAL INTERPRETATION

The paleodepositional environment in central Tennessee during the late Middle and Late Ordovician has been reconstructed on the basis of my analysis of lithic features and the conodont faunas. Previously, the depositional setting of the Hermitage to Leipers formations has been reconstructed by Wilson (1962), and that of the Bigby-Cannon by Alberstadt (1973).

Wilson (1962) regarded the presence and vertical movements of the Nashville Dome as the major factors that governed lateral and vertical changes in facies throughout deposition of the upper Middle and Upper Ordovician formations. According to his study, the Laminated Argillaceous Limestone facies was deposited on the western flank of the Dome, where water was relatively deep; the Granular Phosphatic facies was developed on the shallowly submerged part of the western side of the Dome, where water energy was relatively high; the Dove-Colored facies was deposited in a restricted lagoon at the center of the Dome; limestone with silt and clay (= normal eastern limestone facies of Wilson's terminology) was deposited on the
eastern side of the Nashville Dome, where depositional conditions were more or less restricted. Wilson also concluded that lateral changes in facies were repeated in time by vertical fluctuations of the Cincinnati Arch, the southern expression of which is the Nashville Dome.

In this study, no attempt has been made to relate regional depositional setting to tectonic movement in the Central Basin; however, the conodont data at hand and lithic changes either within a formation or through formations recognized from the sections studied enable me to reconstruct relative water depth and, to a lesser extent, other features of the depositional environment.

Upper Hermitage Formation.—Most rocks of the upper Hermitage Formation were sampled on the western side of the Nashville Basin, and rocks of the formation on the eastern side of the Basin were collected at only one section, 85KC. In most of western sections, the strata sampled belong to the Dalmanella Coquina Member, which is the top unit of the formation, and rocks of one short eastern section possibly belong to the Laminated Argillaceous Limestone Member. The Laminated Argillaceous Limestone Member is represented in the studied section by nearly equal amounts of interbedded calcilutite and shale with no benthic fauna. The calcilutite is in tabular to broadly lens-like beds 7 to 8 inches thick. The interbedded shale is brownish gray and
calcareous. The brachiopod coquina consists of a tightly packed mass of *Dalmanella* valves oriented parallel to the bedding surface, and wavy beds are developed at many localities.

Lithic features of the *Dalmanella* Coquina and Laminated Argillaceous Limestone members are similar to those of the Logana Member of the Lexington Limestone in the Cincinnati Region. Cressman (1973) interpreted the Logana Member as representative of a relatively deep-water environment, the depth of which was probably between 15 and 25 meters.

The interbedded calcilutite and shale of the upper Hermitage Formation accumulated below wave base as shown by its fine grain size and the absence of current structures. The oxygen content of the bottom water was low as evidenced by the paucity of benthic fossils and the absence of animal burrows. The *Dalmanella* Coquina formed in water in which turbulence was sufficient to supply oxygen and nutrients to the brachiopods but not strong enough to break and abrade the valves.

Conodont collections indicate that *Phragmodus undatus* is more abundantly represented in the upper Hermitage than in other formations in the Central Basin, Tennessee. As discussed at various places in the previous chapter, *P. undatus* inhabited relatively deep water in Ordovician seas. Therefore, the abundance of *Phragmodus undatus* supports
lithic features that indicate that the Hermitage Formation was deposited in the deepest water in central Tennessee.

Bigby-Cannon Limestone.--All three facies of the Bigby-Cannon Limestone, termed the Bigby-, Cannon-, and Dove-Colored facies by Wilson (1949), were recognized in sections studied.

The Bigby facies, developed mostly in the western sections of the Nashville Basin, consists of cross-bedded calcarenite composed mostly of fragments of bryozoans, crinoids, and brachiopods. This facies resembles the Tanglewood Member of the Lexington Limestone of Kentucky (Cressman, 1973). The Bigby facies, like the Tanglewood, is interpreted to have been deposited in shallow water with high wave and current energy. The high wave energy was sufficient to break and abrade shells of benthic animals and to sweep away silt and clay. In the Bigby facies, the relative abundance of Phragmodus undatus decreases abruptly and Aphelognathus and Oulodus increase greatly. Aphelognathus and Oulodus have been regarded as relatively shallow-water genera in the Cincinnati Region (Sweet, 1979a). Therefore, interpretation of the conodont fauna of the Bigby facies agrees with interpretation of the depositional environment of the facies from its lithic features.

The Dove-Colored facies is light gray carbonate
mudstone that has a conchoidal fracture and contains numerous sparry calcite birdseyes. Mudcracks are seen on bedding surfaces. Benthic fossils are rare; only ostracodes and gastropods are present. Conodonts are also less abundantly represented in this facies than in the other facies of the Bigby-Cannon and other formations. The facies is similar in lithology to the Salvisa Bed of the Perryville Member of the Lexington Limestone (Cressman, 1973). Based on petrographic study, Alberstadt (1973) concluded that the Dove-Colored facies was deposited in a restricted lagoonal environment that was susceptible to subaerial exposure, which resulted in oxidation of its organic matter and led to the light color of the facies. Although conodonts are not abundantly represented, Plectodina and Aphelognathus, which have been regarded as shallow-water genera, were recovered from the rocks of the facies.

The Cannon facies is represented in one eastern section, 85KD. Rocks of this facies are dark gray fine-grained wackestone and packstone. Alberstadt (1973) reconstructed the paleoenvironment of this facies from petrographic study. He concluded that it was deposited in a more or less restricted shallow-water environment and that its fine carbonate grains were derived from the breakdown of skeletal material preserved in the Bigby facies. Conodonts are mostly represented by Plectodina and
Aphelognathus, as in the other facies, but Rhipidognathus also occurs. Special interest focuses on the fact that Rhipidognathus is more abundant in the Cannon than in the other two facies. Rhipidognathus has been regarded as a shallow-water genus and adapted to shallower water than Plectodina and Aphelognathus (Sweet, 1979a). Therefore, on the basis of lithic features, the Cannon facies may have been deposited in shallower water than the Bigby facies, but in deeper water than the Dove-Colored facies, despite the relative abundance of Rhipidognathus.

Catheys-Leipers Formation.—In this study, I treat Wilson's (1949) Catheys and Leipers formations as one formation, termed the "Catheys-Leipers" Formation, because lithology of Wilson's two formations appears to be identical. As discussed in another chapter of this report, the Catheys-Leipers Formation is divided into two units on the basis of stratigraphic position.

Rocks of the Catheys-Leipers Formation are thin and irregularly to nodularly bedded fossiliferous limestone with shale partings. In most sections studied, these strata represent Wilson's (1949, 1962) Nodular or Normal Eastern facies; however, Wilson's (1962) Dove-Colored or Pale-Colored facies is also represented in eastern sections. Rocks of the Nodular facies are easily distinguished from those in the underlying formations by an abrupt increase of
silt and clay. The Dove-Colored facies, on the other hand, is almost identical in lithology to the Dove-Colored facies of the Bigby-Cannon Formation. The abrupt increase in terrigenous clastics may reflect more intense tectonic activity in the eastern part of the Appalachian mobile belt.

Limestones of the Nodular facies are fine- to coarse-grained wackestone to packstone with shale partings. Either whole or fragments of benthic fossils are abundantly represented. The most conspicuous fossils are brachiopods and bryozoans. The Nodular facies is similar in lithology to the Grier Member of the Lexington Limestone in the Cincinnati Region (Cressman, 1973). Cressman (1973), who reconstructed the paleoenvironment of the Grier Member, concluded that it was deposited in shallow, aerated, only moderately agitated water of approximately normal marine salinity, and that nodular and lenticular beds were formed by burrowing organisms. Currents were sufficient to supply oxygen and food to the large fauna of suspension feeders and to distribute crinoid columnals, but they were too weak to comminute and sort the skeletal debris thoroughly or to remove all of the lime mud. Cressman estimated that the Grier Member accumulated in water less than 15 meters deep.

The conodont fauna of the Catheys-Leipers is composed mostly of species of Plectodina, Oulodus, and Aphelognathus. Phragmodus undatus constitutes a small
percentage of the fauna of the formation and is slightly more abundantly represented in the upper Catheys-Leipers than in the lower Catheys-Leipers. Therefore, the conodont fauna and lithic features suggest that the formation was deposited in shallower water than the Hermitage and in deeper water than the Bigby-Cannon. Further, the upper unit was deposited in slightly deeper water than the lower unit.

In the upper Catheys-Leipers, *Rhipidognathus* is more abundantly represented in eastern sections than in western sections, and the lower part of the eastern sections also contains the Dove-Colored facies. The higher relative abundance of *Rhipidognathus* is reminiscent of the situation in the underlying Bigby-Cannon Limestone. From this information, the eastern side of the Nashville Basin was covered by shallower water, at least during the time of the upper Catheys-Leipers, than was the western side of the Nashville Basin. This has been recognized in previous studies (Wilson, 1962; Alberstadt, 1973).

From observation of lithic features and determination of the relative abundance of conodonts in upper Middle and Upper Ordovician rocks of central Tennessee, it is concluded that the area was covered by water that reached its greatest depth during Hermitage time and became shallower during the time of the Bigby-Cannon. Subsequently, sea-level rose during the time when the lower Catheys-Leipers was deposited, but water was not deeper
than that in which the Hermitage was deposited. The sea-
level increased again slightly early in the time of
deposition of the upper Catheys-Leipers, then decreased
toward the end of upper Catheys-Leipers time.

A relative-abundance log of the southeastern
Cincinnati Region (Sweet, 1979a) indicates that sea-level
decreased abruptly there in middle Shermanian time,
increased from the beginning of Edenian time, then decreased
in the middle Edenian and increased again in late Edenian
and early Maysvillian time. After this, the area was
covered by shallow water during the latter half of
Maysvillian and Richmondian time. Logs of the entire
Cincinnati Region (Sweet, 1979a) indicate that the northern
part of the region was more deeply submerged than the
southern part of the region in the Late Ordovician.

Comparison of relative-abundance logs for the
southeastern Cincinnati Region and central Tennessee
indicates that central Tennessee was more shallowly
submerged in the Maysvillian, which accounts for the lower
relative abundance of *Phragmodus undatus*. Also, logs for
the Cincinnati Region indicate that the optimum conditions
for *Rhipidognathus symmetricus* migrated from south to north
in Maysvillian and Richmondian time. A major peak in
abundance of *R. symmetricus* appears earlier in central
Tennessee than in the Cincinnati Region. Thus it may be
suggested that the optimum conditions for *R. symmetricus*
were available earlier in central Tennessee, then migrated north to the Cincinnati Region.

As described earlier in this chapter, eastern and western sides of the Central Basin differ both lithologically and faunally. The lithic and faunal patterns can be explained by presence of the Nashville Dome in Ordovician time as recognized by Wilson (1949, 1962), Borella and Osborne (1978), and Sterns and Reesman (1986), among others. The western side of the Dome was covered by relatively deeper water than the eastern side of the Dome and was connected with the open ocean (Cressman, 1973). Western sections of this study are located at sites where wave energy was relatively high, as is indicated by the Bigby facies of the Bigby-Cannon Limestone. The eastern side of the Dome was relatively shallowly submerged and represented a somewhat restricted environment as is indicated by a higher relative abundance of *Rhipidognathus symmetricus*, the Cannon facies of the Bigby-Cannon Limestone, and the Dove-Colored facies of the Catheys-Leipers Formation.
CHAPTER IV
SUMMARY AND CONCLUSIONS

Biostratigraphy of a portion of the Middle and Upper Ordovician sequence in central Tennessee has been achieved from a study of conodonts and has better resolution than biostratigraphies achieved by previous studies of megafossils.

For this study, 13 sections were measured and sampled on the eastern and western sides of the Central Basin, Tennessee. The sections include the upper Hermitage, Bigby-Cannon, Catheys, and Leipers formations. The traditional Catheys and Leipers formations are combined into one formation because of similar lithology and tentatively referred to as the "Catheys-Leipers Formation." The Catheys-Leipers Formation is subdivided into lower and upper parts on the basis of stratigraphic position.

A total of 31,633 identifiable conodonts elements has been recovered from the 174 1-kg samples. These elements are referable to 32 species of 16 genera. Seventy four percent of the total collection represents species characteristic of the Ohio Valley Province of the Ordovician warm-water realm. Endemic species of the cold-
Most of conodonts represented in the sections studied have long ranges, therefore it is difficult to determine the age of a formation by traditional qualitative biostratigraphic methods. However, nontraditional biostratigraphic methods, such as graphic correlation and relative-abundance analysis, serve to determine age of the rocks more precisely.

A correlation of Middle and Upper Ordovician sections with that of the southeastern Cincinnati Region indicates that the upper Hermitage, Bigby-Cannon, and lower 9 feet of the lower Catheys-Leipers formations are Shermanian in age; that the upper 44 feet of the lower Catheys-Leipers is early Edenian in age; and that the upper Catheys-Leipers is of Maysvillian age. My conclusions as to the age of the lower Catheys-Leipers, which may correspond to Wilson's Catheys Formation, differ from those reached in previous studies, in which the Catheys has been regarded as Middle Ordovician in age.

Changes in conodont faunas from the eastern to the western sides of the Central Basin support the presence of the Nashville Dome during Middle and Late Ordovician time, as has been suggested in previous studies.

Comparison of relative-abundance logs of conodonts represented in the Nashville Basin with those of the Cincinnati Region indicates that central Tennessee was more
shallowly submerged than the Cincinnati Region at least during early Edenian and Maysvillian time.

Aphelognathus n. sp. A, Aphelognathus n. sp. B, Aphelognathus sp. aff. A. kimmswickensis, Aphelognathus floweri?, Oulodus sp. aff. O. velicuspis, and Plectodina sp. aff. P. aculeata are recognized for the first time in central Tennessee in this study. Among the new species, Aphelognathus n. sp. B and Aphelognathus sp. aff. A. kimmswickensis may partially fill a gap in the evolutionary lineage of Aphelognathus; and it is suggested that O. sp. aff. O. velicuspis might be an ancestor of O. velicuspis.
CHAPTER V
SYSTEMATIC PALEONTOLOGY

All conodont collections identified and described for this study are stored in the micropaleontology collections of the Department of Geology and Mineralogy, The Ohio State University. Figured specimens are on file in the Orton Museum of Geology at The Ohio State University.

Genus APHELOGNATHUS Branson, Mehl, and Branson, 1951

Type species.—Aphelognathus grandis Branson, Mehl, and Branson, 1951.


Zygognathus n. gen. Branson, Mehl, and Branson, 1951, p. 11, 12.

Remarks.—The present concept of Aphelognathus is of conodonts with a sexi- or septimembrate skeletal apparatus. The close relationship with Plectodina has been discussed (Sweet, 1981). In fact, some species of Aphelognathus, such as A. politus (Hinde) and A. rhodesi (Rhodes) are closely similar to Plectodina tenuis (Branson and Mehl). Their apparatuses are differentiated on the basis of the Pb
element. The Pb element of Aphelognathus is aphelognathiform, whereas that of Plectodina is ozarkodiniform. In the collection at hand, many Pb elements are intermediate in shape between the two genera. The Pb element of Aphelognathus was originally described for elements having a distinct gap at the proximal end of the anterior process. But many Pb elements in my collection have two to three shorter, fused anterior denticles right next to the cusp. I identify such elements as Plectodina tenuis rather than as species of Aphelognathus because associated Pa or M elements are closer in shape to those of Plectodina tenuis than to ramiform elements of Aphelognathus. The Pb elements might be regarded as elements of a premature stage of Aphelognathus, but that is not likely because not only Pb element but also the other associated elements are robust. Thus, taxonomies of P. tenuis and some species of Aphelognathus might need to be revised.

APHELOGNATHUS FLOWERI Sweet, 1979?

Plate I. 1-7

?Aphelognathus floweri n. sp. Sweet, 1979, p. 56, fig. 10 (2, 6, 10-12, 16, 17).

Description.—Pa element is angulate and bowed; cusp is slightly reclined. Anterior process is long and directed downwardly with at least 8 denticles that point at a right angle to the process. Posterior process is broken. Only upper parts of anterior and posterior processes are joined. Base is more flared on inner side than outer side.

Pb element is carminate. Anterior process is much longer than posterior process. Two denticles at proximal end of anterior process are smaller than the other denticles and form aphelognathiform profile. Underside of element beneath cusp is slightly flared.

M element is angulate with proclined cusp. Base is inwardly flared. Anterior process has weakly developed denticles.

Sa element is alate with laterally compressed posterior process and anteroposteriorly compressed lateral processes. Only one denticle is weakly developed on posterior process.

Sba element is asymmetrically alate. Posterior process is short and lacks denticles. One lateral process is longer than the other and is directed more or less posteriorly. Denticles are anteroposteriorly compressed.

Sbb element is digyrate. Lateral processes are unequal in length. Short adenticulate posterior process is weakly developed.
Sc element is bipennate with long erect cusp. Anterior process is deflected laterally with denticles that point apically. Posterior process is long and has 9 denticles, which decrease in size posteriorly. One denticle at the proximal end of posterior process is much smaller than the others.

Remarks.—Sweet (1979b) based the skeletal apparatus of *Aphelognathus floweri* on materials from Upper Ordovician rocks of the western North American Midcontinent. The specimens at hand, which I identify as *A. floweri?*, are closely similar to the syntypes of *A. floweri* described by Sweet (1979b), but differ slightly mostly in features of the Pa element.

Anterior and posterior processes of Pa elements at hand are not completely joined by a delicate sheath as in the type specimen; only the upper parts of posterior and anterior processes are joined. Anterior process is conspicuously longer than posterior process, but the latter is broken in all my material and its original length is impossible to determine.

The under side of the Pb element beneath the cusp is not conspicuously flared.

*M*, *Sbb*, and *Sc* elements are closely similar to those of *Aphelognathus floweri*.

Denticles of Sa elements are laterally compressed like those of *Aphelognathus floweri*, but only one denticle is
faintly seen on posterior process.

**Ocurrence.**—Represented in the upper Catheys-Leipers Formation in section 85KW, 85KF.

**Materials.**—52 specimens.

**Figuried specimens.**—OSU 32032-32038.

**APHELOGNATHUS GRANDIS** Branson, Mehl, and Branson, 1951

Plate I. 8-13

Aphelognathus grandis n. sp. Branson, Mehl, and Branson, 1951, p. 9, Pl. 2, figs. 11, 13, 14 [not Pl. 2, figs. 12 = **A. pyramidalis** (Branson, Mehl, and Branson, 1951)] [Pb].

A. acutidentata n. sp. Branson, Mehl, and Branson, 1951, p. 9, 10, Pl. 2, figs. 15, 16 [Pb].

Trichonodella undulata n. sp. Branson, Mehl, and Branson, 1951, p. 14, Pl. 4, figs. 10, 11, 22 [not Pl. 3, figs. 24-26 or Pl. 4, fig. 14 = Aphelognathus pyramidalis (Branson, Mehl, and Branson, 1951)] [Sa].

Zygognathus plebia? Branson, Mehl, and Branson, 1951, Pl. 4, figs. 1-9 [Sb, Sc].

Aphelognathus grandis Branson, Mehl, and Branson. Sweet, 1979, p. 56, 57, fig. 10 (20-22, 26-29) [Multielement apparatus].

Plectodina undulata (Branson, Mehl, and Branson). Kohut and Sweet, 1968, p. 1471, 1472, Pl. 186, figs. 1-3, 14,
Remark.—Sweet (1979b) established and thoroughly described the skeletal apparatus of the species. Elements of Aphelognathus grandis are characterized by the robust and irregularly aligned peglike denticles, and recurved cusp of ramiform elements.

Aphelognathus grandis is similar to A. pyramidalis (Branson, Mehl, and Branson) and A. divergens Sweet but differs in morphology of the Pa element. Collections of A. grandis from the Nashville Basin lack the Sa element, but other elements conform well to the description by Sweet (1981).

Occurrence.—Represented in the upper Catheys-Leipers Formation in section 85KL.

Material.—53 specimens.

Figured specimens.—OSU 32039–32044.

APHELOGNATHUS sp. aff. A. KIMMSWICKENSIS Sweet, Thompson, and Satterfield, 1975

Plate I. 14–15, 18–19, 23–24

aff. Aphelognathus kimmswickensis n. sp. Sweet, Thompson, and Satterfield, 1975, p. 31–33, Pl. 2, figs. 18–23.


?Ozarkodina(?) equilatera n. sp. Branson and Mehl, 1933,
Remarks.—The skeletal apparatus of *Aphelognathus* sp. aff. *A. kimmswickensis* is closely similar to that of *A. kimmswickensis* described by Sweet, Thompson, and Satterfield (1975). Although most of Pa elements are broken at the anterior-basal corner, the lateral process appears to have been less well developed than in Pa elements of *A. kimmswickensis*.

The M element is different from that of *Aphelognathus kimmswickensis* in having only one or two denticles on the anterior process. This condition is similar to that of *A. politus*, but the M element of that species is bowed whereas the elements at hand are not.

*Aphelognathus* sp. aff. *A. kimmswickensis* also differs from *A. politus* in having a pastinate rather than an angulate Pa element.

Discussion.—Sweet (1981) described the evolutionary relationship between *Aphelognathus kimmswickensis* and its descendant *A. politus* (Hinde). In his study, the pastinate Pa elements of *A. kimmswickensis* are said to have evolved into the angulate Pa elements of *A. politus* through progressive anteriorward rotation of the lateral process and concurrent closure of the outer process angle. Furthermore, the anterior process of the M element of *A. kimmswickensis* gradually shortened into the shorter anterior process of *A. politus*. 
I interpret the specimens at hand to be evolutionarily intermediate between Aphelognathus kimmswickensis and A. politus. The specimens share morphologies characteristic of both species. As described above, M elements favor A. politus, whereas Pa elements are similar to those of A. kimmswickensis. The stratigraphic occurrence of the specimens at hand supports the interpretation; that is, A. sp. aff. A. kimmswickensis occurs before the first occurrence of A. politus.

Occurrence.—Represented in the Bigby-Cannon and the lower part of the lower Catheys-Leipers formations in sections 61A, 86KP, 85KH, 85KA.

Material.—469 specimens.

Figured specimens.—OSU 32045-32050.

APHELOGNATHUS POLITUS (Hinde, 1879)

Plate I. 16-17, 20-22, 25-26

Prioniodus? politus n. sp. Hinde, 1879, p. 358, Pl. 15, fig. 11 [Pb].

Bryantodus politus (Hinde), Holmes, 1928, p. 7, Pl. 5, fig. 16 [Pb].

Ozarkodina(?) polita (Hinde), Branson and Mehl, 1933, p. 155, 156, Pl. 12, fig. 16 [Pb].

Ozarkodina polita (Hinde), Bergström and Sweet, 1966, p. 351-353, Pl. 31, figs. 6-11 [Pb].

Aphelognathus irregularis n. sp. Pulse and Sweet, 1960, p.
Aphelognathus politus (Hinde), Sweet, 1979a, p. G15; Sweet, 1981, p. 41, 43, Pl. 3, figs. 7-12 (Multielement apparatus).

Remark.—Except for Sc elements, the elements of Aphelognathus politus at hand agree with those described by Sweet (1981). Sc elements in my collections are of two types, dolabrate and bipennate. Previously, the Sc element of A. politus has been described as cordylodontiform (=probably dolabrate), but Sweet (1979a, p.G15) briefly mentioned the development of Sc element from cordylodontiform to eoligonodiniform (=probably bipennate) when he compared the apparatus of A. politus with that of Plectodina tenuis.

In the Bigby-Cannon and the lower half of the Catheys-Leipers formations, Sc elements of Aphelognathus politus are mostly dolabrate whereas, in the upper half of the Catheys-Leipers, bipennate elements tend (but not exclusively) to replace dolabrate elements in the Sc position.

Occurrence.—Represented in the middle Bigby-Cannon to top of the section studied, in 61A, 86KP, 85KD, 85KA, 61B, 85KW, 85KT, 85KB, and 85KF.

Material.—2424 specimens.

Figured specimens.—OSU 32051-32057.
APHELOGNATHUS RHODESI (Lindström, 1959)

Plate II. 1-6

Ozarkodina rhodesi n. sp. Lindström, 1959, p. 441, Pl.1, figs. 1-9, text-fig. 3:6 [Pb].

?Prioniodina pulcherrima n. sp. Lindström, 1959, p. 442, 443, Pl. 3, figs. 28-30 [?Pb].

?Cordylodus cf. spurius Branson and Mehl. Lindström, 1959, p.438, Pl. 4, figs. 19-21 [?M, Pl. 4, fig. 21; ?Sc, Pl. 4, figs. 19, 20].

?Zygognathus crugensis n. sp. Lindström, 1959, p. 451, Pl. 1, figs. 11-15, text-fig. 3:5 [?Sb].

?Trichonodella parabolica n. sp. Lindström, 1959, p.450, Pl. 1, figs. 18-22 [?Sa].


Remarks.—Sweet (1981) established the skeletal apparatus of Aphelognathus rhodesi from the form species represented in the Crug Limestone, described by Lindström (1959). He noted that Ozarkodina rhodesi Lindström is certainly the Pb element of a species of Aphelognathus and O. rhodesi is accompanied by an array of ramiform and pectiniform elements that probably represent other skeletal component of multielement A. rhodesi. Therefore, he provisionally included the array of elements that Lindström (1959) had described as the form species Ozarkodina
rhodesi, Prioniodus pulcherrima, Cordylodus cf. spurius, Zygognathus crugensis, and Trichonodella parabolica from the Crug Limestone of south Wales into A. rhodesi.

As Sweet (1981) mentioned, except for the Pb element, the skeletal apparatus of Aphelognathus rhodesi is closely similar to that of Plectodina tenuis and the ramiform and pectiniform elements of A. rhodesi have been included by others in the skeletal apparatus of P. tenuis.

Aphelognathus rhodesi is also similar to A. politus. Sweet distinguished the two species on the basis of the angle between the anterior and posterior processes of the Pa element. That is, the angle of Plectodina tenuis is smaller than that of Prioniodina pulcherrima named by Lindström (1959).

Savage and Bassett (1985) reported Aphelognathus rhodesi as a multielement species from the Crug Limestone. They distinguished A. rhodesi from other congeneric species by its short Sb element, lack of denticles on anterior process of M and Sc elements, and more reclined denticles of Pa element.

Most specimens at hand are robust and Pa, Pb, Sb, and Sc elements at hand identified as Aphelognathus rhodesi are closely similar to the form species Prioniodus pulcherrima, Ozarkodina rhodesi, Zygognathus crugensis, and Cordylodus cf. spurius respectively. However, M elements are bipennate with 4 denticles on anterior process rather than dolabrate.
The Sa element at hand has a reclined cusp; the angle between lateral processes is narrower than that of the type specimens *Trichonodella parabolica*; and denticles tend to be discrete.

**Discussion.**—From the limited number of specimens of *Aphelognathus rhodesi* and other morphologically similar species, it would be risky to address its phylogenetic relationship with other species. However, close similarity between specimens of *Plectodina tenuis* and *A. rhodesi* from the Nashville Basin suggests a close phylogenetic relationship.

In this study, I include Pb elements with 2 or 3 fused denticles at the proximal end of the anterior process in *Plectodina tenuis*. Many Pb elements of *Aphelognathus rhodesi* in my collections do not show a conspicuous gap at the proximal end of the anterior process, but associated Pa and M elements are more closely similar to those of *Aphelognathus* than to those of *Plectodina*.

**Occurrence.**—*Aphelognathus rhodesi* has not previously been reported outside of Wales. In central Tennessee, it is represented in the upper half of the Catheys-Leipers Formation in sections 61B, 85KW, 85KB, and 85KF.

**Material.**—1438 specimens.

**Figured specimens.**—OSU 32058-32063.
APHELOGNATHUS n. sp. A

Plate II. 7-12

Diagnosis.—Apparatus is seximembrate. Pa is an angulate pectiniform element; Pb is a carminate pectiniform element with a gap in the denticle profile just anterior of the cusp. M element is digyrate with shallowly excavated base. Sa element is alate with fused denticles on lateral processes. Sb element is asymmetrically alate (or digyrate) with short adenticulate posterior process. Sc element is bipennate. Elements are small and denticles are aligned irregularly.

Description.—Pa element is angulate and bowed. Cusp is long and suberect. Base is deeply excavated. Inner side of sheath is more flared than outer side. Denticles are at right angle to processes and discrete.

Pb element is laterally compressed, carminate; although the distal ends of both processes are broken, the anterior process is conspicuously longer than posterior process. Base is not distinctly flared, but more flared on inner side than on outer. Sheath is straight and carina is in the middle of the sheath. Upper edge has at least 9 denticles on the anterior process and two on the posterior process. Three denticles at proximal end of the posterior process are smaller than the other denticles to form aphelognathiform gap.
M element is nearly symmetrical and either alate or digyrate; base is shallowly excavated. Posterior process is not sharply set off from lateral processes, as is the case with M elements of Aphelognathus divergens or A. pyramidalis, but rather broadly expanded as is the case with M elements of A. grandis. Lateral processes are longer than those of M elements of A. grandis, and have 3 to 4 discrete denticles. Cusp is anteroposteriorly compressed, triangular in cross section, and slightly reclined.

Sa element is alate. Laterally compressed posterior process bears 3 to 4 small denticles. Denticles on lateral processes are fused and triangular in outline.

Sb element is asymmetrically alate with an adenticulate posterior process. Denticles on lateral processes are more discernible than those on Sa element. Cusp is slightly reclined.

Sc element is bipennate, at least 4 rounded denticles are on the posterior process and 8 denticles on the laterally deflected anterior process. Denticles are slightly irregular in alignment.

Remarks.—The specimens at hand are similar to elements of Aphelognathus grandis, but differ in that ramiform elements have anteroposteriorly compressed denticles. Lateral processes of the M element are longer than those of the M elements of A. grandis. The species is also similar to A. floweri Sweet but differs in having an
alate M element with a much shorter posterior process than that of *A. floweri*. Furthermore, the Pa element of the new species has irregularly aligned denticles.

**Occurrence.**—Represented in the upper half of the Catheys-Leipers Formation in sections 85KW and 85KT.

**Material.**—75 specimens.

**Figured specimens.**—OSU 32064-32069.

APHELOGNATHUS n. sp. B

Plate II. 13-19

**Diagnosis.**—Apparatus is septimembrate. Pa element is pastinate; Pb element is carminate with gap in denticle profile at proximal end of anterior process; M element is digyrate; Sa element is alate with denticulate posterior process; Sba element is asymmetrically alate with adenticulate posterior process; Sbb is digyrate; Sc element is bipennate. Denticles of elements are irregular in alignment.

**Description.**—Pa element is pastinate. Anterior and lateral processes diverge conspicuously. Lateral process is much longer than posterior process, and denticles at proximal end are fused.

Pb element is carminate and similar to that of *Aphelognathus gigas* Sweet, 1983. Anterior process is much longer than posterior process. Base is deeply excavated. Denticles on upper edge are laterally fused, discrete
apically, sharply pointed, and increase in size toward distal ends of process. Cusp reclined.

M element is digyrate. Denticles and cusp are semicircular in cross section. Inner side is sharply set off from smooth adenticulate posterior process but grades smoothly into opposite lateral process. At least 8 denticles on longer lateral process are closely spaced and at least 5 denticles are on shorter lateral process. Denticles are aligned irregularly, especially on shorter process.

Sa element is alate with long denticulated posterior process. At least 5 denticles are irregularly aligned on posterior process. Lateral processes meet at angle of 40 degrees, and apically pointed denticles increase in size proximally. Axis of denticles parallel to that of cusp. Cusp is recurved.

Sba element is asymmetrically alate and similar to Sa element, from which it differs primarily in having an adenticulate posterior process. Dentine axes are normal to processes rather than parallel to the cusp, as in Sa elements.

Sbb element is digyrate and has short adenticulate posterior process.

Sc element is bipennate. Denticles are round in cross section.
Remarks.—The new species is similar to *Aphelognathus gigas* Sweet in many respects, especially in having pastinate Pa elements and irregularly aligned denticles. However, the Pa element is different.

In that it is less massive, the Pa element of the new species is closer in morphology to that of *Aphelognathus kimmswickensis* than to that of *A. gigas*.

*Aphelognathus gigas* is seximembrate, whereas *A. n. sp. B* is septimembrate.

Discussion.—Sweet (1983) divided species of *Aphelognathus* into two groups largely on the basis of denticulation pattern. One group includes species with stout, discrete, peglike, and irregularly aligned denticles. This group includes *A. divergens* Sweet, *A. grandis* Branson, Mehl, and Branson, *A. pyramidalis* (Branson, Mehl, and Branson), *A. shatzeri* Sweet, and *A. shoshonensis* Sweet. Sweet added *A. gigas* Sweet to this group when he established the species from Oklahoma. The other group includes *A. kimmswickensis* Sweet, Thompson, and Satterfield, *A. floweri* Sweet, *A. politus* (Hinde), and *A. rhodesi* (Lindström). Denticles of this group are compressed and regularly aligned. M elements of two groups are also different. The M element of the first group is digyrate, whereas that of the latter group is either bipennate or dolabrate. The Sc element of the latter group lacks denticles on the anterior process.
Except for Pa and M elements, the specimens at hand are more like those of the first group in having irregularly aligned, discrete denticles. The digyrate M element and fragile Pa elements at hand are reminiscent of the second group.

The oldest species of the first group is *Aphelognathus gigas*, which has been reported only from the upper Fite Formation of Kirkfieldian age (Sweet, 1983). However, the earliest appearance of the other species of the "gigas" group is not earlier than mid-Edenian, although an isolated M element of *A. grandis* type was reported from mid-Shermanian strata in the Lexington Limestone (Sweet, 1979a).

The oldest species of the second group, *Aphelognathus kimmswickensis*, ranges from the Kirkfieldian to mid-Shermanian, and is replaced in younger rocks by *A. politus*, which is continuously represented until mid-Maysvillian.

In the sections studied, *Aphelognathus* n. sp. B appears earlier than *A. sp. aff. A. kimmswickensis*, which is interpreted in this study to be a younger species than *A. kimmswickensis*.

Based on its morphology and stratigraphic range, I conclude that *Aphelognathus* n. sp. B evolved from *A. gigas* and *A. kimmswickensis*, presumably in Shermanian time. After Shermanian time, the two stocks evolved individually in different environments as suggested by Sweet (1981).
Occurrence.—Represented in the upper Hermitage and lower Bigby-Cannon formations in sections 86KP, 85KH, 85KD, 85KA, and 85KC.

Material.—1028 specimens.

Figured specimens.--OSU 32070-32076.

?Genus BRYANTODINA Stauffer, 1935

Type species.—Bryantodina typicalis Stauffer, 1935


BRYANTODINA? STAUFFERI Bergström and Sweet, 1966

Plate II. 21-22

Bryantodina? staufferi Bergström and Sweet, sp. nov. 1966, Pl. 33, figs. 10, 11; Pl. 34, figs. 1, 2, 3, 4; Text-fig. 8E-H.

Remarks.—The skeletal apparatus of Bryantodina? staufferi was reconstructed by Bergström and Sweet (1966). In it they included specimens referable to the form-genera Bryantodina and Ozarkodina and assigned the apparatus provisionally to Bryantodina because the skeletal apparatus of B. typicalis, its type species was not known. Sweet (1979a) added to the apparatus a specimen referable to the form-genus Trichonodella and a fragile hindeodelliform element, both of which were tentatively included as parts of the apparatus of B.? staufferi by Bergström and Sweet (1966). Thus the current concept of the species is of one
with a quadrimembrate skeletal apparatus.

Among the 29 specimens recovered, 24 are carminate or slightly arched angulate and 5 are angulate. Alate and bipennate ramiform elements were not recovered.

The pectiniform elements of Bryantodina? staufferi are differentiated on the basis of sinuosity of the base. The angulate element at hand is only slightly arched.

Occurrence.—In the Nashville Basin, Bryantodina? staufferi constitutes less than 0.1 percent of the total collection, it is represented in the upper Hermitage and Bigby-Cannon in sections 61A, 85KA, 85KH, and 86KP. It ranges from 16 feet to 89.9 feet above the base of the Tennessee composite section.

Materials.—29 specimens.

Figured specimens.—OSU 32083-32084.

Genus DREPANOISTODUS Lindström, 1971

Type species.—Oistodus forceps Lindström, 1955

DREPANOISTODUS SUBERECTUS (Branson and Mehl, 1933)

Plate III. 1-3

Oistodus suberectus Branson and Mehl, 1933, p. 11, Pl. 9, fig. 7.

Drepanodus suberectus (Branson and Mehl). Bergström and Sweet, 1966, p. 330-333, Pl. 35, figs. 22-27 (includes synonymy); Oberg, 1966, p. 137, 138, Pl. 16, fig. 1;
Weyant, 1968, p. 47, Pl. 47, figs. 11, 12; Bradshaw, 1969, p. 1150, Pl. 135, fig. 7; Ethington and Schumacher, 1969, p. 461, 462.

**Drepanodus homocurvatus** Lindström. Oberg, 1966, p. 137, Pl. 15, fig. 16; Andrew, 1967, p. 889, Pl. 113, fig. 16, Pl. 114, figs. 8, 15; Serpagli, 1967, p. 38, 39, Pl. 15, figs. 7a-c; Barnes, 1967, p. 236; Weyant, 1968, p. 46, 47, Pl. 2, figs. 13, 14; Bradshaw, 1969, p. 1150, Pl. 135, fig. 8; Ethington and Schumacher, 1969, p. 461.


**Drepanoistodus suberectus** (Branson and Mehl). Votaw, 1972, p. 87, 88, Pl. 1, figs. 6-8; Carnes, 1975, p. 129-132, Pl. II, text-figs. 16A-C; Schmidt, 1982, p. 136-137, Pl. 1, figs. 3-5; Bauer, 1983, p. 50-51, Pl. 1, figs. 15-17, 22; Hall, 1987, p. 152-154, figs. 3-10.

?**Distacodus arcuatus** Stauffer, 1930, p. 123, Pl. 10, fig. 21; Stauffer, 1932, p. 258.

**Remarks.**—The skeletal apparatus of **Drepanoistodus suberectus** was reconstructed by Bergström and Sweet (1966). In it they included specimens formerly referred to the form-species **Drepanodus suberectus**, **D. homocurvatus**, and
**Oistodus inclinatus.**

In the collection at hand, the ratio of representatives of form-species *Drepanodus suberectus* to *D. homocurvatus* to *Oistodus inclinatus* is 1 : 7 : 2.

In the Middle and Upper Ordovician sections of central Tennessee, about 70 percent of the specimens have been recovered from the lower sections, which include the Hermitage, Bigby-Cannon, and lower Catheys-Leipers formations.

Sweet (1979a) discussed the ecologic significance of *Drepanoistodus suberectus* by comparing its occurrence with that of *Rhipidognathus symmetricus*. He concluded that the optimum habitat of *D. suberectus* was an offshore, open-water environment rather than a shallow, nearshore environment.

In central Tennessee, *Drepanoistodus suberectus* tends to occur abundantly in samples in which *Phragmodus undatus* is also abundantly represented. *P. undatus* has been regarded as a relatively deep-water species. Therefore the occurrence pattern of *D. suberectus* in Tennessee agrees with Sweet's interpretation of its ecologic significance.

**Occurrence.**—Represented in nearly all samples, from base to top of the sections.

**Materials.**—1055 specimens. 99 (*D. suberectus*), 738 (*D. homocurvatus*), 218 (*O. inclinatus*).

**Figured specimens.**—OSU 32085-32087.
Fibrous Conodonts
Plate II. 20, 23-27

Remarks.—In this study, fibrous conodonts include specimens that have little or no white matter. The specimens at hand represent the form-genera *Erismodus*, *Curtognathus*, *Polycaulodus*, and *Microcoelodus*. The specimens may be components of several multielement species. But, late Middle and Late Ordovician fibrous conodonts have not been grouped into multielement species because available materials are not adequate.

Occurrence.—Fibrous conodonts are more abundantly represented in the Hermitage and the lower Bigby-Cannon formations than in the upper Catheys-Leipers Formation, from which only one specimen has been recovered. 183 of the 199 specimens were recovered from section 85KD.

Materials.—199 specimens.

Figured specimens.—OSU 32077-32082.

Genus *ICRIODELLA* Rhodes, 1953

Type species.—*Icriodella superba* Rhodes, 1953.


*ICRIODELLA SUPERBA* Rhodes, 1953
Plate III. 4-7, 11

*Icriodella superba* Rhodes, 1953, p. 288, Pl. 20, figs. 54, 58, 62, 65, 78; Bergström and Sweet, 1966, p. 337-
Remarks.—The quinquimembrate apparatus of Icriodella superba was reconstructed by Bergström and Sweet in 1966. Elements of the apparatus were formerly referred to the form-species Icriodella superba Rhodes, Sagittodontus robustus Rhodes, Sagittodontus dentatus Ethington, Rhynchognathodus divaricatus (Rhodes), and Rhynchognathodus typicus (Ethington). Specimens at hand of I. superba include 73 percent of form-species I. superba, 24 percent of form-species S. robustus, 0.5 percent of form-species S. dentatus, 0.7 percent of form-species R. divaricatus, and 1.8 percent of form-species R. typicus.

Occurrences.—Represented more in the Hermitage and lower Catheys-Leipers formations than in the upper Catheys-Leipers Formation. The species occurs from the base to 128 feet above the base of the Tennessee composite section. It is represented in every section but 85KD.

Materials.—549 specimens. 397 specimens of I. superba, 130 of S. robustus, 4 of S. dentatus, 6 of R. divaricatus, and 10 of R. typicus.

Figured specimens.—OSU 32088-32092.
Genus OULODUS Branson and Mehl, 1933

Type species.—Cordylodus serratus Stauffer [=senior subjective synonym of Oulodus mediocris Branson and Mehl, 1933, the originally designated type species.]

Oulodus Branson and Mehl, Sweet and Schönlaub, 1975, p. 45-46 [Multielement apparatus].

Remarks.—Oulodus has 6 morphologically distinct elements in its apparatus: Pa and Pb elements are extensiform digyrate elements; M is dolabrate or bipennate; and in the symmetry-transition series, Sa is alate, Sb is breviform digyrate, and Sc is dolabrate or bipennate. Specimens at hand show that denticles on processes are stout, discrete, and peglike in adult stage, as described previously, but they tend to be compressed in premature stages.

OULODUS OREGONIA (Branson, Mehl, and Branson, 1951)

Plate III. 8-10, 12-14
Prioniodina oregonia n. sp. Branson, Mehl, and Branson, 1951, p. 15, 16, Pl. 3, fig. 18; Pl. 4, figs. 28-32.

Oulodus oregonia (Branson, Mehl, and Branson), Bergström and Sweet, 1966, p. 342-347, Pl. 32, figs. 20, 21; Pl. 33, fig. 5; Pl. 34, figs. 13-16; text-figs. 9G-L;


Remarks.—Bergström and Sweet (1966) reconstructed the skeletal apparatus of Oulodus oregonia from an assemblage of prioniodiniform (Pa), oulodontiform (Pb) and cordyloodontiform (Sc) elements. Later (1972), trichonodelliform (Sa), zygognathiform (Sb) and prioniodiniform elements with short anterior process (M) were included.

Kohut (1967) and Kohut and Sweet (1968) subdivided Oulodus oregonia into three subspecies; those are O. oregonia oregonia, O. oregonia ulrichi, and O. oregonia velicuspis. The latter two subspecies were defined on the basis of a bipennate M element referable to the form-species Eoligonodina ulrichi Stone and Furnish, and a bipennate M element assigned to the form-species Prioniodina velicuspis Pulse and Sweet. As a result of subsequent stratigraphic studies, these subspecies have been treated as species, O. oregonia, O. ulrichi, and O.
velicuspis.

Sweet and Schönlaub (1975) used the name Oulodus subundulatus (Sweet and others) for the species named Oulodus oregonia by Bergström and Sweet because the type specimen of Prioniodina oregonia Branson, Mehl, and Branson was thought to have been a component of a multielement apparatus distinguished by a M element of the type named Prioniodina velicuspis by Pulse and Sweet (1960).

Sweet (1981) returned to the nomenclature advocated by Bergström and Sweet (1966) because the velicuspiform M element does not range as high as the level of type Prioniodina oregonia Branson, Mehl, and Branson.

In short, the present concept of the skeletal apparatus of Oulodus oregonia is that of O. subundulatus as described by Sweet and Schönlaub (1975).

The specimens at hand agree well with the description of Oulodus subundulatus by Sweet and Schönlaub (1975).

Discussion.—Oulodus oregonia has the least morphologically distinct elements in its skeletal apparatus of any congeneric species. Therefore, the species can be identified only on the basis of collective characters of elements.

Occurrence.—Represented from the top of the Hermitage or the base of the Bigby-Cannon to the lower Catheys-Leipers. There are some isolated elements in the upper Catheys-Leipers that are closely similar to Oulodus.
oregonia. But, I did not refer the elements to this species because all elements are not represented.

**Materials.**—1066 specimens.

**Figured specimens.**—OSU 32093-32098.

**OULODUS ROBUSTUS** (Branson, Mehl, and Branson, 1951)

**Plate III. 15-20**

*Eoligodonina robusta* n. sp. Branson, Mehl, and Branson, 1951, p. 15, Pl. 4, figs. 33, 35-37.

*Trichonodella? sp.* Branson, Mehl, and Branson, 1951, p. 14, Pl. 3, fig. 27.

*Zygognathus* sp. Branson, Mehl, and Branson, 1951, Pl. 4, fig. 19 (not Pl. 4, figs. 13, 18, 20, 21, 35).

*Oulodus* sp. Branson, Mehl, and Branson, p. 12, Pl. 3, fig. 19.

*Plectodina robusta* (Branson, Mehl, and Branson), Kohut and Sweet, 1968, p. 1471, Pl. 185, figs. 12, 14, 15, 17, 24.

*Oulodus robustus* (Branson, Mehl, and Branson), Sweet and Schönlaub, 1975, p. 48-49, Pl. 2, figs. 7-12; Sweet, 1981, p. 201, 202, Pl. 2, figs. 7-12.

**Remarks.**—*Oulodus robustus* is characterized by large elements that have stout, discrete denticles of subcircular cross section, and a deep honey color. The specimens at hand agree well with those described by Sweet and Schönlaub (1975) and Sweet (1981).
Occurrences.—Represented in the upper Catheys-Leipers Formation in sections 61B, 85KW, and 85KB. Eight questionable Pa elements that are closely similar to that of this species were recovered from the top of the lower Catheys-Leipers Formation. I did not include the stout Pa elements in this species because of a lack of the other elements.

Materials.—247 specimens.

Figured specimens.—OSU 32651-32656.

OULODUS ULRICHI (Stone and Furnish, 1959)

Plate III. 21-23, 25-27

Eoligonodina ulrichi n. sp. Stone and Furnish, 1959, p. 222, Pl. 32, figs. 16-18.

Erismodus tantus Stauffer, Stone and Furnish, 1959, p. 223, Pl. 32, fig. 11.

Microcoelodus sweeti n. sp. Stone and Furnish, 1959, p. 224, Pl. 31, fig. 18.

Oulodus mediocris Branson and Mehl. Stone and Furnish, 1959, p. 224, 225, Pl. 32, figs. 4, 5.

Trichonodella barbara (Stauffer). Stone and Furnish, 1959, p. 227, Pl. 32, fig. 15.

Cyrtoniodus sinclairi n. sp. Ethington and Furnish, 1960, p. 270, 271, Pl. 38, fig. 16.

Oulodus oregonia ulrichi (Stone and Furnish). Kohut and Sweet, 1968, p. 1468, Pl. 185, figs. 7, 11.

Remarks.—Oulodus ulrichi is characterized by its Sc and M elements. The Sc element is bipennate, with a laterally deflected, posteriorly directed, bar-like anterior process with peglike denticles. The M element is bipennate with one or two node like denticles on the anterior process.

Kohut and Sweet (1968) included the form-species Eoligonodina ulrichi Stone and Furnish as the Sc element of the multielement species. Sweet (1979b) recognized that the form-species Cyrtoniodus sinclairi Ethington and Furnish was the M element of Oulodus ulrichi.

The specimens at hand agree well with the original descriptions of the skeletal components of this species, which were described as form-species.

Occurrences.—Represented in the top of the upper Catheys-Leipers Formation only in section 61B.

Materials.—14 specimens.

Figured specimens.—OSU 32657-32662.

OULODUS VELICUSPIS (Pulse and Sweet, 1960)

Plate IV. 1-6


Oulodus casteri n. sp. Pulse and Sweet, 1960, p. 255, Pl. 36, figs. 1, 8, 12.


Zygognathus maysvillensis n. sp. Pulse and Sweet, 1960, p. 262, Pl. 37, figs. 9, 12.

Cordylodus excavatus Sweet et al. Pulse and Sweet, 1960, p. 251, Pl. 35, figs. 11, 15.


Remarks.—Sweet and Schönlaub (1975) reconstructed the skeletal apparatus of Oulodus velicuspis but used the name O. oregonia (Branson, Mehl, and Branson) for the species. Later, the name of the species returned to O. velicuspis as indicated under my discussion of O. oregonia.

Oulodus velicuspis is distinguished by an M element that has a conspicuous sail-like flange on the posterior margin of the cusp. M elements among the specimens at hand agree well in character with the form-species Prioniodina
velicuspis Pulse and Sweet.

Occurrences.—Represented in the mid-upper Catheys-Leipers Formation in sections 61B and 85KT.

Materials.—192 specimens.

Figured specimens.—OSU 32589-32594.

OULODUS sp. aff. O. VELICUSPIS (Pulse and Sweet, 1960)

Plate IV. 7-11, 13

Diagnosis.—Except for the M element, the skeletal apparatus of this species is the same as that of Oulodus velicuspis (Pulse and Sweet). The M element is somewhat different in having closely spaced to fused denticles on the posterior process and in lacking a sail-shaped flange on the posterior margin of the cusp.

Remarks.—Although the fused denticles on the posterior process of the M elements are closely similar to those of Oulodus velicuspis, the sail-shaped M element is such a diagnostic element of O. velicuspis, that I refer to this species tentatively as O. sp. aff. O. velicuspis.

Discussion.—The stratigraphic range of this species indicates that Oulodus sp. aff. O. velicuspis appears to be older than O. velicuspis, because the former appears before the first occurrence of the latter, except in section 85KT, in which O. sp. aff. O. velicuspis occurs after one occurrence of O. velicuspis. The prospective phylogenetic lineage is best shown in section 61A, in which O. sp. aff.
O. velicuspis gives rise to O. velicuspis.

Occurrence.--This species occurs from the lower Catheys-Leipers to the upper Catheys-Leipers Formation.

Materials.--686 specimens.

Figured specimens.--OSU 32595-32600.

Genus PANDERODUS Ethington, 1959

Type species.--Paltodus unicostatus Branson and Mehl, 1933

Panderodus Ethington, 1959, p.284.

Remarks.--Panderodus includes species with a quinquemembrate skeletal apparatus. Sweet (1979b) used several terms to describe elements of the skeletal apparatus. Those were falciform, arcuatiform, tortiform, similiform, and asimiliform.

Falciform elements are compressed, and have a rounded anterior margin and sharp-edged posterior margin. The inner, unfurrowed face is smooth, whereas the furrowed outer face may have a costa or costae.

Arcuatiform elements have a sharp-edged posterior margin and a costate anterior margin. The outer face has an inflated segment below the furrow; the inner face is smooth or has a longitudinal median depression.

Tortiform elements are similar to arcuatiform elements but the base is twisted toward the inner face.
Similiform elements are bilaterally symmetrical except for the presence of a panderodont furrow on one face and have a rounded anterior margin and a posterior costa.

Asimiliform elements are similar to arcuatiform elements but differ in having a median costa on the inner face.

The specimens at hand represent all 5 types of elements, so I use the five terms to describe the apparatus of Panderodus in this study.

PANDERODUS FEULNERI (Glenister, 1957)
Plate IV. 14-18

Paitodus feulneri Glenister, 1957, p. 728, Pl. 85, fig. 11.
Panderodus feulneri (Glenister). Ethington, 1959, p. 284, 285, Pl. 39, fig. 2; Stone and Furnish, 1959, p. 225, Pl. 31, fig. 3; Schopf, 1966, p. 66, Pl. 5, fig. 30; Webers, 1966, p. 38, Pl. 3, figs. 1a, 1b, 2a, 2b; Weyant, 1968, p. 56, Pl. 5, fig. 4; Barnes, 1977, Pl. 3, figs. 11, 12.
Panderodus feulneri (Glenister). Sweet, 1979b, p. 64, Fig. 7 (1, 8, 11-14, 17, 18, 22).
Panderodus gracilis (Branson and Mehl). Hall, 1986, p. 166-169, Pl. II, figs. 1-5, not fig. 5 (= P. gracilis).
Remarks.--Sweet (1979b) reconstructed the skeletal apparatus of Panderodus feulneri from collections made in the western Midcontinent. P. feulneri is characterized
mostly by its falciform element, which has well-defined anterior costae on both faces.

Falciform elements at hand have rounded costae rather than well-developed costae, and all specimens are dark brown in color. Sweet (1979b) mentioned ontogenetic development of costae. That is, small immature specimens lack the costae or have rounded costae. However, falciform elements with rounded costae in my collection are fully grown specimens.

Occurrences.—*Panderodus feulneri* is represented at the base of the Bigby-Cannon and ranges up to the mid-upper Catheys-Leipers.

Materials.—2915 specimens.

Figured specimens.—OSU 32665-32669.

**PANDERODUS GRACILIS** (Branson and Mehl)
Plate IV. 12, 19-21, 25

*Paltodus gracilis* Branson and Mehl, 1933, p. 108, Pl. 8, figs. 20, 21.


*Panderodus sp. cf. P. gracilis* (Branson and Mehl). Carnes,
Remarks.—Bergström and Sweet (1966) included the form-species *Panderodus gracilis* (Branson and Mehl) and *P. compressus* (Branson and Mehl) in the apparatus of *P. gracilis*. Subsequently, Carnes (1975), Barrick (1977), and Sweet (1979b) recognized 5 different elements.

Carnes (1975) and Hall (1986) used several terms to describe the apparatus of *Panderodus gracilis*. Those were: arcuatiform, asymmetrical graciliform, P element, feulneriform, symmetrical graciliform, and compressiform.

The P elements of Carnes (1975) and Hall (1986) may have corresponded to the tortiform elements of Sweet (1979b). Sweet's compressiform includes Carnes and Hall's feulneriform and compressiform. However, the feulneriform of Carnes and Hall is a diagnostic component of *Panderodus feulneri* described by Sweet (1979b).

In the collections at hand, five different elements are recognized in the apparatus of *Panderodus gracilis*: those are compressiform, arcuatiform, tortiform, similiform, and assimiliform elements. In this study, the feulneriform elements of Carnes and Hall are excluded from the apparatus of *P. gracilis* and are included in *P. feulneri*.

Occurrences.—Represented from the base to top of the sections, but rare in the upper Catheys-Leipers.
Materials.--846 specimens.  
Figured specimens.--OSU 32670-32674.  

Genus PERIODON Hadding, 1913  
Type species.--Periodon aculeatus Hadding, 1913  

PERIODON GRANDIS (Ethington, 1959)  
Plate III. 28  

Loxognathus grandis Ethington, 1959, p. 281, Pl. 40, fig. 6.  
Eoligonodina magna Ethington, 1959, p. 277, Pl. 40, figs. 3, 4.  
Trichonodella insolita Ethington, 1959, p. 289, Pl. 41, fig. 9.  
Prioniodina aerea Webers, 1966, p. 58, Pl. 12, fig. 13.  
Prioniodina? n. sp. 1 & 2 Lindström, 1957, p. 175, Pl. 1, figs. 22, 23.  
Periodon grandis (Ethington, 1959). Ethington and Schumacher, 1969, Pl. 68, fig. 6; Roscoe, 1973, p. 80-81 (not illustrated); Carnes, 1973, p. 176, 177, Pl. VII, fig. 9; Sweet, Thompson, and Satterfield, 1975,
Falodus aff. prodentatus (Graves and Ellison, 1941).

Ethington and Schumacher, 1969, Pl. 67, fig. 13.


Remarks.—Bergström and Sweet (1966) included pastinate, alate, angulate, and dolabrate elements with two types bipennate elements, one with an adenticulated posterior process, in the apparatus of Periodon grandis.

In this study, representatives of the species are rare, only M elements have been recovered. However, these elements of Periodon grandis are the most characteristic of the species. The M element of P. grandis differs from the corresponding element of P. aculeatus Hadding in having a large, subtriangular base, an essentially straight basal margin, and anterior denticles that are appressed to the anterior margin of the cusp rather than being developed on a more or less conspicuous anterior process.

Occurrences.—Represented only in the Hermitage Formation in sections 85KH, 61A, and 86KP.

Materials.—Only 8 bipennate elements with adenticulated posterior process are represented.

Figured Specimens.—OSU 32664.
Genus PHRAGMODUS Branson and Mehl, 1933

Type species.—*Phragmodus primus* Branson and Mehl, 1933

*Phragmodus* Branson and Mehl, 1933.

*Cyrtoniodus* Branson and Mehl, 1933

*Subcordylodus* Stauffer, 1935.

?*Dichognathus* Branson and Mehl, 1933.

PHRAGMODUS UNDATUS Branson and Mehl, 1933

Plate IV. 22-24, 26-28

*Phragmodus undatus* Branson and Mehl, 1933, p. 115, 116, Pl. 8, figs. 22-26.

*Dichognathus brevis* Branson and Mehl, 1933, p. 113, Pl. 9, figs. 24-26.

*D. typica* Branson and Mehl, 1933, p. 113, 114, Pl. 9, figs. 27-29.

*Oistodus abundans* Branson and Mehl, 1933, p. 109, Pl. 9, figs. 11, 17.

*O. breviconus* Branson and Mehl, 1933, p. 109, Pl. 9, figs. 13, 14.

Remarks.—*Phragmodus undatus* is the second most abundantly represented species in central Tennessee. It occupies 22 percent of the total collection.

Bergström and Sweet (1966) emended and thoroughly described the skeletal apparatus of the species. The specimens at hand agree well with their description.

Occurrence.—*Phragmodus undatus* is represented from the base to top of the sections studied, but it is most abundantly represented in the Hermitage Formation. Seddon and Sweet (1971) and Sweet (1979) regarded the species as an inhabitant of relatively deeper water than other indigenous conodonts in the Cincinnati Region.

The occurrence pattern of the species related to lithic features in central Tennessee supports the conclusion. That is, the Hermitage Formation is interpreted from lithic features to have been deposited in the relatively deepest water among the formations studied.

Materials.—6977 specimens.

Figured specimens.—OSU 32675-32680.

Genus PLECTODINA Stauffer, 1935

Type species.—*Plectodina aculeata* (Stauffer, 1930)

*Plectodina* Stauffer, 1935.

*Trichonodella* Branson and Branson, 1947.
PLECTODINA sp. aff. P. ACULEATA (Stauffer, 1930)

Plate IV. 29

?Proniodus aculeatus n. sp. Stauffer, 1930, p. 126, Pl. 10
fig. 12.

Remarks.—Four poorly preserved pastinate elements from the Hermitage Formation may represent Plectodina aculeata, but can not be identified with certainty as representatives of that species. Among the described species of Plectodina, pastinate elements are referable to P. aculeata (Stauffer, 1930), P. aculeatoides Sweet, 1979, and P. dakota Sweet, 1982. Pa elements of P. aculeata have well-developed posterior and lateral processes and a proclined cusp. The Pa element of P. dakota has an erect cusp, a sharp-edged keel-like costa on the adenticulated anterior process, and a short posterior process. The Pa element of P. aculeatoides has a distinctly denticulated posterior process and a compressed denticulated lateral process that projects anterolaterally rather than laterally.

The pastinate elements at hand are closer to those of Plectodina aculeata than to the others in having a proclined cusp and well-developed lateral process. Posterior processes are broken, however.

The occurrence of pastinate elements without the other elements make it difficult to identify the specimens with certainty.
Occurrence.—Represented only at the base of the Hermitage Formation in section 61A.

Materials.—4 pastinate elements.

Figured specimens.—OSU 32698.

PLECTODINA TENUIS (Branson and Mehl, 1933)

Plate V. 1-6

Ozarkodina tenuis Branson and Mehl, 1933, p. 128, 129, Pl. 10, figs. 19-21, 23.

O. inclinata Glenister, 1957, p. 735, Pl. 88, figs. 3, 7.

Cordyloodus? delicatus Branson and Mehl, 1933, p. 129, Pl. 10, figs. 14, 15.

C. elongatus Rhodes, 1953, p. 299, 300, Pl. 21, figs. 114-118.

C. geniculatus Rhodes, 1953, p. 300, Pl. 21, fig. 113.

Phragmodus mirus Branson and Mehl, 1933, p. 123, Pl. 10, fig. 12.

Gyrognathus? superbus Rhodes, 1953, p. 319, Pl. 20, figs. 43-45; Pl. 21, fig. 13.

Trichognathus tenuis Branson and Mehl, 1933, p. 131, Pl. 10, fig. 18.

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

T. angulata Sweet et al. 1959, p. 1064, Pl. 131, figs. 9, 13.

Plectodina furcata tenuis (Branson and Mehl). Sweet, Thompson, and Satterfield, p. 42, 43, Pl. 2, figs. 9-11, 14-17.


Remarks. — Plectodina tenuis is the most abundantly represented conodont species in the late Middle to Late Ordovician rocks of the Central Basin, Tennessee.

Bergström and Sweet (1966) emended the skeletal apparatus of the species. They included dolabrate, angulate, alate, and digyrate elements for Sc, Pa, Sa, and Sb positions respectively. Kohut (1969) added the form-species Cyrtoniodus flexuosus Branson and Mehl, 1933 as the M element. Later, Sweet and Bergström (1970) added the form-species Ozarkodina tenuis as the Pb element of the apparatus.

The species represented by this skeletal apparatus was initially named Plectodina furcata (Hinde), but the name was changed to P. tenuis because the nominate form-species, Prioniodus furcatus Hinde, was discovered to be part of the apparatus of a species of Aphelognathus (Sweet, 1981).

Sweet, Thompson, and Satterfield (1975) recognized two subspecies of Plectodina furcata, P. furcata furcata
Plectodina furcata furcata has a Pa element with posterior and anterior processes of equal size and an Sc element with a short posterior process that is adenticulate or has only a few denticles. The Pa element of P. furcata inclinata has an anterior process that is much longer than its posterior process and an Sc element with a long denticulate posterior process. The former are represented in the Cincinnati Region, whereas the latter occur in Iowa, Minnesota, New York, and Ontario.

The species of Tennessee belong to Plectodina tenuis tenuis, which was named P. furcata furcata but was changed into P. tenuis tenuis as mentioned above, based on morphologic characters of Pa and Sa elements.

Plectodina tenuis is similar to some species of Aphelognathus in many respects. The two genera have been distinguished by Pb elements. That is, Pb elements of Aphelognathus have a prominent gap in the denticle profile at the proximal end of the anterior process, whereas Pb elements of P. tenuis and other species of Plectodina lack a gap at the same site.

Pb elements of Plectodina tenuis in Tennessee are closely similar to those of Aphelognathus. Although a prominent gap is not recognized, 2 to 3 denticles at the proximal end of the anterior process are shorter than the other denticles. Such elements might be considered to be
immature stages of Aphelognathus, but this is not likely because the specimens are large, well-developed specimens.

In samples in which the Pb elements have such a character, the other elements are large and bowed. These specimens are most abundantly represented in the upper Cathey-Leipers Formation.

Intermediate specimens suggest that the phylogenetic relationship between Plectodina tenuis and some species of Aphelognathus may be closer than is indicated by their separation into different genera.

Occurrence.—Represented in virtually all samples in all sections.

Materials.—9462 specimens.

Figured specimens.—OSU 32681-32686.

Genus PSEUDOBELODINA Sweet, 1979

Type species.—Pseudobelodina kirki (Stone and Furnish)

Pseudobelodina Sweet, 1979, p. 68.

Remarks.—Sweet (1979b) reconstructed and thoroughly described the skeletal apparatus of Pseudobelodina. It is similar to the apparatus of Belodina, but the two genera are differentiated by the number of elements in the apparatus. That is, the apparatus of Pseudobelodina is quadrimembrate, whereas Belodina is trimembrate and includes a rastrate coniform element.
PSEUDOBELODINA INCLINATA (Branson and Mehl, 1933)

Plate V. 9-10

Belodus inclinata Branson and Mehl, 1933, p. 125, 126, Pl. 10, fig. 24.

B. ornatus Branson and Mehl, 1933, p. 124, 125, Pl. 10, figs. 26-28; Glenister, 1957, p. 730, 731, Pl. 87, figs. 7, 9a,b, 10.

B. diminutivus Branson and Mehl, 1933, p. 125, Pl. 10, fig. 27.

B. profundus Branson and Mehl, 1933, p. 125, Pl. 10, fig. 25.

Pseudobelodina inclinata (Branson and Mehl). Sweet, 1979b, p. 69, fig. 6 (11, 15, 16, 22); Sweet, 1981, p. 337-338, Pl. 1, figs. 1-4.

Remarks.—Sweet (1979b) reconstructed and fully described the quadrimembrate skeletal apparatus of the species. In the collection at hand, only Sa and Sb elements occur. The Sa element has anterolateral costae on both the furrowed and unfurrowed sides, and the Sb element has a costa on only the unfurrowed side. The specimens at hand have only two preserved denticles.

Occurrences.—Represented at the top of the upper Catheys-Leipers only in section 61B.

Materials.—2 specimens.

Figured specimens.—OSU 32689-32690.
PSEUDOBELODINA VULGARIS VULGARIS Sweet, 1979

Plate V. 7-8

Pseudobelodina vulgaris vulgaris Sweet, 1979, p. 71, fig. 5 (2, 3, 4).

Belodina profunda (Branson and Mehl). Stone and Furnish, 1959, p. 221, Pl. 31, figs. 16, 17; Ethington and Furnish, 1959, p. 542, Pl. 73, fig. 5; Ethington and Furnish, 1960, p. 270, Pl. 38, figs. 10, 11; Weyant, 1968, p. 38-39, Pl. II, fig. 5; Kohut and Sweet, 1968, p. 1467, Pl. 185, figs. 2, 3; Sweet, Ethington, and Barnes, 1971, Pl. 1, fig. 21; Barnes, 1974, Pl. 1, fig. 22; Barnes, 1977, p. 105, Pl. 4, fig. 11; Harris et al., 1979, p. 21, 22, fig. 5(6).


Remarks.—Pseudobelodina vulgaris vulgaris has a quadririmembrate apparatus like those of P. inclinata and P. kirki. The species is characterized by elements with a much shorter radius of curvature and narrower, higher heel than those of P. inclinata and P. kirki. P. vulgaris vulgaris is distinguished from P. vulgaris ultima by its wider heel.

The specimens at hand represent Sb and Sc elements of the apparatus. Those elements have 2 denticles as does the syntype of the species.

Occurrences.—Represented in the same sample with P. inclinata in section 61B.
Materials.--2 specimens.
Figured specimens.--OSU 32687-32688.

Genus RHIPIDOGNATHUS Branson, Mehl, and Branson, 1951
Type species.--Rhipidognathus symmetricus Branson, Mehl, and Branson, 1951,
Rhipidognathus Branson, Mehl, and Branson, 1951.

RHIPIDOGNATHUS SYMMETRICUS Branson, Mehl, and Branson, 1951
Plate V. 11-16
[Rhipidognathus symmetricus symmetricus]
Rhipidognathus symmetricus Branson, Mehl, and Branson, 1951, p. 10, Pl. 2, figs. 29-37, Pl. 3, fig. 31.
R. paucidentata Branson, Mehl, and Branson, 1951, p. 10, Pl. 2, figs. 18-28, Pl. 3, fig. 30.
R. spuria Branson, Mehl, and Branson, 1951, p. 11, Pl. 2, fig. 17, Pl. 3, figs. 8, 9.
[Rhipidognathus symmetricus discretus]
R. *symmetrica discreta* Bergström and Sweet. Kohut, 1967, p. 69-71, figs. 8, 18, 19, 22; Kohut and Sweet, p. 1473, Pl. 185, figs. 8, 18, 19.


Remarks.—Bergström and Sweet (1966) included angulate and alate elements in the skeletal apparatus of *Rhipidognathus symmetricus*.

Kohut and Sweet (1968) recognized two subspecies of *Rhipidognathus symmetricus, R. symmetricus symmetricus* and *R. symmetricus discretus*. The two subspecies have the same skeletal components assignable to form-species *R. symmetricus, R. paucidentatus*, and *R. curvatus*.

*Rhipidognathus symmetricus discretus* differs from *R. symmetricus symmetricus* in having elements with more robust, discrete, semicircular denticles. In the collections at hand, both subspecies are represented. The apparatus of *R. symmetricus symmetricus* has all three types of elements. Alate elements have two types, one is slightly arched in the base, the other has highly arched base.

*Rhipidognathus symmetricus discretus* is represented in collections at hand as angulate and highly advanced angulate elements.

Occurrences.—Represented from the base of the Bigby-Cannon to the mid-upper Catheys-Leipers. The species is more abundantly represented in the eastern sections of the
Central Basin than in the western one. The eastern side of the Central Basin has been interpreted to have been covered by more restricted, shallower water than the western side of the Basin. Therefore, *R. symmetricus* inhabited a shallower water environment in central Tennessee as was evidently with the case in the Cincinnati Region.

**Material.**—917 specimens.

**Figured specimens.**—OSU 32691-32696.

**Genus RHODESOGNATHUS** Bergström and Sweet, 1966

**Type species.**—Ambalodus elegans Rhodes, 1953

**RHODESOGNATHUS ELEGANS** (Rhodes, 1953)

*Plate III. 24*

**Ambalodus elegans** Rhodes, 1953, p. 278, Pl. 20, figs. 21-25; Lindström, 1959, p. 435, Pl. 3, figs. 20-22;
Sweet, Turco, Warner, and Wilkie, 1959, p. 1040, Pl. 132, fig. 9; Bergström, 1964, p. 11, text-fig. 3;
Barnett, 1965, p. 67, Pl. 1, fig. 3, Pl. 2, fig. 6;
Schopf, 1966, p. 38, Pl. 4, fig. 11.

**A. pulcher** Rhodes, 1953, p. 279, Pl. 20, figs. 38-41;
Lindström, 1959, p. 435, Pl. 3, figs. 14-16.;
Bergström, 1964, text-fig. 4; Barnett, 1965, p. 68, Pl. 2, fig. 12; Schopf, 1966, p. 38, Pl. 4, fig. 12;
Globensky and Jauffred, 1971, p. 53, Pl. 2, fig. 7.

**A. robustus** Rhodes, 1953, p. 279, Pl. 20, figs. 26, 27, 32,
33.


Roscoe (1973) suggested that some of elements of the multielement species Tetraprioniodus delicatus (Branson and Mehl) might have been parts of R. elegans.

In the collections at hand, only 32 specimens of the pastinate element have been identified. All are assignable to the form-species Ambalodus elegans.

Occurrences.—Represented from the Hermitage to the mid-upper Catheys-Leipers.

Materials.—32 specimens.

Figured specimens.—OSU 32663.
Genus WALLISERODUS Serpagli, 1967

Type species.—Acodus curvatus Branson and Mehl, 1947

WALLISERODUS sp.
Plate V. 17

Remarks.—Cooper (1975) reconstructed the skeletal apparatus of Walliserodus. The specimens at hand are acodontiform elements in his terminology. But the elements cannot be identified with certainty although the specimens are similar to elements of W. curvatus (Branson and Branson).

Occurrences.—Represented in the Fernvale Limestone.

Materials.—Only 9 acodontiform elements have been recovered.

Figured Specimens.—OSU 32697.

Genus YAOXIANOGNATHUS An, 1985

Type species.—Yaoxianognathus yaoxiannensis An, 1985

YAOXIANOGNATHUS ABRUPTUS (Branson and Mehl, 1933)
Plate V. 18-19

Ozarkodina (?) abrupta Branson and Mehl, 1933, vol. 8, p. 100, Pl. 6, fig. 11.


44, Pl. 4, figs. 13, 14.

**Rhipidognathus paucidentata** Branson, Mehl, and Branson. Schopf, 1966, p. 72, Pl. 2, fig. 21.


**Remarks.**—When Bergström and Sweet (1966) reconstructed the skeletal apparatus of this species, they included only carminate and angulate elements, the former identical to the holotype of **Ozarkodina? abrupta**. The species was referred tentatively to **Bryantodina** whose skeletal apparatus was not then known.

Sweet (1979a) broadened the concept of **Bryantodina? abrupta** by adding to its skeletal apparatus the elements formerly identified as **Pletodina? posterocostata** Bergström and Sweet and **Cyrtoniodus** sp. nov. Bergström and Sweet.

The apparatus of **Plectodina posterocostata** includes bipennate, two types of alate, and digyrate elements. **Cyrtoniodus** n. sp. was found to be the dolabrate M element.

Therefore, the apparatus of **Bryantodina? abrupta** was septimembrate until 1985 when An proposed a new name for Chinese specimens that seem to be morphologically similar to B.? abrupta.
An (1985) described a species from China that contained in its apparatus bipennate elements, two types of alate elements, as well as digyrate, carminate, and angulate elements. He named the species *Yaoxianognathus yaoxiannensis* An.

The skeletal components of *Yaoxianognathus yaoxiannensis* are closely similar to those of *Bryantodina? abrupta*. The only easily discernible morphologic difference is in the carminate element, which has posteriorly pointing denticles on the anterior process, whereas that of *B.? abrupta* has erect anterior denticles. The other difference is that *Y. yaoxiannensis* is not known to include a dolabrate M element, and is thus seximembrate.

*Yaoxianognathus yaoxiannensis* and *Bryantodina? abrupta* seem not be the same species, but the similar skeletal apparatus and similar morphology indicate that they belong to the same genus.

**Occurrences.**—Represented in the Hermitage and Bigby-Cannon.

**Materials.**—19 specimens.

**Figured Specimens.**—OSU 32099-32100.
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of the eastern Midcontinent, North America.
Unpublished Ph.D. Dissertation, The Ohio State University, Columbus, Ohio, 170p.


Descriptions of the measured sections and their locations are given below. Sections are geographically subdivided into two parts: western sections and eastern sections. The western sections and eastern sections are located on the western and eastern sides of the Nashville Basin, respectively. All sample designations are given in feet above the base of the measured section. 

$T = \text{thickness in feet, } CT = \text{cumulative thickness in feet.}$

**Western Sections**

85KA.--Lebanon Pike Section

This section is located on the east bluff of the Stones River, north of the bridge over this river on Lebanon Pike (State H.W. 70 N) in Nashville, Tennessee. The location of the Lebanon Pike section is in the east-central part of the Nashville East, Tennessee 7 1/2' Quadrangle. (UTM grid, zone 16S; 4,004,500 m N; 533,000 m E) This section includes the upper Hermitage and Bigby-Cannon formations. Section designation is 85KA.

**Bigby-Cannon Limestone:**

<table>
<thead>
<tr>
<th>T</th>
<th>CT</th>
<th>Facies and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>40</td>
<td>(Cannon facies) dark gray, fine-grained packstone; medium bedded.</td>
</tr>
</tbody>
</table>
85KA-40

12 35 [Dove-Colored facies] medium to light gray cryptocrystalline lime mudstone; medium, evenly bedded, brittle.

85KA-35
85KA-32
85KA-29
85KA-26

3 23 [Bigby facies] bluish gray, coarse-grained grainstone; massive bedded, cross bedded; fossil fragments abundant.

85KA-23
85KA-20

11 20 Covered interval

Hermitage Formation:

9 9 [Dalmanella Coquina Member] light to medium-gray fine- to medium-grained wackestone; medium bedded; crowded with the brachipod Dalmanella fertilis.

85KA-9
85KA-4
85KA-0

85KB.—Bellevue Section

This section is located along State H.W. 70 S on the curve of the highway above the Harpeth River, 3.75 miles west of Nine Mile Hill. The location of the section is in the east-central part of the Bellevue, Tennessee 7 1/2' Quadrangle. (UTM grid Zone 16S; 3,992,380 m N; 503,476 m E)
This section includes the upper Catheys-Leipers Formation. Section designation is 85KB.

Upper Catheys-Leipers:

5  35  [Nodular facies] bluish gray fine- to medium-grained wackestone to packstone with shale partings; thin bedded, nodular bedded; fossiliferous.

85KB-35
85KB-30

15  30  Covered interval

15  15  [Nodular facies] medium to dark gray fine- to coarse-grained wackestone with shale partings; thin to medium bedded; fossiliferous.

85KB-15
85KB-8
85KB-5
85KB-2
85KB-0

85KH.—Blind School Section

This section is located behind a state school for the blind, Nashville, Tennessee. The location of the section is in the east part of the Nashville East, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 4,002,375 m N; 531,285 m E) This section includes the upper Hermitage and Bigby-Cannon formations. Section designation is 85KH.

Bigby-Cannon Limestone

10.5  45.5  [Bigby facies] gray, coarse-grained grainstone; medium bedded.
10 35 [Dove-Colored facies] medium light gray to medium gray, weather to a light-gray lime mudstone; medium and evenly bedded; conchoidal fracture; numerous birdseyes.

4 25 [Bigby facies] light to medium gray, medium-grained grainstone; medium bedded.

Hermitage Formation

21 21 [Dalmanella Coquina Member] light to bluish gray, fine- to medium-grained wackestone, packstone; abundant brachiopods.

61A.--Ropers Knob Section

This section is located along east side of Ropers Knob, 1.7 miles northeast of town square in Franklin, Tennessee. The location of the Ropers Knob section is in the west central part of the Franklin, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 3,976,810 m N;
This section includes the upper Hermitage, Bigby-Cannon, and Lower Catheys-Leipers formations. Section designation is 61A; samples collected by Drs. Sweet and Bergström.

**Lower Catheys-Leipers Formation:**

49.8 149.8  [Nodular facies] dark gray to brownish gray, fine-grained to coarse-grained wackestone, packstone with shale partings; thin to medium bedded, nodular bedded; fossiliferous.

61A-149.8
61A-145.2
61A-139.6
61A-134
61A-128.4
61A-122.8
61A-117.2
61A-111.6
61A-106

**Bigby-Cannon Formation:**

42.2 100  [Bigby facies] gray, medium-grained in middle section to coarse-grained in lower and upper section grainstone; medium bedded; fossil fragment abundant.

61A-100
61A-95.5
61A-89.9
61A-84.3
61A-78.7
61A-73.1
61A-69
61A-63.4

5.6 57.8  [Dove-Colored facies] light gray,
cryptocrystalline lime mudstone; birdseyes.

61A-57.8

21.5  52.2  [Bigby facies] gray, coarse-grained grainstone. Lowermost unit contains vuggy, porous light gray, coarse-grained packstone.

61A-52.2
61A-47.2
61A-41.9
61A-36.3

Hermitage Formation:

28.7  28.7  [Dalmanella Coquina Member] light to medium gray, fine-to medium-grained wackestone, packstone; brachiopods are packed together; lowermost unit contains coarse-grained grainstone, which is similar to the Bigby facies of the Bigby-Cannon Formation.

61A-28.7
61A-21.6
61A-16
61A-11.2
61A-5.6
61A-0

61B.—Grassland School Section

This section is located 1 mile northwest of Grassland school, which is on south side of hill bounded on east by US highway 431; southeast and south by Old Hillsboro Road; west by Harpeth River; and north by Cartwrite Creek. The location of the section is in the southeast part of the Bellevue, Tennessee 7 1/2’ Quadrangle. (UTM grid, Zone
This section includes the upper Catheys-Leipers and Fernvale formations. Section designation is 61B; samples collected by Drs. Sweet and Bergström.

Fernvale Limestone:

16.2 247 reddish gray, fine- to coarse-grained packstone.

   61B-247
   61B-230.8

Upper Catheys-Leipers Formation:

9.2 225.2 [Nodular facies] dark gray, fine- to medium-grained wackestone with shale partings; thin to medium bedded, nodular beded; fossiliferous.

   61B-225.2
   61B-219.6

10.2 216 [Nodular facies] light gray, coarse-grained wackestone, porous, fossiliferous.

   61B-216

74.6 205.8 [Nodular facies] dark gray, medium-grained packstone with shale partings; fossiliferous.

   61B-205.8
   61B-200.2
   61B-194.6
   61B-186.6
   61B-181
   61B-175.4
   61B-169.8
   61B-164.2
   61B-158.6
5.6 131.2 [Granular facies] dark gray, fine-grained packstone; medium bedded.
61B-131.2

17.2 125.6 [Nodular facies] medium to dark, medium-grained wackestone; medium, nodular bedded; fossiliferous.
61B-125.6
61B-119.6
61B-114

11.2 108.4 [Nodular facies] dark gray, fine-grained wackestone, packstone; fossiliferous.
61B-108.4
61B-182.8

24.4 97.2 [Nodular facies] gray, fine- to medium-grained wackestone; thin, nodular bedded; fossiliferous.
61B-97.2
61B-91.6
61B-86
61B-78.4

5.6 72.8 [Granular facies] dark gray, fine-grained packstone.
61B-72.8

11.2 61.6 [Granular facies] light to medium gray, coarse-grained packstone; fossiliferous; medium bedded.
61B-61.6
85KF.--Franklin Section

This section is located near the top of the narrow spur overlooking the Harpeth River, east of Hillsboro Pike just north of the place at which it crosses the river about 5 miles northwest of Franklin. Location of the section is in the northeast part of the Leipers, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 3,983,000 m N; 508,860 m E) This section include the upper Catheys-Leipers Formation. Section designation is 85KF.

Upper Catheys-Leipers Formation:

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 41</td>
<td>[Nodular facies] medium gray, fine-grained wackestone; fossiliferous; medium bedded.</td>
</tr>
<tr>
<td>85KF-41</td>
<td></td>
</tr>
<tr>
<td>85KF-21</td>
<td></td>
</tr>
<tr>
<td>19 19</td>
<td>[Nodular facies] yellowish gray, argillaceous, coarse-grained wackestone with shale partings; fossils abundant; nodular bedded.</td>
</tr>
<tr>
<td>85KF-19</td>
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<td>85KF-14</td>
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<td>85KF-8</td>
<td></td>
</tr>
<tr>
<td>85KF-0</td>
<td></td>
</tr>
</tbody>
</table>

86KP.--Peytonsville Section

This section is located in a quarry about 4 miles southeast of the Town square in Franklin, Tennessee. Location of the section is in the north central part of the Bethesda, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone
This section comprises the upper Hermitage, Bigby-Cannon, and lower Catheys-Leipers formations. Section designation is 86KP.

**Lower Catheys-Leipers Formation:**

**21 95** [Nodular facies] medium gray, medium- to coarse-grained wackestone, packstone with shale partings; fossiliferous; thin, nodular bedded.  
86KP-95

**Bigby-Cannon Limestone:**

**17 74** [Bigby facies] medium gray, medium- to coarse-grained grainstone, packstone, lower unit contains fine- to medium-grained grainstone; sparry calcite replaced fossils (brachiopods); thin to medium bedded, nodular bedded.  
86KP-74  
86KP-67  
86KP-62

**35 57** [Dove Colored facies] light to tannish gray, cryptocrystalline lime mudstone; numerous birdseye; conchoidal fracture; fossils except for ostracodes and gastropods rare. Medium, evenly bedded.  
86KP-57  
86KP-52  
86KP-47  
86KP-42  
86KP-36  
86KP-31  
86KP-26  
86KP-25
Upper Hermitage Formation:

22  22  [Dalmanella Coquina Member] light to medium gray, fine- to medium-grained slightly argillaceous wackestone; brachiopods pack together; ripple marks are seen on the top of the formation.

86KP-22
86KP-15
86KP-10
86KP-5
86KP-0

Eastern sections

85KC.—South Carthage Section

This section is located along US Highway 70 N at South Carthage. Location of the section is in the north-central part of the Gordonsville, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 4,011,833 m N; 593,642 m E) This section includes the upper Hermitage and Bigby-Cannon formations. Section designation is 85KC.

Bigby-Cannon Limestone:

25  35  [Cannon facies] medium to dark gray microcrystalline packstone; whole fossils are rare; thin to medium, evenly bedded.

85KC-35
85KC-30
85KC-25
Hermitage Formation:

8  8  [Argillaceous Laminated Limestone facies] light to medium gray, very fine-grained silty limestone interbedded with dark gray thin shale; thin bedded; fossils rare.

85KD.—Dowelltown Section

This section is located along the road climbing eastward from the valley of Dry Fork at the Dry Fork School, about 4 1/2 miles south of the place at which the road along this fork leaves State Highway 26, a mile east of Dowelltown, DeKalb County, Tennessee. Location of the section is in the northeast part of the Gassaway, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 3,981,240 m N; 597,642 m E) This section includes the Cannon facies of the Bigby-Cannon Limestone. Section designation is 85KD.

Bigby-Cannon Limestone:

40  40  [Cannon facies] dark gray, fine-grained packstone, some wackestone; medium bedded.
85KL. — Lafayette Section

This section is located along the State Highway 10, nearly 1 mile southwest of Lafayette, Macon County, Tennessee. Location of the section is in the south-central part of the Lafayette, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 4,040,715 m N; 585,850 m E) This section includes the upper Catheys-Leipers Formation. Section designation is 85KL.

Upper Catheys-Leipers Formation:

20 20 [Nodular facies] dark gray to brownish gray, argillaceous, fine-grained wackestone with shale partings; fossils abundant, mostly brachiopods and bryozoans; thin, nodular bedded.

85KL-20
85KL-10
85KL-5
85KL-0

85KS. — Shop Spring Section

This section is located along a branch on the northeast slope of a hill about 1 1/2 miles northeast of Shop Spring, Wilson County, Tennessee. Section is reached by turning northeastward off State Highway 26 at Shop Spring, crossing prominent topographic divide. Section is west of the road. Location of the section is in south-central part of the Shop Spring, Tennessee 7 1/2'
Quadrangle. (UTM grid, Zone 16S; 3,999,000 m N; 571,547 m E) This section includes the Bigby-Cannon Formation. Section designation is 85KS.

Bigby-Cannon Limestone:

20  23 [Cannon facies] medium, but mostly dark gray, fine-grained packstone; thin to medium bedded.

85KS-23
85KS-18
85KS-15.5
85KS-11
85KS-8

3   3 [Dove-Colored facies] light to medium gray, cryptocrystalline lime mudstone; birdseyes; medium, evenly bedded; no fossils.

85KS-3
85KS-0

85KT.—Temperance Hall Section

This section is along the road, southward up Evans Hollow about 2 1/2 miles south of Temperance Hall, DeKalb County, Tennessee. Location of the section is in the east-central part of the Liberty County, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 3,991,595 m N; 599,476 m E) This section includes the upper Catheys-Leipers Formation and is overlain by the Chattanooga Shale. Section designation is 85KT.

Upper Catheys-Leipers Formation:

30  50 [Nodular facies] medium to dark gray, medium-grained wackestone in lower unit, fine- to
medium-grained wackestone to packstone in upper unit; thin shales intercalate limestone unit; fossils abundant; medium, nodular bedded.

85KT-50
85KT-45
85KT-40
85KT-35
85KT-30
85KT-25
85KT-21

[Dove-Colored facies] medium gray to bluish gray, cryptocrystalline lime mudstone; medium bedded; no fossils; breaks with conchoidal fracture. This facies is identical in lithology to the Dove-Colored facies of the underlying Bigby-Cannon Limestone, but birdseyes are not developed.

85KT-20
85KT-15
85KT-10
85KT-5
85KT-0

85KW.—Woodbury Section

This section is located along the north side of U.S. Highway 70 S and 1 1/2 miles east of Woodbury, Cannon County. Location of the section is in the central part of the Woodbury, Tennessee 7 1/2' Quadrangle. (UTM grid, Zone 16S; 3,963,571 m N; 587,380 m E). This section includes the upper Catheys-Leipers Formation and is overlain by the Chattanooga Shale. Section designation is 85KW.

Upper Catheys-Leipers Formation
65 95  [Nodular facies] medium to dark gray, fine-grained argillaceous wackestone with shale partings; thin bedded shaley limestone in the lowermost unit; thin to medium, nodular bedded; fossiliferous.

85KW-95
85KW-90
85KW-85
85KW-75
85KW-70
85KW-65
85KW-60
85KW-55
85KW-50
85KW-40
85KW-35
85KW-31

31 30  [Dove-Colored facies] dark gray, cryptocrystalline lime mudstone; medium bedded; conchoidal fracture.

85KW-30
85KW-25
85KW-20
85KW-10
85KW-5
85KW-0
APPENDIX B

CONODONT DISTRIBUTION AND FREQUENCY
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APPENDIX E

PERCENTAGE OF Phragmodus, Plectodina, Aphelognathus + Oulodus, AND Rhipidognathus IN SECTIONS FOR RELATIVE-ABUNDANCE ANALYSIS

A Phragmodus
B Plectodina
C Aphelognathus + Oulodus
D Rhipidognathus

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APPENDIX F

CONODONT PLATES
PLATE I


All specimens are from collection 85KW-70.


All specimens are from collection 85KL-10.


All specimens are from collection 61A-28.7.

All specimens are from collection 61B-175.4.

All specimens are from collection 85KW-90.

All specimens are from collection 85KS-11.

All specimens are from collection 85KD-10.

All specimens are from collection 85KH-45.5.
PLATE III

1–3 *Drepanoistodus suberectus* (Branson and Mehl);  
1. homocurvatiform element, 28X, OSU 32085;  
2. suberectiform element, 20X, OSU 32086;  
3. inclinatiform element, 38X, OSU 32087.  
All specimens are from collection 61B-225.2.

4–7, 11 *Icriodella superba* Rhodes; 4. robustiform element (P), 40X, OSU 32088; 5. typicus form element (Sa), 52X, OSU 32089; 6. divaricatiform element (Sb), 64X, OSU 32090; 7. dentatiform element (M), 88X, OSU 32091; 11. icriodelliform element (P), 40X, OSU 32092.  
All specimens are from 85KH-1.

All specimens are from 85KA-40.

Specimens of Pb, M, and Sc elements are from collection 85KL-30, specimens of Pa, Sa, and Sb elements are from 85KW-0.

All specimens are from collection 61B-225.2.

24 *Rhodesognathus elegans* (Rhodes); pastinate element, 64X, OSU 32663. 86KP-10.

28 *Periodon grandis* (Ethington); M element, 66X, OSU 32664. 86KP-22.
PLATE IV


All specimens are from 85KT-21.


All specimens are from 86KP-95.

14-18 Panderodus feulneri (Glenister); 14. asimiliform element, 30X, OSU 32665; 15. falciform element, 44X, OSU 32666; 16. similiform element, 44X, OSU 32667; 17. arcuatiform element, 48X, OSU 32668; 18. tortiform element, 40X, OSU 32669.

All specimens are from 85KW-90.


All specimens are from 85KH-5.

All specimens are from 85KH-1.

29 *Plectodina* sp. aff. *P. aculeata* (Stauffer); Pa element, 32X, OSU 32698. 61A-base.
PLATE V


All specimens are from collection 85KA-20.

7-8 *Pseudobelodina vulgaris vulgaris* Sweet; 7. Sb element, 80X, OSU 32687; 8. Sc element, 80X, OSU 32688.

All specimens are from collection 61B-225.2.


All specimens are from collection 61B-225.2.


All specimens are from collection 85KW-50.

15-16 *Rhipidognathus symmetricus discretus* Bergström and Sweet; All 32X, OSU 32695-32696. All specimens are from 85KW-60.

17 *Walliserodus* sp.; acodontiform element, 48X, OSU 32697.

18-19 *Yaoxianognathus abruptus* (Branson and Mehl); 18. angulate element, 96X, OSU 32099; 19. carminate
element, 60x, OSU 32100.

All specimens are from collection 85KH-5.