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The Ohio State University, Ph.D., 1975
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CONODONT BIOSTRATIGRAPHY IN THE LOWER MIDDLE ORDOVICIAN
OF THE WESTERN APPALACHIAN THRUST-BELTS
IN NORTHEASTERN 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
John B. Carnes, B.A., B.S.

The Ohio State University
1975

Reading Committee:

Approved by

Professor S. M. Bergström, Chairman
Professor W. C. Sweet
Professor Gunter Faure

Department of Geology
and Mineralogy
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VITA

May 8, 1943 .... Born, Canton, Ohio

1965 .... B. A., Kenyon College, Gambier, Ohio.

1970 .... B. S., The University of Akron, Akron, Ohio

1970-1971 Teaching Assistant, Research Assistant, Department of Geology and Mineralogy, The Ohio State University, Columbus, Ohio.

1972-1974 National Science Foundation Trainee, The Ohio State University, Columbus, Ohio.

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INTRODUCTION

In the Great Valley of East Tennessee, Ordovician rocks are exposed within several northeast-trending, imbricate thrust blocks between the Cumberland Plateau and the Unaka Mountains. Facies changes and faunal differences from thrust belt to thrust belt are quite abrupt in many cases and, in some areas, much of the Ordovician succession has been cut out by large-scale thrust faulting. Therefore, lithostratigraphic and biostratigraphic correlation across the strike of the thrust faults has been difficult and often extremely tenuous. A particularly critical problem in this region has been our lack of knowledge about the precise relative ages of several Middle Ordovician rock units that have been collectively referred to as "lower and middle parts of Chickamauga Limestone and equivalent rocks" (Rodgers, 1953).

Rocks in the lowermost part of this interval rest disconformably on Lower Ordovician Knox dolomites and represent a transgressive sequence of mainly carbonates. In the thrust belts on the west side of the Great Valley of East Tennessee, most of the Middle Ordovician succession is limestone. However, in the thrust belts on the east side of the Great Valley, calcareous rocks at the base of the Middle Ordovician succession are overlain by a thick sequence of predominantly clastic deposits, presumably derived from an eastern source developed during an early phase (Blountian disturbance of Kay, 1942) of the
Taconic Orogeny (Rodgers, 1953). Some of the most interesting and long-standing controversies in Southern Appalachian stratigraphy have revolved around interpretation of the age relations between carbonate units in the western thrust belts and units within the carbonate-clastic succession in the eastern thrust belts. Until recently, most attempts at detailed correlation of Middle Ordovician rock units across the Valley of eastern Tennessee have either been primarily lithostratigraphic or based mainly on benthic macrofossils. Biostratigraphic correlations have often been contradicted by lithostratigraphic evidence, with the accompanying argument that the fossils are "facies fossils". This suggests the necessity of establishing a regional biostratigraphy based on geographically widespread, non-benthic fossils.

A few years ago, Bergström (1971a) introduced a detailed Middle Ordovician conodont zonation that has been successfully employed in many areas of Europe and North America, including the easternmost thrust belts in eastern Tennessee (Bergström, 1971a, 1971b, 1973c). However, the use of this zonation has only recently (Carnes and Bergström, 1973) been extended into the western thrust belts, that is, those belts west of the Saltville fault. Difficulties of correlating across this particular fault system are compounded because the Saltville fault not only separates rocks of different lithology in most areas but it also represents a prominent Middle Ordovician biogeographic boundary, separating both macrofossil and microfossil faunas of North American Midcontinent affinity in the western thrust belts from faunas of European character in the eastern thrust belts (Bergström, 1971a, 1973a; McLaughlin, 1973).
The purpose of the present study, which may be considered an outgrowth of Bergström's work, is to evaluate the biostratigraphic age relations, based on conodont evidence, of several Middle Ordovician rock units in key sections within some of the western thrust belts of eastern Tennessee. The author hopes to provide a nucleus of biostratigraphic reference sections for each of the three belts of Middle Ordovician outcrops immediately west of the Saltville fault, the so-called "middle belts" of Rodgers (1953). The rocks dealt with in this report represent the lowermost part of the Middle Ordovician succession in the middle belts and correspond to Chickamauga Limestone Unit 1 and the lower part of Chickamauga Limestone Unit 2 of Rodgers (1953). Rock units in this interval were included in the Marmor, Ashby, and Porterfield Stages by Cooper (1956). Bergström (1971a, 1971b, 1973c) has dealt previously with the type sections of the Marmor and Porterfield Stages and one of the principal goals of the present paper is to establish the relative ages of the rock units that were used as a basis for definition of the Ashby Stage. Further goals of this study are to describe the previously unknown conodont faunas from strata in the western thrust belts of eastern Tennessee and to evaluate possible relationships between the North Atlantic conodont zonation of Bergström (1971a) and the Midcontinent faunal succession of Sweet and others (1971).

As so well summarized by Rodgers (1953), the problems surrounding Middle Ordovician rocks in eastern Tennessee involve subdivision and nomenclature as well as correlation. Within the middle belts, formation boundaries have been drawn and redrawn, and rock units have been named
and renamed, frequently with reference to broadly defined local type areas or with reference to type sections in other areas in the Appalachians. As a result, there are no well-described and precisely defined lithostratigraphic reference sections in the middle thrust belts of eastern Tennessee. Eventually, the Middle Ordovician succession in these belts will have to be examined in detail and new formation names will probably have to be introduced for certain rock units. However, such measures are far beyond the scope of this report. Information presented herein is primarily biostratigraphic, with occasional comments and opinions regarding previous and current schemes of local lithostratigraphic subdivision and nomenclature. No attempt is made to present a comprehensive revision of either lithostratigraphic subdivision or terminology throughout the middle belts.

The stratigraphic part of the present paper is partly a critical analysis, based on conodont biostratigraphy, of correlations made by G. A. Cooper (1956) in "Chazyan and Related Brachiopods", and some of the conclusions drawn here do not agree with those reached by Cooper. Cooper's remarkable study is a landmark in Middle Ordovician biostratigraphy in North America and it provides a model to be tested. Without this model, much of the information about Middle Ordovician stratigraphy that has come to light in the last dozen years in North America might still be a decade or more away. It should be stated from the outset, therefore, that information provided herein is, by no means, intended to minimize the immense contribution "Chazyan and Related Brachiopods" has made to our knowledge of Middle Ordovician brachiopods and stratigraphy in the Southern Appalachians.
THE STUDY AREA

The middle belts of Ordovician outcrop in the Valley of East Tennessee lie between the Saltville fault system on the southeast and the Whiteoak Mountain-Hunter Valley fault system on the northwest (Rodgers, 1953). The area of study for this report (Fig. 1) includes those segments of the three middle belts east of the longitude of Knoxville, in Grainger, Claiborne, Hancock, and Hawkins Counties. The short easternmost belt (Hawkins belt of Safford, 1869), in Hawkins County just west of Rogersville and between Cedar Grove and Mooresburg, is cut off at both ends by the southwest and northeast ends of a recess in the trace of the Saltville fault. The central belt (Copper Creek belt of Prouty, 1946) enters Tennessee west of Clinch Mountain and continues through the study area between Clinch Mountain and Copper Ridge. The westernmost of the three middle belts (St. Paul belt of Prouty, 1946) lies north of Copper Ridge, between the Copper Creek fault and the Hunter-Valley fault, in Raccoon Valley, Hogskin Valley, Dutch Valley, Dry Valley, and the valley of Clinch River. Both the St. Paul and Copper Creek belts extend beyond the study area northeastward into Virginia and southwestward into McMinn County, Tennessee, although the Copper Creek belt is broken at the southwestern end. The Hawkins belt, which is isolated within the study area, is regarded by Rodgers (1953) as a northeastern segment of the broken belt that also
Figure 1. Sketch map of the study area. Middle Ordovician rocks (lower and middle parts of Chickamauga Group) are patterned and major thrust faults are hachured. Sections investigated for the present report are circled. Geology based on Geologic Map of Tennessee, East Sheet (Hardeman, 1966). Terminology from Safford (1869), Prouty (1946), Rodgers (1953).
Figure 1.
lies just northwest of the Saltville fault between the southwestern end of Clinch Mountain and Riddles Store (McMinn County).

Five sections within this area have been selected for biostratigraphic analysis based on conodonts, namely the well-known sections at Eidson, Thorn Hill and Evans Ferry and the previously undescribed sections at Cuba and Lay School (Fig. 1). All these sections are readily accessible, structurally uncomplicated, and most parts of them are well-exposed. Collectively, these sections provide a reasonably comprehensive representation of rock units and lateral facies changes within the lower part of the Middle Ordovician succession in the study area.

Although geographically small, this particular area has been extremely important in previous work on Middle Ordovician stratigraphy and paleontology in eastern Tennessee. The Eidson section (Copper Creek belt) is in the type area for the Eidson Member of the Lincolnshire Formation and the Lay School section is in Hogskin Valley (St. Paul belt), which is the type area for the Ashby Stage and is also the type area for the Hogskin Member of the Lincolnshire Formation (Cooper, 1956). The sections at Thorn Hill (Copper Creek belt) and Evans Ferry (St. Paul belt) provide excellent exposures of rock units included in the Ashby Stage by Cooper (1956) and these two sections, as well as the Eidson section, are frequently referred to in the literature and have often figured as key sections in regional correlation of rock units and in interpretations of facies relationships from thrust belt to thrust belt in eastern Tennessee (Prouty, 1946; B. N. Cooper in Twenhofel and others, 1954; G. A. Cooper, 1956). Also, the Thorn Hill section and
the Cuba section (Hawkins belt) provide excellent exposures of the Holston Formation, which has been the subject of detailed stratigraphic and paleoenvironmental studies in recent years (Ferrigno, 1972; Ferrigno and Walker, 1973; Walker and Ferrigno, 1973a, 1973b; Walker, 1974; Bergström and Carnes, 1975).
Previous Work. Subdivision of the Middle Ordovician succession in
the Valley of East Tennessee has undergone a long and complex history
but is still far from being finalized. In the past hundred years, three
schemes of stratigraphic subdivision have been applied to Middle
Ordovician rock units in the middle belts (Figs. 2, 3). The litho­
stratigraphic terminology used within the study area during the early
part of this century (i.e., Gordon, 1924; Hall and Amick, 1934) was
derived primarily from the work of early geologists for the State of
Tennessee (Safford, 1869; Safford and Killebrew, 1876, 1900), the
U. S. Geological Survey folio mappers of the 1890's (Campbell, 1894,
1899; Keith, 1895, 1896a, 1896b, 1901), and E. O. Ulrich (1911; also
Ulrich and Schuchert, 1902). Some of the terms in this older classifi­
cation were never clearly defined and, in some cases, a type section
was not specified (Rodgers, 1953, p. 68-69). Therefore, the concept
of certain formations has changed considerably from author to author
(i.e., Ulrich, 1911, p. 555-557; Hall and Amick, 1934, p. 161; Butts,
1940, p. 171, 174, 179; B. N. Cooper, 1942; Rodgers, 1953, p. 83).
A great part of this problem is due to the fact that, whereas the
State Geologists and the folio mappers used fossils as tools for
correlation but lithology as the only criterion for defining rock units,
Ulrich (1911) often used fossils, as well as lithology, for recognizing
Figure 2. Schemes of stratigraphic terminology previously applied to lower Middle Ordovician rocks in the St. Paul belt and in the northeastern part of the Copper Creek belt (in the Eidson area).
Figure 3. Schemes of stratigraphic terminology previously applied to lower Middle Ordovician rocks in the southwestern part of the Copper Creek belt (in the Thorn Hill area) and in the Hawkins belt.
formations. In fact, in some areas within the St. Paul and Copper Creek belts, Ulrich (i.e., 1911, p. 556-557) relied on fossils alone to distinguish formations, regardless of lithology. The practice of applying a rock-stratigraphic term to what is essentially a biostratigraphic unit imparts a dual meaning to the concept of a formation. Ulrich's influence in this regard is strongly evident in subsequent studies of Southern Appalachian stratigraphy spanning more than four decades.

Extensive field investigations in the Southern Appalachians during the 1930's and 1940's led some workers to the conclusion that older lithostratigraphic terms such as "Mosheim Limestone", "Holston Marble", "Ottosee Shale" and "Lowville Limestone" are of little use in many areas since the rock units to which these names had commonly been applied are actually stratigraphically recurrent and laterally discontinuous facies (Cooper and Prouty, 1943; B. N. Cooper, 1944, 1945; Cooper and Cooper, 1946; G. A. Cooper, 1956). These workers also recognized that many of the well-known index fossils (Maclurites, Tetradium, Nidulites, Cryptophragmus) so widely used by Ulrich (1911) and other workers (i.e., Butts, 1926, 1933, 1940) to recognize and correlate formations throughout the Southern Appalachians are actually "facies fossils", which have greater stratigraphic ranges than was previously supposed. For these reasons, Cooper and Prouty (1943) proposed a reclassification of lower Middle Ordovician rocks based on the succession in Tazewell County, Virginia. The formations described within the framework of this classification were intended as mapping units (Cooper and Prouty, 1943, p. 862) but many of them, in the manner of Ulrich, are defined on the basis of both
lithological and faunal characteristics. Nevertheless, this new classification has been applied, with some modifications and additions, to rock units in the middle belts of eastern Tennessee (B. N. Cooper, 1943; Prouty, 1946; Twenhofel and others, 1954; G. A. Cooper, 1956).

Rodgers and Kent (1948), uncertain of the precise meaning of older formation names and at the same time evidently unwilling to accept as mapping units for eastern Tennessee new names that were derived from Virginia sections, assigned Middle Ordovician rocks at Lee Valley (Copper Creek belt; see Fig. 1.) to thirteen lithologic units designated by letters A through M. Later, Rodgers (1953) divided the lower part of the Middle Ordovician succession throughout the middle and western thrust belts into two broadly defined but mappable units, Chickamauga limestone Units 1 and 2. Within the study area, recent mappers have also either avoided detailed subdivision (Finlayson, 1964; Hardeman, 1966), or, following Rodgers and Kent (1948), have designated distinctive units only by letters of the alphabet (Finlayson and others, 1965; Swingle and others, 1967; Harris and Mixon, 1970).

**Stratigraphic Succession.** Middle Ordovician strata in the middle belts strike generally northeast and dip regionally to the southeast. The beds are folded, in places overturned, and are locally cut by minor faults. In order to place the rock units described at the selected sections within a regional lithostratigraphic framework, the lithic character and distribution of the various rock units that can be recognized in the study area will first be described briefly. This information is derived in part from the literature, especially Rodgers
(1953), and in part from direct observation. Formation names previously applied to rock units in the middle belts are reviewed below and are summarized in Figures 2 and 3.

In the St. Paul belt, the lowermost Middle Ordovician unit is a few feet to somewhat more than 200 feet thick and includes a wide variety of interbedded rock types, including gray "birdseye" calcilutites (Mosheim lithology); fine-grained, dolomitic or argillaceous limestones; white and gray calcarenites; and brown, red, and green calcareous mudstones and shales. In some areas, the base of this unit is marked by a dolomite- and chert-pebble conglomerate. These beds have been referred to the Blackford Formation by Prouty (1946), to the Tumbez Formation by Cooper (1956) and they correspond to the lower part of Chickamauga Limestone Unit 1 of Rodgers (1953), to Unit A of Harris and Mixon (1970) and, lithologically, to Zone I of McLaughlin (1973). The succeeding unit is 200 to 250 feet thick, although locally it is much thicker (almost 570 feet in Hogskin Valley), and consists of bluish, cherty limestones interbedded with brown, red, and gray, calcareous mudstones and shales. This unit corresponds to the upper part of Chickamauga Limestone Unit 1 of Rodgers (1953), to Unit B1 of Harris and Mixon (1970), and to the lower part of Zone II of McLaughlin (1973). Prouty (1946) included these cherty limestones in the Lincolnshire Formation and Cooper (1956) referred them in part to the Elway Formation and in part to the Eidson Member of the Lincolnshire Formation. The cherty limestones are overlain by a shaly unit (lowermost part of Chickamauga Limestone Unit 2 of Rodgers, 1953) that consists of gray
and brown calcareous mudstones and shales interbedded with nodular, gray and blue, commonly yellowish-weathering and commonly cherty, argillaceous limestones. This unit is almost 250 feet thick in Hogskin Valley (Hogskin Member of the Lincolnshire Formation of Cooper, 1956) but it thins to less than 60 feet to the northeast, in Dry Valley (Unit C of Harris and Mixon, 1970), and it also thins to about 60 feet to the southwest, in Raccoon Valley (upper part of Zone II of McLaughlin, 1973). In the vicinity of Evans Ferry, two beds (each 3 feet thick) of gray, Holston-like calcarenite are present in this interval. Prouty (1946) referred these shaly beds to the Lincolnshire Formation in the southwest part of the St. Paul belt, but he apparently included them in the Thompson Valley Limestone northeast of Evans Ferry. The next unit in the St. Paul belt (also included in the lower part of Chickamauga Limestone Unit 2 by Rodgers, 1953) consists of 100 to 200 feet of generally thick-bedded, fine- to coarse-grained, gray limestone (Thompson Valley Limestone and lower Benbolt of Prouty, 1946; Rockdell Formation of Cooper, 1956; lower part of Zone III of McLaughlin, 1973). In places, this unit contains shaly and nodular limestones and it is difficult to distinguish it from the underlying unit. Locally, the limestones in this interval are very pure and approach Holston lithology (i.e., Unit D of Harris and Mixon, 1970). These generally more pure limestones grade upward into nodular-weathering, more or less argillaceous, gray limestones interbedded with fine-grained, gray and yellow, calcareous clastics. In some areas, thin beds of gray or pink Holston-type calcarenites appear in this interval. This interval is several
hundred feet thick and it corresponds to the upper part of Chickamauga Limestone Unit 2 of Rodgers (1953) and to the upper part of Zone III and lower part of Zone IV of McLaughlin (1973). Prouty (1946) and Cooper (1956) recognized the Benbolt and Wardell Formations in this interval, which is overlain by red beds of the Moccasin Formation.

In the Copper Creek belt, the lowermost unit (lower part of Chickamauga Limestone Unit 1 of Rodgers, 1953) consists of blue and gray, crystalline limestones interbedded with gray, aphanitic limestones (Mosheim lithology); argillaceous dolostones; gray and green, calcareous mudstones and shales; and a few beds of gray calcarenite (Stones River Limestones of Gordon, 1924; Unit A of Rodgers and Kent, 1948; Unit A of Harris and Mixon, 1970). The thickness of this unit is extremely variable, but it is between 75 and 100 feet thick in most places. In the northeastern part of the Copper Creek belt, in the vicinity of Eidson, the rocks in this interval were referred in part to the Blackford Formation and in part to the Lincolnshire Formation (lower part) by Prouty (1946) and to the Marcem Formation by Cooper (1956). Locally, especially in the southwestern part of the Copper Creek belt, the gray, aphanitic limestones that are characteristic of this interval form a discrete unit, which is at most localities at or near the base of the Middle Ordovician sequence. These distinctive calcilutites have been called Mosheim Limestone (Ulrich, 1911; Gordon, 1924; Hall and Amick, 1934) and the Mosheim facies of the Lenoir Formation (Cooper, 1956). This lowermost unit is overlain, in the vicinity of Eidson in the northeastern part of the Copper Creek belt, by a little more than 200 feet of blue, commonly cherty, limestone. These rocks (upper part
of Chickamauga Limestone Unit 1 of Rodgers, 1953) are lithologically similar to the bluish limestones that occupy this same stratigraphic interval in the St. Paul belt and they have been referred to the Lincolnshire Formation (upper part) by Prouty (1946) and to the Eidson Member of the Lincolnshire Formation by Cooper (1956). Southwestward in the Copper Creek belt, this unit maintains a thickness of somewhat more than 200 feet but in Lee Valley, beds of lighter-colored, Holston-type calcarenites are interbedded with the darker limestones (Unit B of Rodgers and Kent, 1948). In the Thorn Hill area about half the stratigraphic thickness of this unit consists of generally thick-bedded, gray, pink, and red, fine- to coarse-grained calcarenites (lower 223 feet of the Holston Marble of Hall and Amick, 1934; Unit B of Harris and Mixon, 1970). Further southwest, in the Powder Springs and Luttrell areas, Holston-type beds predominate over the blue limestones and the thickness of this unit increases locally to over 300 feet (Holston Marble of Gordon, 1924; Unit Ocha of Finlayson and others, 1965; Unit Ocha of Swingle and others, 1967). Prouty (1946) assigned this unit at Thorn Hill to the Benbolt Limestone and Cooper (1956) included these beds in the Lincolnshire Formation. As in the St. Paul belt, the rocks that correspond to Chickamauga Limestone Unit 1 (Rodgers, 1953) are succeeded throughout the Copper Creek belt within the study area by an interval, in most cases between 100 and 200 feet thick, of shaly, nodular limestone (Unit C of Rodgers and Kent, 1948; Unit Ochb of Finlayson and others, 1965; Unit Ochb of Swingle and others, 1967; Unit C of Harris and Mixon, 1970). Like the nodular-limestone unit above the cherty limestones at Evans Ferry, mentioned in the previous
discussion of the St. Paul belt, this interval locally contains beds that approach Holston lithology. In the northeastern part of the Copper Creek belt, Prouty (1946) included these rocks in the Thompson Valley Limestone; further to the southwest, he referred them in part to the Gratton Limestone and in part to the Wardell Limestone. Cooper (1956) assigned these shaly beds to the Hogskin Member of the Lincolnshire Formation. The shaly, nodular limestones are overlain by variously-colored calcarenites of typical Holston lithology (Unit D of Rodgers and Kent, 1948; Unit Ochc of Finlayson and others, 1965; Unit Ochc of Swingle and others, 1967; Unit D of Harris and Mixon, 1970). This unit is between 50 and 100 feet thick in most cases but locally, as in the Thorn Hill area, it attains a thickness of over 400 feet. This "marble" unit, which is stratigraphically the second Holston-like unit in the southwestern part of the Copper Creek belt, was included in the Holston Marble by Hall and Amick (1934) and, judging from thicknesses provided in the literature, other earlier workers also regarded most of these calcarenites, at least at Thorn Hill, as Holston Marble (Bassler, 1907; Ulrich, 1911). Prouty (1946) referred this unit to the Benbolt Limestone in the northeastern part of the Copper Creek belt and to the Wardell Limestone in the southwestern part of the belt. Cooper (1956) included these rocks in the Rockdell Formation. The Holston-like beds are overlain by several hundred feet of argillaceous, nodular limestones and fine-grained, calcareous clastics, which are in turn overlain by the Moccasin Formation (Units E through M of Rodgers and Kent, 1948; Units Ochd through Om of Finlayson and others, 1965; Units Ochd through Om of Swingle and others, 1967; Units EFGH through
L.M. of Harris and Mixon, 1970). Bodies of Holston-type calcarenite occur at several levels in the shaly interval beneath the Moccasin Formation. Some of these calcarenite bodies are lens-like (i.e., Member "a" of Harris and Mixon, 1970) but others can be traced for several miles along strike and they reach in some areas a thickness of about 100 feet (Unit Oche of Finlayson and others, 1965; Unit Oche of Swingle and others, 1967). It is probable that at least some of these calcarenite bodies represent tongues of the exceptionally thick upper "marbles" at Thorn Hill. Earlier workers recognized the Ottosee Shale (Hall and Amick, 1934), or the Lowville Formation (Gordon, 1924), or both the Ottosee and the Lowville (Ulrich, 1911) beneath the Moccasin in this belt. Prouty (1946) referred these pre-Moccasin shaly beds to the Wardell (part), Witten and Bowen Formations and Cooper (1956) recognized the Benbolt, Wardell, Witten and Bowen Formations in this interval.

The lowermost rock unit in the Hawkins belt (lower part of Chickamauga Limestone Unit 1 of Rodgers, 1953) consists of about 75 to 100 feet of light gray, aphanitic limestones interbedded with dark gray and blue, aphanitic to finely crystalline limestones. Gordon (1924) referred to these beds as Stones River Limestones (=Mosheim Limestone and Lenoir Limestone) and locally recognized the Mosheim Limestone as a discrete unit. Cooper (1956, Fig. 3) includes the rocks in this interval in the Lenoir Formation. The next unit (upper part of Chickamauga Limestone Unit 1 of Rodgers, 1953) can be traced throughout the length of the short Hawkins belt and consists of 100 to over 300 feet of thick-bedded, medium- to coarse-grained, gray, pink, and red calcarenites. These rocks are of typical Holston lithology and were
referred to the Holston Marble by Gordon (1924). Cooper (1956, Fig. 3) included these variously-colored, coarsely-crystalline beds in the Lincolnshire Formation. The calcarenites are overlain by several hundred feet of calcareous shales and mudstones interbedded with argillaceous and silty limestones (Chickamauga Limestone Unit 2 of Rodgers, 1953). This shaly interval is overlain by the Moccasin Formation. Beds and lenses of Holston-type calcarenite occur throughout the pre-Moccasin shaly interval in this belt, but nowhere, to the best of my knowledge, do these "marble" beds form thick and laterally persistent units like those that characterize the corresponding stratigraphic interval in the Copper Creek belt. Gordon (1924) included the pre-Moccasin shaly beds, although with reservation, in the Ottosee Shale and Cooper (1956) recognized the Benbolt, Bowen and Witten Formations in this interval.

**Terminology Used in This Report.** As is evident from the foregoing review, there is little agreement about lithostratigraphic nomenclature in the middle thrust belts of eastern Tennessee. The present paper deals mainly with rock units, and with specific sections, which Cooper (1956, Figs. 2, 3, Chart 1) used as reference standards in the construction of his facies diagrams and in the construction of some of the Tennessee columns on his correlation chart. Cooper has allowed considerable lithic latitude in the definition of some of the formations he recognizes in the middle belts but, for the time being, such broad definitions may be warranted. Facies changes occur rapidly within certain stratigraphic intervals, both across the strike of the middle
thrust belts and along strike within these belts. Restricted definition of rock-stratigraphic units in this area would necessitate the introduction of numerous new formation names, which would, at this stage, only create confusion. As discussed in later sections of this paper, some of the formations recognized by Cooper in the middle belts are not distinguishable purely on the basis of lithology. However, the general stratigraphic succession in the lower part of the Middle Ordovician sequence, as represented on Cooper's Chart 1 (Hogskin Valley and Eidson columns) in "Chazyan and Related Brachiopods", can be recognized throughout the St. Paul belt within the study area and throughout much of the Copper Creek belt. Therefore, the stratigraphic terminology used in this paper for the sections at Lay School, Eidson, and Evans Ferry is that of Cooper (1956). Some of these terms are based on type sections in Virginia and there is some question as to whether these particular names are appropriate in eastern Tennessee, but that problem cannot be resolved here. Cooper's terminology can also be used for certain rock units in the upper part of the Thorn Hill section. On the other hand, for units in the lower part of the Thorn Hill section and for units at the Cuba section, such terms as Holston Formation and Mosheim Member are useful as currently defined and, in my opinion, a return to these older names can be justified.

Keith (1895, p. 8) introduced the name Holston Marble, although he did not define it as a formation, for "lentils of variegated marbles of many colors" in the Chickamauga Limestone near Knoxville. Safford and Killebrew (1900, p. 105, 121) proposed the term Knoxville Marble as a formation name for Keith's Holston but this name was not accepted
and Bassler (1907, p. 135-136) later elevated the Holston to formation rank.

The term Mosheim Limestone was introduced by Ulrich (1911, p. 543, Pl. 27) for "a fine grained limestone, in contact with the Knox beneath and the Holston above". Rodgers (1953, p. 69, 77) recognized that rocks of Mosheim lithology occur as isolated lenses and he re-defined the Mosheim as a member of the Lenoir Limestone.

The Holston Formation and the Mosheim Member have been recognized by modern workers over large areas within the eastern thrust belts of eastern Tennessee (i.e., Rodgers, 1953; Hardeman, 1966; Walker and Ferrigno, 1973b; see Bergström, 1973c, for additional references and a summary of lithostratigraphy and terminology in the eastern belts). These units have also been recognized, and the Holston has been mapped, in the middle belts southwest of the present study area (Rodgers, 1952; Cattermole, 1958, 1960, 1966a, 1966b; Milici and others, 1973).

As previously noted, rocks of Holston lithology occur through more than one stratigraphic interval in the Hawkins and Copper Creek belts but the lowermost calcarenite unit, the one that corresponds to the upper part of Chickamauga Limestone Unit 1 of Rodgers (1953), is in most cases the thickest and most persistent. This unit has been traced throughout the Hawkins belt by the author and it has previously been mapped by other workers through much of the southwestern part of the Copper Creek belt within the study area (Unit Ocha of Finlayson and others, 1965; Unit Ocha of Swingle and others, 1967). Furthermore, this lowermost calcarenite unit occupies approximately the same
stratigraphic position (Rodgers, 1953, p. 83), and the available
evidence indicates that it is also approximately the same age (Bergström
and Carnes, 1975), as rocks now referred to the Holston Formation in
the eastern thrust belts.

As currently interpreted in the eastern belts, the Holston Formation
is a complex of anastomosing, reef and near-reef facies (Rodgers, 1953;
rocks in the lowermost calcarenite unit within the Hawkins and Copper
Creek belts are typically Holston lithologically and are probably,
I believe, a marginal part of the Holston reef complex. Therefore, on
the basis of lithology, mappability, stratigraphic position and age,
rock units within the study area that consist predominantly of Holston-
type calcarenite and correspond to the upper part of Chickamauga
Limestone Unit 1 of Rodgers (1953), are herein referred to the Holston
Formation.

Rock units at the Thorn Hill and Cuba sections that have, in the
past, been called Mosheim Limestone conform to descriptions of limestones
referred to the Mosheim Member of the Lenoir Formation by Stephenson
and others (1973) and are lithologically indistinguishable from rocks
of the Mosheim Member in its type area at Mosheim in Greene County.
The blue and gray limestones with which rocks of Mosheim lithology are
commonly associated within the study area, and in some parts of the
middle belts farther southwest (Cattermole, 1958, 1960), are not of
typical Lenoir lithology and are not included in the Lenoir Formation
here. However, the absence of the Lenoir Formation in the area dealt
with here is of no consequence for recognition of the Mosheim Member in this area (American Commission on Stratigraphic Nomenclature, 1970, p. 7, Article 7(b)). Therefore, where limestones of Mosheim lithology occur as a discrete unit, in the stratigraphic interval between the Knox and the Holston Formation, these rocks are herein referred to as the Mosheim Member.
Previous Work. Although the use of fossils for correlation of rock units in Tennessee dates back well over a hundred years (i.e., Troost, 1840; Safford, 1856), detailed biostratigraphic analyses of Middle Ordovician strata in the middle belts of eastern Tennessee have appeared only in relatively recent years and these have been based mainly on the brachiopod faunal succession (Prouty, 1946; Cooper, 1956). However, the reliability of brachiopods, which were probably facies controlled, as tools for correlation in this area has been questioned (Rodgers, 1953; Bergström, 1971a, 1973c; McLaughlin, 1973).

G. A. Cooper (1956, p. 7-9, Chart 1) recognized several successive major brachiopod associations upon which he based many revisions of previous correlations and a new stadial classification for Middle Ordovician rocks in North America. Cooper proposed five new stage names, in stratigraphically ascending order, the Whiterock, Marmor, Ashby, Porterfield, and Wilderness Stages; and he redefined the overlying Trenton Stage. Type areas for four of these stages (all except the Whiterock) are in the Southern Appalachians and type areas for two of them (Marmor and Ashby) are in eastern Tennessee.

Bergström (1971a, 1973c) has re-evaluated the biostratigraphic age relations of several rock units in the Southern Appalachian Valley and has concluded that some of Cooper's (1956) correlations in the easternmost
thrust belts of Tennessee, Virginia, and Alabama are not substantiated by the conodont evidence. For instance, Bergström has been able to demonstrate that certain formations assigned by Cooper to the Ashby Stage in this region are at least partly equivalent in age to rock units that Cooper regarded as Porterfield in age. Carnes and Bergström (1973) have further demonstrated that some of Cooper's correlations in the middle belts of eastern Tennessee are, likewise, not substantiated by the conodont evidence since rocks assigned to the Ashby in Hogskin Valley, the type area of the Ashby Stage, are also of Porterfield age.

Conodont Biostratigraphy. The known configuration of Ordovician conodont faunal provinces, in particular the North American Midcontinent Province and the North Atlantic Province, has recently been reviewed by Bergström (1973a), Barnes and others (1973), and Sweet and Bergström (1974).

Sweet and others (1971) recognized a Middle and Upper Ordovician Midcontinent succession of twelve conodont faunas but those authors state explicitly (p. 166) that the intervals of these faunas are not to be regarded as definitive conodont zones. The multielement taxonomy, stratigraphic distribution, and phylogenetic relationships of many Midcontinent species are not yet sufficiently documented to permit confident establishment of a detailed biostratigraphic zonation. Even so, the faunal succession of Sweet and others (1971) is extremely useful for regional comparison of conodont faunas and, within the limits of its definition, it provides a basis for at least general biostratigraphic orientation. Also, Midcontinent conodonts have proved useful for local
correlation based on analysis of variations in the relative abundance of selected indigenous species through certain stratigraphic intervals (Sweet and others, 1965; Bergström and Sweet, 1966; Kohut and Sweet, 1968; Sweet and Bergström, 1971).

The North Atlantic conodont zonation introduced by Bergström (1971a) is based on several rapidly evolving conodont lineages and, in the past few years, it has been used with consistent success in various parts of Europe and North America (Bergström, 1971a, 1971c, 1973c; Bergström and Drahovzal, 1972; Drahovzal and Neatherly, 1971; Carnes and Bergström, 1973; Sweet and Bergström, 1973; Sweet and others, 1973; Bergström and Carnes, 1975). This conodont zone succession is of special importance because many of the biostratigraphic boundaries within it have been closely tied in with standard graptolite zones (Bergström, 1971b, 1973b).

In eastern North America, the boundary between Middle Ordovician conodont faunas of Midcontinent character and coeval conodont faunas that display a pronounced North Atlantic influence coincides with the trend of the Saltville fault and its extensions (Bergström, 1971a). Invasions of representatives of North Atlantic species deep into areas normally characterized by Midcontinent faunas has been noted for some time in the upper Middle Ordovician and also in the Upper Ordovician (Sweet and others, 1959; Bergström and Sweet, 1966; Schopf, 1966; Sweet and Bergström, 1971; Sweet and others, 1971). However, in the case of lower Middle Ordovician conodont faunas in the Southern Appalachians, the boundary between the Midcontinent Province and the
North Atlantic Province has heretofore appeared sharp and exclusive (Bergström, 1971a, 1973a). The lower Middle Ordovician conodont faunas so far reported by Bergström (1971a, 1973c) from the easternmost thrust belts in the Southern Appalachians are somewhat mixed faunas but do not include species that make it possible to establish relationships between the Midcontinent faunal succession and the North Atlantic zone succession.

The Conodont Collections. For the present study, a collection of almost 21,000 identifiable, amber to dark brown, conodont elements has been obtained by means of acetic acid dissolution, magnetic separation, and heavy liquid separation, from 254 samples of crushed limestone (out of a total of 270 samples — 15 samples were barren and 1 was lost in transit). The weight of individual samples processed ranged from 1 to 3.3 kilograms.

Most of the conodont elements in this collection can be identified as components of some type of multielemental apparatus. However, the status of some elements is unclear in terms of multielement taxonomy and these are designated by a form-taxonomic name included in quotation marks (i.e., "Phragmodus" sp). Also, the assignment of some apparatuses to a particular genus is in doubt and these are also provisionally designated by a name included in quotation marks (i.e., "Aassocus" mutatus).

The majority of the conodont elements in the collections at hand (Table I) represent either common and long-ranging simple-cone genera or are of Midcontinent type and referable to species that are especially characteristic of Faunas 6 and 7 of Sweet and others (1971). However, representatives of several biostratigraphically important North Atlantic
Table I—Conodont species represented in the study area.

<table>
<thead>
<tr>
<th>Genus and Species</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. &quot;Acodus&quot; mutatus (Branson and Mehl)</td>
<td>23</td>
</tr>
<tr>
<td>2. &quot;Acodus&quot; variabilis (Webers)</td>
<td>47</td>
</tr>
<tr>
<td>4. Appalachianathus delicatulus Bergström, et al.</td>
<td>65</td>
</tr>
<tr>
<td>5. Belodella nevadensis Ethington and Schumacher</td>
<td>82</td>
</tr>
<tr>
<td>6. Belodella n. sp. A. Bergström</td>
<td>64</td>
</tr>
<tr>
<td>7. Belodella sp. cf. B. devonica (Stauffer)</td>
<td>5</td>
</tr>
<tr>
<td>8. Belodina monitorensis (Ethington and Schumacher)</td>
<td>653</td>
</tr>
<tr>
<td>9. Bryantodina typicalis Stauffer</td>
<td>63</td>
</tr>
<tr>
<td>10. Curtognathus sp.</td>
<td>206</td>
</tr>
<tr>
<td>11. &quot;Distacodus&quot; falcatus Stauffer</td>
<td>13</td>
</tr>
<tr>
<td>12. &quot;Distacodus&quot; n. sp.</td>
<td>117</td>
</tr>
<tr>
<td>13. &quot;Distocodus&quot;? sp.</td>
<td>2</td>
</tr>
<tr>
<td>14. Drepanocistodus suberectus (Branson and Mehl)</td>
<td>992</td>
</tr>
<tr>
<td>15. Drepanocistodus n. sp.</td>
<td>117</td>
</tr>
<tr>
<td>16. Eoplacognathus elongatus (Bergström)</td>
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</tr>
<tr>
<td>17. Eoplacognathus sp.</td>
<td>2</td>
</tr>
<tr>
<td>18. Erismodus sp. 1</td>
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</tr>
<tr>
<td>19. Erismodus sp. 2</td>
<td>75</td>
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<tr>
<td>20. Leptochirognathus sp.</td>
<td>13</td>
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<tr>
<td>22. New Genus B. n. sp</td>
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</tr>
<tr>
<td>23. &quot;Oistodus&quot; pseudoabundans (Schopf)</td>
<td>25</td>
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<tr>
<td>24. &quot;Oistodus&quot; sp. cf. &quot;o.&quot; venustus Stauffer</td>
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<td>25. Paltodus? sp.</td>
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<td>26. Panderodus sp. cf. P. gracilis (Branson and Mehl)</td>
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<tr>
<td>27. Panderodus sp. A cf. P. panderi (Stauffer)</td>
<td>1342</td>
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<tr>
<td>28. Panderodus sp. B cf. P. panderi (Stauffer)</td>
<td>6</td>
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<tr>
<td>29. Periodon grandis (Ethington)</td>
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<td>30. Periodon sp.</td>
<td>3</td>
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<td>31. Phragmodus flexuosus Moskalenko</td>
<td>498</td>
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<tr>
<td>32. Phragmodus inflexus Stauffer</td>
<td>1534</td>
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<tr>
<td>33. &quot;Phragmodus&quot; sp.</td>
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<td>34. Plectodina aculeata (Stauffer)</td>
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<tr>
<td>35. Plectodina? joachimensis? (Andrews)</td>
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<td>36. Plectodina n. sp.</td>
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<td>37. Plectodina?</td>
<td>73</td>
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<td>38. Polycaulodus sp.</td>
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<td>39. Polyplacognathus sweeti Bergström</td>
<td>1301</td>
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<tr>
<td>40. Prioniodus gerdae Bergström</td>
<td>119</td>
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<tr>
<td>41. Prioniodus variabilis Bergström</td>
<td>650</td>
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<tr>
<td>42. Prioniodus variabilis-Prioniodus gerdae transition forms</td>
<td>304</td>
</tr>
<tr>
<td>43. Prioniodus sp.</td>
<td>91</td>
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<tr>
<td>44. Protopanderodus varicostatus (Sweet and Bergström)</td>
<td>309</td>
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<tr>
<td>45. Pygodus anserinus Lamont and Lindström</td>
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</tr>
<tr>
<td>46. &quot;Roundya&quot; bispicata Sweet and Bergström</td>
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</tr>
<tr>
<td>47. Triangulodus sp. cf. T. brevibasis (Sergeeva)</td>
<td>667</td>
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<tr>
<td>48. Walliserodus trigonius (Schopf)</td>
<td>4</td>
</tr>
<tr>
<td>49. Walliserodus sp. cf. W. trigonius (Schopf)</td>
<td>1188</td>
</tr>
<tr>
<td>50. Walliserodus tuatus (Hamar)</td>
<td>19</td>
</tr>
</tbody>
</table>

20,844
species have also been recovered and the occurrence of these forms makes it possible to evaluate the relative age of several Middle Ordovician rock units within the study area in terms of the North Atlantic conodont zonation. Species of importance in this regard are those that index the upper part of the *Pygodus anserinus* Zone and the lower part of the *Amorphognathus tvaerensis* Zone, namely, *Pygodus anserinus* Lamont and Lindström, *Polyplacognathus sweeti* Bergström, *Prioniodus variabilis* Bergström, *Prioniodus gerdae* Bergström, and *Eoplacognathus elongatus* (Bergström). The distribution of representatives of *Prioniodus* is especially important because the upper boundary of the *Prioniodus variabilis* Subzone of the *Amorphognathus tvaerensis* Zone, which is defined by the evolution of *P. variabilis* into *P. gerdae* (Bergström, 1971a), can be recognized in at least one section in all three of the middle thrust belts. Based on the distribution of key species in the sections discussed below, it is also possible, at least in general terms, to evaluate the relative age of the base of Midcontinent Fauna 7 of Sweet and others (1971) in terms of the North Atlantic zonation.
Considerable efforts have been made to locate a number of stratigraphically representative, well-exposed, and suitably located sections that can serve as reference sections for the various parts of the study area. Five such sections have been studied in detail. The rock units dealt with in this paper have been sampled throughout their exposed stratigraphic extent in each of these sections. In some cases, each exposed bed was sampled. In the case of exceptionally thick or continuously exposed units, samples were taken at regular intervals, usually every 20 feet, and especially productive or biostratigraphically critical intervals were later re-sampled at much thinner intervals (1 - 5 feet). For this reason, the sample numbers that are provided for orientation at the right side of the stratigraphic columns in Figures 4 through 8 are not consecutive in all cases. Details of the stratigraphic and geographic distribution of conodont species within the study area, as far as has been determined in the course of the present study, are presented below. Sample-by-sample numerical data are provided in Appendix B.
Lay School Section

Location. The Lay School section (Fig. 4) is in Hogskin Valley, Grainger County, Tennessee (SW 1/4 east-central rectangle, Powder Springs 7-1/2' Quadrangle, Tenn. Div. Geol. Map GM 154-SW, Finlayson and others, 1965). The section begins on the Lay Farm, on the southeast slope of Hinds Ridge, and extends across Hogskin Creek to the road intersection just southeast of Lay School. Lay School is on the Hogskin Valley road, 1.7 miles northeast of the Union Co.-Grainger Co. line and 0.2 mile northeast of Mt. Eager Church. A locality map and a detailed description of this section are provided in Appendix A.

Cooper (1956, p. 8) defined the Ashby Stage as including the Elway Formation and the Lincolnshire Formation in Hogskin Valley. The name Ashby is taken from a road intersection on Hogskin Creek on the Maynardville 30' Quadrangle. Although Cooper (1956, p. 394, 403, 482, 565, 566, 580, 598, 659, 662, 731, 845, 869, 893) lists several collecting localities for Ashby brachiopods in the vicinity of this road intersection, he does not specify a particular type section for the Ashby stage. The collecting localities listed by Cooper (3/4 mi., 0.8 mi., 2.1 mi., and 2.65 mi. southwest of Mt. Eager Church; 1/2 mi. southwest of Beeler Cemetery) provide poor exposures of rocks in the Ashby interval. On the other hand, the Lay School Section, which is 3.3 miles northeast of the Ashby road intersection, provides almost continuous hill-side and road-cut exposures of the Ashby formations. Since this section is readily accessible and provides better exposures of Ashby rocks than any other section in this part of Hogskin Valley,
Figure 4. Stratigraphic distribution of conodonts in the Lay School Section, Hogskin Valley. In the case of rock units of variable lithology (i.e., Tumbez, Hogskin, Benbolt), lithologic patterns are drawn schematically and do not represent the true detailed stratigraphic distribution of different rock types. Sample numbers are on the right side of the stratigraphic column (Appendix A); unit numbers are on the left side (Appendix A).

Gray and/or pink calcarenite.

Fine-grained, gray calcilutite (Mosheim-type).

Dark, cherty limestone.

Argillaceous and/or nodular, dark limestone.

Mudstone

Dolomite and dolomitic limestone.

Chert- and dolomite-pebble conglomerate.

Covered interval.
it is here proposed that the Lay School section be regarded as the type section of the Ashby Stage.

Stratigraphic succession. The lowermost rock unit in the Middle Ordovician succession at this locality, the Tumbez Formation, is 229 feet thick but is poorly exposed. The Knox-Tumbez contact is marked by a chert- and dolomite-pebble conglomerate, the exposed thickness of which is 6 feet. The Tumbez is characterized by a variety of rock-types, including Mosheim-type calcilutites; fine-grained, gray calcarenites; gray dolomitic limestones; mottled red-and-green, argillaceous limestones; brown, slabby, calcareous mudstones; and a few 1-inch to 6-inch thick black-chert beds. The dolomitic limestones occur mainly in the lower part of the formation, as far as can be determined from available outcrops, and the gray calcarenites are concentrated in the upper part.

The Tumbez Formation is overlain by 563 feet of dark blue and blue-gray, gray-weathering, cherty limestones interbedded with gray, calcareous mudstones. Cooper (1956, Chart 1) recognized the Elway Formation and the Eidson Member of the Lincolnshire Formation in this interval. Although these cherty limestones have been closely examined on four separate occasions, in the Lay School section and in other sections closeby, the distinction between the Elway Formation and the Eidson Member on the basis of lithology is not apparent. I suspect that the boundary between the Elway and the Eidson was drawn on the basis of fossils and am of the opinion that the entire thickness of blue, cherty limestone in this area should be included in a single rock-stratigraphic
However, because this area is of special importance in Cooper's (1956) scheme of Middle Ordovician stadial classification, the stratigraphic terminology is best left unaltered as far as is practical. Therefore, the dark, cherty limestones overlying the Tumbez Formation at the Lay School section are here referred to as the Elway-Eidson "Formation".

The Elway-Eidson "Formation" is overlain by the Hogskin Member of the Lincolnshire Formation, which consists of 244 feet of more or less argillaceous, nodular, yellowish-weathering, gray limestones with shaly interbeds.

The Hogskin Member is succeeded by the Rockdell Formation, which is 376 feet thick and consists predominantly of gray-weathering, argillaceous, gray limestones — mainly calcilutites — interbedded with brown and gray shales and mudstones. Beds of yellowish-weathering, nodular limestone (Hogskin lithology) are also present in this interval and green and red-brown mudstones and shales appear in the upper one-third of the unit. As mentioned previously, Cooper interpreted the Rockdell Formation in eastern Tennessee very broadly. At the Lay School section, the Rockdell Formation, as here interpreted, includes beds of nodular limestone that are identical lithologically to the nodular beds here assigned to the Hogskin Member. Although Hogskin Valley is evidently the type area for the Hogskin Member, Cooper (1956, p. 66) does not specify a type section in his description of the Hogskin Member, nor does he mention the thickness of the unit. Since some beds in the interval here included in the Rockdell are of Hogskin lithology,
selection of a Hogskin-Rockdell contact, which is also the upper boundary of the Ashby Stage, is largely arbitrary. The top of the Hogskin Member is placed at the level at which gray-weathering, non-nodular limestone becomes dominant over yellowish-weathering, nodular limestone.

The Rockdell is overlain by an undetermined thickness of brown mudstone and shale with thin, argillaceous, limestone interbeds. Most of the interval above the Rockdell is covered and the beds that are exposed have apparently been deformed. Cooper (1956, Chart 1) referred these beds to the Benbolt Formation.

Conodont Biostratigraphy. Samples from the lower part of the Tumbez Formation have yielded poor conodont collections (up to 13 spms/kg) but the largest and most diverse collections of the entire Lay School section have been obtained from beds of fine-grained, gray calcarenite in the upper part of the Tumbez (up to 484 spms/kg). Conodont faunas in this interval are dominated by representatives of Midcontinent species, especially Phragmodus inflexus and Plectodina n. sp. Phragmodus inflexus, the index species of Midcontinent Fauna 7 and the most abundantly represented species in the Tumbez, first appears 143 feet above the base of the Tumbez. Panderodus sp. cf. P. gracilis, Walliserodus sp. cf. W. trigonius, and Drepanoistodus suberectus are also prominent constituents of the upper Tumbez faunas whereas the other species listed in Fig. 4 are relatively sparsely represented.
Specimens of several North Atlantic species are also present in the upper Tumbez, namely *Periodon grandis*, *Protopanderodus varicostatus*, *Walliserodus tuatus*, and, most significantly, *Prioniodus variabilis* (late form) and *Prioniodus gerdae* (early form). As discussed in the systematics part of this report, elements here referred to *P. variabilis* (late form) are not typical of *P. variabilis* but are characterized by features suggestive of a trend toward development of a postero-lateral process. Likewise, elements that are here referred to *P. gerdae* (early form) display features that are intermediate between specimens of *P. variabilis* (late form) and typical specimens of *P. gerdae*.

Bergström (1971a, p. 99) has defined the top of the *Prioniodus variabilis* Subzone of the *Amorphognathus tvaerensis* Zone as the level at which *P. variabilis* evolved into *Prioniodus gerdae*. At the Lay School section, *P. gerdae* (early form) first appears, in association with representatives of *P. variabilis* (late form), 149 feet above the base of the Tumbez; and, on this basis, the top of the *P. variabilis* Subzone of the *A. tvaerensis* Zone is drawn in this section at a level 149 feet above the base of the Tumbez Formation. The base of the *P. gerdae* Subzone, which is defined as the level at which typical representatives of *P. gerdae* appear (Bergström, 1971a, p. 100), cannot be recognized in this section. Elements of *P. gerdae* (early form) occur 195 feet above the base of the Tumbez and ramiform elements similar to those in the *P. gerdae* (early form) apparatus occur in the uppermost Tumbez, in the lower Elway-Eidson and in the lower Hogskin. Whether the elements in the uppermost Tumbez, Elway-Eidson, and Hogskin represent *P. gerdae* (early form) or typical *P. gerdae* cannot be
determined without the diagnostic amorphognathiform elements. However, it is most probable that at least the specimens in the lower Hogskin represent typical *P. gerdae*.

Conodont collections from post-Tumbez formations in the Lay School section are less rich numerically and also less diverse than those of the upper Tumbez. Collections of fair abundance have been obtained from a few beds in the lower Elway-Eidson (150-300 spms/kg), the lower Hogskin (about 100 spms/kg), and the upper part of the Rockdell (100-200 spms/kg) but the majority of the samples yield fewer than 100 specimens per kilogram, most commonly fewer than 50 specimens per kilogram.

Except for a single specimen of *Walliserodus tuatus* in the lower Elway-Eidson, none of the North Atlantic species that occur in the Tumbez can be positively identified in post-Tumbez formations. However, well-preserved specimens of *Eoplacognathus elongatus* are present from 13 feet to 18 feet above the base of the Elway-Eidson. A small, presumably juvenile, ambalodiform element that probably represents a species of *Eoplacognathus* is also present in the lower Hogskin but this specimen is not identifiable. *Eoplacognathus elongatus* is known to range from the uppermost part of the *Pygodus anserinus* Zone into the lowermost part of the *Prioniodus gerdae* Subzone of the *Amorphognathus tvaerensis* Zone (Bergström, 1971a, p. 100, 138). Therefore, since *P. gerdae* (early form) occurs in the Tumbez, the lowermost part of the Elway-Eidson "Formation" is no younger than the lower part of the *P. gerdae* Subzone and the base of the *P. gerdae* Subzone is probably within the uppermost Tumbez or the lower Elway-Eidson.
Throughout the Elway-Eidson, Hogskin, and lower Rockdell, conodont collections are dominated by simple cones (Drepanoistodus, Panderodus, Triangulodus, Walliserodus) and by representatives of Plectodina n. sp. which is consistently the most abundantly represented species. Hyaline forms (Erismodus, Polycaulodus, etc.) occur throughout this interval but rarely constitute more than a small percentage of the collection in any one sample. Specimens of Appalachignathus delicatulus occur with relative consistency, but in small numbers, in the lower Elway-Eidson and in the lower Hogskin.

In contrast to collections from the upper Tumbez, which are characterized by abundant representatives of Phragmodus inflexus, elements of Phragmodus species occur intermittently in the post-Tumbez formations and are present only in small numbers, most commonly less than 10 specimens per kilogram, even in the more productive samples. Phragmodus inflexus is not present in the lower part of the Elway-Eidson but representatives of Phragmodus flexuosus appear and range through the lower 154 feet of the "formation". Phragmodus inflexus re-appears in the lower part of the Hogskin Member, although elements that may be assignable to this species occur much lower, and ranges into the upper Rockdell. The monotony of the conodont faunas in the Elway-Eidson through lower Rockdell interval is broken somewhat by the appearance, primarily in the Hogskin, of representatives of Belodella nevadensis, Belodina monitorensis, "Distacodus" falcatus, Drepanoistodus n. sp., and "Oistodus" pseudoabundans.

The character of upper Rockdell collections is quite different. Representatives of Plectodina aculeata appear 214 feet above the base
of the Rockdell (questionable specimens occur a little lower), as does the Oulodus-like Plectodina? sp. At this same level, hyaline conodont elements (Erismodus, Polycaulodus, etc.) become prominent constituents of the collections (50% +). Plectodina? sp. is short-ranging and poorly represented but P. aculeata continues through most of the Rockdell and is especially abundant in the interval from 224 to 236 feet above the base of the Rockdell. Plectodina n. sp. continues, in association with P. aculeata, up to a level 236 feet above the base of the Rockdell. Representatives of P. aculeata and a few simple cones occur above this level but most samples are dominated by hyaline forms.

**Remarks.** The distribution of key North Atlantic faunal elements in this section demonstrates that the base of the Elway-Eidson "Formation", hence the base of the Ashby Stage, is younger than the top of the Prioniodus variabilis Subzone of the Amorphognathus tvaerensis Zone but that it is no younger than the lower part of the Prioniodus gerdae Subzone of the A. tvaerensis Zone. The age of the upper boundary of the Hogskin Member, which is also the upper boundary of the Ashby Stage, cannot be determined in this section in terms of the North Atlantic conodont zonation. However, it can be stated, on the basis of the range of Phragmodus inflexus, that this boundary is within the interval of Midcontinent Fauna 7.

No biostratigraphic significance is attached here to the appearance of Plectodina aculeata in the upper part of the Rockdell Formation. Plectodina aculeata is reported to range from the base of Midcontinent Fauna 7, which is within the Tumbez at the Lay School section, through
the interval of Fauna 8 (Sweet and others, 1971). Furthermore, Dr. S. M. Bergström has provided me with several collections of conodont elements from the Lenoir City section (Bergström, 1973c, p. 269, Fig. 3) and in one of these collections elements that I interpret as representatives of *P. aculeata* occur in association with elements that index the *Pygodus serrus* Zone, an interval much older than even the upper part of the Tumbez at Lay School. The appearance of representatives of *P. aculeata* in relatively large numbers in this section (up to 135 spms/kg in Units 41 and 42 of the measured section) coincides with an increase in the relative abundance of hyaline forms and this occurs in a stratigraphic interval that is characterized by especially argillaceous limestones, much mudstone, and some reddish shale. Raring (1972) reports that the appearance of specimens of *P. aculeata* also coincides with a relative increase in the number of hyaline forms in the upper part of the Valcour Formation in the Lake Champlain area. Sweet and Bergström (1972, p. 35) have speculated that hyaline forms may have been adapted primarily to shallow-water environments. It is probable that the *P. aculeata*-hyaline element association represents a particular type of shallow-water conodont "recurrent species association", in the sense of Bergström and Carnes (1975).

Cooper (1956, Chart 1) correlated the Tumbez Formation in Hogskin Valley with beds he recognized as Tumbez beneath the Lenoir Formation s.s. at Friendsville, Tennessee, which is the type section of the Marmor Stage (Cooper, 1956, p. 8). Cooper (1956, Chart 1) apparently did not recognize what he regarded as a Lenoir brachiopod fauna in
Hogskin Valley so he postulated a stratigraphic gap, representing the upper part of the Marmor Stage, between the Tumbez and the Elway-Eidson "Formation". However, there is no evidence in the Lay School section for a disconformity between the Tumbez and the Elway-Eidson. At the best exposures of the contact that could be found, the transition from calcareous mudstones and argillaceous limestones in the uppermost Tumbez to cherty limestones of the Elway-Eidson appears to be gradational. Likewise, there is no apparent gap in the conodont fossil record since the upper Tumbez is younger than the top of the Prioniodus variabilis Subzone whereas the lower Elway-Eidson is no younger than the lower part of the succeeding Prioniodus gerdae Subzone. Since there is neither lithostratigraphic or biostratigraphic evidence for hiatus at this section, it is concluded that no stratigraphic gap exists between the Tumbez Formation and the Elway-Eidson "Formation" at the type section of the Ashby Stage.

Bergström (1971a, 1971b, 1973c) has shown that the unit that Cooper (1956) called Tumbez at Friendsville is no younger than the lowermost part of the Pygodus serrus Zone. As demonstrated here, the upper part of the Tumbez at Lay School is considerably younger than this, well within the Amorphognathus tvaerensis Zone. Therefore, although the age of the base of the Tumbez at Lay School has not been determined, it is most likely that the entire Tumbez at Lay School is younger than the rocks Cooper referred to the Tumbez at Friendsville. Consequently, it is evident that the brachiopod assemblage that Cooper (1956) used to recognize lower Marmor equivalents is diachronous since it occurs in
rocks in Hogskin Valley that are much younger than rocks that contain this assemblage at Friendsville.

Furthermore, Bergstrom (1971a, 1971b, 1973c) has shown that the top of the Lenoir Formation s.s., which is the top of the Marmor Stage (Cooper, 1956, Chart 1), is also within the Pygodus serrus Zone at Friendsville. It has been shown here that the base of the type Ashby is younger than the top of the Prioniodus variabilis Subzone and available evidence indicates that the top of the P. variabilis Subzone at Friendsville is no lower than the lower part of the Holston Formation (Bergstrom, 1971a, 1971b, 1973c; Bergstrom and Carnes, 1975), which is separated from the Lenoir Formation s.s. by the Arline "Formation" of Cooper (1956). Therefore, it is clear that there is a considerable post-Marmor, pre-Ashby stratigraphic interval in the Southern Appalachians, which includes rocks that correspond to the upper part of the P. serrus Zone, the Pygodus anserinus Zone, and the P. variabilis Subzone of the Amorphognathus tvaerensis Zone.

Evans Ferry Section

**Location.** The Evans Ferry section (Fig. 5) is in the road cut along U. S. Highway 25E just east of a broad meander in the Clinch River and 1 mile north of Indian Creek on the Howard Quarter Quadrangle in Grainger County (SW 1/4 south-central rectangle, USGS Map GQ-842, Harris and Mixon, 1970). This excellent section was exposed during construction of a segment of road that cuts out the sharp curve in Highway 25E
Figure 5. Stratigraphic distribution of conodonts in the Evans Ferry section. For additional explanation, see explanation of Figure 4.
Stratigraphic Succession. Harris and Mixon (1970) recognized several mappable units in the Evans Ferry area and designated these units, in accordance with Rodgers and Kent (1948), by letters of the alphabet. The units cited below parenthetically are those of Harris and Mixon (1970). The Evans Ferry Section is in the St. Paul belt, directly along strike from the Lay School section, and the same general succession recognized by Cooper (1956) in Hogskin Valley can also be recognized at Evans Ferry.

The lowermost Middle Ordovician rock unit at this section (Unit A) is largely concealed but ledges of Mosheim-type calcilutite are exposed on the north side of a small creek that transects the lower part of the Evans Ferry section and empties into the east side of Clinch River. As described by Harris and Mixon (1970), this unit is similar to the Tumbez Formation in Hogskin Valley and therefore it is also referred to the Tumbez herein. Based on field approximations and map calculations, the poorly exposed Tumbez at Evans Ferry is approximately 65 feet thick.

The Tumbez is overlain by 195 feet of mainly dark blue and blue-gray, cherty limestone with intercalations of calcareous shale and mudstone (Unit B₁). Shaly beds are especially prominent toward the base of the unit. Limestones in this unit are lithologically indistinguishable from limestones of the Elway-Eidson "Formation" in Hogskin Valley and are also identical to rocks of the Eidson Member in its type area near Eidson. These same dark limestones have also been
observed northeast in the St. Paul belt, in the area just north of Frog Level, which is almost directly across the strike of the Copper Creek fault from Eidson. I believe that these dark, cherty limestones at Evans Ferry and Frog Level, together with those of the Elway-Eidson "Formation" in Hogskin Valley and the Eidson Member at Eidson, represent a single rock-stratigraphic unit. Cooper (1956, p. 396, 566) reports Elway brachiopods from the Evans Ferry section but, as in Hogskin Valley, the Elway Formation cannot be distinguished lithologically at Evans Ferry. The name Elway was retained at the Lay School section to prevent misunderstanding about the lower boundary of the Ashby Stage. At the Evans Ferry section, the entire thickness of dark, cherty limestones that overlies the Tumbez is here referred to the Eidson Member.

The Eidson Member is succeeded by the Hogskin Member, which is 53 feet thick in this section and consists of thin-bedded, argillaceous and nodular limestone interbedded with gray shales and mudstones (Unit C). Two beds of gray calcarenite, each 3 feet thick and separated by 4 feet of shaly limestone, occur near the middle of this unit.

The Hogskin Member is overlain by 199 feet of gray calcarenite, which is pinkish through some intervals and very similar to Holston lithology. Although these rocks are unlike the argillaceous calcilutites that comprise much of the Rockdell in Hogskin Valley, they occupy the same stratigraphic position and are similar to rocks that Cooper (1956) included in the Rockdell in the Copper Creek belt. Therefore, they are here referred to the Rockdell Formation.

The Rockdell is overlain by several hundred feet of shale and limestone, the lower 430 feet of which (Unit EFGH) would probably be
referred to the Benbolt Formation in Cooper's (1956) terminology. The Evans Ferry section was sampled to a level 6 feet below the base of Member "a" of Harris and Mixon (1970).

**Conodont Biostratigraphy.** Samples from the lower Eidson in this section have yielded from 100 to 800 well-preserved specimens per kilogram, whereas samples from the upper Eidson and higher units yield fewer than 100 specimens, most commonly fewer than 50 specimens, per kilogram.

Conodont collections from the Evans Ferry section are essentially the same, in terms of species represented, as those from the post-Tumbez formations at Lay School, with the exception that the *Plectodina aculeata*-hyaline genera association does not appear at the Evans Ferry section, at least within the interval sampled. Another noticeable difference is that hyaline forms are relatively more abundant in the lower Eidson at Evans Ferry than in the lower Elway-Eidson at Lay School (Appendix B).

The numerically rich conodont collections from the lower part of the Eidson are primarily from medium-gray, medium-grained calcarenites and are dominated by representatives of *Plectodina n. sp.*, species of *Phragmodus*, and hyaline forms. Representatives of *Phragmodus inflexus* occur only in the lower part of this section, at levels 12 feet and 32 feet above the base of the Eidson Member. Elements of *Phragmodus flexuosus* appear 12 feet above the base of the Eidson and range upward at least to a level 33 feet above the base of the Hogskin Member.
Elements of *Plectodina* n. sp. and elements of species of *Phragmodus* occur together in approximately equal numbers through the lower 54 feet of the Eidson but above this level elements of *Phragmodus* are relatively rare. Collections from the upper Eidson and higher units are characterized mainly by simple cones, which are also common in the lower Eidson, and by elements of *Plectodina* n. sp., which is generally the most abundantly represented species in any single sample.

North Atlantic species are poorly represented at this locality. A single specimen of *Walliserodus tuatus* has been recovered from the lower Eidson and ramiform elements of an unidentified species of *Prioniodus* occur in the lower Eidson (1 specimen) and in the upper Rockdell (4 specimens). Two specimens of *Eoplacognathus elongatus* occur in a single sample 48 feet above the base of the Eidson Member. This does not permit precise classification of the lower Eidson in terms of the North Atlantic conodont zonation but it can at least be stated that the Tumbez Formation and the lower part of the Eidson Member at Evans Ferry are no younger than the lower part of the *Prioniodus gerdæ* Subzone.

**Eidson Section**

**Location.** Cooper (1956, p. 62) notes that the type section of the Eidson Member of the Lincolnshire Formation "is just north of Eidson". The section described here is 0.5 mile northeast of Eidson in Hawkins County, in the field on the southeast side of Tennessee Route 70 (south
Stratigraphic Succession. Rocks in this section (Fig. 6) are mostly poorly exposed but exposures are sufficient to identify most of the units Cooper (1956, Chart 1) recognized in the lower part of the Middle Ordovician succession in the vicinity of Eidson.

A covered interval between the highest exposure of Knox dolomite and the lowest exposure of Eidson limestone represents a stratigraphic thickness of 133 feet and corresponds to the interval Cooper (1956) referred to the Marmell Formation. Several ledges of gray, Holston-like calcarenite are exposed within this interval in the field south of Route 70 and east of the gravel road to Eidson.

The Eidson Member consists of 222 feet of dark, blue and gray, cherty, calcilutites and calcarenites. Most of the lower 75 feet of this unit is concealed.

The Eidson Member is succeeded by a covered interval, which represents a stratigraphic thickness of 130 feet and is here assumed to correspond to the argillaceous, less-resistant limestones of the Hogskin Member. Two ledges of pink and gray, Holston-type calcarenite are exposed in the lower part of this interval.

The Hogskin Member is overlain by the Rockdell Formation, which is 194 feet thick and consists of pink and gray calcarenites of Holston lithology. The Rockdell is overlain by an undetermined thickness of
Figure 6. Stratigraphic distribution of conodonts in the Eidson section. For additional explanation, see explanation of Figure 4.
Panderodus sp. cf. P. gracilis
Panderodus sp. A cf. P. panderi
Plactodina n. sp.
Walliserodus sp. cf. W. trigonus
Bryantina typicalis
Drepanoistodus suberectus
Phragmodus inflexus
Triangulodus sp. cf. T. brevibasis
Plactodina? janschimensis?
Erismodus sp.
Polycaulodus sp.
Appalachignathus delicatus
Prioniodus sp.
"Oistodus" sp. cf. "O." venustus
Belodina monitorensis
"Oistodus" pseudoabundans
"Acodus" varieffilis
Walliserodus trigonius
Eoplagognathus sp.
Curtognathus spp.
Prioniodus gerdae
Drepanoistodus n. sp.
Belodella nevadensis
Prioniodus gerdae
MIDCONTINENT FAUNA 7
nodular, argillaceous limestone and fine-grained, calcareous clastics, which Cooper (1956) assigned to the Benbolt Formation.

Conodont Biostratigraphy. Samples from the Marcem Formation and the Hogskin Member at this locality have yielded relatively poor conodont collections (fewer than 50 spms/kg). Most samples from the Eidson Member and the Rockdell Formation produce between 50 and 150 specimens per kilogram but one sample from 75 feet above the base of the Eidson Member has yielded almost 900 specimens per kilogram.

Conodont collections from the Eidson section differ little from those in the post-Tumbez formations at Lay School and at Evans Ferry. Simple cones are common and Plectodina n. sp. is the most commonly occurring and most abundantly represented species. Specimens of Phragmodus inflexus are present in small numbers (1-12 spms/kg) from the base of the Eidson into the upper Rockdell and questionable representatives of this species also occur in the Marcem.

Ramiform elements of Prioniodus occur in most of the collections from the Eidson Member. These represent either Prioniodus variabilis or Prioniodus gerdæ but only fragmentary and unidentifiable specimens of the diagnostic amorphognathiform elements have been recovered. Representatives of Prioniodus are not abundant in this section (4.5% of the total in the largest collection) but the relative consistency with which they occur in the Eidson is notable in view of the fact that specimens of Prioniodus are very rare and occur sporadically at Evans Ferry and in the post-Tumbez formations at Lay School. Identifiable specimens of P. gerdæ occur high in this section, 10 feet above the
base of the Rockdell. Of the five sections studied for this report, the Eidson section is the only one at which representatives of a diagnostic North Atlantic species have been recovered from rocks younger than those included in the Ashby Stage by Cooper (1956). None of the rocks in this section can be dated with great precision but it is clear that the lowermost Rockdell, hence probably also the top of the Hogskin, is within the P. gerdæ Subzone. This is of little significance in determining the age of the upper boundary of the Hogskin in the type section of the Ashby Stage, which is separated from the Edison section by a thrust fault, but it can at least be said that in one of the sections that Cooper (1956, Chart 1) used as an example of Ashby age rocks, the top of the Ashby is no younger than the P. gerdæ Subzone.

Thorn Hill Section

Location. The Thorn Hill section (Fig. 7) is in the road cut along U. S. Highway 25E, on the west side of Clinch Mountain, 0.5 mile north of Thorn Hill Post Office in Grainger County (NW 1/4 north-central rectangle, Avondale Quadrangle, USGS 7-1/2' Topographic Map 162-SW, 1960). A detailed measurement and description of this section is provided by Hall and Amick (1934) and unit numbers cited below are taken from those authors.

Stratigraphic Succession. At Thorn Hill, 75 feet of fine-grained, calcilutites of the Mosheim Member (Units 688-715) rest on Knox dolomites
Figure 7. Stratigraphic distribution of conodonts in the Thorn Hill section. For additional explanation, see explanation of Figure 4.
and are overlain by 223 feet of gray and pink Holston-type calcarenites interbedded with nodular, more or less argillaceous limestones. The nodular limestones, which constitute about half the stratigraphic thickness of this unit, are less cherty but are otherwise similar to limestones of the Eidson Member and Cooper (1956, Fig. 3) included this unit in the lower part of the Lincolnshire Formation. However, the Eidson Member at Evans Ferry and at Eidson lacks beds of Holston lithology. As discussed in a previous part of this report (page 25), since half the stratigraphic thickness of this unit at Thorn Hill consists of typical Holston calcarenite, the unit is here referred to the Holston Formation.

The Holston is succeeded by a covered interval (upper 77 feet of unit 744) which is succeeded by 84 feet of nodular, argillaceous, gray limestones (Units 745-756). Although less yellowish-weathering, these rocks are similar to limestones of the Hogskin Member in Hogskin Valley, so they, and the underlying covered interval, are herein included in the Hogskin Member.

The Hogskin is overlain by more than 400 feet of Holston-type calcarenite (Units 757-756) which Cooper (1956, Fig. 3) apparently included in the Rockdell Formation and that designation is also used here.

The Rockdell is overlain by over 470 feet of blue and yellowish, argillaceous limestones and calcareous shales (Units 775 to 785) which are in turn overlain by red beds of the Moccasin Formation. The classification of post-Rockdell, pre-Moccasin rocks in this section is not clear in terms of the terminology of Cooper (1956, Fig. 3) who recognized
the Wardell, Bowen, and Witten formations in this interval. For the purpose of the present discussion, rocks in this interval are designated only by the unit numbers of Hall and Amick (1934).

Conodonts from the upper part of the Hogskin and the Rockdell have been studied by Fetzer (1973) for a report on Middle Ordovician bentonite complexes in the Southern Appalachians and conodont collections from the uppermost part of the Hogskin Member have kindly been provided by Mr. Fetzer. The Rockdell Formation and Unit 775 of Hall and Amick (1934) are omitted from the column in Fig. 7.

Conodont Biostratigraphy. The best collections (300-600 spms/kg) at this section were obtained from beds of gray, fine- to medium-grained calcarenite in the lower 22 feet of the Holston Formation. Samples from the upper 200 feet of the Holston generally yield between 20 and 70 specimens per kilogram but a few beds produce about 200 specimens per kilogram. Conodont yield from the Hogskin Member and from beds above the Rockdell is poor (fewer than 20 spms/kg) and Fetzer (1973) reports that samples from the Rockdell also produce poor collections of conodont elements.

Conodonts from the Holston Formation at Thorn Hill represent mixed Midcontinent-North Atlantic-type faunas and are essentially the same, in terms of species represented, as those from the upper Tumbez at Lay School. One notable difference is the occurrence of specimens of *Polyplacognathus sweeti* in the lowermost part of the Holston. Midcontinent forms, especially *Phragmodus* and *Plectodina*, are predominant
but representatives of several North Atlantic species are present in substantial numbers (Appendix B).

Identifiable amorphognathiform elements of *Prioniodus variabilis* (late form) range from 35 feet to 44 feet above the base of the Holston and elements of *Prioniodus gerdae* (early form) first appear at a level 40 feet above the base of the Holston. Therefore, the top of the *P. variabilis* Subzone of the *Amorphognathus tvaerensis* Zone is drawn in this section at a level 40 feet above the base of the Holston Formation. Specimens of typical *P. gerdae* first appear 111 feet above the base of the Holston Formation and the base of the *P. gerdae* Subzone is accordingly drawn at this level. Specimens of *Eoplacognathus elongatus* range from 170 feet to 200 feet above the base of the Holston and elements of *Protopanderodus varicostatus*, which is so far known to range only into the lower part of the *P. gerdae* Subzone (Bergström, 1971a, p. 100), also occur up to a level 200 feet above the base of the Holston. This suggests that the top of the Holston is probably also within the lower part of the *P. gerdae* Subzone.

Representatives of *Polyplacognathus sweeti* range through the lower 22 feet of the Holston Formation and Bergström (1971a, 1971c) reports *P. sweeti* only from strata within the Zone of *Pygodus anserinus*. Elements of this species from the basal foot of the Holston are typical of *P. sweeti* as described and illustrated by Bergström (1971a, p. 143, Fig. 14, Pl. 1, figs. 1, 2). However, ambalodontiform elements of *P. sweeti* in collections from 17 feet and 22 feet above the base of the Holston exhibit a characteristic feature that has not previously been described and which I interpret as representing a late-stage development in the
evolution of this species (see discussion of P. sweeti in the systematics part of this report). These late forms of P. sweeti range up to a level just 18 feet below the top of the P. variabilis Subzone. In the absence of specimens of Pygodus anserinus and Amorphognathus tvaerensis, the range of P. sweeti (late form) in relation to the upper boundary of the P. anserinus Zone cannot be determined but I believe it is possible, unless the P. variabilis Subzone of the A. tvaerensis Zone is extremely thin in this section, that elements of P. sweeti (late form) may range into the lowermost part of the A. tvaerensis Zone. Therefore, the top of the P. anserinus Zone is tentatively drawn in this section at the highest occurrence of typical forms of P. sweeti, which is one foot above the base of the Holston.

Elements of Phragmodus flexuosus range through the lower 22 feet of the Holston, and possibly a little higher. Representatives of Phragmodus inflexus appear 39 feet above the base of the Holston and range into the units above the Rockdell. This indicates that most of the Holston, all of the Hogskin, all of the Rockdell, and at least 23 feet of the post-Rockdell beds at this section are within the interval of Midcontinent Fauna 7.

Collections from the Hogskin and beds above the Rockdell are poor and are characterized by simple cones, elements of Plectodina n. sp., and rare specimens of Phragmodus inflexus. Likewise, Fetzer (1973) reports poor collections from the Rockdell at Thorn Hill and only Drepanoistodus suberectus, Panderodus sp. cf. P. gracilis, Panderodus sp. A. cf. P. panderi, Walliserodus sp. cf. W. trigonius, and
unidentifiable specimens of *Plectodina* and *Phragmodus* are known from this interval.

**Remarks.** *Prioniodus variabilis-Prioniodus gerdae* transition forms range through a stratigraphic interval of 71 feet in this section between the top of the *P. variabilis* Subzone and the base of the *P. gerdae* Subzone. Bergström (1971a, p. 146) has noted that these same transition forms occur in the Balto-Scandic area within a stratigraphic interval less than 0.5 meters thick. Therefore, the stratigraphic interval through which these transition forms occur at the Thorn Hill section is more than 40 times thicker than the corresponding interval in the Balto-Scandic area. Bergström (1971a, p. 101) reports a similar situation regarding the thickness of the *Prioniodus gerdae* Subzone in the Balto-Scandic area and in the Southern Appalachians. It is evident that these transitional forms are excellent tools for trans-Atlantic correlation and that the stratigraphic interval of their occurrence at Thorn Hill can be tied into the Baltic succession with unusual precision.

**Cuba Section**

**Location.** The Cuba section (Fig. 8) is in a field bordering the grounds of the Gills Chapel Baptist Church, on the north side of U. S. Highway 11W, at Cuba, in Hawkins County (SE 1/4 southeast rectangle,
Figure 8. Stratigraphic distribution of conodonts in the Cuba section. For additional explanation, see explanation of Figure 4.
Stratigraphic Succession. The beds in the Cuba section are overturned and dip 58 degrees southeast. At the base of this section (stratigraphically), Knox dolomites are overlain by 40 feet of light-to medium-gray calcilutites of the Mosheim Member. The Mosheim is separated by a covered interval, which represents a stratigraphic thickness of 15 feet, from 55 feet of medium- to dark-gray and blue-gray, fine- to medium-grained limestone. For the present, lithostratigraphic classification of these blue and gray limestones must remain unsettled. They occupy the same stratigraphic position as the Lenoir Formation in thrust belts farther east and they have previously been termed Lenoir (Cooper, 1956, Fig. 3) but they are not of typical Lenoir lithology. Therefore, since most of the rocks in this interval exhibit a bluish cast on fresh surfaces, they are here informally termed the "blue limestone member".

The blue limestone member is overlain by gray and pink calcarenites of the Holston Formation. In the Cuba field exposure, the Holston Formation is exposed as prominent ledges, 2 to 5 feet thick stratigraphically, which are separated by grass-covered intervals that represent stratigraphic thicknesses ranging from one or two feet to about 45 feet. The top of the Holston is drawn at the top of the stratigraphically-highest prominent ledge of calcarenite, 310 feet above the base of the formation.

The lower 50 feet of the Holston at this locality consists of gray-weathering, light to medium-gray, medium-grained calcarenites, which
are here informally termed the "gray member" of the Holston Formation.
The upper 260 feet of the Holston consists of reddish-weathering, medium- to coarse-grained calcarenites. These rocks are composed of gray, pink, and red calcite grains with interstitial concentrations and irregular, thin streaks of hematitic, clastic matrix. The reddish-weathering rocks at this locality are here referred to informally as the "red member" of the Holston Formation. A similar two-fold subdivision of the Holston Formation, a lower gray unit overlain by a reddish unit, is also recognized in some areas in the thrust belts southeast of the Saltville fault (Milici, 1973, p. 17).

Rock units above the Holston are poorly exposed in this area but scattered ledges of Holston-type calcarenite occur in the hillsides north of (and stratigraphically above) the Holston outcrops. These are the lenses of "marble" in Chickamauga limestone Unit 2 of Rodgers (1953), which is not observed at this locality but which is described by Rodgers (1953, p. 85) as consisting of limy shale and argillaceous limestone. At nearby localities, Gordon (1924) referred rocks in this interval questionably to the Ottosee Shale.

Conodont Biostratigraphy. Very few conodont elements (fewer than 10 spms/kg) have been recovered from the Mosheim Member and collections of only moderate size (20-100 spms/kg) have been obtained from most of the blue limestone member and from the red member of the Holston. On the other hand, one sample from the uppermost bed of the blue limestone and several samples from the gray member of the Holston have produced several hundred (200-1100) specimens per kilogram.
The rich conodont collections from the gray member of the Holston
differ markedly from any so far observed in the study area. Within this
narrow stratigraphic interval, elements of Polyplacognathus sweeti and
Prioniodus variabilis are present in large numbers and, in most cases,
are the most abundant forms in a sample. Elements of Belodina
monitorensis, which occur elsewhere in the study area (Figs. 4-7) but
only in relatively small numbers, are also prominent in several collec­
tions. Representatives of "Distacodus" n. sp. and Drepanoistodus
n. sp. are not present in exceptional abundance but they occur in
larger numbers and with greater consistency here than in the other
sections investigated. Also, several forms occur in small numbers in
the gray member of the Holston at this section that do not appear in the
other sections, namely Pygodus anserinus, Paltodus? sp., New Genus cf.
"A." curvatus.

Unlike other sections studied, representatives of Phragmodus and
Plectodina do not constitute a major part of the collections from Cuba.
Specimens of Phragmodus inflexus appear in the blue limestone and occur
as high as the upper part of the red member of the Holston but representa­
tives of this species are abundant only in the uppermost part of the
blue limestone. Elements of Plectodina n. sp., which is the most
abundantly represented species in most collections from the other
sections in the study area, have a range in this section similar to that
of P. inflexus. One sample from the uppermost part of the gray member
of the Holston contains approximately equal numbers of elements of
Polyplacognathus sweeti (428 spms.) and Plectodina n. sp. (454 spms.)
but otherwise *Plectodina* n. sp. is not especially prominent in the Cuba collections.

Typical specimens of *Prioniodus variabilis* occur through the lower 21 feet of the gray member of the Holston and questionable representatives of this species, which are unidentifiable because the amorphognathiform elements are fragmentary, occur as high as the lowermost part of the red member. Representatives of a form of *Prioniodus gerdae* appear 135 feet above the base of the Holston. The evolutionary stage of these specimens cannot be determined because the distal ends of the lateral processes on the amorphognathiform elements are broken. However, it is certain that they represent either *P. gerdae* (typical form) or an advanced *P. variabilis*-*P. gerdae* transition form. Therefore, the top of the *P. variabilis* Subzone of the *Amorphognathus tvaerensis* Zone at this section is within the stratigraphic interval between 21 feet and 135 feet above the base of the Holston, and the base of the *P. gerdae* Subzone, although it cannot be positively recognized, is probably very near a level 135 feet above the base of the Holston.

Elements of *Polyplacognathus sweeti* are present only in small numbers (22 spms.) in collections from the blue limestone. In contrast, almost 1200 specimens of this distinctive species have been recovered from beds in the gray member of the Holston. Only typical specimens of *P. sweeti* occur in the blue limestone and in the lowermost part of the gray member of the Holston. Upward through most of the gray member, ambalodiform elements of *P. sweeti* (late form) appear but they are not abundant relative to typical specimens. However, in the uppermost sample
from the gray member, which is also the highest occurrence of *P. sweeti*, nearly all (251 of 255) ambalodiform elements of *P. sweeti* are of the advanced type and are identical to specimens of *P. sweeti* (late form) that occur just beneath the top of the *Prioniodus variabilis* Subzone in the lower Holston at Thorn Hill. The upward range of *P. sweeti* (late form) is not yet firmly established but there is no evidence at hand to indicate that these forms range above the top of the *P. variabilis* Subzone. Therefore, it is tentatively concluded that the top of the *P. variabilis* Subzone is no lower in this section that the highest occurrence of *P. sweeti* (late form), which is 45 feet above the base of the Holston.

Specimens of *Pygodus anserinus* occur through a stratigraphic interval from 4 feet to 21 feet above the base of the Holston. Elements of *Prioniodus variabilis* and typical forms of *Polyplacognathus sweeti* also occur in this interval and this association is characteristic of the upper subzone of the *P. anserinus* Zone (Bergström, 1971a). As mentioned in the discussion of the Thorn Hill section, there is a possibility that *P. sweeti* (late form) may range into the lower part of the *Amorphognathus tvaerensis* Zone. Therefore, the top of the *P. anserinus* Zone at the Cuba section is drawn at the highest occurrence of *P. anserinus*, which is 21 feet above the base of the Holston.
CORRELATION

**Local Correlation.** Figure 9 summarizes the distribution of representatives of biostratigraphically diagnostic conodont species, and the position of major biostratigraphic boundaries, in the sections discussed above. Sections are drawn to scale in this figure and datum is the top of the *Prioniodus variabilis* Subzone of the *Amorphognathus tvaeakensis* Zone, the only major biostratigraphic boundary that can be recognized in at least one section in all three of the middle thrust belts. This boundary is drawn on the basis of successive evolutionary stages within the *Prioniodus* lineage and it is here regarded as representing a time line within the study area (see Bergström, 1973c, p. 267-268).

Conodont biostratigraphic control is excellent in the Holston Formation at Cuba and Thorn Hill and in the upper part of the Tumbez Formation at Lay School. Therefore, correlation from thrust belt to thrust belt can be instituted with considerable confidence in this interval. The top of the *Prioniodus variabilis* Subzone can be located precisely in the upper Tumbez at Lay School and in the lower Holston at Thorn Hill. The position of this boundary, and the distribution of early forms and typical forms of *Prioniodus gerdæ* and specimens of *Eoplacognathus elongatus*, indicates that the upper part of the Tumbez and at least some part of the Elway-Eidson at Lay School are equivalent.
Figure 9. Known vertical distribution of representatives of biostratigraphically diagnostic conodont species in the sections investigated. Dotted lines represent:

1. Pygodus anserinus—Amorphognathus tvaerensis zonal boundary (the position of this boundary in sections in the Copper Creek belt is based on the distribution of forms of Polyplacognathus sweeti).

2. Top of the Prioniodus variabilis Subzone (first appearance of early forms of Prioniodus gerdæ).

3. Base of the Prioniodus gerdæ Subzone (first appearance of typical forms of P. gerdæ).
in age to the Holston Formation at Thorn Hill. Therefore, the lower Tumbez at Lay School is probably equivalent, at least in part, to the Mosheim at Thorn Hill. Although the top of the *P. variabilis* Subzone cannot be located precisely at the Cuba section, it can be bracketed within a stratigraphic interval of 114 feet in the lower part of the Holston. The approximate position of this subzonal boundary in the Cuba section, and the distribution of *Polyplacognathus sweeti* (typical forms and late forms) and forms of *P. gerdae*, indicates that the Holston Formation at Cuba is, as nearly as can be determined within the resolution of the conodont zonation, the same age as the Holston Formation at Thorn Hill. As interpreted here, the base of the Holston in both these sections is within the uppermost part of the upper subzone of the *Pygodus anserinus* Zone, although the base of the Holston at Thorn Hill may be slightly younger within this subzone than it is at Cuba (see Fig. 9), and the top of the formation at both localities is no older than the lower part of the *P. gerdae* Subzone of the *Amorphognathus tvaerensis* Zone.

Conodont biostratigraphic control is poor in the post-Tumbez interval at Lay School and in the post-Holston interval at Thorn Hill and Cuba. Likewise, biostratigraphic control is poor in the Eidson and Evans Ferry sections and no major biostratigraphic boundary can be bracketed in either section. However, the existing scant conodont evidence and the lithostratigraphic evidence (discussed below) suggests that the position of the upper boundary of the *Prioniodus variabilis* Subzone in these latter two sections, as indicated in Figure 9, is not greatly in error.
At Evans Ferry, rock units here termed Tumbez, Eidson, Hogskin, and Rockdell are much thinner than the same units at the Lay School section (Fig. 9), which is less than 15 miles southwest along the strike of the St. Paul belt. B. N. Cooper (1964) noted similar variations in thickness of lower Middle Ordovician rock units in Virginia and suggested that these variations are due to differential subsidence within the Middle Ordovician depositional basin. At the present time it cannot be conclusively demonstrated that the thick (1417 feet) stratigraphic interval that includes the Tumbez, Elway-Eidson, Hogskin, and Rockdell in Hogskin Valley represents the same time-span as the much thinner (512 feet) interval that includes these same units at Evans Ferry. However, due to the closely similar lithostratigraphic successions in these two sections, and due to their geographic proximity within the same thrust belt, I suspect that the Tumbez-through-Rockdell interval at Lay School represents approximately the same period of time as the corresponding interval at Evans Ferry. The disparity in thickness between the rock units at these two localities is probably due to differential subsidence and concomitant variation in depositional rate during the lower Middle Ordovician. If this assumption is correct, the upper boundary of the P. variabilis Subzone at Evans Ferry, as at Lay School, is most likely within the upper part of the Tumbez Formation. There is no substantive biostratigraphic evidence for this conclusion but it may be significant that specimens of Eoplacognathus elongatus, which occur through a very narrow stratigraphic interval in the lower part of the Elway-Eidson at Lay School, occur at Evans Ferry only in the
lower part of the Eidson. The occurrence of representatives of this species in closely similar stratigraphic intervals may reflect a single, short-lived incursion of *E. elongatus* into the area now represented by lower Eidson (and Elway-Eidson) rocks in the St. Paul belt. This would suggest that the lower part of the Eidson at Evans Ferry and the lower part of the Elway-Eidson at Lay School are of approximately the same age.

Rock units at Thorn Hill here termed Mosheim, Holston, Hogskin, and Rockdell have been traced by Rodgers and Kent (1948, Units A through E) northeastward along their strike in the Copper Creek belt to Lee Valley and equivalents of these units can easily be recognized in the Eidson section, which is only about 7 miles northeast of Lee Valley within the Copper Creek belt. According to Rodgers and Kent (1948, p. 34), their Unit B at Lee Valley is equivalent to rocks at Thorn Hill that are here included in the Holston Formation. The Eidson Member at Eidson occupies the same stratigraphic position and is of almost exactly the same thickness as Unit B at Lee Valley and as the Holston at Thorn Hill. At Thorn Hill, about half the stratigraphic thickness of the Holston consists of dark, nodular and argillaceous limestone, whereas the remaining half is Holston-type calcarenite (see Hall and Amick, 1934). Unit B at Lee Valley, as described by Rodgers and Kent (1948, p. 34-35), includes nodular limestones like those in the Holston at Thorn Hill and several beds of less argillaceous, cherty, Eidson-like limestone, whereas "marbles" like those of the Holston comprise only a small part of the unit. It is apparent that Unit B at Lee Valley is lithologically transitional between the Holston at Thorn Hill and the
Eidson at Eidson and that northeastward in the Copper Creek belt "marbles" of the Holston Formation interfinger with and are gradually replaced by the darker and generally finer-grained, cherty limestones of the Eidson Member. For this reason, I believe that the calcarenites and dark limestones of the Holston at Thorn Hill represent a marginal facies of the Holston reef complex that is characterized by interfingering of "nearer-reef" calcarenites with farther "off-reef" dark limestones of the Eidson Member. If this interpretation is correct, then rocks of the Holston Formation at Thorn Hill must be very nearly the same age as rocks of the Eidson Member at Eidson and the upper boundary of the *P. variabilis* Subzone is probably within the lower Eidson at Eidson. Likewise, rocks at Thorn Hill that are here assigned to the Hogskin Member (Unit C of Rodgers and Kent, 1948) are probably approximately the same age as rocks included in that unit at Eidson. The Rockdell at Eidson corresponds to Unit D of Rodgers and Kent (1948, p. 36) which those authors have traced into rocks at Thorn Hill that are here included in the lower Rockdell. Rodgers and Kent (1948, p. 36-37) note that their Unit E consists largely of "red marble" at Thorn Hill but that "it includes no marble and much shale" at Lee Valley. Unit E was traced along the strike by Rodgers and Kent into rocks at Thorn Hill that are here included in the upper Rockdell. At Eidson, the equivalent of the upper Rockdell at Thorn Hill and of Unit E at Lee Valley is within the interval of shaly limestone that Cooper (1956) referred to the Benbolf Formation.

Figure 10 depicts correlation of the various rock units dealt with in the present study area as nearly as can be determined on the basis
Figure 10. Suggested correlation of rock units within the study area.

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<tr>
<th>ST. PAUL BELT</th>
<th>LA SALLE</th>
<th>LAY FERRY</th>
<th>EDSON</th>
<th>COPPER CREEK BELT</th>
<th>HAWKINS BELT</th>
<th>CONODONT CONODONT NUCLEITE</th>
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- Prioniodus variabilis (late)
- Prioniodus gerdæ (early)
- Eoplacognathus elongatus
- Prioniodus gerdæ
- Eoplacognathus elongatus
- Polyplacognathus sweeti
- Prioniodus variabilis (late)
- Prioniodus gerdæ (early)
- Prioniodus gerdæ
- Eoplacognathus elongatus
- Polyplacognathus sweeti
- Pygodus anserinus
- Prioniodus gerdæ
- Pygodus anserinus
- Prioniodus variabilis
- P. gerdæ
- N. variabilis
- P. variabilis
- Prioniodus gerdæ
- Pygodus anserinus
- N. variabilis
- P. variabilis
- Prioniodus gerdæ
of existing lithostratigraphic and biostratigraphic evidence. The lithostratigraphic correlations suggested in this figure within the St. Paul and Copper Creek belts can, in my opinion, be viewed with considerable confidence for there is most likely no great age difference between similar rock units in sections that are separated by only a few miles along the strike within a single thrust belt. However, the lithostratigraphic correlations that are indicated in Figure 10 between the St. Paul and Copper Creek belts must be viewed with some skepticism. It is evident that the base of the Elway-Eidson "Formation" in the St. Paul belt is younger than the base of the Holston Formation and the base of the Eidson Member in the Copper Creek belt. Possibly, therefore, the boundaries of all the post-Tumbez units in the St. Paul belt may be somewhat younger than the corresponding lithic boundaries in the Copper Creek belt. Since there are no biostratigraphic data available to confirm this possibility, the age of formation boundaries in these two thrust belts in the upper Eidson-upper Holston through lower Benbolt interval can only be expressed relative to known biostratigraphic boundaries. The age of these formation boundaries relative to each other from belt to belt may not be exactly as represented in Fig. 10.

At the present time, there is no precise biostratigraphic control for the exact relative age of the very base of the Middle Ordovician succession in the middle belts. However, typical forms of Polyplacognathus sweeti, which indicates the upper subzone of the P. anserinus Zone, are present in the basal Holston just 75 feet above the base of the Mosheim at Thorn Hill and these same forms are also present in the blue limestone at Cuba just 60 feet above the base of the Mosheim. Rocks of
the Mosheim Member have recently been interpreted as mudflat deposits (Stephenson and others, 1973) and, as pointed out by Bergström and Carnes (1975), it is unlikely that rocks of this type in a transgressive sequence represent a great deal of time. It would not be illogical to surmise that the base of the Middle Ordovician sequence becomes slightly younger northwestward from belt to belt but there is currently no biostratigraphic evidence to prove this. In any event, it is highly unlikely that the base of this transgressive sequence becomes any older to the northwest. Therefore, as nearly as can be determined with the present conodont evidence, and assuming that the thin stratigraphic interval occupied by the Mosheim Member and its equivalents does not represent a great deal of geologic time, the base of the Middle Ordovician succession in the middle belts is no older than the upper subzone of the Pygodus anserinus Zone. Consequently, in terms of the standard graptolite zonation, which has been tied in with the North Atlantic conodont zonation by Bergström (1971b, 1973b), the base of this sequence is also probably within the lower part of the Nemagraptus gracilis Zone.

Regional Correlation. A great deal of information has recently been published about Middle Ordovician conodont biostratigraphy in the middle and eastern thrust belts in eastern Tennessee (Bergström, 1971a, 1971b, 1973c; Carnes and Bergström, 1973; Bergström and Carnes, 1975). Part of this information, together with the data provided herein, is summarized in Figure 11. Note that in the "Conodont Subzones" column of this figure the dashed line is the actual top of the
Figure 11. Correlation of rock units in the middle belts of eastern Tennessee with rock units in the eastern belts of eastern Tennessee and western Virginia. Formations used by Cooper (1956) to define the Marmor (Friendsville), Ashby (Lay School) and Porterfield (Porterfield Quarry, Va.) Stages are stippled. Post-Holston formation names have been added to the Lenoir City and Friendsville columns of Bergström (1973c). Section localities in Tennessee are illustrated in Figure 12. The location of Porterfield Quarry is indicated by Cooper (1956, Fig. 1) and by Bergström (1971a, Fig. 9). See text for additional explanation.
Figure 11.
Figure 12. Sketch map of eastern Tennessee showing the distribution of Ordovician rocks, major thrust belts, and the location of sections mentioned in the text (figure and caption from Bergström and Carnes, 1975).
Prioniodus variabilis Subzone as that boundary is currently defined (Bergström, 1971a). Prioniodus variabilis-Prioniodus gerdæ transition forms occur at Thorn Hill through a stratigraphic interval of 71 feet between the top of the *P. variabilis* Subzone and the base of the *P. gerdæ* Subzone. It is possible that when the distribution of these distinctive forms becomes better known they may be used as basis for definition of an additional subzone within the lower part of the Amorphognathus tvaerensis Zone.

Bergström and Carnes (1975) have recently discussed the age of the Holston Formation in the eastern and middle belts of eastern Tennessee. These authors conclude that, as nearly as can be determined within the limits of resolution of the North Atlantic conodont zonation, rocks of the Holston Formation are of approximately the same age throughout the Valley of East Tennessee. In both the eastern belts and the middle belts, the base of the Holston is within the upper subzone of the *Pygodus anserinus* Zone and the top of the Holston is no older than the lower part of the *Prioniodus gerdæ* Subzone of the Amorphognathus tvaerensis Zone. It is probable that the base of the Holston, as well as the top of the unit, may vary slightly in age from section to section but whatever age differences there may be are within the limits of one conodont subzone and are probably of no great magnitude in geological terms. This interpretation is contrary to those of many previous workers, who have concluded that the rocks that are here included in the Holston Formation differ considerably in age across the strike of the thrust faults (i.e., Prouty, 1946; Cooper, Cooper, and Bridge, in Twenhofel, 1954; Cooper, 1956).
One of the most notable features illustrated in Figure 11 is the age difference between lowermost Middle Ordovician rocks exposed in the eastern belts relative to those in the middle belts. Bergström (1973c) has demonstrated that in belts south of the Saltville fault the base of the Middle Ordovician succession is no younger than the base of the Pygodus serrus Zone. In the middle belts within the present study area, there is no evidence for rocks of P. serrus Zone age, or for rocks of lower Pygodus anserinus Zone age, and the conodont evidence available suggests that the oldest Middle Ordovician rocks exposed are no older than the upper subzone of the P. anserinus Zone. Therefore, the lowermost part of the Middle Ordovician sequence in the middle belts is equivalent to the uppermost part of the Lenoir in the Lenoir City and Friendsville belts, to some part of the Blockhouse-Sevier succession in the Bays Mountain Synclinorium, and to some part of the Blockhouse-Tellico succession in the Tellico-Sevier belt. Absence of equivalents in the middle belts for most of the Lenoir and its equivalents in the eastern belts, which includes several hundred feet of rock (Bergström, 1973c), indicates that Middle Ordovician seas existed for a considerable amount of time in areas now represented by rocks south of the Saltville fault before transgression progressed into the area of the present middle belts. This conclusion is also contrary to that of most previous workers who have concluded that lowermost Middle Ordovician rocks in the middle belts are of approximately the same age as those in the eastern belts (i.e., Prouty, 1946; Rodgers, 1953; Cooper, Cooper and Bridge, in Twenhofel, 1954; Cooper, 1956).
Conodont biostratigraphic control is poor in the middle belts, and also in the eastern belts, in the interval above the Holston and its equivalents. Within the present study area, rocks of the Hogskin Member and overlying units are clearly younger than the base of the Prioniodus gerdae Subzone and, at least in the Copper Creek belt, it can be shown that the Hogskin and the lower Rockdell are no younger than the P. gerdae Subzone (Fig. 9). Specimens of P. gerdae are also known to occur in the lowermost part of the Chapman Ridge Formation (Bergström and Carnes, 1975) and in the Meadow Marble (Bergström, 1973c; Bergström and Carnes, 1975) in the Friendsville belt, and specimens of this species have been found in the uppermost part of the Chota Formation at the type section of the Chota (Bergström and Carnes, 1975). This indicates that the Hogskin-Rockdell-Benbolt interval in the middle belts is equivalent to some part of the Chapman Ridge-Ottosee succession in the Friendsville belt and to some part of the Chota-Sevier succession in the Tellico-Sevier belt.

Another interesting feature expressed by Figure 11 is the age of the base of the Holston relative to the age of the oldest Middle Ordovician rocks in the middle belts. The period of major reef development during which the extensive Holston complex was deposited apparently did not begin until shortly after the expansion of Middle Ordovician seas into the area of the present middle belts.

Facies Relations. Facies relations within each of the middle belts are relatively straightforward because the rock units involved can be followed along strike. For instance, in the St. Paul belt, the mainly
argillaceous calcilutites of the Rockdell at Lay School become purer and almost Holston-like northeastward to Evans Ferry. Also, within the Copper Creek belt, Holston calcarenites give way northeastward to cherty Eidson limestones and the upper Rockdell grades northeastward into generally non-calcarenitic, shaly beds that have been referred to the Benbolt by Cooper (1956).

Across the strike of the thrust faults that separate the middle belts of Middle Ordovician outcrops, because of the age relations determined here, it is evident that the lithologically varied Tumbez of the St. Paul belt passes southeastward into the lower Holston and probably also into the Mosheim of the Copper Creek belt. Also, some part, if not all, of the Eidson limestones in the St. Paul belt grade into the Holston of the Copper Creek belt, just as the Eidson grades into the Holston southwestward within the Copper Creek belt. The Rockdell, in passing from the St. Paul belt into the Copper Creek belt, becomes even more Holston-like than at Evans Ferry and it cannot be distinguished lithologically in outcrop from the Holston. There is also a significant change within the Holston between the Copper Creek belt and the Hawkins belt. At Thorn Hill, most of the calcarenites in the Holston are the gray and pink, relatively pure type that have been interpreted as reef-flank deposits (Ferrigno and Walker, 1973; Walker and Ferrigno, 1973a, 1973b). However, at Cuba, only the rocks of the gray member of the Holston are of this type and rocks of the superjacent red member are relatively coarser grained and contain a small amount of hemititic, clastic matrix, similar to rocks of the Holston that have been interpreted as reef-core deposits (Ferrigno and Walker, 1973, etc.). Reef bodies
like those described by Walker and Ferrigno (1973a, 1973b) have not been observed in the red member at Cuba but it seems certain that these rocks represent, if not a core facies, then a more near-core facies than the underlying gray member or than the entire Holston at Thorn Hill. Gordon (1924, p. 52, Pl. XI, A) describes and illustrates Holston rocks from a locality near Cuba that appear especially similar to reef-core rocks described by Walker and Ferrigno (1973a, 1973b). The Rockdell is not present in the Hawkins belt so it is apparently replaced southeastward by the shaly limestones and fine-grained clastics that overlie the Holston in this belt. Perhaps some of the calcarenite bodies that occur in the interval above the Holston in the Hawkins belt are tongues of the Rockdell that occurs in the Copper Creek belt, but those that have been observed at Cuba are small, lens-like, and appear to have no great lateral extent.

Facies relations across the strike of the middle belts as interpreted here are schematically illustrated in Figure 13. An attempt is also made in this figure to express possible facies relations between rock units in the middle belts and Middle Ordovician rock units in the area of the Bays Mountain Synclinorium, which is directly southeast across the Saltville fault from the Hawkins belt (Figs. 1, 12). The part of this diagram that represents Middle Ordovician successions south of the Saltville fault is taken from Bergström (1973c).

The change in lithology of Middle Ordovician rocks across the Saltville fault from Cuba to the St. Clair section, which is less than 5 miles from Cuba and which is one of the northwestern-most exposures of Middle Ordovician rocks in the Bays Mountain Synclinorium, is
Figure 13. Facies relations across the strike of the middle belts and across the Bays Mountain Synclinorium. The right side of the diagram, which represents an area southeast of the Saltville fault, is taken from Bergström (1973c, Fig. 11). Area within the dashed lines is hypothetically reconstructed and represents that part of the lower Middle Ordovician succession that is cut out by the Saltville fault. Dotted lines represent major biostratigraphic reference levels:

1. The first appearance of a primitive type of *Polyplacognathus friendsvillensis* (Bergström, 1973c, p. 287).

2. The first appearance of a more advanced type of the same species (Bergström, 1973c, p. 287).

3. The first appearance of a primitive type of *Pygodus serrus* (Bergström, 1973c, p. 287).

4. The level of the *Pygodus serrus-P. anserinus* transition (that is, the *P. serrus-P. anserinus* zonal boundary) (Bergström, 1973c, p. 287).

5. The *Pygodus anserinus-Amorphognathus tvaerensis* zonal boundary (the position of this boundary at Thorn Hill is based on the distribution of forms of *Polyplacognathus sweeti*).

6. The top of the *Prioniodus variabilis* Subzone (first appearance of early forms of *Prioniodus gerdae*).

7. The base of the *Prioniodus gerdae* Subzone (first appearance of typical forms of *P. gerdae*).
Figure 13.
particularly striking. The thick, gray and pink Holston calcarenites that are exposed throughout the length of the Hawkins belt stand in marked contrast to their lateral equivalents at St. Clair, which are the dark-gray shales of the Blockhouse Formation (see Bergström, 1973c). There are no rocks in the Bays Mountain Synclinorium similar in lithology and thickness to the rocks of the Holston Formation, which is extensively developed in the belts south of the Saltville fault in the Knoxville region. Rodgers (1953, p. 82, 134) has suggested that the Hawkins belt may be a continuation of the belt next northwest of the Saltville fault in the Knoxville area and that a segment of this belt may be overridden by the salient in the Saltville fault between House Mountain and Short Mountain (see Hardeman and others, 1966). It is also possible that counterparts of the Lenoir City and Friendsville belts (see Bergström, 1973c), which are recognizable only southwest of the Cherokee anticline (see Rodgers, 1953), are present south of the Hawkins belt but are concealed, perhaps by the Carter Valley fault.

Since it is not known whether the abruptness of the change in lithology from the Hawkins belt to the Bays Mountain Synclinorium is real or apparent, any interpretation of facies relations across the Saltville fault in this part of eastern Tennessee must be regarded as highly speculative.

**The Ashby Stage.** Since Cooper (1956) introduced a new stadial classification for Middle Ordovician rocks in North America, several authors have suggested on the basis of evidence other than that from conodonts that some of the stages as defined by Cooper may overlap
As illustrated in Figure 14, the various rock units dealt with in the present study area were included by Cooper (1956) in either the Marmor, the Ashby, or the Porterfield Stage. Comparison of Figure 14 with Figure 11 reveals the fact that conodont-based correlation of rock units at the type sections of these stages differs greatly from the age relations suggested by Cooper (1956) on the basis of brachiopods. Comparison of these two figures also illustrates the major differences between the correlations of rock units across the Saltville fault that are suggested in the present paper and those indicated by Cooper (1956, Chart 1).

Cooper (1956, p. 8) proposed the Marmor Stage, with type section at Friendsville, Tennessee, to include Chazy and correlative rocks. The Ashby Stage, which has its type section in Hogskin Valley, Tennessee, was defined by Cooper (1956, p. 8), on the basis of brachiopods "such as the coarse-ribbed dinorthids" that do not appear in rocks of the Chazy Group, to include the Elway and Lincolnshire formations. The Porterfield Stage, with type section at Porterfield Quarry, Virginia, was defined by the appearance of the Christiania fauna in the Southern Appalachians.

Bergström (1971a, 1971b, 1973c) has dealt previously with the type sections of the Marmor and Porterfield stages and with several other sections in the Southern Appalachians that include rock units Cooper assigned to the Marmor, Ashby, and Porterfield Stages. Bergström (1971a) has demonstrated that, according to conodont evidence, the first appearance of the Christiania fauna is diachronous in the Southern Appalachians and that some units that Cooper (1956) referred to the
Figure 14. Correlation of lower Middle Ordovician rock units in eastern Tennessee and southwestern Virginia suggested by Cooper (1956, Chart 1). Formations used to define the Marmor, Ashby and Porterfield Stages are stippled.
<table>
<thead>
<tr>
<th>Stage</th>
<th>HOGSKIN VALLEY</th>
<th>EIDSON</th>
<th>LENOIR CITY</th>
<th>FRIENDSVILLE</th>
<th>ST. CLAIR-BAYS MTN.</th>
<th>TELlico-SEVIER</th>
<th>PORTERFIELD QUARRY</th>
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<td>SEVIER</td>
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<td>SEVIER</td>
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<td>ROCKDELL</td>
<td>FARRAGUT</td>
<td>ARLINE</td>
<td>PAPERVILLE</td>
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<td>MOSHEIM</td>
<td>DOUGLAS LAKE</td>
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Figure 14.
Ashby Stage in Virginia are at least partly of Porterfield age.

The Porterfield stage was defined by Cooper (1956, Chart 1) to include the Arline, Effna, Rich Valley and Chatham Hill formations at Porterfield Quarry. According to Bergström (1971a, p. 118-119), the base of the Arline at Porterfield Quarry is within the upper subzone of the Pygodus anserinus Zone and the transition from Prioniodus variabilis to Prioniodus gerdæ occurs in the uppermost part of the Effna Formation and in the lowermost part of the Rich Valley Shale. It has been shown above that the base of the Elway-Eidson "Formation" at the Lay School section, which is taken here as the type section of the Ashby Stage, is younger than the top of the P. variabilis Subzone but no younger than the lower part of the P. gerdæ Subzone. Therefore, it is clear that the base of the type Ashby is equivalent to some level in the uppermost Effna or lowermost Rich Valley at Porterfield Quarry and that it is actually younger than the base of the type Porterfield.

The age of the top of the type Ashby, which is the top of the Hogskin Member in Hogskin Valley, cannot be established in terms of the North Atlantic conodont zonation except to say that it is younger than the top of the P. variabilis Subzone and probably within the P. gerdæ Subzone. Likewise, the age of the base of the Wilderness Stage, which succeeds the Ashby Stage according to Cooper (1956), cannot be evaluated at this time in terms of the North Atlantic conodont zonation. The type section of the Wilderness Stage is at Hagan, Virginia, and the type Wilderness includes rocks assigned by Cooper (1956, Chart 1) to the upper part of the Hurricane Bridge Formation, the Woodway Formation, the Ben Hur Formation, and the lower part of the Hardy Creek Formation.
The base of the Wilderness Stage occurs at an unspecified level within the Hurricane Bridge, which is poorly exposed at Hagan. Bergström (1971a, p. 127-128) has studied this section but reports that conodont collections from Hagan are dominated by hyaline forms. The interval that includes the base of the Wilderness at Hagan has been sampled by me on four separate occasions but I have also been unable to recover conodont elements that at the present time are biostratigraphically diagnostic. Conodont collections from the Martin Creek (underlies Hurricane Bridge) through Woodway interval are generally poor, few yield more than 25 specimens per kilogram, and consist almost exclusively of hyaline forms such as "Erismodus", "Microcoelodus", "Ptiloconus", "Polycaulodus", "Cardiodella", "Trucherognathus", and "Curtognathus". A few samples in this interval have yielded one or two elements of Drepanoistodus suberectus and Plectodina n. sp. and a few unidentifiable fragments of some Phragmodus species.

The Base of Midcontinent Fauna 7. According to Sweet and others (1971, p. 175), the interval of Midcontinent Fauna 7 "is distinguished by the multielement species Phragmodus inflexus Stauffer" and, "over much of the interior of North America, Fauna 7 is apparently at the base of the transgressive Middle Ordovician succession". The interval of Midcontinent Fauna 6 is characterized by, among other forms, representatives of Phragmodus flexuosus Moskalenko (=Phragmodus sp. A of Sweet and others, 1971, p. 174). Sweet and Bergström (1973) note that, within the lower part of the Bromide Formation in Oklahoma, the P. flexuosus (=Phragmodus n. sp. of Sweet and Bergström, 1973)-P. inflexus
boundary approximates the *Prioniodus variabilis-Prioniodus gerdae* boundary of the North Atlantic conodont zonation. Sweet, Bergström, and Carnes (1973) and Bergström and others (1974, p. 233, Text-Fig. 5) report a similar situation from rocks in the middle thrust belts of eastern Tennessee.

In the Lay School section and in the Thorn Hill section (Fig. 9), the first appearance of representatives of *Phragmodus inflexus* does coincide almost exactly with the top of the *Prioniodus variabilis* Subzone. In both these sections, *P. inflexus* is preceded stratigraphically by *Phragmodus flexuosus* and in the Lay School section the range of *P. flexuosus* overlaps with that of *P. inflexus*. The range of *P. flexuosus* also overlaps that of *P. inflexus* in the Evans Ferry section. At Cuba, however, representatives of *P. flexuosus* do not occur and specimens of *P. inflexus* are present in the blue limestone member, which is within the upper subzone of the *Pygodus anserinus* Zone. Bergström (1973c, Figs. 3-8) reports forms that he calls *Phragmodus* *cf. P. inflexus* from rocks of *Pygodus serrus* Zone age and from rocks of *P. anserinus* Zone age in the eastern thrust belts of Tennessee but, to date, not a single specimen of *P. inflexus* has been reported from rocks known to be older than those of the blue limestone member at Cuba, even though very extensive conodont studies have been carried out on rocks of *P. serrus* Zone age and *P. anserinus* Zone age in recent years (Bergström, 1971a, 1973c; Raring, 1972; Fetzer, 1973; Roscoe, 1973). Therefore, the present evidence indicates that the lower limit of the range of representatives of *P. inflexus*, hence the base of Midcontinent Fauna 7, is within the
upper subzone of the *P. anserinus* Zone, and probably within the upper part of that Subzone.

It should be noted that caution must be exercised in any attempt to correlate rock units on the basis of the *Phragmodus flexuosus*-*Phragmodus inflexus* succession. As mentioned above, the range of *P. flexuosus* overlaps that of *P. inflexus* and in the Lay School and Evans Ferry sections specimens of *P. flexuosus* occur in rocks that are probably within the *Prioniodus gerdae* Subzone. This means that a level at which *P. inflexus* appears to replace *P. flexuosus*, like that in the lower Holston at Thorn Hill (Fig. 9), could be of upper *Pygodus anserinus* Zone age or of lower *Amorphognathus tvaerensis* Zone age at least up to the lower part of the *P. gerdae* Subzone.
Lithostratigraphic subdivision and nomenclature in the middle thrust belts of eastern Tennessee are still in an unsatisfactory state. However, for practical purposes, most of the rock units recognized by Cooper (1956) in the middle belts can be recognized throughout the study area, even though some of the formation names (i.e., Rockdell, Benbolt) used by Cooper in Tennessee are questionable. It is suggested that the names Holston and Mosheim be revived for rock units in the middle belts that fit the current concept of those names as applied in the eastern thrust belts of eastern Tennessee.

Within the present study area, conodont evidence does not substantiate many of the brachiopod-based correlations of Cooper (1956). However, for the most part, correlations based on conodont evidence are consistent with previous belt-to-belt lithostratigraphic correlations (i.e., Rodgers, 1953).

There are no equivalents in the middle belts within the present study area for most of the Lenoir Limestone and its equivalents in the eastern thrust belts of eastern Tennessee. Current conodont evidence suggests that the base of the Middle Ordovician succession in the middle belts is significantly younger, probably within the upper part of the Pygodus anserinus Zone, than the base of the Middle Ordovician succession in the eastern belts, which is no younger than the lower part of the
Pygodus serrus Zone (Bergström, 1971a, 1973c). The predominantly carbonate lower Middle Ordovician succession in the middle belts is equivalent to some part of the predominantly clastic Blockhouse-Sevier succession in the Bays Mountain Synclinorium, to the Holston-Chapman Ridge-Ottosee succession in the Knoxville area, and to some part of the Tellico-Chota-Sevier succession in the Tellico-Sevier belt.

As nearly as can be determined within the current resolution of the North Atlantic conodont zonation, the Holston Formation is approximately the same age in the middle belts as it is in the eastern belts. The base of the formation is within the upper part of the Pygodus anserinus Zone and the top of the formation, the uppermost part of which has yet to be precisely dated, is probably within the Prioniodus gerdae Subzone of the Amorphognathus tvaerensis Zone. This indicates that development of the vast Holston reef complex did not begin until after the Middle Ordovician transgression progressed into the area of the present middle belts. Rocks of the Hogskin Member, which overlie Holston in the Copper Creek belt, can be traced southwestward beyond the present study area into rocks that previously have been mapped as Ottosee (Cattermole, 1958, 1960, 1966a, 1966b). Various authors have concluded that the Ottosee and the Chapman Ridge Formation in the eastern belts are, at least in some part, contemporaneous (Cattermole, 1955, 1958, 1960, 1962, 1966a, 1966b; Milici, 1973, p. 19; Walker and Ferrigno, 1973a, p. 135; Kashfi, 1974, p. 1844). Since the scant conodont evidence available suggests that the Hogskin of the middle belts is in some part equivalent to the Chapman Ridge-Ottosee succession in the eastern belts, it is evident that the Hogskin-Ottosee-Chapman Ridge complex is a vast clastic
wedge that becomes thicker and coarser-grained to the southeast. Influx of clastic material that produced this wedge brought to a close the period of Holston reef development in the Middle Ordovician Southern Appalachian basin (see Rodgers, 1953, p. 92-93; Walker and Ferrigno, 1973a, p. 135, 1973b, p. 300). The Rockdell of the middle belts represents a return of reef conditions, which apparently were optimum in the present Thorn Hill area. It is probable that the Rockdell represents the same period of reef development during which the post-Holston Meadow Marble and Vestal Marble of the eastern belts were produced (see Rodgers, 1953, p. 93; Ferrigno and Walker, 1973, p. 121; Walker and Ferrigno, 1973b, p. 300-301). In view of the interpretation presented here that the Hogskin is at least partially equivalent to the Ottosee, it is interesting to note that Cooper (1956, p. 66) introduced the name Hogskin for rocks "of 'Ottosee type'... usually confused with that formation". As already noted by Bergström (1973c, p. 285), Cooper (1956, p. 67, 90) recognized brachiopods "similar to those of the Hogskin" in certain rocks that he included in the Sevier Formation in the eastern thrust belts. Interestingly enough, the particular rocks in which Hogskin-type brachiopods occur (Cooper, 1956, p. 67: "some parts of the Sevier, as at Miser and south of Athens") have been mapped as Ottosee (Rodgers, 1953; Hardeman, 1966). Therefore, as also noted by Bergström (1973c, p. 285), the brachiopod evidence agrees well with the age relations suggested here for the Hogskin and the Ottosee.

The base of the Ashby Stage of Cooper (1956) is younger than the base of the Porterfield Stage of Cooper (1956), hence the name Ashby cannot be accepted as a stage designation for rocks of pre-Porterfield Age.
Present evidence indicates that *Phragmodus inflexus*, which is the index for the interval of Midcontinent Fauna 7 of Sweet and others (1971), ranges as low as the upper Subzone of the *Pygodus anserinus* Zone.
All conodont elements collected in the course of the present project are retained in the Micropaleontological collections of the Department of Geology and Mineralogy at The Ohio State University. Figured specimens and reference specimens are stored in the Orton Museum of Geology at The Ohio State University. Figured specimens are gold-coated and permanently fixed to 1/2" aluminum pin-type specimen mounts for the Cambridge Scanning Electron Microscope. Reference specimens are mounted in single-hole specimen slides with water-soluble glue.

Genus ACODUS Pander, 1856

Acodus Pander, 1856, p. 21.

Type species: Acodus erectus Pander, 1856.

Remarks: Bergström and Sweet (1966) regarded representatives of the form-species Acodus mutatus (Branson and Mehl) and Distacodus procerus Ethington as components of a multielement apparatus, which they referred to Acodus mutatus (Branson and Mehl), although they expressed reservation about the use of the genus name Acodus. Barnes and Poplawski (1973, p. 779) have suggested that elements of the form-species Acodus mutatus (Branson and Mehl) may have been associated in an apparatus with
elements that have been assigned to the form-species Oistodus venustus Stauffer, and that such an apparatus may be assignable to the genus Paroistodus Lindström. Pending confirmation of the latter suggestion, the provisional name "Acodus" is used here for apparatuses of the type referred to Acodus mutatus by Bergström and Sweet, 1966.

"ACODUS" MUTATUS (Branson and Mehl)

(Pl. II, figs. 13, 14)

Belodus (? ) mutatus Branson and Mehl, 1933, p. 126, Pl. 10, fig. 17.

Acodus inornatus Ethington, p. 268, Pl. 39, fig. 11.

Distacodus procerus Ethington, 1959, p. 275, Pl. 39, fig. 8.

Acodus mutatus (Branson and Mehl), Bergström and Sweet, 1966, p. 303-305, Pl. 35, figs. 7-9 (synonymy list to 1966).

?Acontiodus procerus (Ethington), Serpagli, 1967, p. 46-47, Pl. 9, figs. 6a-11c.

?Acodus mutatus (Branson and Mehl), Serpagli, 1967, p. 41-42, Pl. 6, figs. 1a, 1b, 6a, 6b.

Remarks: The distacodontiform elements and the acodontiform elements included here are finely striated longitudinally, a feature not noted in the descriptions of the type specimens of Belodus (? ) mutatus, Acodus inornatus, or Distacodus procerus. Also, some of the distacodontiform elements assigned to this species bear several very fine costae just anterior to the major costa on each lateral face (Pl. II, fig. 14). Otherwise, the elements of "Acodus" mutatus conform exactly to the descriptions of Acodus inornatus Ethington and Distacodus procerus Ethington (Ethington, 1959).
Distribution of representatives of "Acodus mutatus" within the study area is similar to the distribution of elements here referred to "Oistodus" sp. cf. "O" venustus Stauffer (figs. 4, 5, 8). However, the number of these forms at hand is small and it cannot be shown here, with a reasonable degree of probability, that elements of "Acodus mutatus" and elements of "Oistodus" venustus-type were associated in a single apparatus, as suggested by Barnes and Poplawski (1973).

Occurrence: Specimens of "Acodus" mutatus have been recovered from the Tumbez and Elway-Eidson at Lay School, the Eidson at Evans Ferry, and the Holston at Cuba.

Collection: 23 specimens (15 distacodontiform, 8 acodontiform).

Figured specimens: OSU 31701, OSU 31702.

Reference specimens: OSU 31873 (distacodontiform), OSU 31874 (acodontiform).

"ACODUS" VARIABILIS (Webers)

(Pl. II, figs. 15, 16)

Distacodus variabilis Webers, 1966, p. 28-29, Pl. 2, figs. 4, 5; Atkinson, in Clark, 1971, p. 128, Pl. 5, figs. 1, 2, 6.

?Acontiodus nevadensis Ethington and Schumacher, 1969, p. 450-452, Pl. 67, figs. 21, 22, Text-Fig. 4C.

?Distacodus aff. D. bigdoeyensis Hamar, Ethington and Schumacher, 1969, p. 460-461, Pl. 68, fig. 23, Text-Fig. 4G.

Remarks: Webers (1966, p. 22, 28) noted the great similarity between elements he named Distacodus variabilis and elements he referred to Acodus mutatus. Due to the morphological similarity of individual elements, and due to an apparent similarity of apparatus composition, I believe
that "Acodus" mutatus and Distacodus variabilis Webers are congeneric.

The distacodontiform and acodontiform components of this apparatus have been sufficiently described by Webers (1966). Elements of this species are characterized by the upward curvature of the upper basal edge and the "knoblike keel" (Webers, 1966, p. 28) at the postero-basal corner. None of the specimens at hand displays longitudinal striae or costae as do the elements herein referred to "Acodus" mutatus.

It is interesting to note that in three of the sections investigated (Evans Ferry, Eidson, Cuba) the range of "Acodus" variabilis is almost exactly the same as the range of elements here assigned to "Oistodus" pseudoabundans Schopf. Representatives of these species also occur together through much of the Platteville Formation in Minnesota (Webers, 1966, Pl. 1). Specimens of "Oistodus" pseudoabundans and "Oistodus" venustus are morphologically very similar. Therefore, if it can be confirmed that the elements of "Acodus" mutatus were associated in an apparatus with oistodontiform elements of the type commonly referred to "Oistodus" venustus, as suggested by Barnes and Poplawski (1973), then the possibility is raised that elements here referred to "Acodus" variabilis may have been associated in an apparatus with representatives of "Oistodus" pseudoabundans.

Occurrence: Specimens of "Acodus" variabilis occur in the Hogskin at Lay School; in the Rockdell at Evans Ferry; in the Eidson, Hogskin and Rockdell at Eidson; in the Holston and in Unit 780 at Thorn Hill; and in the blue limestone and Holston at Cuba. Representatives of this species have also been reported from the Platteville Formation in Minnesota (Webers, 1966) and from the Platteville Formation in Wisconsin.
(Atkinson, in Clark, 1971). Votaw (1971, Pl. III, fig. 1) illustrates a specimen, which I interpret as an element of "Acodus" variabilis, from the Pierce Limestone in the Central Basin of Tennessee. Elements that may be conspecific with this species have also been reported from the Copenhagen Formation in Nevada by Ethington and Schumacher (1969).

Collection: 47 specimens (33 distacodontiform, 14 acodontiform).

Figured specimens: OSU 31703, OSU 31704.

Reference specimens: OSU 31875 (distacodontiform), OSU 31876 (acodontiform).

Genus ACONTIODUS PANDER, 1856

Acontiodus Pander, 1856, p. 28.

Type species: Acontiodus latus Pander, 1856.

Remarks: The generic designation "Acontiodus" is used here provisionally and in a form-taxonomic sense in order to express morphological similarities between the elements described below and previously described form-species.

"ACONTIODUS" sp. cf. "A." CURVATUS Mound

(Pl. II, figs. 8, 9)


cf. Acontiodus? curvatus Mound, Sweet and others, 1971, Pl. 2, fig. 35.

Description: Hyaline cones with a narrowly rounded anterior margin, an erect cusp and at least one costa on each lateral face. The posterior margin of the cusp and the upper edge of the base are keeled. The costa
on one lateral face is medial on the cusp but anterior on the base. The
costa on the opposite lateral face is anterior on both cusp and base.
One fragmentary specimen has two costa on one lateral face; these costae
are close together and located posteriorly on the lower part of the
cusp (which is all that remains) but they diverge basally, one being
anterior on the base and the other medial.

Remarks: The affinity of these elements is unknown but elements
that have one costa on each lateral face are very similar to an illustrated
specimen referred to Acontiodus? curvatus Mound by Sweet and others (1971).

Occurrence: Holston Formation at Cuba.
Collection: 7 specimens.
Figured specimens: OSU 31705, OSU 31706.
Reference specimen: OSU 31877.

Genus APPALACHIGNATHUS Bergström, Carnes,
Ethington, Votaw and Wigley, 1974

Appalachignathus Bergström, Carnes, Ethington, Votaw and Wigley, 1974,
p. 227-228.

Type species: Appalachianathus delicatulus Bergström, Carnes, Ethington,
Votaw and Wigley, 1974.

APPALACHIGNATHUS DELICATULUS Bergström, Carnes,
Ethington, Votaw and Wigley

(P1. III, figs. 16-23)

Appalachignathus delicatulus Bergström, Carnes, Ethington, Votaw and
Wigley, 1974, p. 228-234, P1. 1, figs. 1-10.
Remarks: This species has been thoroughly diagnosed and the elements of the apparatus have been sufficiently described by Bergström and others (1974). They (1974, p. 228) note that "apart from the apparent absence of an oistodiform (or neopriniodiform) type of element" the apparatus of *A. delicatulus* is basically an Ozarkodina-type apparatus (Jeppsson, 1969). The collection of elements of *A. delicatulus* at hand is not large but among these elements are three specimens that are unlike any of those previously described and which are probably the neopriniodontiform components of the apparatus. The base of each of these units (Pl. III, figs. 17, 18) is highly compressed and the upper edge of the base is laterally deflected so that the unit as a whole is strongly concavo-convex. The degree of lateral deflection, or twisting, of the upper edge of the base increases in the anterior direction and the upper edge of the base merges laterally into several confluent denticles that flank the cusp. The cusp is flanked on the opposite side by a row of denticles that decrease in size away from the cusp and merge into the anterior margin of the base, which is laterally deflected in the direction opposite to that of the upper edge of the base. These elements are similar to zygognathiform elements in having denticles on both sides of the cusp but on zygognathiform elements the upper edge of the base (= upper margin of the posterior process) is deflected in the opposite direction (see Bergström and others, 1974, p. 230). This element differs from eoligonodiniform elements in that the upper edge of the base is laterally deflected and merges into denticles flanking the cusp. Like the other elements in the apparatus of *A. delicatulus*, this element has a weak ledge parallel to the basal margin.
With the addition of the type of element just described, it is possible to recognize seven distinct types of elements in the apparatus of *Appalachignathus delicatulus*: trichonodelliform, zygognathiform with a straight or nearly straight posterior process that is adenticulate or bears one or two denticles, zygognathiform with a posterior process that is laterally flexed and bears several denticles, eoligonodiniform, ozarkodiniform, spathognathodontiform, and the type of element described above.

**Occurrence**: *Appalachignathus delicatulus* is represented in the Tumbez, Elway-Eidson, and Hogskin at Lay School; in the Eidson, Hogskin, and Benbolt at Evans Ferry; and in the Marcem and Eidson at Eidson. The known distribution of this species outside the present study area is summarized by Bergström and others (1974, p. 232-233). Bergström and others (1974, p. 232) note that the present author reported elements of *A. delicatulus* from the Lincolnshire Formation (= Holston of this paper) at Thorn Hill. However, representatives of *A. delicatulus* have not been recovered at the Thorn Hill Section up to the present time. The elements from Thorn Hill, mistakenly identified by me as components of the *A. delicatulus* apparatus, are identical to elements described by Raring (1972) as representatives of a new genus (=New Genus B of this paper) that is apparently distinct from *Appalachignathus*.

**Collection**: 65 specimens (11 trichonodelliform, 23 zygognathiform, 7 eoligonodiniform, 12 ozarkodiniform, 9 spathognathodontiform, 3 neoprioniodontiform).

**Figured specimens**: OSU 31707, OSU 31708, OSU 31709, OSU 31710, OSU 31711, OSU 31712, OSU 31713.
Reference specimens: OSU 31878 (trichonodelliform), OSU 31879 (zygognathiform with a nearly straight posterior process), OSU 31880 (zygognathiform with a flexed posterior process), OSU 31881 (eoligonodini-form), OSU 31882 (ozarkodiniform), OSU 31883 (spathognathodontiform), OSU 31884 (neoproniodontiform).

Genus BELODELLA Ethington, 1959


Type species: Belodus devonicus Stauffer, 1940.

Remarks: Prior to 1967, elements assigned to different form-species of Belodella were distinguished mainly by differences in transverse section of the base (triangular, plano-convex or biconvex). Serpagli (1967) demonstrated that belodelliform elements of different basal profile are morphologically intergradational and concluded that basal profile is not a useful criterion for establishing form-species of Belodella. Based on differences in denticulation and differences in thickness of the basal walls, Serpagli (1967, p. 53) recognized two species of Belodella, B. devonica and B. erecta, to each of which he referred triangular, planoconvex and biconvex belodelliform elements.

Several authors have concluded that variation in basal profile among belodelliform elements, which Serpagli (1967, p. 53) attributed to intraspecific variation, reflects symmetry-transition within one type of multielement apparatus (Fåhraeus, 1971, p. 674; Sweet and Bergström, 1972, p. 40; Barnes and Poplawski, 1973, p. 769). Fåhraeus (1971) and Barnes and Poplawski (1973) have further suggested that, in addition to
denticulated belodelliform elements of a form-transition series, the apparatuses of some Ordovician Belodella species may also have contained Belodella-like elements that are weakly denticulated or adenticulate.

Bergström (1974, pers. comm.) has suggested, on the basis of extensive investigations in the Appalachians, that some Ordovician Belodella apparatuses also contained oistodontiform components (i.e., Belodella n. sp. A and Belodella n. sp. B of Bergström, 1971a, 1973c). This suggestion is substantiated by the material at hand and the association of belodelliform elements with distinctive oistodontiform elements is also known in Nevada (Ethington and Schumacher, 1969) and in the central basin of Tennessee (Votaw, 1971). Therefore the apparatuses referred to Belodella herein are each interpreted to include a symmetry-transition series of belodelliform elements, Belodella-like elements that are adenticulate or weakly denticulate, and oistodontiform elements.

BELODELLA NEVADENSIS (Ethington and Schumacher)

(Pl. IV, figs. 3-5, 10-13)

Oistodus nevadensis Ethington and Schumacher, 1969, p. 467-468, Pl. 68, figs. 1-4, Text-fig. 5C.

Oepikodus copenhagensis Ethington and Schumacher, 1969, p. 465, Pl. 68, figs. 5, 9, Text-fig. 4L.

Oepikodus? aff. O. copenhagensis Ethington and Schumacher, 1969, p. 465, Pl. 68, fig. 14, Text-fig. 4I.

New Genus A Ethington and Schumacher 1969, p. 478, Pl. 68, figs. 1-4, Text-fig. 4J.

Belodella n. sp. B Bergström, 1971a, p. 113-118, Fig. 10; Bergström, 1973c, p. 269-280, Figs. 3-9.

?Roundya n. sp. Sweet and Bergström, 1962, p. 1244-1245, Text-fig. 5.
Remarks: Components of this apparatus have been sufficiently described by Ethington and Schumacher (1969). Belodelliform elements are characterized by fine, hair-like denticulation. Oepikodontiform elements have a fine costa on each lateral face and short, compressed and slender denticles on the upper basal margin. On some oepikodontiform elements, denticulation is indistinct. Oistodontiform elements are typified by an inflated base and a relatively short cusp.

Occurrence: Hogskin and Rockdell at Lay School, Rockdell at Eidson, Holston at Cuba. Representatives of this species occur in several sections in the eastern thrust belts of the Southern Appalachians (Bergström, 1971a, 1973c; Bergström and Carnes, 1975) and in the Pierce and Ridley Limestones of the Central Basin of Tennessee (Votaw, 1971). Belodella nevadensis also occurs in the Copenhagen Formation of Nevada (Ethington and Schumacher, 1969) and in the Stinchar Limestone in the Girvan area of southwestern Scotland (Bergström, 1971a, p. 113). Bergström (1971a, p. 105) reports specimens of the form-species "Oistodus" nevadensis Ethington and Schumacher, which are probably components of the B. nevadensis apparatus, from the Hølonda Limestone of the Trondheim region, Norway.
Forms that may be conspecific with \textit{B. nevadensis} are reported from the Pratt Ferry of Alabama (Sweet and Bergström, 1962), the Table Head of Newfoundland (Fåhraeus, 1970), the Mystic Formation of Quebec (Barnes and Poplawański, 1973), the San Juan Formation of Argentina (Serpagli, 1974), and the Cobbs Arm Limestone of Newfoundland (Bergström, Riva and Kay, 1974).

Collection: 82 specimens (13 belodelliform, 35 oepikodontiform, 34 oistodontiform).

Figured specimens: OSU 31714, OSU 31715, OSU 31716, OSU 31717, OSU 31718, OSU 31719, OSU 31720.

Reference specimens: OSU 31885 (triangular belodelliform), OSU 31886 (biconvex belodelliform), OSU 31887 (denticulate oepikodontiform), OSU 31888 (adenticulate oepikodontiform), 31889 (oistodontiform).

\textbf{BELODELLA n. sp. A}

(Pl. IV, figs. 6-9, 14)

\textit{Belodella n. sp. A} Bergström, 1971a, p. 118, fig. 10; Bergström, 1973c, p. 269-280, figs. 3, 4, 6.


\textit{?Belodella n. sp. s. f.} Barnes, 1974, p. 230, 236-237, Pl. 1, fig. 11.

Description: Belodelliform elements of this apparatus are similar to those of \textit{Belodella nevadensis} but they are more robust and have coarser denticulation. The denticles are discrete on some specimens but confluent on others. On some of the latter forms, denticles are of unequal size and larger ones alternate with smaller ones.
Elements of the same general form as oepikodontiform elements of *Belodella nevadensis* also occur in association with elements of *B. n. sp. A*. However, these elements do not have a costa on either lateral face, although one face is prominently carinate. None of the oepikodontiform specimens at hand display distinct denticulation on the upper basal margin.

Oistodontiform elements are laterally bowed and the cusp is long relative to the length of the base. The cusp is laterally compressed and bears a carina on the inner face that becomes more distinct basally. The cusp has anterior and posterior keels and the anterior keel is flexed inward, very sharply so on some specimens. The outer face of the base is nearly flat and the outline of the basal margin is slightly sinuous. The inner side of the base is laterally inflated and the outline of the basal margin is strongly sinuous. A shallow, trough-like depression parallels the upper basal margin on the inner face of the base. The base is slightly indented at the basal margin forming a ridge that parallels the basal margin.

Occurrence: Holston at Thorn Hill, blue limestone and Holston at Cuba. *Belodella n. sp. A* is known from several sections in the eastern thrust belts of the Southern Appalachians (Bergström, 1971a, 1973c; Bergström and Carnes, 1975), from rocks of the Chazy Group of New York (Raring, 1972), and from the St. Dominique Limestone of Quebec (Roscoe, 1973). Elements that may be conspecific with *Belodella n. sp. A* occur in the Copenhagen Formation of Nevada (Ethington and Schumacher, 1969) and in the Ship Point Formation of the Canadian Arctic (Barnes, 1974).
Collection: 64 specimens (38 belodelliform, 11 oepkodontiform, 15 oistodontiform).

Figured specimens: OSU 31721, OSU 31722, OSU 31723, OSU 31724, OSU 31725.

Reference specimens: OSU 31890 (belodelliform with spaced denticles), OSU 31891 (belodelliform with confluent denticles), OSU 31892 (oepkodontiform), OSU 31893 (oistodontiform).

**BELODELLA sp. cf. B. DEVONICA (Stauffer)**

(Pl. III, fig. 3)

cf. _Belodus devonicus_ Stauffer, 1940, p. 420, Pl. 59, figs. 47, 48.

cf. _Belodella devonica_ (Stauffer), Serpagli, 1967, p. 53-54, Fig. 6.

Description: The base is long, biconvex, and thin walled. The basal cavity is deep and extends to the base of the erect cusp. The upper edge of the base is surmounted by 12 or more short, slender, compressed denticles of unequal size. These denticles are confluent basally but discrete apically on some specimens; on other specimens, the denticles are discrete. The denticles are erect, decrease in size posteriorly, and merge into a low, thin keel in the posterior quarter of the base. The anterior face of the cusp is broad and flat or slightly depressed. The cusp is bicostate with a pronounced costa directed laterally at each antero-lateral corner. These costae converge basally and continue along the lower margin of the base, much reduced in size, to the basal margin. The narrow area between these costae is flat. Some units are straight, bilaterally symmetrical and the antero-lateral costae are equally developed.
Other units are slightly bowed and the antero-lateral costae are unequally developed, the stronger costa being on the inner (concave) side. The posterior face of the cusp is flat or rounded and bears a fine median costa.

Remarks: These specimens are similar to an element illustrated by Serpagli (1967) as Belodella devonica (Stauffer) but they have fewer, less slender denticles. None of the specimens at hand displays a cross section like the illustrated types of Belodus devonicus Stauffer or Belodus triangularis Stauffer, both of which Serpagli (1967) includes in Belodella devonica (Stauffer). To the best of my knowledge, belodelliform elements of this type have not previously been reported from strata of known Ordovician age but I have also observed such elements in undescribed collections at The Ohio State University from rocks of the Bromide Formation in Oklahoma. Only five specimens of this type are present in the collections at hand and these are from a single sample (73CC2-12) from the Holston Formation at Cuba. It is evident that these elements are members of a symmetry-transition series but nothing more can be surmised at this time about the nature of the apparatus of which these elements were components.

Figured specimen: OSU 31726.
Reference specimen: OSU 31894.

Genus BELODINA Ethington, 1959

Belodina Ethington, 1959, p. 271.

Type Species: **Belodus compressus** Branson and Mehl, 1933.

**BELODINA MONITORENSIS** Ethington and Schumacher

(Pl. V, figs. 7-10)


**Belodina monitorensis monitorensis** Ethington and Schumacher, 1969, p. 456, Pl. 67, figs. 3, 5, 8, 9, Text-fig. 5D.

**Belodina monitorensis marginata** Ethington and Schumacher, 1969, p. 456, Pl. 67, figs. 1, 2, 5, 6, Text-fig. 5E.

**Eobelodina occidentalis** Ethington and Schumacher, 1969, p. 462-463, Pl. 67, figs. 16, 20, Text-fig. 5H.

Remarks: Ethington and Schumacher (1969, p. 462) note that elements they describe as **Belodina monitorensis** and **Eobelodina occidentalis** are associated in the Copenhagen Formation of Nevada. Representatives of these two form-species are also consistent associates in the collections at hand and I do not hesitate to include them in a multielement apparatus assigned to **Belodina** as the genus reinterpreted by Bergström and Sweet (1966, p. 311-312).

The apparatus of **Belodina monitorensis** includes belodiniform elements that Ethington and Schumacher (1969, p. 455) assigned to two form-subspecies based on differences in development of the anterior margin and lateral costae. Marginatiform elements have a thin, sharp, anterior keel and display morphological intergradation from forms with equally developed anterior costae on the lateral faces to forms with the anterior costa on one lateral face relatively less well developed, to forms that have one anteriorly costate lateral face and one anteriorly smooth lateral face. Complete descriptions of these elements are provided

In overall shape and curvature, belodiniform components of Belodina monitorensis are similar to the corresponding elements of Belodina compressa (Branson and Mehl). Several authors (Sweet and Bergström, 1962, p. 1224; Ethington, 1959, p. 272; Sweet and others, 1959, p. 1042-1043) have described ornamentation, in the form of grooves and ridges, on the lateral faces of various form-elements included in B. compressa by Bergström and Sweet (1966). None of these descriptions, and none of the specimens of B. compressa that I have observed in the Micropaleontological Collections at The Ohio State University, suggests lateral ornamentation akin to that of elements assigned to B. monitorensis.

Eobelodiniform elements exhibit more variation that reported by Ethington and Schumacher (1969), particularly in the relative height (distance from the longitudinal groove to the postero-basal corner measured along the basal margin) and width (shortest distance between the basal margin and the acute juncture of cusp and heel) of the "heel." Some specimens have a relatively high and narrow heel, about one-and-one-half times as high as the cusp is wide and about one-fourth as wide as the base is high (measured along the basal margin). Other elements have a relatively short and wide heel, about as high as the cusp is wide and slightly more than one-third as wide as the base is high (measured along the basal margin). The great majority of eobelodiniform elements have a heel with dimensions between these extremes and closer to the short and wide type. None of the specimens at hand exhibits a heel that is only two-thirds as high as the maximum width of the cusp as described by Ethington and Schumacher. However, judging from the illustrations
provided by those authors (Pl. 67, figs. 16, 20), not even the holotype and figured paratype of the form-species *Eobelodina occidentalis* exhibit this character in the way described by Ethington and Schumacher. I have been unable to recognize an objective criterion that would be useful to distinguish these elements from homologous elements in the apparatus of *Belodina compressa* (Branson and Mehl).

Most small, presumably juvenile, belodiniform elements are miniature duplicates of larger specimens and, like larger specimens, have four or five small denticles between the cusp and the heel. On all large and on some small specimens, the posteriormost denticle, that is, the one adjacent to the heel, is erect or slightly reclined. Toward the cusp, the vertical orientation of the denticles grades from suberect to slightly proclined. Some small specimens (Pl. V, fig. 7) have six or seven, all proclined, denticles behind the cusp. Elements of this type have in the past been assigned to the form-species *Belodina dispansa* (Glenister) but the "dispansiform condition" is regarded by recent workers (Bergström and Sweet, 1966, p. 314; Ethington and Schumacher, 1969, p. 454) as an early growth stage in at least two species of *Belodina* (*B. compressa* and *B. monitorensis*).

Occurrence: Representatives of *Belodina monitorensis* occur throughout the study area and in most of the rock units dealt with (figs. 4-8). Specimens of this species are reported from the Copenhagen Formation of Nevada (Ethington and Schumacher, 1969); the Stinchar Limestone of the Girvan area of Scotland (Bergström, 1971a, p. 113); and the Holston Formation, Lenoir Limestone, Sevier Shale, and Chota Formation in the eastern thrust belts of eastern Tennessee (Bergström and Carnes, 1975).
Collection: 653 specimens (492 belodiniform, 161 eobelodiniform).

Figured specimens: OSU 31727, OSU 31728, OSU 31729, OSU 31730.

Reference specimens: OSU 31895 (monitorensiform), OSU 31896 (marginatiform), OSU 31897 (eobelodiniform).

Genus BRYANTODINA Stauffer, 1935


Type species: *Bryantodina typicalis* Stauffer, 1935.

**BRYANTODINA TYPICALIS** Stauffer

*(Pl. V, figs. 1, 2, 18, 19)*

*Bryantodina typicalis* Stauffer, 1935a, p. 134, Pl. 10, figs. 16, 18, 19, 23-25, 29; Webers, 1966, p. 50, Pl. 1, figs. 4-7 (synonymy to 1966); Ethington and Schumacher, 1969, p. 458, Pl. 69, fig. 17; Sweet, Ethington and Barnes, 1971, Pl. 2, fig. 15.

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

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

*Tortoniodes politus* Stauffer, 1935a, p. 155, Pl. 10, figs. 39, 42.

*Hibbardella variabilis* (Stauffer), Webers, 1966, p. 51, Pl. 1, figs. 3, 9.

*Hibbardella varians* (Stauffer), Webers, 1966, p. 51-52, Pl. 7, figs. 14-16.

*Phragmodus inversus* Webers, 1966, p. 52, Pl. 7, figs. 1, 2, 11, 13.

*Prioniodina polita* (Stauffer), Webers, 1966, p. 53, Pl. 7, figs. 8, 10, 17.

Remarks: Webers (1966) has suggested that representatives of the form-species *Hibbardella variabilis* (Stauffer), *Hibbardella varians* (Stauffer), *Phragmodus inversus* Webers, *Prioniodina polita* (Stauffer) and *Bryantodina typicalis* (Stauffer) may have been associated in a
multielement apparatus. Representatives of these form-species, which were included by Webers (1966, p. 49) in "Bryantodina typicalis Informal Group", also occur together in the collections at hand, but they are rare so the association suggested by Webers cannot be confirmed here. However, I believe that this suggestion is reasonable for the element-types involved on the basis of mutual occurrence, mutual morphological characteristics, and comparison of the resulting reconstructed apparatus with other Middle Ordovician conodont apparatuses. Therefore, although the evidence is not yet conclusive, the forms listed above are grouped together in B. typicalis.

Webers (1966) noted considerable variation, in terms of degree of lateral compression and mode of denticulation, among each of the form-types he included in his Bryantodina typicalis Informal Group. All five form categories include variants that are strongly compressed with fused denticles and variants that are weakly compressed with discrete, peg-like denticles. All the elements in the present collections are the strongly compressed type with fused denticles.

Occurrence: Tumbez and Elway-Eidson at Lay School, Eidson at Evans Ferry, Marcem and Eidson at Eidson, Holston at Thorn Hill, blue limestone at Cuba. Representatives of Bryantodina typicalis also occur in the Glenwood of Minnesota (Stauffer, 1935a; Webers, 1966; Sweet, and others, 1971), in the Decorah of Minnesota (Webers, 1966), and in the Winnipeg Formation of North Dakota (Carlson, 1960). Specimens of the form-species Phragmodus inversus Webers are reported by Clark (in Clark, 1971) from the Glenwood of Wisconsin.
Collection: 63 specimens (3 variabiliform, 21 variansiform, 12 phragmodontiform, 6 prioniodiniform, 21 bryantodiniform).

Figured specimens: OSU 31731, OSU 31732, OSU 31733, OSU 31734.

Reference specimens: OSU 31898 (bryantodiniform), OSU 31899 (phragmodontiform), OSU 31900 (variansiform), OSU 31901 (prioniodiniform).

Genus CURTOGNATHUS Branson and Mehl, 1933

Curtognathus Branson and Mehl, 1933, p. 87.

Type species: Curtognathus typus Branson and Mehl, 1933, p. 87.

CURTOGNATHUS spp.

(not illustrated)

Remarks: As noted by Sweet and Bergström (1972, p. 40), some representatives of the form-genus Curtognathus Branson and Mehl may have been associated in an apparatus with cardiodelliform and trucherognathi-form elements. Curtognathiform elements occur in several samples in the collections at hand but in most samples only a few, most commonly less than a dozen, specimens are present. Therefore it has not been possible to speculate about the type of apparatus of which these elements were components.

The elements at hand are of the types that have previously been referred to the form-species Curtognathus coronata Branson and Mehl, C. typa Branson and Mehl, C. limitaris Branson and Mehl, and C. peculiaris Branson and Mehl. It is possible that some of these forms, especially representatives of C. limitaris, may belong with the elements here included
in *Polycaulodus* sp. However, this cannot be substantiated on the basis of the present collections.

Occurrence: Curtognathiform elements occur in most of the units investigated in the Lay School and Evans Ferry sections, in the Eidson and the Rockdell at Eidson, and in the Holston and the Hogskin at Thorn Hill.

Collection: 206 specimens.

Genus DISTACODUS Hinde, 1879

*Machairodus* Pander, 1856, p. 22.

**Distacodus** Hinde, 1879, p. 357.

Type species: *Machairodus incurvus* Pander, 1856.

Remarks: Sweet, Thompson, and Satterfield (1975, in press) include elements formerly referred to the form-species *Acontiodus alveolaris* Stauffer, 1935, and *Distacodus falcatus* Stauffer, 1935, in a multielement apparatus for which they propose a new genus name. Pending publication of that paper, the provisional generic designation "Distacodus" is used here for apparatuses of this type. "Distacodus" falcatus Stauffer is sparsely represented in the present collections but a similar apparatus is recognized and clearly it should also be assigned to this genus.

"DISTACODUS" FALCATUStauffer

(P1. III, fig. 4)

*Distacodus falcatus* Stauffer, 1935a, p. 142, Pl. 12, fig. 16; Stauffer, 1935b, p. 605, Pl. 74, fig. 30; Ethington, 1959, p. 275, Pl. 39, fig. 9; Webers, 1966, p. 27, Pl. 3, fig. 4; Bergström and Sweet, 1966, p. 329, Pl. 35, figs. 10-13.

Occurrence: Hogskin Member at Lay School. One distacodontiform element, which is probably a representative of "Distacodus" falcatus, occurs in the Tumbez Formation at Lay School.

Collection: 14 specimens (5 acontiodontiform, 9 distacodontiform).

Figured specimen: OSU 31735.

Reference specimen: OSU 31902 (acontiodontiform).

"DISTACODUS" n. sp.

(Pl. III, figs. 6-9; Fig. 15A-C)

Acontiodus? sp. Ethington and Schumacher, 1969, p. 453, Pl. 68, fig. 24, Text-figs. 4D, 4E.

?Scandodus nevadensis Ethington and Schumacher, 1969, p. 476, Pl. 68, figs. 20, 21, Pl. 69, fig. 10.


Diagnosis: A species with a multielemental simple-cone apparatus that includes acontiodontiform elements and a morphologically intergradational series of distacodontiform elements.

Description: Ethington and Schumacher (1969) have described acontiodontiform elements of this apparatus and, although based on only two fragmentary specimens, their description is accurate and sufficient. All that can be added here is that the antero-lateral, wing-like costae taper gradually toward the apex of the cusp, which is gently recurved. All faces of these elements are finely straited longitudinally, the
striations being most obvious on the base and on the posterior side of the cusp. The structure on the upper edge of the base and posterior side of the cusp, referred to by Ethington and Schumacher as a median posterior keel, would, in the terminology of this paper, be called a costa.

Distacodontiform elements generally conform to Stauffer's (1935a, p. 142, Pl. 12, fig. 16) description and illustration of Distacodus falcatus and, in form-taxonomy, would be referred to that form-species without hesitation. Sweet and Bergström (1972, p. 32) note that distacodontiform elements commonly referred to "D. falcatus" Stauffer display symmetry transition and this is also true of distacodontiform elements of the apparatus described here. Five different types of distacodontiform elements can be recognized and these can be segregated into two general groups, those with long bases and those with short bases. All distacodontiform elements display fine longitudinal striations.

Long-base elements have a straight or slightly bowed midplane and they are recurved at about mid-length. The basal cavity is conical and deep and extends to the point of recurvature. One type of long-base element (Fig. 15A, cross-section 1) has a rounded anterior costa on each lateral face. These anterior "costae" are slightly asymmetrically disposed and are actually no more than rounded offsets where the lateral faces meet the rounded anterior face. A sharp costa is situated at the juncture of the upper basal margin with one lateral face. This costa, hereafter referred to as the "upper-posterior" costa, continues up the postero-lateral corner of the cusp. Long base elements of a second type (Fig. 15A, cross-section 2) are similar in gross aspect to elements of the first type but have an anterior costa on only one lateral face. The
Figure 15. Distacodontiform elements of "Distacodus" n. sp., X65.
(A) lateral view of a long-base element with cross-sections depicting: (1) anteriorly-bicostate element, (2) anteriorly-unicostate element with the upper-posterior costa on the anteriorly-smooth side, (3) anteriorly-unicostate element with the upper-posterior costa on the anteriorly-costate side. (B) lateral view and cross-section of a short-base, bicostate element. (C) lateral view and cross-section of a short-base, unicostate element.

other lateral face merges smoothly into the anterior face. The upper-posterior costa is situated on the anteriorly-smooth side of the element. Long-base elements of a third type (Fig. 15A, cross-section 3) are like the second type in all respects except the upper-posterior costa is situated on the anteriorly-costate side of the element.

Short-base elements are abruptly recurved within the lower one-third of the element and have an erect to slightly proclined cusp. The basal cavity extends to the point of recurvature and is, therefore, relatively shallow. One type of short-base element (Fig. 15B) has a rounded offset costa on each lateral face and the cusp is slightly twisted so that the
costa on one side is located more posteriorly. The upper-posterior costa is situated on the same side of the element as the anteriormost lateral costa. Short-base elements of a second type (Fig. 15C) have one sharp antero-lateral costa and a cusp that is strongly twisted relative to the base. The acostate lateral face merges smoothly with the anterior face and the upper-posterior costa is situated on the same side of the element as the anteriorly-smooth lateral face. Due to twisting of the cusp, the upper-posterior costa and the costa that is antero-lateral on the base and on the lower half of the cusp rotate to become, in the upper half of the cusp, the sharp lateral margins of an antero-posteriorly compressed cusp.

Remarks: The illustrated holotype of *Scandodus nevadensis* Ethington and Schumacher appears to be morphologically identical to short-base, bicostate, distacodontiform elements of *"Distacodus"* n. sp. However, without direct comparison of specimens, I hesitate to use the trivial name *nevadensis* for elements of *"Distacodus"* n. sp.

Occurrence: Blue limestone and Holston Formation at Cuba. Specimens of *"Distacodus"* n. sp. also occur in the Copenhagen Formation of Nevada (Ethington and Schumacher, 1969).

Collection: 116 specimens (20 acontiodontiform, 96 distacodontiform).

Figured specimens: OSU 31736, OSU 31737, OSU 31738, OSU 31739.

Reference specimens: OSU 31903 (acontiodontiform), OSU 31904 (long-base, bicostate), OSU 31905 (long-base, unicostate, upper-posterior costa on the anteriorly-costate side), OSU 31906 (long-base, unicostate,
upper-posterior costa on the anteriorly-smooth side), OSU 31907 (short-base, bicostate), OSU 31908 (short-base, unicostate).

"DISTACODUS"? sp.

(Pl. III, fig. 5)

Description: Two bilaterally symmetrical acontiodontiform elements have been recovered that are similar in general form to acontiodontiform elements of "Distacodus" falcatus and "Distacodus" n. sp. and which may be congeneric with those species.

The base is short and laterally expanded so that the outline of the basal margin is elliptical. The anterior face of the base and the upper edge of the base are broad and gently convex. The base tapers in the anterior direction and merges smoothly with the cusp, which is slightly proclined. The anterior face of the cusp is rounded and a rounded, antero-lateral, offset-costa is produced at the juncture of each lateral face of the cusp with the anterior face of the cusp. The lateral faces of the cusp are flat and the posterior face of the cusp is deeply channeled by a V-shaped median groove which is deepest at the base of the cusp but does not extend onto the base. The unit is very finely striated longitudinally.

Remarks: This specimen is similar to some elements that have previously been assigned to the form-species Acontiodus staufferi Furnish (i.e., Furnish, 1938, Pl. 42, fig. 11; Ethington and Clark, 1971, Pl. 1, fig. 14). Compared with illustrations of representatives of A. staufferi,
the element described here has a much deeper median-posterior groove
and much more subdued antero-lateral costae.

Occurrence: Tumbez at Lay School, Holston at Thorn Hill.

Collection: 2 specimens.

Figured specimen: OSU 31740.

Reference specimen: OSU 31909.

Genus DREPANOISTODUS Lindström, 1971


Type species: Oistodus forceps Lindström, 1955.

DREPANOISTODUS SUBERECTUS (Branson and Mehl)

(Pl. II, figs. 1-5; Fig. 16A-C)

Drepanodus suberectus (Branson and Mehl), Bergström and Sweet, 1966, p.
330-333, Pl. 35, figs. 22-27 [synonymy through 1966, excluding
D. suberectus (Branson and Mehl), Lindström, 1955, and D. homocurvatus
Lindström, 1955, which are representatives of Drepanoistodus forceps
(Lindström)]; Oberg, 1966, p. 137, 138, Pl. 16, fig. 1; Weyant,
1968, p. 47, Pl. II, figs. 11, 12; Globensky and Jauffred, 1971,
p. 55, Pl. IV, figs. 3-6 (synonymy through 1969); Uyeno, 1974, p. 14,
Pl. 1, figs. 5-9 (synonymy through 1973).

Drepanodus homocurvatus Lindström, Oberg, 1966, p. 137, Pl. 16, fig. 13;
Andrews, 1967, p. 889, Pl. 113, fig. 16, Pl. 114, figs. 8, 15;

Oistodus inclinatus Branson and Mehl, Oberg, 1966, p. 139, Pl. 15, fig. 3;
Andrews, 1967, p. 895, Pl. 114, fig. 19; Weyant, 1968, p. 53, Pl. II,
fig. 8; Ethington and Schumacher, 1969, p. 467, Pl. 68, fig. 7.

Oistodus excelsus Stauffer, Oberg, 1966, p. 139, Pl. 15, fig. 2.
Remarks: The concept of *Drepanoistodus suberectus*, a species with a multielement simple-cone apparatus, subscribed to here is that of Bergström and Sweet (1966) and Lindström (1971). Inclinatiform and suberectiform elements of this apparatus have been discussed elsewhere (Bergström and Sweet, 1966; Bergström, 1962, p. 41) and require no further mention.

The broad range of variation of homocurvatiform elements of *Drepanoistodus suberectus* has been pointed out by Bergström and Sweet (1966) and Webers (1966, p. 30) and, although form-variants are morphologically intergradational in the collections at hand, at least three distinct types can be recognized.

One of these forms (Form A; Fig. 16A) has a compressed, wedge-shaped base with a shallow basal cavity, the apex of which points directly anteriorly. The anterior margin of the cusp and the base are thin and lie in the mid-plane of the element. This element corresponds closely in form to Lindström's (1955, p. 565, Pl. 2, figs. 35, 37, textfig. 4a) description of the form-species "*Drepanodus planus*".

The second type of homocurvatiform element (Form B; Fig. 16B) conforms to Lindström's (1955, p. 563, Pl. 2, figs. 23, 24, 39, textfig. 4d) definition of "*Drepanodus homocurvatus*" and Branson and Mehl's (1933, p. 110, Pl. 9, figs. 4, 10, 12) illustrations of "Oistodus curvatus" in having an expanded base, a relatively deep, almost triangular basal cavity and a thin, laterally flexed keel on the anterior margin.

The third type of homocurvatiform element (Form C; Fig. 16C) has an expanded base and a basal cavity that is shaped like that of "*Drepanodus*
Figure 16. Homocurvatiform elements of *Drepanoistodus suberectus* (Branson and Mehl), lateral views and basal outlines, X65.

(A) Form A. (B) Form B. (C) Form C.

planus" Lindström but is intermediate in depth between that of "D. planus" Lindström and "D. homocurvatus" Lindström. Some specimens of this type display an anterior indentation, or notch, in the basal margin on one side as do some inclinatiform elements of *Drepanoistodus suberectus*. Elements almost identical to this form have previously been illustrated as "*Drepanodus planus*" by Lindström (1955, Pl. 2, fig. 36) and "*Drepanodus homocurvatus*" Lindström? by Weyant. (1968, Pl. 2, fig. 14).

In the collections at hand, these three types of homocurvatiform elements always occur together and can usually be separated based on the shape of the base, the shape and depth of the basal cavity and the
orientation of the anterior margin or keel on the cusp and base. The component elements of the *Drepanoistodus suberectus* apparatus, including at least three types of homocurvatiform elements plus inclinatiform and suberectiform elements, correspond in general form, element for element, with the several form-species brought together in *Drepanoistodus forceps* by Lindström (1971, p. 42). The close correspondence between Lower Ordovician and Middle Ordovician species of *Drepanoistodus*, in apparatus architecture as well as in component-element form, reflects the relative conservativeness of this genus and emphasizes the fact that known species of *Drepanoistodus* can be recognized only by subtle differences in some of the component elements (see Lindström, 1971, p. 42-43).

**Occurrence:** Representatives of *Drepanoistodus suberectus* occur in all rock-units investigated.

**Collection:** 992 specimens (659 homocurvatiform, 192 inclinatiform, 141 suberectiform).

**Figured specimens:** OSU 31741, OSU 31742, OSU 31743, OSU 31744, OSU 31745.

**Reference specimens:** OSU 31910 (homocurvatiform, Form A), OSU 31911 (homocurvatiform, Form B), OSU 31912 (homocurvatiform, Form C), OSU 31913 (suberectiform), OSU 31914 (inclinatiform).

**DREPAANOISTODUS n. sp.**

*(Pl. III, figs. 11-15; Fig. 17A-E)*

**Diagnosis:** A species with a multielement simple-cone apparatus that includes a morphologically intergradational series of drepanodontiform
elements plus oistodontiform elements. One type of oistodontiform
element and at least four types of drepanodontiform elements are present
in this apparatus. The apparatus is characterized by drepanodontiform
elements with a deep basal cavity and by oistodontiform elements
that have a prominent arch on the posterior part of the inner face of
the base.

Description: No representatives of this species have been recovered
intact but it appears that the cusp on all drepanodontiform elements
is evenly curved and is erect or reclined. All elements are finely
striated longitudinally.

One type of drepanodontiform element (Form A; Fig. 17A) is strongly
laterally compressed and biconvex with a deep basal cavity, the apex of
which is near the anterior margin of the unit. The anterior margin of
cusp and base is sharp. A sharp to sharply rounded costa begins at the
antero-basal corner and merges apically, within one-quarter to one-third
the length of the base, into the sharp anterior margin of the base. The
posterior margin of the cusp and the upper edge of the base are sharp and
surmounted by a narrow keel. Some elements of this form are nearly bilat­
erally symmetrical; others are slightly asymmetrical, one side being
more convex than the other.

Drepanodontiform elements of a second type (Form B; Fig. 17B) are
also strongly laterally compressed and biconvex with a deep basal cavity,
the apex of which is very near the anterior margin of the unit. The
anterior margin of the cusp is sharp. The posterior margin of the cusp
and the upper edge of the base are sharp and surmounted by a narrow keel.
Figure 17. Elements of Drepanistodus n. sp.; lateral views, cross-sections, and basal outlines; X65. (A) drepanodontiform element, Form A. (B) drepanodontiform element, Form B. (C) drepanodontiform element, Form C. (D) drepanodontiform element, Form D, with basal outlines depicting (1) an equally biconvex element, (2) an unequally biconvex element, (3) a plano-convex element. (E) inner-lateral view of an oistodontiform element.

The anterior margin of the base is sharp and produced into a broad, thin keel and the anterior margin of the basal cavity recurves to extend beneath this keel at the antero-basal corner. Some elements are nearly bilaterally symmetrical but others are unequally biconvex. On asymmetrical elements, the anterior keel is slightly flexed toward the less-convex
side. These elements differ from drepanodontiform elements of the first type described in having an anterior keel on the base, a relatively more compressed cusp, and a relatively shorter base.

Drepanodontiform elements of a third type (Form C; Fig. 17C) are moderately laterally compressed, are unequally biconvex or plano-convex, and are slightly bowed toward the less-convex or flat side. The basal cavity is deep and extends nearly to the anterior margin of the unit. The anterior margin of the cusp is sharp. The posterior margin of the cusp and the upper edge of the base are sharp and surmounted by a narrow keel. The anterior margin of the base is keeled and the keel is deflected toward the less-convex or flat side. On some specimens the more-convex side of the base merges smoothly into the anterior keel; on other specimens, the more-convex side of the base is anteriorly flattened and, on some specimens, the posterior edge of this flattened area is produced into a costa at the anterior margin of the more-convex side of the base.

Drepanodontiform elements of a fourth type (Form D; Fig. 17D) are moderately to strongly compressed; some specimens are equally biconvex and are nearly bilaterally symmetrical but others are unequally biconvex or plano-convex (Fig. 17D, cross-sections 1-3); and they have a relatively short base and a relatively shallow basal cavity, the apex of which ends short of the anterior margin of the unit. The anterior margin of the cusp is sharp. The posterior edge of the cusp and the upper edge of the base are sharp and bear a narrow keel. The anterior margin of the base bears a wide, thin keel and the anterior margin of the basal cavity is recurved to extend beneath the keel at the antero-basal corner. On asymmetrical specimens, the anterior keel on the base may be either
straight or slightly flexed toward the more-convex side of the element.

Oistodontiform elements (Fig. 17E) are slightly laterally bowed and have a compressed, unequally-biconvex cusp that has anterior and posterior keels and a broad carina on the inner side. The outer face of the base is gently convex and the upper edge of the base is keeled. The posterior part of the inner face of the base is laterally expanded and has an abrupt arch near the upper basal margin.

Remarks: The different forms included here occur together through a narrow stratigraphic interval in the lower part of the Holston Formation at Cuba. These elements are not abundant in the collections at hand but their close morphological similarity and their consistent co-occurrence suggests that they are components of a multielement apparatus.

Drepanodontiform elements of this apparatus that have a long base and a deep basal cavity are similar in outline to specimens that have been referred to Drepanodus? altipes Henningsmoen, 1948? (Sweet and others, 1959; Bergström, 1964) and to Acodus numaltipes Schopf (Schopf, 1966). However, none of the specimens of these types that have been illustrated has a basal cavity that extends to the anterior margin as is the case in long-base drepanodontiform elements of Drepanoistodus n. sp..

Occurrence: Hogskin at Lay School, Rockdell at Eidson, Holston at Thorn Hill, blue limestone and Holston at Cuba.

Collection: 117 specimens (95 drepanodontiform, 22 oistodontiform).

Figured specimens: OSU 31746, OSU 31747, OSU 31748, OSU 31749, OSU 31750.

Reference specimens: OSU 31915 (drepanodontiform, Form A), OSU 31916
(drepanodontiform, Form B), OSU 31917 (drepanodontiform, Form C),
OSU 31918 (drepanodontiform, Form D), OSU 31919 (oistodontiform).

Genus EOPLACOGNATHUS Hamar, 1966

Eoplacognathus Hamar, 1966, p. 58:

Type species: Ambalodus lindstroemi Hamar, 1964.

Eoplacognathus elongatus (Bergström)
(Pl. VIII, figs. 17, 18)

Amorphognathus elongata Bergström, 1962, p. 31-32, Pl. 5, figs. 1-3.

Eoplacognathus extensa Hamar, 1966, p. 59-60, Pl. 4, figs. 3-4, Fig. 5,
no. 1a-1d; Viira, 1974, p. 76-77, Pl. VIII, figs. 23-30, Fig. 84.

Eoplacognathus elongatus (Bergström), Bergström, 1971a, p. 137-138, Pl. 2,
figs. 12, 13, 14 (synonymy through 1969).

Polyplacognathus elongatus (Bergström, 1961), Viira, 1974, p. 105,
Fig. 133.

?Polyplacognathus cf. ringerikensis Hamar, Viira, 1974, p. 111, Fig. 141.

Occurrence: Elway-Eidson at Lay School, Eidson at Evans Ferry,
Holston at Thorn Hill. The known distribution of representatives of this
species up to 1971 is summarized by Bergström (1971a). Specimens of
Eoplacognathus elongatus have recently been reported from Estonia
(Viira, 1974) and from the Sevier Shale, Chapman Ridge Formation, and
Tellico Formation in eastern Tennessee (Bergström and Carnes, 1975).

Collection: 14 specimens (10 polyplacognathiform, 4 ambalodontiform).

Figured specimens. OSU 31751, OSU 31752.

Reference specimens: OSU 31920 (polyplacognathiform), OSU 31921
(ambalodontiform).
EOPLACOGNATHUS sp.
(Pl. VIII, fig. 16)

Remarks: Two ambalodontiform elements are included here. Both specimens have a narrow, twisted, denticulate anterior process; a narrow, straight, denticulate posterior process; a broad, denticulate lateral process; and a laterally compressed cusp at the juncture of the three processes. These specimens are small and their affinity has not been determined but it is possible that they are juvenile sinistral ambalodontiform elements of *Eoplacognathus elongatus*.

Occurrence: Hogskin Member at Lay School, Eidson Member at Eidson.

Collection: 2 specimens.

Figured specimen: OSU 31753.

Reference specimen: OSU 31922.

Genus *ERISMODUS* Branson and Mehl, 1933

*Erismodus* Branson and Mehl, 1933, p. 25.

Type species: *Erismodus typus* Branson and Mehl, 1933.

Remarks: Various authors have suggested that elements referable to form species of *Erismodus* Branson and Mehl, *Microcoelodus* Branson and Mehl and *Ptiloconus* Sweet (=*Pteroconus* Branson and Mehl) may have been associated, as members of a form-transition series, in a multielemental conodont apparatus (i.e., Lindström, 1964, p. 89; Votaw, 1971, p. 88-89; Sweet and Bergström, 1972, p. 34, 35, 40, 41, 42). Hyaline elements that represent the form-genera mentioned above are common in the collections at hand and these could easily be distributed among a dozen or more
previously described form-species. However, by using a small set of morphological criteria for recognition of different element-types, it has been possible consistently to segregate erismodontiform, microelodontiform and ptiloconiform elements in the collections at hand into seven basic shape categories. These shape categories can best be described as symmetrical trichonodelliform, asymmetrical trichonodelliform, zygognathiform, eoligonodiniform, prioniodiniform, oulodontiform and "modified falodontiform". Furthermore, within each of these seven categories it is possible to distinguish two types of elements on the basis of differences in denticulation. One type has relatively short denticles on the processes whereas the other type has relatively long process denticles. Denticulation on elements of the latter type is very Chirognathus-like in some cases and certain elements of this type have, in fact, been referred to form-species of Chirognathus in the past.

I believe that the seven shape categories listed above represent positions in a characteristic type of multielement apparatus and that differences in denticulation within each of these categories can be used to recognize two species of one multielement genus. Two apparatuses are described below and the elements included in each of these are morphologically intergradational and occur in consistent stratigraphic and geographic association within the study area. Aside from almost complete morphological intergradation and mutual occurrence, the most compelling evidence for the element-associations suggested here is the fact that the architectural plan of the resulting apparatuses is basically the "prioniodid plan" of Sweet and Bergström (1969). Components of both the apparatuses
described here can be homologized element-for-element with components of the *Plectodina* and *Oulodus* apparatuses. In fact, the plan of the proposed apparatuses is so strikingly similar to that of the *Oulodus* apparatus that Sweet and Schönlaub (1975, in press) have suggested that *Oulodus* derived from the stock of conodont animals that is represented by the apparatuses described here.

Generic assignment of these apparatuses is uncertain at the present time so use of the name *Erismodus* must be regarded as tentative. Both apparatuses contain erismodontiform elements that are similar, but not identical, in form to representatives of *Erismodus typus*, the type species of *Erismodus*. On the other hand, one of these apparatuses includes elements that are identical in form to the type specimen of *Microcoelodus typus* Branson and Mehl, which is the type species of *Microcoelodus* [this same apparatus also includes elements identical to the type specimen of *Ptiloconus gracilis* (Branson and Mehl), the type species of *Ptiloconus* — such an association has already been suggested by Sweet and Bergström, 1972, p. 42]. *Erismodus* Branson and Mehl (1933, p. 25) is an older name than *Microcoelodus* Branson and Mehl (1933, p. 89) and Andrews (1967, p. 893) has placed *Microcoelodus* in synonymy with *Erismodus*. However, the type of apparatus of which representatives of *E. typus* were components is not known. Therefore, it is possible, as suggested by Sweet and Bergström (1972, p. 41) that *Erismodus* and *Microcoelodus* are distinct genera.

As previously mentioned, most of the elements included here are identical in form to various previously described form-species. However, at the present time, it is not possible to establish meaningful lists of
synonyms and accordingly it would be inappropriate to assign these apparatuses to species. Such ventures must be predicated on extensive restudy of type specimens, of which I have seen only a few, and, if possible, on the study of collections from which type specimens were derived. Hyaline-element apparatuses of the type described here are as yet poorly known and it is possible, as is often the case with conodont elements, that elements of one particular form may occur in more than one type of apparatus. Therefore, the lists of form-species included below are intended only as expressions of similarity in form between elements included here and elements that have been illustrated elsewhere. They are not to be taken as synonymy lists.

**ERISMODUS sp. 1**

*(Pl. VII, figs. 7-14)*

**Diagnosis:** A species with a multielement, hyaline-element apparatus that includes a symmetry-transition series of symmetrical trichonodelliform elements, asymmetrical trichonodelliform elements, zygognathiform elements, and eoligonodiniform elements plus prioniodiniform elements, oulodontiform elements and "modified falodontiform" elements. The elements of this apparatus are characterized by a long, robust cusp and by relatively short, discrete peg-like process denticles.

**Description:** Individual elements of this apparatus, as well as those of the *Erismodus* sp. 2 apparatus, are morphologically highly variable and morphological intergradation between elements of the different form categories is such that some elements are difficult to
classify. The most important criterion for distinguishing the various types of elements in this apparatus is the angle between the processes, here termed simply the "process angle". This angle is the angle between the lateral processes (or between the anterior and posterior processes) measured in a plane perpendicular to the long axis of the cusp. In other words, the process angle is the angle enclosed by the processes when the element is viewed from the apical direction. All the elements in this apparatus bear prominent costae on the cusp that are continuous with the processes. The process denticles also bear very narrow keels, one on each side in the median plane of the process. On some specimens, these keels are weakly developed or are absent.

Symmetrical trichonodelliform elements: The elements are bilaterally symmetrical and are identical in form to elements that have been referred to the form-species Erismodus symmetricus Branson and Mehl (1933, p. 104, Pl. 10, fig. 10). The process angle of these elements varies greatly, from 90 degrees on some specimens to nearly 180 degrees on others, and the upper edge of the base between the processes is flat to broadly rounded.

Similar forms:

Erismodus (?) dubius Branson and Mehl, 1933, p. 104, Pl. 9, figs. 5,6.
Erismodus sp. Schopf, 1966, p. 104-105, Pl. 6, fig. 13.
Erismodus symmetricus Branson and Mehl, Webers, 1966, p. 63, Pl. 4, fig. 7.
Erismodus typus Branson and Mehl, Andrews, 1967, p. 891-892, Pl. 112, figs. 10, 18, not Pl. 112, figs. 9, 11, not Pl. 114, fig. 21.
Asymmetrical trichonodelliform elements: Processes on these elements are slightly skewed relative to the cusp and the process angle is, in most specimens, between 90 and 120 degrees. The upper edge of the base is broadly to sharply rounded. In posterior view many of these elements appear to be bilaterally symmetrical but asymmetry is readily observable in lateral view and in anterior view from which it can be seen that one process is displaced somewhat more toward the posterior than the opposing process.

Similar forms:

- Microcoelodus simplex Branson and Mehl, 1933, p. 94, Pl. 6, fig. 30, Pl. 7, fig. 23; Sweet, 1955, p. 244, Pl. 29, fig. 5.
- Microcoelodus symmetricus Branson and Mehl, 1933, p. 95, Pl. 7, fig. 21.
- Microcoelodus sp. Branson and Mehl, 1933, p. 160, Pl. 7, fig. 6.
- Microcoelodus simplex? Branson and Mehl, 1933, p. 160, Pl. 7, fig. 18.
- Microcoelodus intermedius Branson and Mehl, 1943, p. 384, Pl. 64, figs. 38, 40, 53.
- Erismodus symmetricus Branson and Mehl, Andrews, 1967, p. 893-894, Pl. 112, figs. 5, 16, 21 (not Pl. 112, figs. 4, 13), Pl. 113, fig. 7, Pl. 114, fig. 4, 24 (not Pl. 114, fig. 18).

Zygognathiform elements: Markedly asymmetrical units that are identical in form to elements that have been referred to the form-species Microcoelodus typus Branson and Mehl (1933, p. 90, Pl. 6, figs. 31, 32).

These elements can best be thought of as trichonodelliform elements on
which one process has been rotated apically and posteriorly while the opposing process has been rotated down and anteriorly. The process angle is approximately 90 degrees and the upper edge of the base between the processes is broadly to sharply rounded.

Similar forms:

_Erismodus asymmetricus_ (Branson and Mehl), Andrews, 1967, p. 893-894, Pl. 112, fig. 14 (not Pl. 112, figs. 1, 3, 6, 7, 17, not Pl. 113, fig. 1), Pl. 114, fig. 13 (not Pl. 114, figs. 7, 9).

_Eoligonodiniform elements:_ Markedly asymmetrical units with a short, denticulate posterior process and a short, denticulate anterolateral process. These elements are identical in form to the type specimens of _Pteroconus_ (=_Ptiloconus_ Sweet) _gracilis_ Branson and Mehl (1933, p. 111, Pl. 8, figs. 28, 30, 32, 35). They are also identical to the type specimen of _Pteroconus_ (=_Ptiloconus_ Sweet) _reversus_ Branson and Mehl (1933, p. 99, Pl. 7, fig. 1). As noted by Lindström (1964, p. 179, note 9), the type specimen of _Pteroconus gracilis_, which is here interpreted as an eoligonodiniform element, is very similar to that of _Microcoelodus typus_, which is here interpreted as a zygognathiform element (also see Sweet and Bergström, 1972, p. 41). Eoligonodiniform elements can be thought of as extremes in development of zygognathiform elements, on which one process is rotated completely to the posterior, and they can be distinguished from zygognathiform elements in two ways. On eoligonodiniform elements, the posterior process and the denticles on the posterior process are in the same plane as the cusp. On zygognathiform elements, the plane that bisects all the denticles on the outer-lateral process (the one that is rotated posteriorly) is inclined outward relative
to the plane that passes through the cusp and the upper edge of the base. Also, on zygognathiform elements, the upper edge of the base is rounded so as to produce a distinct fold between the processes (Pl. VII, fig. 12). On the other hand, the base of eoligonodiniform elements is relatively more compressed so that there is no distinct fold between the two processes (Pl. VII, fig. 10).

Similar forms:

*Ptiloconus gracilis* (Branson and Mehl), Sweet, 1955, p. 246, Pl. 28, figs. 6, 20; Webers, 1966, p. 70, Pl. 5, fig. 8.

Prioniodiniform elements: Arched and laterally bowed units with relatively long anterior and posterior processes. The process angle is, in most cases, between 120 and 160 degrees. These elements are distinguished from zygognathiform elements by the longer processes and by the larger process angle.

Similar forms:

*Microcoelodus typus* Branson and Mehl, Branson and Mehl, 1943, p. 383, Pl. 64, fig. 36 (not Pl. 64, figs. 54-56).

*Erismodus symmetricus* (Branson and Mehl), Andrews, 1967, p. 892-893, Pl. 112, figs. 4, 13 (not Pl. 112, figs. 5, 16, 21, not Pl. 113, fig. 7), Pl. 114, fig. 18 (not Pl. 114, figs. 4, 24).

*Erismodus asymmetricus* (Branson and Mehl), Andrews, 1967, p. 893-894, Pl. 112, figs. 1, 3, 6, 7, 17 (not Pl. 112, fig. 14, not Pl. 113, fig. 1), Pl. 114, figs. 7, 9 (not Pl. 114, fig. 13).

Oulodontiform elements: Elements of this type are identical in form to representatives of the form-species *Microcoelodus expansus* Branson and Mehl (1933, p. 93, Pl. 6, fig. 7). These elements are similar in general form to prioniodiniform elements but the process angle is larger, in most case 160 degrees or more; the processes are broader and the
underside of each process is flattened so that the basal cavity is relatively much more shallow; and the posterior process is abruptly arched abapically near the juncture with the cusp.

Similar forms:

?Microcoelodus expansus Branson and Mehl, Sweet, 1955, p. 243-244, Pl. 27, figs. 3, 19.

Microcoelodus expansus Branson and Mehl, Webers, 1966, p. 65, Pl. 5, fig. 6.


"Modified falodontiform" elements: Units with a keeled upper basal margin and a short, denticulate, antero-lateral process. Elements of this type are identical in form to the cotypes of Microcoelodus asymmetricus Branson and Mehl (1933, p. 91, Pl. 7, figs. 5, 10, 11, 14, 15). On some specimens the keel on the upper edge of the base is produced into one or two denticle-like nodes near the postero-basal corner. These are essentially falodontiform elements on which the denticulate anterior margin of the cusp is sharply deflected laterally.

Similar forms:

?Microcoelodus unibranchiatus Branson and Mehl, 1933, p. 95, Pl. 6, fig. 23.

Microcoelodus asymmetricus Branson and Mehl, Branson and Mehl, 1943, p. 383-384, Pl. 64, figs. 37, 39, 41, 46; Webers, 1966, p. 65, Pl. 4, fig. 10.

Occurrence: Erismodus sp. 1 ranges throughout the Lay School and Evans Ferry sections. Representatives of this species also occur in the Marcem and Eidson at Eidson, in the Holston and Hogskin at Thorn Hill, and in the blue limestone and Holston at Cuba.

Collection: 910 specimens (80 symmetrical trichonodelliform, 160 asymmetrical trichonodelliform, 126 zygognathiform, 203 eoligonodiniform,
Diagnosis: A species with a multielement, hyaline-element apparatus that includes a symmetry-transition series of symmetrical trichonodelliform elements, asymmetrical trichonodelliform elements, zygognathiform elements, and eoligonodiniform elements plus prioniodiniform elements, oulodontiform elements and "modified falodontiform" elements. The elements of this apparatus are characterized by a long, robust cusp and by relatively long, compressed process denticles. The process denticles on most of the component element-types are discrete but on prioniodiniform elements, oulodontiform elements, and "modified falodontiform" elements, the process denticles are closely spaced on most specimens.

Description: The various form-categories recognized here are the same as for Erismodus sp. 1 and the main distinguishing features for each element-type are also the same. In addition to having relatively longer and more compressed process denticles than the elements of Erismodus sp. 1, the process denticles on the elements of Erismodus
sp. 2 are also more distinctly keeled. Elements of this apparatus are relatively rare in the collections at hand but I believe that their geographic and stratigraphic co-occurrence, and their close similarity to elements of the more abundantly represented *Erismodus* sp. 2, justifies placing them in a single multielement species.

**Symmetrical trichonodelliform elements:** The anterior face of the cusp is sharply rounded and bears a median costa. The posterior margin of the cusp and the upper edge of the base are sharp.

**Similar forms:**


**Asymmetrical trichonodelliform elements:** The upper edge of the base is sharply rounded to sharp. The anterior face of the cusp is broadly rounded but the posterior face of the cusp is narrowly rounded and some specimens bear a costa on the posterior face of the cusp. An identical specimen from the Glenwood Formation of Minnesota is illustrated as *Microcoelodus* n. sp. C by Webers (1966, p. 66, Pl. 4, fig. 8).

**Similar forms:**

*Chirognathus invictus* Stauffer, 1935a, p. 137, Pl. 9, fig. 43; Webers, 1966, p. 62, Pl. 4, fig. 9; Moskalenko, 1973, p. 62-63, Pl. 18, fig. 3.

**Zygognathiform elements:** These forms are like the corresponding elements in the *Erismodus* sp. 1 apparatus except for the longer, more distinctly keeled process denticles and a somewhat more laterally compressed base. I know of no illustrations of elements of this type in the literature.
Eoligonodiniform elements: These units are relatively more laterally compressed and have a longer posterior process than eoligonodiniform elements of *Erismodus* sp. 1. The proximal two or three denticles on the posterior process are relatively short and specimens with the posterior process missing are difficult to distinguish from corresponding elements of *Erismodus* sp. 1. In being more laterally compressed these elements correspond to the description of *Ptiloconus compressus* (Branson and Mehl) but the type specimen of that form-species has a short posterior process.

Similar forms:

*?Pteroconus compressus* Branson and Mehl, 1933, p. 111, Pl. 8, fig. 31.

*?Ptiloconus compressus* (Branson and Mehl), Sweet, 1955, p. 246, Pl. 28, fig. 1; Webers, 1966, p. 70, Pl. 5, fig. 9.

Prioniodiniform elements, similar forms:

*Microcoelodus* n. sp. B Webers, 1966, p. 66, Pl. 4, fig. 1.

*Microcoelodus expansus* Branson and Mehl, Moskalenko, 1973, p. 70-71, Pl. 18, figs. 11, 12.

Oulodontiform elements, similar forms:

*Chirognathus* cf. *pachydactyla* Branson and Mehl, Branson and Mehl, 1933, p. 103, Pl. 9, figs. 1,2.

*Microcoelodus* n. sp. A Webers, 1966, p. 66, Pl. 4, fig. 2.

"Modified falodontiform" elements, similar forms:

*Chirognathus quadridactylus* Stauffer, 1935a, p. 138, Pl. 9, fig. 35; Webers, 1966, p. 62, Pl. 6, fig. 1.

Occurrence: Hogskin and Rockdell at Lay School.
Collection: 75 specimens (3 symmetrical trichonodelliform, 15 asymmetrical trichonodelliform, 7 zygognathiform, 25 eoligonodiniform, 16 prioniodiniform, 5 oulodontiform, 4 modified falodontiform).

Figured specimens: OSU 31762, OSU 31763, OSU 31764, OSU 31765, OSU 31766, OSU 31767, OSU 31768, OSU 31769.

Reference specimens: OSU 31930 (symmetrical trichonodelliform), OSU 31931 (asymmetrical trichonodelliform), OSU 31932 (zygognathiform), OSU 31933 (eoligonodiniform), OSU 31934 (prioniodiniform), OSU 31935 (oulodontiform), OSU 31936 (modified falodontiform).

Genus LEPTOCHIROGNATHUS Branson and Mehl, 1943

Leptochirognathus Branson and Mehl, 1943, p. 377.

Type species: Leptochirognathus quadrata Branson and Mehl, 1943.

LEPTOCHIROGNATHUS sp.

(not figured)

Remarks: All the leptochirognathiform elements in the collections at hand are fragmentary. These fragments cannot be positively identified but they are suggestive of the form-species Leptochirognathus semiflorealis Branson and Mehl, 1943, and Leptochirognathus quadrata Branson and Mehl, 1943.

Occurrence: Holston at Thorn Hill, Mosheim and blue limestone at Cuba.

Collection: 13 fragmentary specimens.
NEW GENUS cf. NEW GENUS A Sweet, Ethington and Barnes, 1971

(Pl. III, Fig. 10)


Description: Bilaterally symmetrical elements have a long, straight posterior process that is surmounted by numerous, compressed and fused, proclined denticles. The denticles increase in size anteriorly and the anteriormost two or three denticles merge into the sharp posterior edge of the cusp. The anterior face of the proclined cusp is gently convex and produced laterally into symmetrically disposed wing-like processes. Behind these wings, the sides of the cusp are flat and converge to form the sharp posterior margin of the cusp. The lateral wings are surmounted by several low and completely fused, but discernable, denticles. A narrow ledge, at about the base of the denticles, extends along each side of the posterior process from its distal end to about the point where the anterior denticles merge into the cusp. The basal cavity is shallow and has groove-like extensions beneath the lateral wings and the posterior process.

Asymmetrical elements are similar to symmetrical ones except the posterior process is laterally bowed or twisted and the outer lateral wing on the cusp is reduced to an adenticulate, sharp-edge costa.

Remarks: Only six elements of this type are present in the collections at hand but these forms are distinctive and are probably congeneric, if not conspecific, with elements of New Genus A of Sweet and others, 1971.
Occurrence: blue limestone (2 specimens in sample 73CC2-10) and Holston (4 specimens in sample 73CC2-16) at Cuba. Similar forms occur in the Juab Formation in Utah (Sweet and others, 1971).

Collections: 6 specimens (2 symmetrical, 4 asymmetrical).

Figured specimen: OSU 31770.

Reference specimens: OSU 31937 (symmetrical element), OSU 31938 (asymmetrical element).

NEW GENUS B

Remarks: Raring (1972) has described elements from rocks of the Chazy Group that are identical to the elements referred below to New Genus B. n. sp. Raring has provided a new generic and specific name for elements of this type but these are not yet published.

NEW GENUS B. n. sp.

(Pl. II, figs. 6, 7)

Description: Slightly bowed, blade-like units with a long, denticulated anterior process; a relatively short and broad, compressed and reclined cusp; and a shallow, laterally flared base. The anterior process bears several denticles that are fused throughout most of their length but are discrete apically. These denticles are erect on some specimens but on other specimens they are reclined near the cusp, becoming erect and then proclined toward the blunt distal end of the anterior process. The outer face of the base is flat or slightly concave and the upper margin of the
base is short and broadly to sharply rounded. The base flares widely toward the inner side of the element and the basal cavity is shallow, extending beneath the anterior process as a narrow slit. The anterior margin of the inner side of the base merges into a broad ledge that extends along the basal margin of the anterior process. A similar ledge is present on the outer side of these elements but it is much reduced in size and is no more than a fine costa. Several short, completely fused and sharply reclined denticles arise from the lower part of the posterior margin of the cusp.

Remarks: As noted by Raring (1972), these elements are similar to spathognathodontiform elements of Appalachignathus delicatulus. However, on spathognathodontiform elements of A. delicatulus, denticles on the anterior process are reclined and the base does not flare as greatly as on elements of New Genus B n. sp. Also, spathognathodontiform elements of A. delicatulus do not have denticles on the poster margin of the cusp.

As also noted by Raring (1972), it is not known at the present time whether these elements were associated in an apparatus with any other type of element.

Occurrence: Holston at Thorn Hill, blue limestone at Cuba. Identical forms occur in rocks of the Chazy Group and their equivalents in the Châmpain Valley of New York and in the Montreal area (Raring, 1972).

Collection: 9 specimens.

Figured specimens: OSU 31771, OSU 31772.

Reference specimen (fragmentary): OSU 31939.
Genus OISTODUS Pander, 1856

Oistodus Pander, 1856, p. 27.

Type species: Oistodus lanceolatus Pander, 1856.

Remarks: The designation "Oistodus" is used here strictly in a form-taxonomic sense and the elements included in this form-genus do not belong in Oistodus Pander as redefined by Lindström (1971, p. 38).

"OISTODUS" PSEUDOABUNDANS Schopf

(Pl. I, figs. 25, 26)

Oistodus pseudoabundans Schopf, Webers, 1966, p. 34, Pl. 2, figs. 20, 21.
Oistodus venustus Stauffer, Atkinson in Clark, 1971, p. 128, Pl. 5, fig. 10.

Remarks: Two types of oistodontiform elements, which are completely morphologically intergradational, are included here. One type (Pl. I, fig. 25) has a relatively broadly rounded antero-basal corner and a nearly straight basal margin. Elements of this type are identical to the holotype of Oistodus pseudoabundans Schopf, with which they have been directly compared. Elements of the second type (Pl. I, fig. 26) have a relatively sharply rounded antero-basal corner and a sinuous basal margin. Webers (1966) has illustrated similar variation in form among elements he regards as representatives of O. pseudoabundans. Elements of both types also consistently occur together, and are morphologically intergradational, in several collections of oistodontiform elements from the Platteville
Formation of Wisconsin, kindly provided by Dr. D. L. Clark of the University of Wisconsin.

Elements assigned here to "Oistodus" pseudoabundans have been directly compared with specimens, which I interpret to be "Oistodus" venustus Stauffer, from the Glenwood Formation in Minnesota. Except for a relatively longer, less reclined cusp, "O." pseudoabundans is strikingly similar to "O." venustus. The biological affinities of "O." pseudoabundans are unknown (Schopf, 1966, p. 21; Webers, 1966, p. 34) and the nature of the apparatus that included the type specimen of O. venustus is also in question (Lindström, 1971, p. 43; Sweet and Bergström, 1972, p. 32; Barnes and Poplawski, 1973, p. 779). It seems quite likely, however, that "O." venustus and "O." pseudoabundans, if not associated in one apparatus or related in direct phylogenetic lineage, may at least belong in the same multielement genus (see discussion of "Acodus" variabilis, above).

Occurrence: Hogskin at Lay School, Rockdell at Evans Ferry, Eidson and Rockdell at Eidson, Unit 780 at Thorn Hill, blue limestone and Holston at Cuba.

Collection: 25 specimens.

Figured specimens: OSU 31773, OSU 31774.

Reference specimen: OSU 31940.

"OISTODUS" sp. cf. "O." VENUSTUS Stauffer

(Pl. I, figs. 23, 24)

Remarks: Representatives of this species have a pronounced costa on one or both lateral faces of the cusp, and a rounded basal margin.
Elements included here have been directly compared with specimens that I interpret to be representatives of "Oistodus" venustus Stauffer from the Glenwood Formation of Minnesota. Specimens in the collections at hand are similar in general form to specimens of "O." venustus, but none of the specimens of "O." venustus that I have observed has a prominently costate cusp. Webers (1966, p. 34-35) refers both costate and acostate oistodontiform elements to "O." venustus and suggests that the costae were lost during growth. However, some of the largest venustus-like elements in the collections at hand have a well-developed costa on one or both sides of the cusp.

A variety of morphologically different forms (i.e., see Bradshaw, 1969, Pl. 34, figs. 4-7; Uyeno and Barnes, 1970, Pl. XXI, figs. 6, 7) have been referred to "Oistodus" venustus Stauffer. Since the concept of that form-species has been so broadly interpreted, and since the specimens at hand differ slightly from Stauffer's (1935a, p. 147, Pl. 12, fig. 12) description and illustration of the holotype, which appears to be acostate, I hesitate to use the "Oistodus" venustus even in a form sense. Pending further studies, the specimens at hand are only compared to that species.

Oistodontiform elements included here closely resemble illustrations of specimens referred to "Oistodus" venustus Stauffer by Rhodes (1953, Pl. 22, figs. 168-170), Hamar (1964, Pl. 3, figs. 3-6, not Pl. 3, figs. 9, 11), and Bergström, Riva and Kay (1974, p. 1644, Pl. I, fig. 13).

Occurrence: Tumbez at Lay School, Eidson at Evans Ferry, Eidson at Eidson, Holston at Thorn Hill, Holston at Cuba.

Collection: 35 specimens.
Figured specimens: OSU 31775, OSU 31776.
Reference specimen: OSU 31941.

Genus PALTODUS Pander, 1856

Paltodus Pander, 1856, p. 24.

Type species: *Paltodus subaequalis* Pander, 1856.

Remarks: Lindström (1971, p. 44) has redefined *Paltodus* as a multielement genus to include drepanodontiform elements that may be prominently costate, and oistodontiform elements that may be basally flared toward the inner side.

A small number of prominently costate paltodontiform elements, acondontiform elements, and basally expanded oistodontiform elements have been recovered from five samples from the lower Holston Formation at the Cuba section. Because these cones occur together, and because of certain morphological features which they have in common, I suggest that these elements are components of a single multielement apparatus. Pending confirmation of the association suggested below, these forms are questionably assigned to *Paltodus* because they display the general characteristics of that genus as outlined by Lindström (1971) and because some of them bear a superficial resemblance to forms Lindström (1971) has referred to *Paltodus inconstans*.

*PALTODUS?* sp.

*(Pl. II, figs. 17-22; fig. 18A-E)*

Diagnosis: A species with a multielement simple-cone apparatus that includes a morphologically intergradational series of prominently costate
Figure 18. Elements of *Paltodus*? sp.: lateral views, cross-sections, and basal outlines; X 65. (A) Paltodontiform element, form A. (B) paltodontiform element, Form B. (C) paltodontiform element, Form C. (D) acodontiform element. (E) oistodontiform element.
paltodentiform elements, acodontiform elements, and oistodontiform elements with a laterally expanded base.

Description:

Paltodentiform element, Form A: A bilaterally symmetrical element with wide and thin, wing-like, antero-lateral keels (fig. 18A). The anterior face is broad and slightly convex with a low, rounded median costa. The cusp is straight (up to the point of fracture on the single specimen at hand), triangular in cross-section, and has a sharply keeled posterior margin. The cusp meets the base at a sharp angle of a little less than ninety degrees. The basal outline is triangular. The base is short and its three thin walls enclose a shallow, nearly equidimensional, tetrahedral basal cavity. The upper edge of the base is sharp with a low, thin keel. Lateral faces of the cusp and base are slightly concave.

Paltodentiform elements, Form B: Symmetrical or slightly asymmetrical units with anterior and posterior keels and a thin costa on each lateral face (fig. 18B). One lateral costa on some specimens is relatively more toward the anterior than the other lateral costa. The cusp is diamond-shaped in cross-section and meets the short base at a rounded angle of slightly more than ninety degrees. Faces of the base between the keels and the costae are concave. These elements resemble a specimen figured by Ethington and Schumacher (1969, p. 478, Pl. 68, fig. 18) as *Tetraprioniodus* spp. and they are also morphologically close, except for cusp inclination, to *Oistodus* n. sp. Lindström (1955, p. 581, Pl. 3, fig. 26).
Paltodontiform elements, Form C: Markedly asymmetrical units with anterior and posterior keels and a thin costa on each lateral face (fig. 18C). The cusp is compressed, slightly bowed to one side, and lenticular in cross-section. The inner-lateral costa is anteriorly directed and close to the anterior keel, which is flexed outward. The outer-lateral costa is posteriorly directed and displaced toward the posterior keel. The base is short, with a keeled upper margin, and meets the cusp at a rounded angle of a little more than ninety degrees.

Acodontiform elements: These units have a compressed, somewhat bowed cusp with prominent anterior and posterior keels (fig. 18D). The anterior keel is flexed inward. The cusp is weakly carinate on the inner side, strongly carinate on the outer side. The outer carina becomes sharper toward the base and develops into a costa that continues across the base almost to the basal margin. The base is weakly inflated on the inner side, more strongly inflated on the outer side. The base is short, with a sharp upper margin, and meets the cusp at angle of about ninety degrees. A similar, perhaps identical, specimen has been illustrated by Ethington and Schumacher (1969, p. 466, Pl. 69, fig. 3) as ?Oistodus delta Lindström. These elements also resemble some forms referred to the form-species Paltodus inconstans by Lindström (1955, p. 583, Pl. 4, figs. 5, 6).

Oistodontiform elements: Units with a very thin, blade-like cusp (fig. 18E). The cusp has anterior and posterior keels and weak carina on both lateral faces. The basal cavity is shallow with an extremely shallow extension beneath the anterior keel. The outer side of the base is slightly convex and its inner side is broadly inflated. Although
less reclined, these elements are similar to elements assigned to the form-species Oistodus inaequalis by Lindström (1955, p. 576, Pl. 3, figs. 53, 54, 57).

Occurrence: blue limestone and Holston at Cuba.

Collection: 42 specimens (1 Form A, 6 Form B, 8 Form C, 8 acodontiform, 19 oistodontiform).

Figured specimens: OSU 31777, OSU 31778, OSU 31779, OSU 31780, OSU 31781.

Reference specimens: OSU 31942 (Form B), OSU 31943 (Form C), OSU 31944 (acodontiform), OSU 31945 (oistodontiform).

Genus PANDERODUS Ethington, 1959

Panderodus Ethington, 1959, p. 284.

Type species: Paltodus unico3tatus Branson and Mehl, 1933.

Remarks: Bergström and Sweet (1966) included representatives of several previously described Panderodus form-species in a multielemental apparatus, which they referred to Panderodus gracilis (Branson and Mehl). According to this interpretation, the apparatus of P. gracilis consists basically of paired compressiform, graciliform and unico3tiform elements. With some modification, this general model is consistent with the morphologic variety and distribution of gracilis-type apparatus components in the collections at hand.

Bergström and Sweet (1966) also recognized a second type of Panderodus apparatus, which they referred to Panderodus panderi (Stauffer) and which they regarded as including a single, but variable, type of element.
Component elements of panderi-type apparatuses display a pattern of morphological variation that differs from that among component elements of gracilis-type apparatuses but a consistent and regular plan of morphological intergradation can nonetheless be recognized.

Various authors (see list of synonymys under Panderodus panderi in Ethington and Schumacher, 1969, p. 469) have referred specimens to Panderodus panderi but, to the best of my knowledge, the only report of elements that conform exactly to the description of the holotype of P. panderi is that of Craig (1968, p. 221-226). Stauffer's (1940, p. 427, Pl. 60, fig. 8) description and illustration, and Bergström and Sweet's (1966, p. 360, Text-fig. 11) re-illustration, of the holotype of P. panderi (kindly placed at my disposal by A. B. Bulatao of the University of Minnesota) are accurate, most notably in the fact that the antero-lateral costa and the longitudinal groove are on the same side of the specimen. However, most elements previously assigned to P. panderi have either a rounded, acostate anterior margin or an antero-lateral costa on the side opposite the grooved side. This distinction is purely a matter of form but there is reason to believe (see discussion of P. sp. A cf. P. panderi) that many of the elements previously referred to P. panderi are components of a Panderodus apparatus that does not include elements like the type specimen of P. panderi.

Panderodus is in need of revision but that task, if undertaken in the context of multielement taxonomy, must involve restudy of many type specimens and the collections from which they came. Such an endeavor is far beyond the scope of this report so the Panderodus
apparatuses discussed here are provided with neither new nor existing
species names but are merely compared with previously described apparatuses
or elements.

PANDERODUS sp. cf. P. GRACILIS (Branson and Mehl)
(Pl. I, figs. 10-22)

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

cf. Panderodus gracilis (Branson and Mehl), Bergström and Sweet, 1966,
p. 355-359, Pl. 35, figs. 1-6.

Diagnosis: A species with a multielement simple-cone apparatus
that includes compressiform elements and a morphologically intergradational
series of graciliform elements.

Description: In form taxonomy, elements that are termed "compressi-
form" and "graciliform" in the diagnosis of this species could easily
be segregated into nine or ten different form-species. The stratigraphic
and geographic distribution of these various forms within the study
area makes it possible to recognize three slightly different apparatuses,
each of which contains five basic types of elements. These apparatuses
are termed here the "feulneri apparatus", the "compressus apparatus" and,
for want of a better term, the "robust apparatus". Components of these
apparatuses are distributed in a way that suggests that variation in
component-element morphology, which makes it possible to distinguish
the three apparatuses, was due to ecological factors. Elements included
here are generally similar to previously described gracilis-type and
compressus-type panderodontiform elements and lengthy, element-by-element
descriptions are not necessary. Only essential features that serve to
distinguish different form-elements are considered in detail.

Feulneri apparatus: This apparatus includes feulneriform elements, a bilaterally symmetrical graciliform element, asymmetrical graciliform elements, arcuatiform elements, and elements that are here designated as "P-elements".

Feulneriform elements (Pl. I, fig. 14) have a sharp anterior margin that is closely flanked on each side by a short, broadly rounded costa. These elements conform closely to Glenister's (1957, p. 728, Pl. 85, fig. 11) description and illustration of the form-species Paltodus (=Panderodus) feulneri, which is included in Panderodus gracilis by Bergström and Sweet (1966, p. 356, 358).

Bilaterally symmetrical graciliform elements (Pl. I, figs. 19-22) have a sharp offset costa on each lateral face and a longitudinal groove on each lateral face. On some symmetrical elements, the rounded upper edge of the base is surmounted by a median costa or a median costa plus two lateral costae, one on each side of the median costa. On other elements, the edge of the base bears no conspicuous costae but is finely striated. To the best of my knowledge, there is no mention of similar "two-groove" graciliform elements in the literature. However, the type specimen of Paltodus (=Panderodus) belatus Stauffer (1940, p. 427, Pl. 60, fig. 6; specimen B 5645), kindly placed at my disposal by A. B. Bulatao of the University of Minnesota, is a bilaterally symmetrical "two-groove" graciliform element, although this fact is not obvious from Stauffer's description. This specimen is more short-based and basally more robust than similar elements of Panderodus sp. cf. P. gracilis.
A bilaterally symmetrical element, which is actually quite similar to the holotype of *Panderodus belatus* (Stauffer), has also been illustrated, as a component of the *Panderodus gracilis* apparatus, by Kohut and Sweet (1968, Pl. 185, fig. 16; specimen OSU 27937).

Asymmetrical graciliform elements (Pl. I, fig. 10) have an offset costa on both lateral faces, a longitudinal groove on just one lateral face and a rounded upper basal margin that may be acostate and finely striated but that on most specimens bears a rounded costa either in the midplane or displaced toward the grooved side. The lateral offset costae may be nearly symmetrically disposed but on most specimens the costa on the grooved face is displaced more toward the posterior relative to the costa on the ungrooved face. Elements of this form have, in the past, generally been assigned to the form-species *Panderodus gracilis*.

Elements here referred to as arcuatiform (Pl. I, figs. 11, 16) are slightly bowed or twisted toward the ungrooved side and have a sharp upper basal margin. The ungrooved face is flattened and bears a sharp antero-lateral offset costa. The grooved face is convex and on some specimens bears a rounded shoulder just anterior to the groove, as on the holotype of *Panderodus arcuatus* (Stauffer). On many arcuatiform elements this rounded shoulder is sharpened to form a second offset costa as on specimens assigned to *P. arcuatus* (Stauffer) by Weyant (1968, p. 55, Pl. V, fig. 7). These bicostate arcuatiform elements are actually no more than markedly asymmetrical and slightly twisted graciliform elements. However, elements here referred to as graciliform have an approximately straight midplane, which is also true of the holotype of *Panderodus gracilis* (Branson and Mehl, 1933, p. 108), and they
generally have a rounded, even though costate, upper basal margin. Arcuatiform elements are distinctive and are set apart from graciliform elements by the twisted or bowed midplane and by the sharp upper basal margin. Elements similar to arcuatiform elements of *Panderodus* sp. cf. *P. gracilis* were referred to the form-species *P. gracilis* by Sweet and others (1959, p. 1056, Pl. 131, fig. 1) and later included in the apparatus of multielement *P. gracilis* by Bergström and Sweet (1966, p. 356). Ethington and Schumacher (1969, p. 469, Text-fig. 5G) provide a line-drawing cross-section of an element that may also be of this same general form (see also Carlson, 1960, p. 69, Pl. 2, figs. 8, 17; Webers, 1966, p. 38, Pl. 2, figs. 8, 9; and Schopf, 1966, p. 65, Pl. 5, figs. 26, 28).

Elements herein designated as P-elements (Pl. I, fig. 13) are also slightly twisted and have a sharp upper basal margin. They are more compressed anteriorly than arcuatiform elements and the lateral faces meet at a sharp anterior margin which is slightly flexed toward the ungrooved side. In cross-section and in lateral view, from the ungrooved side, these forms look like arcuatiform elements on which the antero-lateral offset costa on the ungrooved side has rotated anteriorly. Also as on arcuatiform elements, the grooved face is ornamented by a rounded shoulder or a sharp offset costa just anterior to the groove. Similar forms, but without an offset costa or obvious shoulder on the grooved side, are described as *Panderodus* n. sp. by Rexroad and Craig (1971, p. 698, Pl. 81, figs. 26, 27) from the Silurian Bainbridge Formation in Missouri.

**Compressus apparatus:** This apparatus includes compressiform elements, symmetrical and asymmetrical graciliform elements, arcuatiform
elements, and P-elements. Except for compressiform elements, components of this apparatus are identical to those of the *feulneri* apparatus.

Compressiform elements (Pl. I, fig. 15) have a sharp anterior margin and smooth lateral faces. These elements conform exactly to the description and illustration of the type specimen of *Panderodus compressus* (Branson and Mehl, 1933, p. 109, Pl. 8, fig. 19).

Robust apparatus: This apparatus includes "robust compressiform" elements, symmetrical and asymmetrical graciliform elements, unicostatiform elements and P-elements. Symmetrical and asymmetrical graciliform elements cannot be distinguished by any consistent criteria from corresponding elements in the *compressus* and *feulneri* apparatuses.

Compressiform elements (Pl. I, fig. 18) are more robust than corresponding elements in either the *feulneri* apparatus or the *compressus* apparatus. They have a sharp or sharply rounded upper basal margin and a broadly rounded anterior margin. One or both lateral faces may bear a broadly rounded, antero-lateral, costa-like shoulder parallel to the anterior margin. On some elements, the anterior margin is flattened on each side of the median plane and the cross-section, though inflated, is *feulneri*-like. Similar elements have been referred to *Paltodus* (=*Panderodus*) *compressus* by Branson, Mehl and Branson (1951, p. 7, Pl. 1, figs. 16-22, fig. 2C), and to *Panderodus* sp. E by Ethington and Schumacher (1969, p. 470, Pl. 69, fig. 1, Text-fig. 5L).

Unicostatiform elements (Pl. I, figs. 12, 17) have a straight mid-plane, an antero-lateral costa on the ungrooved face, and a rounded upper basal margin that bears a costa, which is displaced toward the grooved side. As previously pointed out by Bergström and Sweet (1966, p. 359),
these forms are developmental extremes of graciliform elements and they are interpreted here to be homologues of arcuatiform elements in the feulneri and compressus apparatuses. Unicostatiform elements are distinctive, in some cases quite large and robust, and they are regarded here as discrete components of this Panderodus apparatus, not juvenile graciliform elements as suggested by Rexroad and Craig (1971, p. 695).

"P-elements" are similar to corresponding elements in the feulneri and compressus apparatuses but the upper basal margin tends to be more rounded and there is not distinct shoulder or costa anterior to the longitudinal groove. These elements are apparently identical in form to specimens illustrated by Rexroad and Craig (1971, p. 698, Pl. 81, figs. 26, 27) as Panderodus n. sp.

Remarks: Although some of the corresponding components in the respective apparatuses described above differ in morphologic detail, all three apparatuses are basically the same. In the feulneri and compressus apparatuses the scheme of morphological intergradation, or symmetry-transition, is played out between graciliform elements, arcuatiform elements and laterally costate P-elements. The same pattern is observed in the robust apparatus between graciliform elements, unicostatiform elements and laterally acostate P-elements.

In many collections, components of one type of apparatus are isolated and panderodontiform elements are easily segregated into five form categories. However, components of different apparatuses occur together in some collections and in these mixed collections it is observed that corresponding components of the respective apparatuses are morphologically intergradational. Feulneriform elements intergrade morphologically with
compressiform elements and with robust compressiform elements, arcuatiform elements intergrade with unicostatiform elements, and laterally costate P-elements intergrade with laterally acostate P-elements. In other words, these three apparatuses represent end members within a range of morphological variation exhibited by elements of a single species. That this morphological variety is probably related to ecological factors is suggested by a close correlation between lithology and the distribution of components of the three apparatuses. Although many collections are mixed, components of the feulneri apparatus are consistently predominant in the more pure, fine-grained limestones and calcarenites of the upper Tumbez and the Holston. Components of the robust apparatus occur preferentially in the dark and more argillaceous limestones typical of the Eidson (and Elway-Eidson) and Hogskin. Elements of the compressus apparatus occur, in the present study area, only in the interval of argillaceous limestone and mudstones in the upper Rockdell at Lay School, the same interval through which hyaline elements and representatives of Plectodina aculeata are dominant constituents of conodont collections (see p. 42-44).

**Occurrence:** Representatives of this species occur throughout the study area and in all the formations investigated.

**Collection:** 1850 specimens (1144 graciliform—including graciliform s.s., arcuatiform, unicostatiform, and P-elements; 706 compressiform—including compressiform s.s., feulneriform, and robust compressiform).

**Figured specimens:** OSU 31782, OSU 31783, OSU 31784, OSU 31785, OSU 31786, OSU 31787, OSU 31788, OSU 31789, OSU 31790, OSU 31791, OSU 31792.
Reference specimens: OSU 31946 (symmetrical graciliform), OSU 31947 (asymmetrical graciliform), OSU 31948 (arcuatiform), OSU 31949 (unicostatiform), OSU 31950 (P-element), OSU 31951 (feulneriform), OSU 31952 (compressiform), OSU 31953 (robust compressiform).

PANDERODUS sp. A cf. P. PANDERI (Stauffer)

(Pl. I, figs. 1-7)

cf. Paltodus panderi Stauffer, 1940, p. 427, Pl. 60, figs. 8, 9.

Diagnosis: A species with a multielement, simple-cone apparatus that includes a morphologically intergradational series of at least four different types of panderodontiform elements. The elements of this apparatus are characterized by the development of keels or costae on the anterior margin of the base.

Description: All the elements included here have a longitudinal groove on one lateral face and an abruptly recurved cusp like that which characterizes the holotype of Paltodus panderi Stauffer. Webers (1966) and Bergström and Sweet (1966) note that the specimens referred by them to Panderodus panderi (Stauffer) display variation in the arrangement of costae. This is also true of the collection of specimens at hand, and on the basis of costa disposition and morphology of the base it is possible to recognize four shape categories of panderi-type elements.

Form A (Pl. I, fig. 1): The base is relatively compressed, short (in the anterior-posterior direction), and high (measured along the basal margin from the antero-basal corner to the postero-basal corner). The anterior edge of the cusp is sharp and the lateral faces of the
base taper into a sharp keel on the anterior margin of the base. Some units are equally biconvex; others are unequally biconvex, the grooved side being the more convex side. On specimens of the latter type, the anterior keel on the base is flattened on the ungrooved side of the element. The upper margin of the base is rounded and the posterior margin of the cusp is sharp. A costa arises at mid-length on the upper edge of the base and continues up the posterior margin of the cusp.

Form B (Pl. I, fig. 5): These elements have a relatively expanded, long, low base. As on elements of Form A, the anterior margin of the base is keeled and on some specimens this keel is slightly deflected toward the ungrooved side of the element. The upper edge of the base and the posterior face of the cusp are rounded and bear a costa as on elements of Form A.

Form C (Pl. I, fig. 4): Elements with a relatively expanded, long, low base. The anterior margin of cusp and base is broadly rounded and a distinct antero-lateral offset costa is present at the juncture of the anterior face of the base and the ungrooved face of the base. The upper edge of the base and the posterior edge of the cusp are rounded and bear a costa that is laterally displaced toward the grooved side of the element. These elements can be thought of as developmental extremes of Form B elements on which the anterior keel is displaced laterally.

Form D (Pl. I, figs. 2, 3): In degree of lateral compression and height of the base, these elements are similar to elements of Form A. However, the length of the base on these elements is intermediate between the short base of Form A and the long base of Forms B and C.
The posterior edge of the cusp is sharp and the upper edge of the base is rounded. The posterior edge of the cusp and the upper edge of the base bear a costa as on Forms A, B, and C. The most distinctive feature of this type of element is the anterior edge of the base. The anterior edge of the base is sharp and keeled, as on elements of Forms A and B, and a distinct costa is present on the anterior part of the ungrooved side of the base. The narrow area between this costa and the anterior keel is flattened or concave so as to create the impression that the costa on the ungrooved face was produced as the element grew against an obstruction.

Remarks: The forms described above are morphologically intergrading and they co-occur consistently both geographically and stratigraphically within the study area. Therefore, I believe that all these element-types were components of an apparatus of one species of conodont animal.

Although the elements included here display a variety of form in terms of the disposition of costae and keels, none of the elements at hand is like the holotype of *Panderodus panderi*, which has a single antero-lateral off-set costa on the grooved face. On all the elements in the present collections that have an antero-lateral off-set costa on only one face, that costa is always on the ungrooved face.

It is interesting to note that the same types of elements that are included here can also be recognized among elements that have been referred to *Panderodus recurvatus* (Rhodes). Rexroad and Craig (1971, p. 696-667) recognized two basic types of cones among elements that they referred to the form-species *P. recurvatus*, which they note is
very similar to *Panderodus panderi*. One type of element, their "high cone", has a long base and is anteriorly costate. This is the general type of element that is described as Form B or Form C above. The second type of element described by Rexroad and Craig, a "low cone", has a short base and a keeled anterior margin. In the terminology used here, this is a Form A element. Rexroad and Craig (1971, p. 696) also recognize, among their high cones, an anteriorly costate element which is analogous to the elements of Form D. Rexroad and Craig (1971) interpret the high cones and low cones of *P. recurvatus* as dimorphs of a single species. By analogy, the elements described here as Form A would be dimorphs of Form B. However, I do not believe that the high cone condition as opposed to the low cone condition among elements of otherwise similar morphology necessarily indicates dimorphism. The apparatuses of *"Acodus" mutatus* and *"Acodus" variabilis* both contain elements that are essentially high cones and low cones. Likewise, so do the apparatuses of *"Distacodus" falcatus*, *"Distacodus" n. sp.*, and *Drepanoistodus n. sp.* It would appear that high cone morphology and low cone morphology may be due to position or function within a single apparatus rather than to dimorphism.

By analogy with *Panderodus sp. cf. P. gracilis* and some other simple-cone apparatuses (i.e., *"Distacodus" falcatus*, *"Distacodus" n. sp.*, *Walliserodus sp. cf. W. trigonius*), the apparatus of *Panderodus sp. A cf. P. panderi* might be expected to include a bilaterally symmetrical, "two-groove", element. This possibility exists but it cannot be confirmed on the basis of the present collections (see discussion below of *Panderodus sp. B cf. P. Panderi*).
Most of the elements included here are rather robust forms that display a bulbous, or knob-like, development of the basal margin. Webers (1966) referred elements to *Panderodus panderi* that, in contrast, are long and slender and do not exhibit the abrupt inward curvature of the basal margin that produces this bulbous appearance. These slender forms also occur in the collections at hand (Pl. I, figs. 6, 7). In several collections, robust forms and slender forms occur together and the slender forms are relatively much smaller. These small, slender forms are interpreted here to be juvenile representatives of *Panderodus* sp. A cf. *P. panderi*. In several collections in which *P. sp. A cf. P. panderi* is abundantly represented, a complete series of growth stages can be recognized between small, slender forms and larger, more robust elements.

Occurrence: Representatives of this species occur throughout the study area and in all the formations investigated except the Rockdell at Lay School and the Mosheim at Cuba.

Collection: 1342 specimens.

Figured specimens: OSU 31793, OSU 31794, OSU 31795, OSU 31796, OSU 31797, OSU 31798, OSU 31799.

Reference specimens: OSU 31954 (Form A), OSU 31955 (Form B), OSU 31956 (Form C), OSU 31957 (Form D).

**PANDERODUS sp. B cf. P. PANDERI (Stauffer)**

(Pl. I, figs. 8, 9)

cf. *Paltodus panderi* Stauffer, 1940, p. 427, Pl. 60, figs. 8, 9.
Description: Bilaterally symmetrical coniform elements with an erect cusp and a longitudinal groove at the juncture of each lateral face with the upper face of the base and the posterior face of the cusp. The anterior face of cusp and base are rounded, as is the posterior face of the cusp and the upper face of the base. A small median costa begins in the posterior half of the upper face of the base and continues in the midline of the cusp nearly to the apex of the cusp.

Remarks: These elements are very similar in general morphology to the elements that are here referred to Panderodus sp. A cf. P. panderi. Since a bilaterally symmetrical element has not been observed among the elements of P. sp. A cf. P. panderi, and since by analogy with the apparatus of Panderodus sp. cf. P. gracilis a symmetrical element might be expected in the apparatus of P. sp. A cf. P. panderi, it would be reasonable to suspect that the elements referred here might be the symmetrical elements of the P. sp. A cf. P. panderi apparatus. However, representatives of P. sp. B cf. P. panderi are extremely rare in the present collections and, although they occur in every case in association with elements of P. sp. A cf. P. panderi, they are present in only one sample from the Lay School section and in four samples from the Cuba section. On the other hand, representatives of P. sp. A cf. P. panderi occur in numerous samples from each of the sections investigated and in many samples they are relatively quite abundant. Therefore the present evidence does not justify the association of the elements included here with the elements of Panderodus sp. A cf. P. panderi, although I strongly suspect that such an association may be the case.

Occurrence: Tumbez at Lay School, Holston at Cuba.
Collection: 6 specimens.

Figured specimen: OSU 31800.

Reference specimen: OSU 31958.

Genus PERIODON Hadding, 1913
Emend. Bergström and Sweet, 1966

Periodon Hadding, 1913, p. 33.

Type species: Periodon aculeatus Hadding, 1913.

Remarks: Bergström and Sweet (1966) and Serpagli (1974) have summarized the similarities and differences between component elements of different Periodon apparatuses. Representatives of this genus are rare in the collections at hand and only those specimens that are associated with the diagnostic falodontiform elements are referred to Periodon grandis. Elements that occur without associated falodontiform elements are referred to Periodon sp.

PERIODON GRANDIS (Ethington)

(Pl. VIII, fig. 9)

Loxognathus grandis Ethington, 1959, p. 281, Pl. 40, fig. 6.


Falodus aff. F. prodentatus (Graves and Ellison), Ethington and Schumacher, 1969, p. 463, Pl. 67, fig. 13, Text-fig. 5A.

Remarks: Serpagli (1974, p. 65, Text-fig. 14) has suggested that Periodon grandis evolved from Periodon aculeatus during a time that is
represented by rocks in the upper part of the *Amorphognathus tvaerensis* Zone and in the lower part of the *Amorphognathus superbus* Zone of the North Atlantic conodont zone succession. Representatives of *P. grandis* occur at Thorn Hill in an interval within the lower part of the *Prioniodus gerdae* Subzone of the *A. tvaerensis* Zone and at Lay School in an interval that is probably older than the base of the *P. gerdae* Subzone. Falodontiform elements that appear to be identical to the falodontiform elements of *P. grandis* at hand also occur in the Copenhagen Formation of Nevada (Ethington and Schumacher, 1969) in association with conodonts suggestive of the uppermost part of the *Pygodus anserinus* Zone or the lowermost part of the *Amorphognathus tvaerensis* Zone (Bergström, 1971a, p. 124). This evidence indicates that *P. grandis* ranges down at least into the lower part of the *A. tvaerensis* Zone and possibly into the uppermost part of the *P. anserinus* Zone.

**Occurrence:** Tumbez at Lay School, Holston at Thorn Hill.

**Collection:** 9 specimens (4 periodoniform, 1 prioniodiniform, 1 ligonodiniform, 3 falodontiform).

**Figured specimen:** OSU 31801.

**Reference specimen:** OSU 31959.

**PERIODON sp.**

*(not illustrated)*

**Occurrence:** Eidson Member at Eidson, Holston at Cuba.

**Collection:** 3 specimens (periodoniform).
Genus PHRAGMODUS Branson and Mehl, 1933

Emend. Bergström and Sweet, 1966

Phragmodus Branson and Mehl, 1933, p. 98.

Type species: Phragmodus primus Branson and Mehl, 1933.

PHRAGMODUS FLEXUOSUS Moskalenko

(Pl. V, figs. 11-16)


Phragmodus sp. nov. Moskalenko, 1972, p. 48-50, fig. 1, nos. 1-12, not fig. 1, nos. 13-15.

Phragmodus flexuosus Moskalenko, 1973, p. 73-74, Pl. XI, figs. 4-6.


Subcordylodus sinuatus Stauffer, Moskalenko, 1973, p. 80-81, Pl. XII, figs. 7-9.

Dichognathus decipiens Branson and Mehl, Moskalenko, 1973, p. 66-67, Pl. XV, figs. 7-12.


Remarks: Moskalenko (1972, p. 48-50, fig. 1, Table 2) recently described the apparatus of this new Phragmodus species from the Volginsky beds of the Siberian Platform. In the apparatus of this species she included cyrtoniodontiform elements, typica-type and brevis-type dichognathiform elements, subcordylodontiform elements, and gothodontiform and phragmodontiform elements that she later named Gothodus evenkiensis.
and Phragmodus flexuosus, respectively (Moskalenko, 1973). Moskalenko (1972) also included oistodontiform and acodontiform elements in this apparatus. However, according to the model of the Phragmodus apparatus suggested by Bergström and Sweet (1966) and Sweet and Bergström (1972), the P. flexuosus apparatus is complete without these latter elements and there is no indication in the present collections, or in large undescribed collections at The Ohio State University in which elements of P. flexuosus occur in abundance, that the apparatus of P. flexuosus included oistodontiform and acodontiform elements. As interpreted here, the apparatus of Phragmodus flexuosus Moskalenko consists of a morphologically intergradational series of phragmodontiform and subcordylodontiform elements, and in some cases also gothodontiform elements; dichognathiform elements (breviform and typiciform) and cyrtoniodontiform elements. The apparatus is characterized by its complement of elements, which includes a typiciform element with a small (10-20 degrees) "outer process angle" (Sweet and others, 1959, p. 1056), and by the undulating posterior process on phragmodontiform, subcordylodontiform, and gothodontiform elements (Moskalenko, 1972, p. 48, 49).

As noted by Votaw (1971), elements of the P. flexuosus apparatus are identical to elements of the apparatus from the McLish Formation of Oklahoma that Sweet and others (1971) have illustrated as Phragmodus sp. A.

Moskalenko (1972) refers to one of the elements that she includes in this apparatus as "gothodiform". These are essentially subcordylododontiform elements with an extremely laterally flexed anterior margin. In
the present collections, most of the subcordylosodontiform elements of *Phragmodus flexuosus* have a sharp, slightly laterally flexed anterior margin and they conform to the description and illustrations of the form-species *Subcordylodus sinuatus* Stauffer (1935a, p. 154, Pl. 11, figs. 28, 37, 42, 45). A few of the subcordylosodontiform elements at hand have the anterior margin deflected to the point where it might be described as an antero-lateral offset-costa on an anteriorly-rounded cusp and base but none of these elements reaches the extreme condition that Moskalenko (1973) has described as *Gothodus evenkiensis*. On the other hand, in some collections of elements of *P. flexuosus* from the McLish Formation kindly placed at my disposal by Dr. W. C. Sweet, gothodontiform elements that appear to be identical to those named *G. evenkiensis* by Moskalenko (1973) are predominant, in some cases greatly so, over subcordylosodontiform elements. In addition to the pronounced antero-lateral offset costa on one face, some of the McLish gothodontiform elements also have a costa on the opposite face, in or slightly anterior to the middle of the cusp and continuous onto the base. None of the subcordylosodontiform elements in my collections displays this additional costa. The McLish specimens are very large and robust in comparison to the elements at hand so the gothodontiform condition may simply be a function of size and robustness, which in turn may be related to environmental conditions. However, the specimens referred here to *P. flexuosus* are clearly younger than the McLish specimens. Within the present study area, elements of *P. flexuosus* occur through a stratigraphic interval that has produced representatives of species
characteristic of the upper part of the *Pygodus anserinus* Zone and the lower part of the *Amorphognathus tvaerensis* Zone. As pointed out by Sweet and Bergström (1973), the McLish and the overlying Tulip Creek have produced specimens of *Polyplacognathus friendsvilliensis*, which indicates a *Pygodus serrus* Zone age (Bergström, 1971a). Stratigraphic and geographic variation of the elements of the *P. flexuosus* apparatus must be studied in greater detail than the present collections permit, but it appears that through time gothodontiform elements in the *P. flexuosus* apparatus were replaced by subcordyloodontiform elements. If this idea can be verified, then it may be possible to recognize two subspecies of *P. flexuosus*, or even two distinct species of *Phragmodus*, one of which has gothodontiform elements in the apparatus and the other of which does not. Such a distinction could possibly be of biostratigraphic value.

**Occurrence:** Tumbez and Elway-Eidson at Lay School, Eidson and Hogskin at Evans Ferry, Holston at Thorn Hill. Representatives of this species occur in the McLish Formation of Oklahoma and in the Crystal Peak Dolomite of Utah (Sweet and others, 1971), in the Volginsky beds of the Siberian Platform (Moskalenko, 1972), in rocks of the Chazy Group of New York (Raring, 1972; Roscoe, 1973), in the Tulip Creek and Bromide Formations of Oklahoma (Sweet and others, 1973), and in the Ship Point Formation of the Canadian Arctic (Barnes, 1974).

**Collection:** 498 specimens (97 phragmodontiform, 130 subcordyloodontiform, 136 dichognathiform, 135 cordyloodontiform).

**Figured specimens:** OSU 31802, OSU 31803, OSU 31804, OSU 31805, OSU 31806, OSU 31807.
Reference specimens: OSU 31960 (phragmodontiform), OSU 31961 (phragmodontiform), OSU 31962 (subcordyloodontiform), OSU 31963 (typiciform), OSU 31964 (breviform), OSU 31965 (cyrtoniodontiform).

PHRAGMODUS INFLEXUS Stauffer

(Pl. V, fig. 17)

Phragmodus inflexus Stauffer (part), 1935a, p. 151, Pl. 11, figs. 9, 16, 20, 25, 26 (not Pl. 11, figs. 15, 17, 19, 21, 22, 34); Webers, 1966, p. 40-41, Pl. 3, fig. 8, Pl. 8, figs. 1, 2, 4 (synonymy through 1966); Sweet, and others, 1971, p. 175, Pl. 1, figs. 1, 15.

Cyrtoniodus complicatus Stauffer, 1935a, p. 140, Pl. 11, figs. 44, 46, 48-51.


Remarks: As diagnosed by Webers (1966), and also by Bergström and Sweet (1966, p. 367, 371), the apparatus of Phragmodus inflexus consists of a morphologically intergradational series of phragmodontiform and subcordyloodontiform elements and dichognathiform elements that are characterized by a small denticle on the anterior edge of the cusp. Votaw (1971) and Sweet and Bergström (1972) have subsequently pointed out that the P. inflexus apparatus also included cyrtoniodontiform elements. As noted by Votaw (1971), these latter elements are of the same general form as ones previously referred to the form-species Cyrtoniodus flexuosus (Branson and Mehl) and Cyrtoniodus complicatus Stauffer.

Webers (1966, p. 40) reports that in collections from the Glenwood Formation of Minnesota not all dichognathiform elements of Phragmodus
inflexus possess a well-defined anterior denticle on the cusp but that some specimens lack a denticle whereas others have an "unerupted germ denticle". This is also true in the present collections of dichognathiform elements of *P. inflexus*.

Although the apparatus of *Phragmodus undatus* (see Bergström and Sweet, 1966; Sweet and Bergström, 1972) and that of *Phragmodus flexuosus* both contain two types of dichognathiform elements (breviform and typiciform), only breviform elements are present in the collections of *Phragmodus inflexus* at hand. Webers (1966, p. 4) states that the apparatus of *Phragmodus cognitus* also contains only brevis-type dichognathiform elements.

Occurrence: Tumbez, Elway-Eidson (questionable specimens), Hogskin, and Rockdell at Lay School; Eidson Member at Evans Ferry; Marcem (questionable specimens), Eidson, and Rockdell at Eidson; Holston, Hogskin, Unit 776, Unit 780 (questionable specimens) at Thorn Hill; Mosheim (questionable specimens), blue limestone, and Holston at Cuba.

The known distribution of representatives of this species up to 1971 is summarized by Sweet and others (1971) and by Votaw (1971). Specimens of *Phragmodus inflexus* also occur in the Isle La Motte Limestone of the Champlain Valley of New York (Raring, 1972; Roscoe, 1973), in the Glens Falls Formation of the Champlain Valley of New York (Roscoe, 1973), and in the Bromide Formation of Oklahoma (Sweet and others, 1973).

Collection: 1534 specimens (279 phragmodontiform, 376 subcordy­lodontiform, 510 dichognathiform, 369 cordylo­dodontiform).

Figured specimen: OSU 31808.
Reference specimens: OSU 31966 (phragmodontiform), OSU 31967 (phragmodontiform), OSU 31968 (subcordylodontiform), OSU 31969 (dichognathiform), OSU 31970 (cytoniodontiform).

"PHRAGMODUS" sp.

(Pl. III, fig. 2)

Description: The one representative of this species at hand is a moderately arched hyaline unit with a slightly reclined cusp and several long, slender, compressed denticles on the posterior process. One denticle on the posterior process rivals the cusp in size and the size of the process denticles markedly decreases in both anterior and posterior directions away from the one large process denticle. The cusp and all the process denticles bear thin, narrow, anterior and posterior keels. The anterior keel on the cusp is laterally deflected in the basal direction and is laterally drawn out at the antero-basal corner to form a small, process-like extension that bears a single, stubby denticle.

Remarks: The name "Phragmodus" is used here for this hyaline phragmodontiform element strictly in a form sense and no affinity to the multielement genus Phragmodus sensu Bergström and Sweet (1966) is implied.

Hyaline conodont elements of the same general appearance as this specimen have been reported from the Pratt Ferry Formation of Alabama (Sweet and Bergström, 1962, p. 1249) and from rocks of the Chazy Group in the Montreal area (Raring, 1972). Raring (1972) suggests that elements similar to the one described here may have been associated in an apparatus with elements like those here referred to "Roundya" bispicata Sweet and
Bergström. As also noted by Raring (1972), elements of this type are representative of the Australian faunas mentioned by Bergström (1971a, p. 130; 1973a, p. 53).

Occurrence: Blue limestone at Cuba (sample 73CC2-7).
Collection: 1 specimen.
Figured specimen: OSU 31809.

Genus PLECTODINA Stauffer, 1935

Plectodina Stauffer, 1935a, p. 152.

Type species: Prioniodus aculeatus Stauffer, 1930.

PLECTODINA ACULEATA (Stauffer)

(Pl. VI, figs. 1-7)

Prioniodus aculeatus Stauffer, 1930, p. 126, Pl. 10, fig. 12.
Plectodina aculeata (Stauffer), Bergström and Sweet, 1966, p. 373-377, Pl. 32, figs. 15, 16, Pl. 33, figs. 22, 23, Pl. 34, figs. 5, 6, Text-fig. 9A-F (synonymy to 1966); Sweet and others, 1971, Pl. 2, figs. 12-14.

Ozarkodina? obliqua (Stauffer), Bergström and Sweet, 1966, Pl. 33, figs. 6-9, Pl. 34, figs. 7-8, Text-fig. 10A-F (synonymy to 1966).

Trichonodella recurva (Branson and Mehl), Oberg, 1966, p. 143, Pl. 15, figs. 5, 26.

Zygognathus deformis (Stauffer), Oberg, 1966, p. 145, Pl. 15, fig. 18.

Subcordyloodus delicatus (Branson and Mehl), Oberg, 1966, p. 141-142, Pl. 15, fig. 21.

Dichognathus brevis Branson and Mehl, Oberg, 1966, p. 137, Pl. 15, fig. 16.

Ozarkodina concinna Stauffer, Oberg, 1966, p. 140, Pl. 15, fig. 15.
\textit{PZygognathus?} sp. cf. \textit{Zygnemis} Branson, Mehl, and Branson, Oberg, 1966, p. 145, Pl. 15, fig. 24, Pl. 16, figs. 8, 15.

\textit{Trichonodella recurva} (Branson and Mehl), Globensky and Jauffred, 1971, p. 59, Pl. V, figs. 2, 5.

\textit{Trichonodella flexa} Rhodes, Globensky and Jauffred, 1971, p. 59, Pl. V, fig. 7.

\textit{Zygognathus deformis} (Stauffer), Globensky and Jauffred, 1971, p. 59, Pl. III, fig. 12.

\textit{Cordyloodus delicatus} Branson and Mehl, Globensky and Jauffred, 1971, p. 54, Pl. II, figs. 8, 9.

\textit{Ozarkodina tenuis} Branson and Mehl, Globensky and Jauffred, 1971, p. 56, Pl. V, figs. 6, 9.

\textit{Prioniodina pulcherrima} Lindström, Globensky and Jauffréd, 1971, p. 58, Pl. V, fig. 3.

\textit{Prioniodina robusta} (Stauffer), Globensky and Jauffred, 1971, p. 58, Pl. V, fig. 1.


Remarks: Sweet and Bergström (1970) have suggested that elements referred to \textit{Plectodina aculeata} (Stauffer) and \textit{Ozarkodina? obliqua} (Stauffer) by Webers (1966) and by Bergström and Sweet (1966) should be brought together in one multielement species named \textit{Plectodina aculeata} (Stauffer). This suggestion has been substantiated by subsequent workers (Votaw, 1971; Raring, 1972; Sweet and Bergström, 1972) and it is also verified by the distribution of elements in the present collections. Therefore, as currently conceived, the apparatus of \textit{P. aculeata} includes a symmetry-transition series of trichonodelliform, zygognathiform, and cordyloodontiform elements (in some cases, oeligonodiniform) plus dichognathiform, ozarkodiniform, and prioniodiniform elements.
Bergström and Sweet (1966, p. 375) note that both symmetrical and asymmetrical trichonodelliform elements are present in the apparatus of *Plectodina aculeata*. Sweet and Schönlaub (1975, in press) have also distinguished between symmetrical trichonodelliform elements (Sa elements) and asymmetrical trichonodelliform elements (Sa-Sb elements) in the apparatus of *Oulodus serratus* (Stauffer). In the present collections of elements of *P. aculeata*, and also in the much larger collections of representatives of *Plectodina* n. sp., it has been possible consistently to distinguish between bilaterally symmetrical trichonodelliform elements with a short, denticulate posterior process; slightly asymmetrical trichonodelliform elements with a short, adenticulate posterior process; and the extremely asymmetrical zygognathiform elements. Together with cordylodontiform elements, this results in a symmetry-transition series of four basic types of elements.

**Occurrence:** Rockdell at Lay School, blue limestone at Cuba (questionable specimens).

**Collection:** 460 specimens (44 symmetrical trichonodelliform, 61 asymmetrical trichonodelliform, 32 zygognathiform, 88 cordylodontiform, 56 dichognathiform, 121 ozarkodiniform, 58 prioniodiniform).

**Figured specimens:** OSU 31810, OSU 31811, OSU 31812, OSU 31813, OSU 31814, OSU 31815, OSU 31816.

**Reference specimens:** OSU 31971 (symmetrical trichonodelliform), OSU 31972 (asymmetrical trichonodelliform), OSU 31973 (zygognathiform), OSU 31974 (cordylodontiform), OSU 31975 (dichognathiform), OSU 31976 (ozarkodiniform), OSU 31977 (prioniodiniform).
Ozarkodina joachimensis Andrews, 1967, p. 895, Pl. 113, figs. 5, 15, Pl. 114, fig. 3.


?Subcordylodus delicatus (Branson and Mehl), Andrews, 1967, p. 899, Pl. 13, figs. 12, 13, 23.

?Eoligonodina prima (Branson and Mehl), Andrews, 1967, p. 889, Pl. 113, figs. 8, 22.


Remarks: The association suggested here is highly speculative. Ozarkodiniform elements are identical to the type specimen of the form-species Ozarkodina joachimensis Andrews, with which they have been compared directly. These ozarkodiniform elements are rare in the collections at hand but in samples in which they occur they are almost invariably associated with distinctive types of trichonodelliform, zygognathiform, cordylodontiform (or eoligonodiniform), dichognathiform, and prioniodiniform elements. These elements are also rare in the present collections and they are characterized by widely-spaced, peg-like denticles. These same types of elements also occur in the Joachim Formation of Missouri, from which the type specimen of Oz. joachimensis was collected (Andrews, 1967).
The rare occurrence of these various forms in the present study area provides little in the way of concrete evidence for the association suggested here. However, these elements are united by co-occurrence and by their distinctive mode of denticulation and this justifies, in my opinion, discussing them together in a tentative way as opposed to referring each to a different form-species.

If the proposed association can be verified, the resulting apparatus has an architectural plan that is identical to that of the *Plectodina aculeata* apparatus. For this reason, these elements are tentatively assigned to *Plectodina*.

There is little doubt that the ozarkodiniform elements referred here could be referred to the form-species *Ozarkodina joachimensis* Andrews but there is some doubt as to whether the trivial name, *joachimensis*, would be the oldest available name among the elements in this apparatus if the apparatus proves to be correctly conceived. The trichonodelliform elements included here are very similar in form to the type specimen of the form-species *Trichonodella pumila* (Branson and Mehl), which is also from the Joachim (Branson and Mehl, 1933, p. 100, Pl. 6, fig. 5). Therefore, it is possible that *Trichonodella pumila* (Branson and Mehl) and *Ozarkodina joachimensis* Andrews are conspecific.

Occurrence: Tumbez at Lay School, Marcem at Eidson, Holston at Thorn Hill, blue limestone and Holston at Cuba. Representatives of this species also occur in the Joachim Dolomite of Missouri (Andrews, 1967).

Collection: 35 specimens (2 symmetrical trichonodelliform, 5 asymmetrical trichonodelliform, 4 zygognathiform, 2 cordylodontiform, 1 eoligonodiniform, 4 dichognathiform, 10 ozarkodiniform, 7 prioniodiniform).
Figured specimens: OSU 31817, OSU 31818, OSU 31819, OSU 31820.

Reference specimens: OSU 31978 (ozarkodiniform), OSU 31979
(symmetrical trichonodelliform), OSU 31980 (asymmetrical trichonodelliform),
OSU 31981 (zygognathiform), OSU 31982 (eoligonodiniform), OSU 31983
(dichognathiform), OSU 31984 (prioniodiniform).

PLECTODINA n. sp.

(Pl. VI, figs. 9-18)


?Phragmodus undatus (Branson and Mehl) (part), Atkinson in Clark, 1971,
p. 85-86, Pl. 5, fig. 8, not Pl. 4, fig. 6, Pl. 6, fig. 6.

Diagnosis: As diagnosed for the first time by Votaw (1971), this is
a multielement species of Plectodina with an apparatus that includes a
morphologically intergradational series of trichonodelliform, zygognathi-
form, and cordylodontiform elements in addition to dichognathiform,
ozarkodiniform, and oistodontiform elements. As is the case with the
apparatus of Plectodina aculeata, a distinction is drawn here between
symmetrical trichonodelliform elements and asymmetrical trichodelliform
elements. It can also be added to this diagnosis that some cordylodonti-
form elements develop anterior denticles, hence are eoligonidiniform;
and that some oistodontiform elements develop anterior denticulation,
and hence are falodontiform. The apparatus is distinguished from other
Plectodina apparatuses mainly by the presence of the oistodontiform
(or falodontiform) elements.
Description: Trichonodelliform, zygognathiform, and cordylodontiform (also eoligonodiniform) elements are like the corresponding elements in the apparatus of *Plectodina aculeata* and I have been unable to recognize any criterion by which to distinguish between these elements of the respective apparatuses.

Oistodontiform elements have a reclined laterally compressed, laterally bowed cusp with sharp anterior and posterior margins. The outer face of the base is flat; the inner face is laterally expanded; the sharp upper margin is surmounted by a thin keel; the anterior face is sharp and sinuous in lateral outline; and the antero-basal angle is markedly acute. On some specimens, the antero-basal corner is produced into a denticulate anterior process.

Dichognathiform elements have a relatively long, erect cusp and slightly bowed posterior and antero-lateral processes. The outer process angle (Sweet and others, 1959, p. 1056) is, on most specimens, about forty-five degrees. The proximal denticle on both the posterior and antero-lateral processes is separated from the cusp by a distinct gap.

Ozarkodiniform elements are arched, slightly laterally bowed, and have a relatively long, slightly proclined cusp. The proximal denticle on the anterior process is fused to the cusp but the proximal denticle on the posterior process is separated from the cusp by a distinct gap.

Remarks: As noted by Raring (1972), dichognathiform and ozarkodiniform elements of the apparatus of this species are rarely found intact. Beneath the gap between the cusp and the proximal, posterior process-denticle, the base on both these types of elements is constricted and the basal walls are thin and fragile. Due to this structural weakness,
fragmentary specimens are the norm.

Occurrence: Throughout the study area, in all the rock-units investigated. Representatives of *Plectodina* n. sp. of Votaw (1971) occur in the Platteville Formation of Iowa and in the Pierce, Ridley, Lebanon and Carters Formations of the Central Basin of Tennessee (Votaw, 1971); in the Day Point, Crown Point, and Valcour Formations of the Champlain Valley of New York and in equivalent rocks in the Montreal area (Raring, 1972; Roscoe, 1973); and in the Isle La Motte and Youngman Formations of the Champlain Valley in New York (Roscoe, 1973). Oistodontiform elements that may be representatives of this species occur in the Joachim Dolomite of Missouri (Andrews, 1967) and in the Platteville Formation of Wisconsin (Atkinson, in Clark, 1971).

Collection: 6256 specimens (523 symmetrical trichonodelliform, 810 asymmetrical trichonodelliform, 565 zygognathiform, 1704 cordylodontiform and eoligonodiniform, 777 dichognathiform, 834 ozarkodiniform, 1043 oistodontiform and falodontiform).

Figured specimens: OSU 31821, OSU 31822, OSU 31823, OSU 31824, OSU 31825, OSU 31826, OSU 31827, OSU 31828, OSU 31829, OSU 31830.

Reference specimens: OSU 31985 (symmetrical trichonodelliform), OSU 31986 (asymmetrical trichonodelliform), OSU 31987 (zygognathiform), OSU 31988 (cordylodontiform), OSU 31989 (eoligonodiniform), OSU 31990 (dichognathiform), OSU 31991 (ozarkodiniform), OSU 31992 (oistodontiform), OSU 31993 (falodontiform).
PLECTODINA? sp.
(Pl. VI, figs. 19-23)

Remarks: A small collection of distinctive, very robust Plectodina-like elements has been obtained from a narrow stratigraphic interval (two closely-spaced samples) in the Rockdell Formation at Lay School. This collection includes trichonodelliform, zygognathiform, eoligonidinaform, and prioniodiniform elements that are characterized by stout, discrete, peg-like denticles. These elements are morphologically intergradational and they are similar to the elements here tentatively referred to \textit{Plectodina? joachimensis}? but the distinctive ozarkodiniform element of the latter apparatus has been found no higher in this section that the upper Tumbez. Denticulation of the elements included here is suggestive of that of \textit{Oulodus} (see Sweet and Schönlaub, in press) but there are no oulodontiform elements present in the collections at hand. Associated with these elements are very robust, but also very fragmentary and unidentifiable, dichognathiform and ozarkodiniform elements. Therefore, I suspect that the elements included here are components of an apparatus that is structurally similar to that of \textit{Plectodina aculeata} and is distinguished by the mode of denticulation on the individual elements.

Occurrence: Rockdell at Lay School.

Collection: 73 specimens (7 symmetrical trichonodelliform, 20 asymmetrical trichonodelliform, 7 zygognathiform, 13 eoligonodiniform, 6 dichognathiform—fragmentary, 2 ozarkodiniform—fragmentary, 18 prioniodiniform).
Figured specimens: OSU 31831, OSU 31832, OSU 31833, OSU 31834, OSU 31835.

Reference specimens: OSU 31994 (symmetrical trichonodelliform), OSU 31995 (asymmetrical trichonodelliform), OSU 31996 (zygognathiform), OSU 31997 (eoligonodiniform), OSU 31998 (prioniodiniform).

Genus POLYCAULODUS Branson and Mehl, 1933

*Polycaulodus* Branson and Mehl, 1933, p. 86.

Type species: *Polycaulodus inclinatus* Branson and Mehl, 1933.

Remarks: Sweet and Bergström (1972, p. 41) note that representatives of the type form-species of *Polycaulodus* Branson and Mehl may have been associated in an apparatus with elements assignable to form-species of *Curtognathus* Branson and Mehl, *Cardiodella* Branson and Mehl, and *Trucherognathus* Branson and Mehl. Hyaline conodont elements assignable to these form-genera occur in all the sections studied but are relatively abundant only in the lower part of the Eidson Member at Evans Ferry and in the upper part of the Rockdell Formation at Lay School. Nevertheless, it is possible to recognize a consistent association of morphologically intergradational polycaulodontiform, cardiodelliform, and trucherognathiform elements, which suggests that these elements may have been components of a single type of conodont apparatus.
POLYCAULODUS sp.
(Pl. V, figs. 3, 4)

Diagnosis: A species with a multielement apparatus consisting of morphologically intergradational polycaulodontiform, cardiodelliform, and trucherognathiform elements.

Description: Polycaulodontiform elements display complete morphological intergradation between forms assignable to the form-species Polycaulodus bidentatus Branson and Mehl, Polycaulodus tridentatus Branson and Mehl, and Polycaulodus inclinatus Branson and Mehl. Variations of the latter two forms are similar to representatives of Polycaulodus normalis Branson and Mehl.

Cardiodelliform elements of this apparatus are strongly arched, slightly twisted, and have a central major denticle. Each process bears two to four minor denticles. These elements, which are identical to representatives of the form-species Cardiodella tumida (Branson and Mehl), are essentially arched polycaulodontiform elements with secondary denticles on each side of the major denticle. Variations of this form are similar to representatives of the form-species Cardiodella uniformis (Branson and Mehl).

Trucherognathiform elements have a pronounced lobe, which forms the base of the major denticle, on one side of the base and a corresponding U-shaped depression on the opposite side. The major denticle is inclined toward the lobed side of the element. Processes may be straight but on most specimens they are gently curved, with the concave side toward the lobed side of the element. Each process is surmounted by two to
four minor denticles. Inclination of the process-denticles is irregular but on most specimens the secondary denticles are either erect or inclined toward the lobed side of the element. In apical view, these elements look like cardiodelliform elements with the processes recurved in the direction of inclination of the major denticle. In general form, these elements are similar, but not identical, to representatives of the form-species Trucherognathus expansus Branson and Mehl and Trucherognathus parallelus Branson and Mehl.

Remarks: Generic assignment of the species characterized by this apparatus is questionable, for Polycaulodus Branson and Mehl may be synonymous with Trucherognathus Branson and Mehl (Lindström, 1964, p. 145; Sweet and Bergström, 1972, p. 41-42). The name Polycaulodus is used here tentatively because the suggested apparatus includes elements that are identical in form to representatives of the form-species Polycaulodus inclinatus, the type species of Polycaulodus. The nature of the apparatus that included elements assignable to the form-species Trucherognathus distortus Branson and Mehl, the type species of Trucherognathus, is not known (Sweet and Bergström, 1972, p. 42).

Occurrence: Tumbez, Elway-Eidson and Rockdell at Lay School; Eidson and Hogskin at Evans Ferry; Marcem and Eidson at Eidson; Holston at Thorn Hill; Holston at Cuba.

Collection: 513 specimens.

Figured specimens: OSU 31836, OSU 31837.

Reference specimen: OSU 31999 (trucherognathiform).
Genus POLYPLACOGNATHUS Stauffer, 1935

Emend. Bergström and Sweet, 1966

Polyplacognathus Stauffer, 1935, p. 615.

Type species: Polyplacognathus ramosus Stauffer, 1935.

POLYPLACOGNATHUS SWEETI Bergström

(Pl. VIII, figs. 10-15)

Polyplacognathus sweeti Bergström, 1971a, p. 143-144, Pl. 1, figs. 1, 2, Fig. 14c-d.

Petalognathus bergstroemi Drygant, 1974, p. 54-55, Pl. 1, fig. 1, 2.

Remarks: Bergström (1975, pers. comm.) has pointed out that the generic name Petalognathus is preoccupied (reptile genus name Petalognathus Duméril and Bibron, 1854) and that the type specimen of Petalognathus bergstroemi Drygant, 1974, is the same form as the holotype of Polyplacognathus sweeti Bergström, 1971.

The description provided by Bergström (1971a, p. 143) for the paired polyplacognathiform and ambalodontiform elements of Polyplacognathus sweeti is adequate and, with the exceptions stated below, nothing can be added here, in terms of general diagnostic characteristics, to that description. However, collections of elements of P. sweeti at hand are, to the best of my knowledge, the largest so far reported in the literature and they provide excellent opportunity to study details of ontogeny, intraspecific variation, and evolution.

Within the limits of in-sample and stratigraphic variation described below, all the ambalodontiform elements of Polyplacognathus sweeti
observed display the main features that Bergström (1971a) has diagnosed as characteristic of the species: a wide anterior process with a denticle row that extends from the distal end of the anterior process to the antero-basal corner of the posterior process; and lateral and posterior processes with denticle rows that are discontinuous with the main denticle row. In any one sample, the most obvious differences among ambalodontiform elements are expressed as variations in the shape of the anterior process, curvature of the main denticle row at the distal end of the anterior process, and the shape and denticulation of the posterior process.

The outline of the anterior process distally (Pl. VIII, figs. 10, 11, 13, 14) may be evenly rounded or weakly to strongly indented on the outer side. The anterior denticle row may be straight distally and terminated near the indented side (Pl. VIII, fig. 11) or bent inward and continuous to the extreme anterior margin (Pl. VIII, fig. 14). The posterior process, in most specimens, is about as wide proximally as the proximal end of the much shorter lateral process and it is surmounted by two to eight stubby, more or less widely spaced but never confluent, denticles. Some elements have a relatively much narrower posterior process (Pl. VIII, fig. 13) and some specimens exhibit a posterior process that is about as wide proximally as the proximal end of the anterior process (Pl. VIII, figs. 10, 14).

In smaller, presumably juvenile, ambalodontiform elements, with rare exceptions, the anterior process is evenly rounded distally and the posterior process is short and narrow. Within groups of progressively larger specimens, lateral flattening or indentation near the distal end
of the anterior process becomes more common and the posterior process increases in relative length, being in most large and complete specimens, of about the same length as the anterior process.

The best collections of elements of *Polyplacognathus sweeti* (over 1200 specimens) have been obtained from a narrow stratigraphic interval in the lowermost part of the Holston Formation at Cuba. Ambalodontiform elements in the lower samples from that section (samples from the blue limestone and samples 73CC2-ll and 73CC2-12 from the Holston) display a main denticle row that is proximally straight or slightly curved (Pl. VIII, figs. 11, 14). These specimens are identical to the holotype of *P. sweeti* (Bergström, 1971a, Pl. 1, fig. 2). Upward in the Holston, specimens appear with a main denticle row that proximally is sharply bent (Pl. VIII, figs. 10, 13). The relative abundance of these forms increases upward in the section until, in the uppermost sample in which *P. sweeti* is represented (73CC2-16), all but 4 of 255 ambalodontiform elements exhibit a proximally bent main denticle row. The shape of the main denticle row, whether straight as in the lower samples or sharply bent as in the uppermost samples, is a consistent feature through all growth stages in any one sample.

*Polyplacognathus sweeti* is also represented in the lower Holston at Thorn Hill, although much less abundantly than in the Holston at Cuba (Appendix B, Tables V and VI). Ambalodontiform elements in the lowermost collection (71FC6-2) from the Holston at Thorn Hill have a proximally straight main denticle row, whereas specimens from higher samples (71FC1-27, 71B25-1) have a proximally bent main denticle row.
Ambalodontiform elements of *Polyplacognathus sweeti* that have a proximally bent main denticle row appear at Cuba in an interval that is characterized by the co-occurrence of specimens of *Pygodus anserinus* and *Prioniodus variabilis*. However, ambalodontiform elements of this type are relatively abundant only in the uppermost part of the range of *P. sweeti* at Cuba, which is above the highest occurrence of specimens of *P. anserinus*. At Thorn Hill, the highest occurrence of specimens of *P. sweeti* is just slightly below the top of the *Prioniodus variabilis* Subzone of the *Amorphognathus tvaerensis* Zone. Therefore, it is clear that ambalodontiform elements of *P. sweeti* that have a proximally bent main denticle row no lower within the study area than the uppermost part of the *P. anserinus* Zone, and it is possible that they range into the lowermost part of the *Amorphognathus tvaerensis* Zone. Bergström (1971a, Figs. 4-5; 1973c, Fig. 2) indicates that the highest known occurrence of specimens of *P. sweeti* is within the upper, but not uppermost, part of the *P. anserinus* Zone. Therefore, it is probable that the stratigraphically highest occurrences of specimens of *P. sweeti* within the present study area are the youngest known to date. Because ambalodontiform elements with a proximally bent main denticle row occur in increasing relative abundance through the uppermost part of the range of *P. sweeti*, it is concluded that this feature represents a late-stage development in the evolution of *P. sweeti*.

Compared to the variety of detail displayed by ambalodontiform elements, polyplacognathiform elements of *Polyplacognathus sweeti* are relatively conservative, both stratigraphically and in any one sample.
Most of the specimens at hand conform closely to Bergström's (1971a) description and none of the 178 complete or nearly complete specimens observed shows any development of an anterior lobe on the antero-lateral process like that which typifies polyplacognathiform elements of Polyplacognathus friendsvillensis.

Polyplacognathiform elements exhibit little ontogenetic variation and the smallest elements are generally little more than miniature duplicates of the largest. Many of the smallest specimens, and a few larger ones, possess a triangular postero-lateral process similar to that which is typical of P. friendsvillensis (Bergström, 1971, p. 142). This is not a consistent feature of all juveniles and it is not common among larger specimens.

A few polyplacognathiform elements (11 in the entire collection) have a lobe-like expansion on the anterior side of the postero-lateral process. In some of these specimens, this expansion is surmounted by a short, S-shaped row of 2 or 3 denticles that merges, in the center of the postero-lateral process, with the postero-lateral denticle row (Pl. VIII, fig. 12). Development of a bilobate postero-lateral process is not a gerontic feature for some smaller specimens also have the incipient secondary lobe. Since polyplacognathiform elements that are postero-laterally bilobate are rare, and since they occur throughout the narrow stratigraphic range of Polyplacognathus sweeti in the sections investigated, it is not possible to say whether this feature represents an evolutionary trend, or if it merely represents one extreme within a normal range of variation.
Occurrence: Holston at Thorn Hill, Holston at Cuba. The known distribution of representatives of this species up to 1971 is summarized by Bergström (1971). Specimens of Polyplacognathus sweeti occur in several sections in the eastern thrust belts of the Southern Appalachians (Bergström, 1973c; Bergström and Carnes, 1975), in the Bromide of Oklahoma (Sweet and others, 1973), in the Crown Point and the Valcour in the Champlain Valley of New York (Raring, 1972), and in the Isle La Motte of the Champlain Valley of New York (Roscoe, 1973).

Collection: 1301 specimens (737 ambalodontiform, 564 polyplacognathi-form).

Figured specimens: OSU 31838, OSU 31839, OSU 31840, OSU 31841, OSU 31842, OSU 31843.

Reference specimens: OSU 32000 (ambalodontiform, typical), OSU 32001 (ambalodontiform, late), OSU 32002 (polyplacognathiiform).

Genus PRIONIODUS Pander, 1856

Prioniodus Pander, 1856, p. 29.

Type species: Prioniodus elegans Pander, 1856.

Remarks: As conceived by Bergström (1968, 1971a), Prioniodus encompasses multielement conodont species with hibbardelliform, tetraprioniodontiform, belodontiform, prioniodontiform, and falodontiform (or oistodontiform) elements in the apparatus. In the apparatus of some species, prioniodontiform elements may be differentiated into two morphological types (prioniodontiform and amorphognathiform).
Amorphognathiform elements of the Prioniodus apparatuses discussed here are the most diagnostic, so remarks are limited to them. Other elements of apparatuses of several Prioniodus species have been described and discussed by Bergström (1962, 1968, 1971a).

PRIONIODUS GERDAE Bergström

(Pl. VIII, fig. 8)

Prioniodus gerdae Bergström, 1971a, p. 146, Pl. 2, fig. 3.

Amorphognathus gerdae (Bergström) (part), Viira, 1974, p. 60-61, Fig. 56, not Pl. XI, fig. 38, Fig. 57.

Remarks: All amorphognathiform elements included here have a relatively long, denticulated postero-lateral process.

Occurrence: Rockdell at Eidson, Holston at Thorn Hill. Fragmentary specimens that are probably representative of this species occur in the Holston at Cuba. The known distribution of representatives of this species up to 1971 is summarized by Bergström (1971a). Representatives of Prioniodus gerdae also occur in the Bromide of Oklahoma (Sweet and others, 1973), in the Long Point Formation of Newfoundland (Fåhraeus, 1973a, 1973b), in Estonia (Viira, 1974), and in the Holston and Chota Formations in the eastern thrust belts of eastern Tennessee (Bergström and Carnes, 1975).

Collection: 119 specimens (7 hibbardelliform, 28 tetraprioniodontiform, 25 belodontiform, 39 prioniodontiform, 12 amorphognathiform, 8 oistodontiform).

Figured specimen: OSU 31844.

Reference specimen: OSU 32003.
PRIONIODUS VARIABILIS Bergström

(Pl. VIII, figs. 1-4)


Amorphognathus cf. gerdæ (Bergström), Viira, 1974, p. 61, fig. 57.


Remarks: Most of the amorphognathiform elements here referred to Prioniodus variabilis (Pl. VIII, figs. 1, 3) conform closely to Bergström's (1971a) description and illustration. A few specimens (Pl. VIII, figs. 2, 4) differ from typical forms in that the base of the posterior process is not as high, the posterior process is wider directly behind the cusp, the lateral ledges of the posterior process are wider, and the posterior margin of the postero-lateral expansion is almost normal to the main denticle row. Some of these forms have a distinct lip around the margin of the postero-lateral expansion. These atypical forms display the essential features of _P. variabilis_—lateral ledges on the processes and a triangular expansion on the inner side of the posterior process—but the lateral expansion on the posterior process is modified and almost process-like. Amorphognathiform elements of this type occur at Lay School and at Thorn Hill in association with _P. variabilis_—_P. gerdæ_ transition forms and, for this reason, they are interpreted as representing a late evolutionary stage of _P. variabilis._

Occurrence: Tumbez at Lay School (late forms), Holston at Thorn Hill (late forms), Holston at Cuba (typical forms). Bergström (1971a)
summarizes the known distribution of specimens of *Prioniodus variabilis* up to 1971. Representatives of this species are reported from the Cobbs Arm Limestone of Newfoundland (Bergström, Riva and Kay, 1974), and Viira (1974) figures a specimen from Estonia that is interpreted here as a late form of *P. variabilis*.

Collection: 650 specimens (46 hibbardelliform, 139 tetraprioniodontiform, 142 belodontiform, 174 prioniodontiform, 63 amorphognathiform, 86 oistodontiform).

Figured specimens: OSU 31845, OSU 31846.

Reference specimens: OSU 32004 (typical form), OSU 32005 (late form).

PRIONIODUS VARIABILIS—PRIONIODUS GERDAE transition forms

(Pl. VIII, figs. 5-7)

Remarks: Bergström (1971a, p. 146) notes the occurrence of forms transitional from *Prioniodus variabilis* to *Prioniodus gerdae* through a narrow stratigraphic interval (no more than 0.5m) in Balto-Scandia. Several elements that are morphologically intermediate between representatives of these two distinctive species have also been recovered from a much thicker stratigraphic interval (over 70 feet) in the lower part of the Holston Formation at Thorn Hill. Between the highest occurrence of *P. variabilis* (late form) and the lowest occurrence of *P. gerdae*, amorphognathiform elements of *Prioniodus* exhibit a wide range of variability in development and denticulation of a postero-lateral process. In the small collections at hand, three morphologically distinct
transition forms can be recognized. In the text and Figures of the stratigraphic part of this paper, these forms are referred to as Prioniodus gerdae (early). Numbers indicated below in parentheses designate samples from the Thorn Hill section (see Appendix A).

Form A (Pl. VIII, fig. 5): These elements have a postero-lateral process that is surmounted by a low, nodular ridge that contains white matter. On some specimens, the postero-lateral process is similar in size and shape to that of specimens of Prioniodus variabilis (late form). One specimen of this form (figured in Pl. 8) has a postero-lateral process that is relatively as long as that on typical specimens of Prioniodus gerdae. Elements of this type occur through a stratigraphic interval between 40 feet (71B25-4, 71FC6-44) and 44 feet (71FC6-31) above the base of the Holston at Thorn Hill.

Form B (Pl. VIII, fig. 6): Amorphognathiform elements of this type are characterized by a single, well-developed, discrete denticle on a short postero-lateral process. These forms occur through a stratigraphic interval between 53 feet (71FC6-32) and 101 feet (71FC6-7) above the base of the Holston at Thorn Hill.

Form C (Pl. VIII, fig. 7): These elements have a short postero-lateral process that is surmounted by two or, at most, three denticles. Elements of this type occur through a stratigraphic interval between 79.5 feet (71FC6-34) and 127 feet (71B25-7) above the base of the Holston at Thorn Hill.

The occurrence of these forms at Thorn Hill makes it clear, as recognized by Bergström (1971a), that Prioniodus gerdae evolved from Prioniodus variabilis by development of a denticulated postero-lateral
process. Whether or not these transition forms might be useful for defining an additional subzone within the zone of *Amorphogantthus tvaerensis* cannot be decided until further information is available on their stratigraphic and geographic distribution.

Occurrence: Tumbez at Lay School, Holston at Thorn Hill. Elements of this type occur in the Balto-Scandic area and in the uppermost Effna and lowermost Rich Valley Formations in Virginia (Bergström, 1971a). Viira (1974, Pl. X, fig. 38) illustrates a specimen from Estonia that is probably a *Prioniodus variabilis-Prioniodus gerdæ* transition form.

Collection: 304 specimens (20 hibbardelliform, 66 tetraprioniodontiform, 57 belodontiform, 68 prioniodontiform, 45 amorphognathiform, 48 oistodontiform).

Figured specimens: OSU 31847, OSU 31848, OSU 31849.

Reference specimens: OSU 32006 (Form A), OSU 32007 (Form B), OSU 32008 (Form C).

**PRIONIODUS sp.**

(not illustrated)

Remarks: In several samples, elements occur that surely belong in one of the *Prioniodus* species recognized here but specific determination is not possible either because amorphognathiform elements are absent, or are too fragmentary to allow confident identification. In light of the limited distribution of *Prioniodus* in the western Appalachians, it is worthwhile to note any occurrence of *Prioniodus* elements, even though a positive identification is not possible.
Occurrence: Eidson and Rockdell at Evans Ferry; Marcem, Eidson, and Hogskin at Eidson.

Collection: 91 specimens (3 hibbardelliform, 19 tetraprionidontiform, 12 belodontiform, 35 prioniodontiform, 6 amorphognathiform, 16 cistodontiform).

Genus PROTOPANDERODUS Lindström, 1971

Protopanderodus Lindström, 1971, p. 50.

Type species: Acontiodus rectus Lindström, 1955.

PROTOPANDERODUS VARICOSTATUS (Sweet and Bergström)

(Pl. II, figs. 10-12)

Scolopodus varicostatus Sweet and Bergström, 1962, p. 1247-1248, Pl. 168, figs. 4-9, Text-fig. 1A, C, K; Hamar, 1964, p. 284, Pl. 1, figs. 1-2, Text-fig. 4, no. 7a-b; Bradshaw, 1969, p. 1163, Pl. 132, fig. 10, Pl. 134, figs. 12, 13; Viira, 1974, p. 123, Fig. 160.

Scandodus unistriatus Sweet and Bergström, 1962, p. 1245, Pl. 168, fig. 12, Text-fig. 1E; Bradshaw, 1969, p. 1161, Pl. 135, figs. 5, 6.


"Scolopodus" varicostatus Sweet and Bergström, Bergström, 1971a, p. 92-93, figs. 4-5.

Protopanderodus varicostatus (Sweet and Bergström), Bergström, 1973a, p. 13; Bergström, 1973b, p. 272-280, figs. 5-9; Bergström, Riva and Kay, 1974, Pl. 1, figs. 9-10.

Remarks: Bergström and Sweet (1966, p. 395) have suggested that the form-species Scolopodus varicostatus and Scandodus unistriatus might belong in the same multielement species and that suggestion is followed here.
Varicostatiform elements of Protopanderodus varicostatus in the present collections do not display the prominent anterior notch in the basal margin described by Sweet and Bergström (1962, p. 1247). Rather, the base is anteriorly produced into a thin keel (Pl. II, figs. 11, 12) that is continuous with the sharp anterior margin of the cusp. Many specimens do, however, retain the basal filling, which extends a short distance outside the basal cavity along both sides of this keel and creates the impression of a notched basal margin (see Lindström and Ziegler, 1971).

Unistriatiform elements (Pl. II, fig. 10) in the collections at hand differ from Sweet and Bergström's (1962) illustration of Scandodus unistriatus in having two or three very fine costae posterior to the longitudinal groove on the inner side of the element. This is the only difference and it is not considered taxonomically significant since some topotype unistriatiform elements of Protopanderodus varicostatus, provided by Dr. S. M. Bergström, display similar costation.

A representative collection of conodont elements, also provided by Dr. Bergström, from Hamar's (1964) Kullerud locality (Ampyx Limestone) includes several unistriatiform elements that differ from specimens in the present collections only by lacking minor costae posterior to the longitudinal groove. Hamar (1964) describes two form-species, Scandodus lunatus and Scandodus sp., either of which, if not both, could be based on unistriatiform elements of Protopanderodus varicostatus.

Bradshaw (1969) illustrates specimens from the Fort Pena Formation of Texas that appear identical to elements of Protopanderodus varicostatus, especially her unistriatiform elements, which clearly display fine costae posterior to the longitudinal groove.
Occurrence: Tumbez at Lay School, Holston at Cuba.

Collection: 309 specimens (251 varicostatiform, 58 unistriatiform).

Figured specimens: OSU 31850, OSU 31851, OSU 31852.

Reference specimens: OSU 32009 (varicostatiform), OSU 32010 (unistriatiform).

Genus **PYGODUS** Lamont and Lindström, 1957

**Pygodus** Lamont and Lindström, 1957, p. 67.

Type species: *Pygodus anserinus* Lamont and Lindström, 1957.

**PYGODUS ANSERINUS** Lamont and Lindström

(Pl. VIII, figs. 19, 20)

*Pygodus anserinus* Lamont and Lindström, 1957, p. 67-69, Pl. 5, figs. 12, 13, Fig. 1a-d; Bergström, 1971a, p. 149, Pl. 2, figs. 20, 21 (synonymy to 1969); Viira, 1974, p. 115, Pl. XI, figs. 26, 27; Bergström, Riva and Kay, 1974, Pl. I, figs. 16, 17.

Occurrence: Holston at Cuba.

Collection: 23 specimens (11 pygodontiform, 12 haddingodontiform).

Figured specimens: OSU 31853, OSU 31854.

Reference specimens: OSU 32011 (pygodontiform), OSU 32012 (haddingodontiform).

Genus **ROUNDYA** Hass, 1953


Type species: *Roundya barnettana* Hass, 1953.
"ROUNDYA" BISPICATA Sweet and Bergström

(Pl. III, fig. 1)

Roundya bispicata Sweet and Bergström, 1962, p. 1243, Pl. 171, fig. 6.

Remarks: The two bilaterally symmetrical, hyaline elements included here are fragmentary but they can be recognized as conforming to the description of this form-species provided by Sweet and Bergström (1962). It is possible that elements of this type were associated in an apparatus with elements of the type that are herein referred to "Phragmodus" sp.

Occurrence: Blue limestone at Cuba (samples 73CC2-6, 73CC2-10).

Collection: 2 specimens.

Figured specimen: OSU 31855.

Genus TRIANGULODUS Van Wamel, 1974

Triangulodus Van Wamel, 1974, p. 96.

Type species: Paltodus volchovensis Sergeeva, 1963.

TRIANGULODUS sp. cf. T. BREVIBASIS (Sergeeva)

(Pl. VII, figs. 1-6)

cf. Oistodus brevibasis Sergeeva, 1963, p. 95, Pl. 7, figs. 4, 5.

cf. Scandodus brevibasis (Sergeeva), Lindström, 1971, p. 39-40, Pl. 1, figs. 24-27, Fig. 3.

cf. Triangulodus brevibasis (Sergeeva), Van Wamel, 1974, p. 96-97, Pl. 5, figs. 1-7.

?Protopanderodus n. sp. Barnes and Poplawski (part), 1973, p. 784-785, Pl. 2, figs. 5, 6, 12, Text-fig. 2C-D, not Pl. 3, fig. 10.

Diagnosis: A hyaline-element species, the apparatus of which consists of a form-transition series of laterally costate elements in association with drepanodontiform, scandodontiform, and oistodontiform elements.

Description: Costate elements have a gently recurved, suberect cusp with a rounded anterior margin, a sharply keeled posterior margin, and a thin, prominent costa at the juncture of each lateral face with the anterior face. The lateral costae are produced basally into process-like wings that are joined to the sharply keeled, posteriorly extended, upper edge of the base by thin walls which enclose the basal cavity. Cloudy concentrations of white matter occur in the posterior keel on the cusp, in the keel on the upper edge of the base, and along the sharp edges of the lateral costae, especially in the basal reaches of the latter.

Costate elements are bilaterally symmetrical, slightly asymmetrical or markedly asymmetrical, depending on the disposition of the lateral costae. Costae on symmetrical elements are antero-lateral and lie in a plane that is perpendicular to the mid-plane of the element. Costae on slightly asymmetrical elements are also antero-lateral but the cusp is twisted relative to the base so that one costa is slightly deflected anteriorly and the other posteriorly. Markedly asymmetrical elements are not twisted but one costa is antero-lateral and the other is postero-lateral well within the posterior half of the element.
Drepanodontiform elements are laterally compressed with an erect, gently recurved cusp that has anterior and posterior keels. The sharply keeled posterior margin of the cusp is continuous with the posteriorly extended, sharply keeled upper margin of the compressed base. The anterior margin of the cusp may be straight or laterally flexed and is continuous with the sharp anterior margin of the base which is drawn out, at the antero-basal corner, into a thin process-like keel. In elements with a straight anterior margin, the lateral faces of cusp and base are equally convex. In elements with a laterally flexed (inward) anterior margin, the inner face of both cusp and base is flat or slightly convex; the outer face of both cusp and base is more strongly convex. In lateral view, the basal outline is sinuous on both sides with rounded salients in the area directly beneath the cusp. On the outer side of the base, between the salient and the anterior margin, there is a triangular depression that reaches to about mid-height on the base. Cloudy concentrations of white matter occur along the anterior and posterior keels and in the keel on the upper edge of the base.

Scandodontiform elements are bowed inward at about the cusp-base juncture, have a short, thinly-keeled upper basal margin and an erect cusp with anterior and posterior keels. The anterior keel is flexed inward and drawn out basally into a thin process-like antero-lateral extension. The inner side of these units is gently convex on the cusp between the anterior and posterior keels, and laterally expanded on the base. The outer side of the cusp is strongly convex and merges into a broad lateral expansion in the central part of the base. Concentrations
of white matter occur along the edges of the keels on the cusp and in the thin keel on the upper basal margin.

Oistodontiform elements have thin, wide, anterior and posterior keels that contain concentrations of white matter. The short upper margin of the base also bears a thin keel that contains concentrations of white matter. These units are slightly bowed inward and the anterior keel may be straight or flexed inward. The cusp is unequally biconvex, a little more convex on the outer side. The outer side of the base is flat or slightly convex; the inner side is strongly inflated in the area beneath the cusp.

Remarks: The six form-elements described here are consistent associates both stratigraphically and geographically within the study area. They vary in color from amber to dark brown, but are always the same color in a single sample, and are, in most cases, the largest elements in a single sample.

Components of this apparatus are similar to elements included in *Triangulodus brevibasis* (Sergeeva) by Van Wamel (1974). Since I have not seen elements of the type referred to *T. brevibasis* by Van Wamel, or to *Scandodus brevibasis* by Lindström (1971), the elements included here are only compared to those of *T. brevibasis*.

The costate elements and drepanodontiform elements of this apparatus bear a striking resemblance to elements assigned to *Multioistodus cryptodens* (Mound) by Sweet and others (1971, p. 168, Pl. 2, figs. 17A–C). The component-elements of *M. cryptodens* occur in the Joins Formation of Oklahoma in association with an oistodontiform element that Mound (1965, p. 3, Table 1, p. 26–27, Pl. 3, figs. 21–23, 29) refers to *Oistodus abundans*.
Branson and Mehl. Judging from Mound's photographs, these elements are very similar to oistodontiform elements of *Triangulodus* sp. cf. *T. brevibasis*. If further study should demonstrate that the apparatus of *M. cryptodens* also includes scandodontiform elements and oistodontiform elements, then elements now referred to *M. cryptodens* and *T. brevibasis* may be congeneric.

**Occurrence:** Throughout the study area, in most of the rock-units investigated. Similar forms are reported from the Lévis Formation of Quebec (Uyeno and Barnes, 1970) and from the Mystic Formation of Quebec (Barnes and Poplawski, 1973).

**Collection:** 667 specimens (38 symmetrical costate, 101 slightly asymmetrical costate, 90 markedly asymmetrical costate, 125 drepanodontiform, 178 scandodontiform, 135 oistodontiform).

**Figured specimens:** OSU 31856, OSU 31857, OSU 31858, OSU 31859, OSU 31860, OSU 31861.

**Reference specimens:** OSU 32013 (symmetrical costate), OSU 32014 (slightly asymmetrical costate), OSU 32015 (markedly asymmetrical costate), OSU 32016 (drepanodontiform), OSU 31860 (scandodontiform), OSU 31861 (oistodontiform).

**Genus WALLISERODUS Serpagli, 1967**


**Type species:** *Acodus curvatus* Branson and Branson, 1947.
Remarks: Serpagli (1967) proposed the genus name *Walliserodus* for prominently costate and keeled simple-cones that had previously been referred to *Paltodus* Pander or to *Panderodus* Ethington. Serpagli designated the form-species *Paltodus debolti* Rexroad, 1967, from the Lower Silurian Brassfield Limestone in Indiana, as type species of *Walliserodus*. However, in a recently completed study of conodonts from the Brassfield Limestone in Ohio, Cooper (1974) has concluded that representatives of *P. debolti* were components of a multielement simple-cone apparatus that also included elements previously assigned to the form-species *Paltodus dyscritus* Rexroad, 1967, *Paltodus multicostatus* Branson and Mehl, 1933, *Acodus curvatus* Branson and Branson, 1947, and *Acodus unicostatus* Branson and Branson, 1947. The concept of *Walliserodus* is therefore broadened to include both paltodontiform and acodontiform elements, and by priority Cooper (1974) has designated *Acodus curvatus* Branson and Branson, 1947, as the type species of *Walliserodus* (in Cooper's opinion, the type specimen of *P. multicostatus* Branson and Mehl, 1933, may have been a component of a somewhat younger Silurian *Walliserodus* apparatus and the trivial name of that specimen, although older, should not be used in association with the Brassfield species).

Three species are referred to *Walliserodus* here. One of these, *Walliserodus* sp. cf. *W. trigonius*, is represented in the collections at hand by almost 1200 specimens, including acodontiform elements and a morphologically intergradational series of paltodontiform elements. The composition of this apparatus was deduced independently, yet the components of the *W. sp. cf. W. trigonius* apparatus can be homologized, element for
element, with the components of *Acodus curvatus* Branson and Branson sensu Cooper (1974). Furthermore, there is reason to believe, as discussed below, that representatives of the form-species *Distacodus* trigonius Schopf and *Scolopodus tuatus* Hamar are paltodontiform components of apparatuses that are structurally identical to that of *W. sp. cf. W. trigonius* and that of *Acodus curvatus sensu* Cooper (1974). For these reasons, in my opinion, Cooper’s (1974) interpretation of the *Walliserodus* apparatus is correct.

**WALLISERODUS TRIGONIUS** (Schopf)

(Fig. 19A-B)


*Acodus sp. aff. A. unicostatus* Branson and Branson, Schopf, 1966, p. 33-34, Pl. 5, fig. 18.

*?Oistodus aff. delta* Lindström, Hamar, 1964, p. 268, Pl. 1, fig. 8.

*?Paltodus n. sp.* Hamar, 1964, p. 271, Pl. 1, figs. 21, 22, Text-fig. 4, no. 6.


*?Acodus trullatus* Hamar, 1966, p. 50, Pl. 1, fig. 15, Text-fig. 3, no. 2.

*?Scandodus inflexus* Hamar, 1966, p. 72, Pl. 3, figs. 15-17.

*?Drepanodus aff. cavus* Webers, Viira, 1974, p. 68, Fig. 68.

*?Paltodus iniquus* Viira, 1974, p. 99-100, Pl. XI, figs. 16, 17, Figs. 124, 125.

*?Scandodus tortus* Viira, 1974, p. 118, Pl. V, figs. 31-33, Figs. 149, 150.

Remarks: Dyscritiform elements included here have a triangular base with a sharp, keeled upper margin; a broad anterior face that is slightly
depressed or broadly rounded (convex); and a laterally directed costa at the juncture of the anterior face with each lateral face. The keel on the upper edge of the base is flanked closely by a well-developed postero-lateral costa. The distinctive feature of these elements is the fact that the antero-lateral costae are directed laterally, perpendicular to the mid-lane.

The fragmentary dyscritiform element illustrated in Figure 19 differs from the holotype of *Distacodus? trigonius* Schopf, with which it has been compared directly, mainly by the presence of a postero-lateral costa. The lateral faces of the holotype of *Distacodus? trigonius* are acostate, but two of Schopf's unfigured paratypes (NYSM 11775) display a distinct costa on one lateral face of the base and these specimens are nearly identical to the element figured here.
Schopf (1966, p. 52-53) states that "the affinities of D.? trigonius are with Acodus aff. unicostatus Branson and Branson in terms of basal cavity development, size, and occurrence." Also, one of Schopf's unfigured plesiotypes (NYSM 11701) of Acodus sp. aff. A. unicostatus, which has a faint lateral costa and was interpreted by Schopf (1966, p. 34) to be a juvenile unicostatiform element, is actually a small multicostatiform element. For these reasons, although the apparatus of D.? trigonius has not yet been reconstructed on the basis of large collections, I believe it is most probable that the apparatus of this species is a Walliserodus apparatus.

Several forms that may be components of the Walliserodus trigonius apparatus have been illustrated in the literature (see synonymy). Representatives of the form-species Panderodus nakholmensis Hamar and Paltodus iniquus Viira appear to be identical to the dyscritiform elements referred here to Walliserodus trigonius. Also, it is possible that representatives of Acodus trullatus Hamar and Scandodus tortus Viira are deboltiform elements of W. trigonius. The illustration provided by Viira (1974) of Drepanodus aff. cavus Webers is similar to Schopf's illustration of Acodus sp. aff. A. unicostatus, and Scandodus inflexus Hamar may be a curvatiform element of W. trigonius. I have seen none of these specimens so their affinity to W. trigonius is suggested with question.

Occurrence: Eidson Member at Eidson. Representatives of this species also occur in rocks of the Trenton Group (Schopf, 1966).

Collection: 4 specimens (dyscritiform).

Reference specimen (figured): OSU 32019.
WALLISERODUS sp. cf. W. TRIGONIUS (Schopf)

(Pl. IV, figs. 1-2, 15-19)

cf. Walliserodus trigonius (Schopf), 1966, p. 52-53, Pl. 5, figs. 2, 3, 4.

Diagnosis: A species with a multielement simple-cone apparatus that consists of three main types of morphologically intergradational paltodontiform elements (dyscritiform, multicostatiform, deboltiform) and two types of acodontiform elements (unicostatiform, curvatiform). Walliserodus sp. cf. W. trigonius is distinguished from similar species of Walliserodus by the anteriorly directed antero-lateral costae on the base of dyscritiform elements.

Description: Dyscritiform elements are curved, symmetrical or slightly asymmetrical units with an erect or slightly proclined cusp. The greatest curvature is near the tip of basal cavity which is deep and apically deflected toward the anterior margin. The base is thin-walled; it is triangular in anterior view, lateral view and cross-section; and has a well-developed costa at the juncture of each lateral face with the anterior face. These costae are directed anteriorly or slightly antero-laterally; they begin at the antero-basal corners of the basal margin, converge upward, and merge at the point of greatest curvature into the rounded anterior face of the cusp. The upper edge of the base is narrowly rounded and surmounted by at least three distinct costae that continue, greatly reduced in size, up the rounded posterior face of the cusp. The median costa on the upper edge of the base extends to the postero-basal corner but the lateral costae, situated at
the juncture of each lateral face with the upper edge of the base, terminate in the posterior one-third of the base. In some specimens, one or two relatively finer costae occur between each lateral costa and the median costa. Lateral faces are flat to slightly convex, acostate on some specimens but, on most specimens, they are ornamented by one to three or four fine costae that begin at about mid-length on the base and continue, much reduced in size, up the rounded lateral faces of the cusp. In symmetrical units, the anterior costae are of equal size and symmetrically disposed; the base is laterally compressed anteriorly so that both anterior costae are very near the mid-plane, and the anterior face of the base is no more than a narrow groove formed by the inner sides of the anterior costae. The median costa on the upper edge of the base is straight and bifurcates near the point of greatest curvature resulting in two, much finer, costae that continue up the cusp. A faint costa originates between these two branches just above the point of bifurcation and continues up the posterior face of the cusp. Lateral costae are of equal size and symmetrically disposed. In slightly asymmetrical units, the anterior costae are subequal in size and asymmetrically disposed, the smaller one being deflected somewhat more laterally than the larger one. The anterior face of the base is gently convex at the basal margin, narrows upward and becomes concave as the anterior costae converge. The median costa on the upper edge of the base is bowed to one side (outer side); it is bifid in some specimens but in most asymmetrical elements it continues undivided up the cusp. The inner-lateral costa on the upper edge of the base is greatly reduced but the outer-lateral costa is nearly as well-developed as the median costa
and continues strongly up the postero-lateral corner of the cusp. Multicostatiform elements differ from asymmetrical dyscritiform elements in development and disposition of the anterior costae and in that the median costa on the upper edge of the base does not bifurcate. The outer anterior costa is displaced medially, and is situated almost in the mid-plane of the element. The inner anterior costa is greatly reduced, directed laterally, and continues strongly up the inner-lateral side of the cusp.

Deboltiform elements have just one anterior costa, which is directed laterally at the juncture of the anterior face with the inner-lateral face. The outer-lateral face and anterior face of the cusp are acostate and form one continuous, convex surface. The central costa on the upper edge of the base is displaced toward the outer side and is flanked on each side by one or two lateral costae. One of the outer-lateral costae is better developed than the others and continues strongly up the postero-lateral corner of the cusp. One or two fine costae may occur in the upper-half of the inner-lateral face of the base.

Curvatiform elements are laterally flexed units with sharp margins. They conform closely with the descriptions given for representatives of the form-species _Acodus curvatus_ by Branson and Branson (1947) and Rexroad (1967). However, none of the specimens at hand display a costate inner face as observed by Rexroad (1967, p. 26).

Unicostatiform elements are laterally compressed with a proclined cusp that has sharp anterior and posterior margins. The sharp posterior margin of the cusp continues along the upper edge of the base as a thin keel. The anterior margin of the cusp also continues basally, about in
the nearly straight mid-plane of the element, as a keel that is not distinctly set off from the lateral faces, and disappears slightly above the antero-basal corner. The basal cavity is deep and apically deflected toward the anterior margin. The base is thin-walled and biconvex; one of its sides is slightly convex, the other is expanded to form an evenly rounded antero-lateral carina that continues at least half-way up the cusp. Except for the lack of a costa on the antero-lateral carina, these units are morphologically very close to the description provided by Branson and Branson (1947, p. 554) for the form-species *Acodus unicostatus*.

All elements of this species are finely striated longitudinally and have a narrow, indistinct "basal wrinkle zone" similar to that observed on elements of *Panderodus* by Lindström and Ziegler (1971).

Remarks: The different form-elements included here are morphologically intergradational, have the same stratigraphic and geographic distribution within the study area, are constant associates in many samples, and in any one sample are of similar size, color, and state of preservation. Furthermore, in terms of basic symmetry plan, each form-element can readily be homologized with one of the elements included in *Walliserodus curvatus* (Branson and Branson) by Cooper (1974). The costate paltodontiform elements of *Walliserodus* sp. cf. *W. trigonius* constitute a form-transition series (see Sweet and Bergström, 1972, p. 42) from symmetrical or slightly asymmetrical, anteriorly bicostate elements (dyscritiform) to asymmetrical elements with one anterior and one antero-lateral costa (multicostatiform) to asymmetrical, anteriorly unicostate elements (deboltiform). The acodontiform components of the apparatus, which are
acostate and have sharp margins, differ basically from one another
only in the degree of lateral flexure of the midplane.

Dyscritiform elements of this apparatus are similar to dyscritiform
elements referred here to *Walliserodus trigonius* (Schopf) but they are
distinguished by the fact that the antero-lateral costae on the base are
directed anteriorly or slightly antero-laterally, rather than directly
laterally as on dyscritiform elements of *W. trigonius*. This difference
may be taxonomically significant, or it may merely reflect morphological
variation within a single species. Pending further investigation of the
latter possibility, the species described here is compared to *W. trigonius*
rather than provided with a new species name.

Atkinson (in Clark, 1971, Pl. 6, figs. 2, 3) illustrates a specimen,
which he refers to *Distacodus*? aff. *D.? trigonius*, that may be a dyscriti­
form element of *Walliserodus* sp. cf. *W. trigonius*. Unicostatiform elements
of *W. sp. cf. W. trigonius* are very close to the illustrations and descrip­
tion of the form-species *Drepanodus cavus* Webers (1966, p. 28-29, Pl. 2,
figs. 4, 5), but the affinities of *D. cavus* are not known (Webers, 1966,
p. 29). Forms that appear to be similar to elements of *W. sp. cf. W.
trigonius* have also been illustrated by Igo and Koike (1967, Pl. III,
figs. 4, 5) and by Weyant (1968, Pl. VI, figs. 7-9).

It is interesting to note several similarities between the apparatus
of *Walliserodus sp. cf. W. trigonius* and apparatuses referred here to
*Belodella*. Triangular, or bicostate, belodelliform elements of *Belodella
nevadensis* and *Belodella n. sp. A* are essentially dyscritiform elements
with a denticulate upper basal margin. Likewise, biconvex belodelliform
elements can be thought of as denticulate multicostatiform and deboltiform elements. Oepikodontiform elements of the *Belodella* apparatuses are little more than denticulate unicostatiform elements. The similarity between unicostatiform elements of *W.* sp. cf. *W. trigonius* and oepikodontiform elements of *Belodella* n. sp. A is particularly striking (compare Pl. IV, figs. 6, 15). Aside from denticulation, a major difference between these apparatuses is the fact that the *Walliserodus* apparatus contains a curvatiform element whereas the *Belodella* apparatus includes an oistodontiform element. This difference may not be as great as it seems, however, for curvatiform elements are simply cones that are flexed laterally whereas oistodontiform elements are cones that are flexed posteriorly. Perhaps this difference in direction of flexure is related in some way to the presence or absence of denticulation on the other elements in the apparatus, for the same situation is observed between the *Belodina* apparatus, which includes an oistodontiform element, and the *Panderodus* apparatus (gracilis-type), which does not. Whatever the reason for differences in apparatus composition, it is evident that the *Belodella* apparatus is similar to the *Walliserodus* apparatus and it is probable that these two genera are phylogenetically closely related.

**Occurrence:** Throughout the study area, in all the rock units investigated.

**Collection:** 1188 specimens (342 dyscriform, 68 multicostatiform, 105 deboltiform, 108 curvatiform, 565 unicostatiform).

**Figured specimens:** OSU 31862, OSU 31863, OSU 31864, OSU 31865, OSU 31866, OSU 31867, OSU 31868.
Reference specimens: OSU 32020 (symmetrical dyscritiform), OSU 32021 (asymmetrical dyscritiform), OSU 32022 (multicostatiform), OSU 32023 (deboltiform), OSU 32024 (unicostatiform), OSU 32025 (curviform).

WALLISERODUS TUATUS (Hamar)

(Pl. IV, figs. 20, 21; Pl. V, figs. 5, 6)

Scolopodus tuatus Hamar, 1964, p. 283, Pl. 2, figs. 5, 9, Text-fig. 4, no. 13; Hamar, 1966, Pl. 3, fig. 3.

Panderodus ethingtoni Fåhraeus, 1966, p. 26, Pl. III, figs. 5a, 5b.

Walliserodus ethingtoni (Fåhraeus), Bergström, Riva and Kay, 1974, p. 1644, Pl. I, fig. 12.


?Scandodus formosus Fåhraeus, 1966, p. 30-31, Pl. III, fig. 11, Text-fig. 2K.

?Nordiodus n. sp. A Fåhraeus, 1970, Fig. 3N.

?Scandodus flexuosus Barnes and Poplawski, 1973, p. 785-786, Pl. 2, figs. 1-4, Text-fig. 2L.

?Scandodus mysticus Barnes and Poplawski, 1973, p. 786, Pl. 4, figs. 1, 2, Text-fig. 2K.

Remarks: Dr. S. M. Bergström has kindly provided me with topotype collections from Hamar's (1964) Kullerud locality (Ampyx Limestone) and Fåhraeus' (1966) Gullhögen Quarry locality (Vikarby and Skövde Limestones). Based on direct comparison of topotype specimens, it is my opinion that representatives of the form-species Scolopodus tuatus Hamar, 1964, and Panderodus ethingtoni Fåhraeus, 1966, are conspecific.
Serpagli (1967, p. 104) placed *Panderodus ethingtoni* Pähraeus, which here is considered a junior synonym of *Scolopodus tuatus* Hamar, in *Walliserodus* and several authors have concurred (Pähraeus, 1970, p. 2067; Bergström, 1973c, Figs. 5-9; Bergström, Riva and Kay, 1974, p. 1644, Table 6, Table 10). Also in my opinion, this transfer is justified for there is evidence that the apparatus of *Walliserodus tuatus*, like the apparatus of *Walliserodus* sp. cf. *W. trigonius*, contained two types of acodontiform elements. In the several samples of topotype material at my disposal, the variably costate tuatiform elements, which are homologous to the paltodontiform elements of *Walliserodus* sp. cf. *W. concavus*, are consistently associated with two types of acostate cones. One of these is straight, has sharp margins, and is basally expanded on one side. These elements appear identical in form to a specimen illustrated by Pähraeus (1970) as *Nordiodus* n. sp. A, which is associated with "*Walliserodus ethingtoni*" in the Table Head Formation of Newfoundland (Pähraeus, 1970, Fig. 2). Representatives of *Scandodus formosus* Pähraeus, which occur with "*Panderodus ethingtoni*" in the Vikarby and Skövde Limestones of Sweden (Pähraeus, 1966, p. 10, Table 2), also appear to be elements of this type. Similar elements were referred to *Scandodus mysticus* by Barnes and Poplawski (1973). The second type of cone differs from the first, except in minor detail, only in being laterally flexed. Elements of this type have been referred to *Scandodus flexuosus* by Barnes and Poplawski (1973). These two forms are, respectively, the unicostatiform and curvatiform elements of the *Walliserodus tuatus* apparatus.
I have not seen the elements referred to *Scandodus formosus* or to *Nordiodus* n. sp. A by Pähraeus, or those referred to new species of *Scandodus* by Barnes and Poplawski (1973), so these names are provisionally included in synonymy with *Walliserododus tuatus*.

Specimens of *Walliserododus tuatus* are rare in the writer's collections, but both symmetrical and asymmetrical tuatiform elements occur (see Hamar, 1964, p. 203).

**Occurrence:** Tumbez and Elway-Eidson at Lay School, Eidson at Evans Ferry, Holston at Thorn Hill, Holston at Cuba. Representatives of this species are known from the Ampyx Limestone in Norway (Hamar, 1964, 1966); from the Vikarby and Skövde Limestones in Sweden (Pähraeus, 1966); from the Biseriata Limestone in Sweden (Bergström, Riva, and Kay, 1974); from the Table Head Formation (Pähraeus, 1970) and the Cobbs Arm Limestone (Bergström, Riva, and Kay, 1974) of Newfoundland; from the Lenoir, Blockhouse, and Whitesburg Formations in eastern Tennessee (Bergström, 1973c); and from the Chota Formation of eastern Tennessee (Bergström and Carnes, 1975). Specimens of *Walliserododus tuatus* also occur in a collection, provided by Dr. S. M. Bergström, from the Pratt Ferry Formation of Alabama.

**Collection:** 19 specimens (4 symmetrical tuatiform, 7 asymmetrical tuatiform, 4 unicostatiform, 4 curvatiform).

**Figured specimens:** OSU 31869, OSU 31870, OSU 31871, OSU 31872.

**Reference specimens:** OSU 32026 (symmetrical tuatiform), OSU 32027 (asymmetrical tuatiform), OSU 32028 (unicostatiform), OSU 32029 (curvatiform).
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APPENDIX A

Measured Section and Sample Locations

A detailed measurement and description of the Lay School section are provided below (stratigraphy by S. M. Bergström, J. A. Fetzer, and J. B. Carnes). Figure 20 is a map of the Lay School locality. Unit numbers for the Thorn Hill section are taken from Hall and Amick (1934), who provide a detailed measurement and description of the Thorn Hill section. The sections at Evans Ferry, Eidson, and Cuba were not measured in detail but these sections are described in the text (p. 46, 51, 62). Unless otherwise noted below, one kilogram (abbreviated Kg) of each sample was processed.

Lay School Section

The designation for this section is 71FC1. Samples designated by 69B3 and 70B17 were placed at the author's disposal by Dr. S. M. Bergström.

T = thickness in feet; CT = cumulative thickness in feet.

Tumbez Formation

<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>53</td>
<td>53</td>
<td>Covered interval. Knox-Tumbez contact marked by a chert- and dolomite-pebble conglomerate, the exposed thickness</td>
</tr>
</tbody>
</table>
Figure 20. Map of the Lay School locality (after Finlayson and others, 1965). North is toward the top of the figure. The Lay School section was measured in five legs (lined pattern) designated by circled Roman numerals I through V. Stippled pattern represents an area in which the rocks are deformed, perhaps cut by a minor fault. Circled asterisk (just north of leg II) represents the location of the rocks from which samples 71FCl-130 and 71FCl-131 were taken (see discussion of Unit 4 of the measured section). Dashed lines represent formation contacts. T = Tumbez, E-E = Elway-Eidson, H = Hogskin, R = Rockdell.
of which is 6 feet. This unit marks the start of leg I of the measured section (Fig. 20).

2.  27  80

Gray dolomite; gray calcilutite (Mosheim-type); mottled red, green, and gray calcilutite and calcisiltite; gray, fine-grained calcarenite.

71FC1-132..57' above base of Tumbez (mottled red, green, and gray calcilutite with calcite "birdseyes").
71FC1-133..67' above base of Tumbez (mottled red, green and gray calcisiltite--sample barren).
71FC1-134..79' above base of Tumbez (very fine-grained) medium-gray calcarenite--sample barren).

3.  23  103

Dense, medium-gray calcilutite (Mosheim-type) with calcite "birdseyes".

4.  74  177

Covered interval--a few isolated ledges of: gray, fine-grained calcarenite; mottled red, green, and gray argillaceous calcilutite and calcisiltite; gray calcilutite (Mosheim type); a thin (2"-4") layer of black chert is present 57' above the base of the unit.

71FC1-130..143' above base of Tumbez (fine-grained, medium-gray calcarenite).
-131..149' above base of Tumbez (fine-grained, medium-gray calcarenite).
-135..149' above base of Tumbez (medium-grained, medium-gray calcarenite with white calcite veins.

[71FC1-135 was collected on leg I of the measured section. 71FC1-130 and 71FC1-131 were collected in the area marked by a circled askterisk in Figure 20.]

5.  38  215

Calcarenite, fine- to coarse-grained, medium- to dark-gray, medium- to thick-bedded; brownish-gray calcisiltite; and slabby, brown mudstone.

71FC1-136..179' above base of Tumbez (brownish-gray, argillaceous calcisiltite).
-137..195' above base of Tumbez (fine-grained, medium-gray calcarenite).
-1....205' above base of Tumbez (coarse-grained, dark-gray calcarenite).
Unit | T | CT | Description
--- | --- | --- | ---
| 71FC1-138.. | 212' above base of Tumbez (fine- to medium-grained, medium-gray calcarenite).
| -139.. | 214' above base of Tumbez (fine- to medium-grained, medium-gray calcarenite).
| [a thin (2"-4") black chert bed occurs 215' above the base of the Tumbez and this marks the end of leg I of the measured section. Samples 71FC1-136 through 71FC1-139 were collected on leg I of the measured section. Sample 71FC1-1 was collected on leg II of the measured section and marks the start of leg II].

6. 14 229 Calcilutite, argillaceous light- to dark-gray, weathering greenish-gray to light-brown, medium-bedded; and slabby, brown mudstone. A bed of gray calcilutite (Mosheim-type), 1' thick, occurs 1-1/2' below the top of the unit.

71FC1-125.. | 228' above the base of the Tumbez.

Elway-Eidson "Formation".

Unit | T | CT | Description
--- | --- | --- | ---
| 7. 86 86 Calcarenite, fine- to medium-grained, dark-gray weathering dark-gray, massive to thick-bedded; cherty in lower part of unit; silicified fossils, especially toward top of unit.

71FC1-2...lowermost foot of Elway-Eidson.

-126..2' above base of Elway-Eidson (barren).
-127..10'
-128..13'
-74..15'
-129..18'
-3...20'
-75..30'
-4...40'
-76..47'
-5...60'
-77...69'
-6...75'
-7...uppermost foot of Unit 7.
<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>46</td>
<td>132</td>
<td>Calcilutite, mottled dark-gray, thin- to medium-bedded, with black and gray chert nodules; shaly interbeds; silicified fossils.</td>
</tr>
<tr>
<td></td>
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<td>71FC1-8...lowermost foot of Unit 8.</td>
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<tr>
<td></td>
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<td>-78...101' above base of Elway-Eidson.</td>
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<td></td>
<td></td>
<td></td>
<td>-9...106'.</td>
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<tr>
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<td></td>
<td>-10...uppermost foot of Unit 8.</td>
</tr>
<tr>
<td>9.</td>
<td>33</td>
<td>165</td>
<td>Mudstone, calcareous; and argillaceous calcilutite, light-gray weathering white, thin-bedded to shaly; poorly exposed.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>71FC1-79...154' above base of Elway-Eidson.</td>
</tr>
<tr>
<td>10.</td>
<td>19</td>
<td>184</td>
<td>Calcarenite, coarse-grained and argillaceous with calcite veins, light-gray weathering medium-gray, thin- to medium-bedded; gradational with underlying calcilutite; poorly exposed except upper three feet.</td>
</tr>
<tr>
<td></td>
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<td>71FC1-11...lowermost foot of Unit 10 (barren).</td>
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<tr>
<td></td>
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<td></td>
<td>-80...173' above base of Elway-Eidson.</td>
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<tr>
<td></td>
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<td></td>
<td>-12...183'.</td>
</tr>
<tr>
<td>11.</td>
<td>50</td>
<td>234</td>
<td>Mudstone, calcareous, light-gray weathering white, thin-bedded to shaly; thin calcarenite interbeds; poorly exposed except upper two feet.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-81...204' above base of Elway-Eidson.</td>
</tr>
<tr>
<td>12.</td>
<td>9</td>
<td>243</td>
<td>Calcarenite, coarse-grained with calcite veins, light-gray weathering light-gray, medium-bedded; fossiliferous.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>71FC1-13...lowermost foot of Unit 12 (barren).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-14...uppermost foot of Unit 12 (barren).</td>
</tr>
<tr>
<td>13.</td>
<td>12</td>
<td>255</td>
<td>Calcilutite, argillaceous, medium-gray weathering light yellowish-brown, nodular, thin and irregular bedding; contains well-preserved brachiopods; poorly exposed.</td>
</tr>
<tr>
<td>Unit</td>
<td>T</td>
<td>CT</td>
<td>Description</td>
</tr>
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</tr>
</tbody>
</table>
| 14.  | 32| 287| Calcarenite, fine-grained, medium- to dark-gray weathering medium-gray, thin-bedded; fossiliferous.  
71FC1-82...lowermost foot of Unit 14.  
-15...262' above base of Elway-Eidson.  
-83...268'  
-16...283'  
-17...uppermost foot of Unit 14. |
| 15.  | 31| 318| Calcilutite, argillaceous, medium- to dark-gray weathering light-gray, thin and irregular bedding; poorly exposed.  
71FC1-18...289' above base of Elway-Eidson.  
-84...299'  |
| 16.  | 77| 395| Calcarenite, very fine-grained, medium-gray weathering light-gray, lower 17' of unit medium- to thick-bedded, upper 60' of unit medium-bedded; contains black chert nodules; fossiliferous, especially toward top of unit; forms a prominent ledge.  
71FC1-19...320' above base of Elway-Eidson.  
-20...329'  
-21...335'  
[Sample 71FC1-21 was taken from a thick bed of calcarenite, 17' above the base of Unit 16. This thick bed, which marks the end of leg II of the measured section, was followed along strike to the southwest to the start of leg III (Fig. 20)].  
71FC1-22...337' above base of Elway-Eidson.  
-23...369'  
-24...uppermost foot of Unit 16. |
| 17.  | 26| 421| Covered interval. |
| 18.  | 12| 433| Calcarenite, very fine-grained, medium-gray weathering light-gray, medium-bedded, with black chert nodules.  
71FC1-25...lowermost foot of Unit 18. |
<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
</table>
| 19.  | 16 | 449| Calcarenite, medium- to coarse-grained, medium- to dark-gray weathering light-gray; medium- to thick-bedded, a few chert flakes; forms a resistant ledge.  
71FCl-26...lowermost foot of Unit 19.  
-85...441' above base of Elway-Edison.  
-27...uppermost foot of Unit 19. |
| 20.  | 35 | 484| Calcarenite, coarse-grained, light-gray weathering light-gray, medium- to thick-bedded, fossiliferous; base of a two-foot-thick bed of light-gray, calcilutite (Mosheim-type) occurs 19' above base of unit.  
71FCl-28...lowermost foot of Unit 20.  
-29...470' above base of Elway-Eidson.  
-30...uppermost foot of Unit 20 (barren). |
| 21.  | 24 | 508| Calcilutite (Mosheim-type), light-gray weathering light-gray, medium- to thick-bedded, fossiliferous; one-foot-thick bed of coarse-grained, light-gray calcarenite 12' above base of unit.  
71FCl-31...497' above base of Elway-Eidson (in calcarenite). |
| 22.  | 60 | 568| Calcarenite, coarse-grained at base of unit, grain size decreases toward top of unit, light-gray weathering medium-gray, thin- to medium-bedded; lower half of unit contains calcilutite (Mosheim-type) lenses; exposure poor in upper part of unit.  
71FCl-32...lowermost foot of Unit 22.  
-33...517' above base of Elway-Eidson.  
-34...526'  
-86...538'  
-35...543'  
-36...549'  
-111...560'  
-37...uppermost foot of Unit 22. |
<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
</table>
| 23.  | 47 | 47 | Calcarenite, medium-grained, dark blue-gray weathering yellowish-brown, thin-bedded and nodular; thick-bedded, darker blue-gray, non-nodular, fine-grained calcarenite, 8' thick, begins 20' above base of unit.  
71FC1-113..at Elway-Eidson/Hogskin contact.  
-38...lowermost foot of Unit 23.  
-112..10' above base of Hogskin.  
-39...20'  
-40...40'  |
| 24.  | 14 | 61 | Calcarenite, fine-grained, dark blue-gray weathering yellowish-brown, thick-bedded.  
71FC1-106..50' above base of Hogskin.  
-41...59'  
-107..uppermost foot of Unit 24 (3 Kg).  |
| 25.  | 14 | 75 | Calcarenite, fine-grained, medium blue-gray weathering, yellowish-brown, medium-bedded and nodular; grades upward into calcilutite of overlying unit.  
71FC1-87...66' above base of Hogskin.  
-108..67'  
-42...uppermost foot of Unit 25.  |
| 26.  | 3  | 78 | Calcilutite, dark-gray weathering white, thin- to medium-bedded with thin, interbedded shale laminae, blocky fracture, abundant black chert nodules.  
71FC1-43...76' above base of Hogskin.  
-109..77'  |
<p>| 27.  | 4  | 82 | Calcarenite, medium-grained, medium-gray weathering light-gray, thin- to medium-bedded with blocky fracture; forms a resistant ledge. |</p>
<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.</td>
<td>12</td>
<td>94</td>
<td>Calcilutite, argillaceous; and fine-grained, argillaceous calcarenite, medium-gray weathering yellowish-brown, thin-bedded and nodular; fossiliferous; forms a rubble-covered slope.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-88...80' above base of Hogskin. -44...uppermost foot of Unit 27.</td>
</tr>
<tr>
<td>29.</td>
<td>13</td>
<td>107</td>
<td>Calcarenite, medium-grained, medium-gray, weathering light-gray to medium-gray, medium-bedded with blocky fracture; petroliferous odor; forms a resistant ledge.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-110...lowermost foot of Unit 28. -45...uppermost foot of Unit 28.</td>
</tr>
<tr>
<td>30.</td>
<td>61</td>
<td>168</td>
<td>Calcilutite to fine-grained calcarenite, medium-gray weathering medium-gray, thin-bedded and nodular; two resistant beds of calcarenite, each 2' thick, at 17' and 59' above base of unit; Receptaculites in lower calcarenite bed; unit poorly exposed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-46...125' above base of Hogskin. -47...uppermost foot of Unit 29.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[The calcarenite bed in the upper 2' of Unit 30 marks the end of leg IV of the measured section. This bed forms a resistant ledge that was traced southwest along strike to the point of origin of leg V, which is approximately 75 yards northwest of Lay School (Fig. 20)].</td>
</tr>
<tr>
<td>31.</td>
<td>76</td>
<td>244</td>
<td>Calcilutite, argillaceous, medium-gray, weathering yellowish-brown, thin-bedded and nodular; thin, shaly interbeds; at 40' and 64' above base of unit are intervals of thicker bedded, more resistant limestone, 14' thick and 12' thick, respectively.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-50...188' above base of Hogskin. -51...208' &quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-52...227 &quot; (0.75 Kg).</td>
</tr>
<tr>
<td>Unit</td>
<td>T</td>
<td>CT</td>
<td>Description</td>
</tr>
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</tr>
<tr>
<td>70B17-1</td>
<td>-2</td>
<td>239'</td>
<td>234' above base of Hogskin.</td>
</tr>
<tr>
<td>-3</td>
<td>241.5'</td>
<td>&quot;</td>
<td></td>
</tr>
<tr>
<td>-4</td>
<td>uppermost foot of Unit 31.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Rockdell Formation**

<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.</td>
<td>30</td>
<td>30</td>
<td>Calcilutite, medium-gray, weathering white or light-gray, evenly thin-bedded, blocky fracture; fossiliferous, especially toward top of unit, including brachiopods and <em>Receptaculites</em>. 71FC1-53...15' above base of Rockdell.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.</td>
<td>63</td>
<td>93</td>
<td>Calcilutite, medium-gray, weathering yellowish-brown, thin- to medium-bedded, middle part of unit thinner bedded; thin, shaly interbeds; abundantly fossiliferous including <em>Receptaculites</em>. 71FC1-54...lowermost foot of Unit 33. 89...42' above base of Rockdell.</td>
</tr>
<tr>
<td>-95...50'</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-90...58'</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-91...60'</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-92...64'</td>
<td>&quot; (barren).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-56...70'</td>
<td>&quot; (barren).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-93...73'</td>
<td>&quot; (barren).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.</td>
<td>12</td>
<td>105</td>
<td>Calcilutite, dark-gray, weathering light-gray to white, medium-bedded, blocky fracture; thin shale interbeds. 71FC1-57...lowermost foot of Unit 34. 94...98' above base of Rockdell.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.</td>
<td>16</td>
<td>121</td>
<td>Calcilutite, dark-gray, weathering yellowish-brown to white, thin-bedded and nodular with mudstone interbeds.</td>
</tr>
</tbody>
</table>

251
<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
</table>
| 36.  | 14| 135| Calcilutite to fine-grained calcarenite, medium- to dark-gray, weathering yellowish-brown, thin- to medium-bedded, nodular with mudstone interbeds.  
71FC1-59...126' above base of Rockdell.  
-60...uppermost foot of Unit 36. |
| 37.  | 15| 150| Calcilutite, argillaceous, medium-gray, weathering yellowish-brown, thin-bedded to slabby; mudstone interbeds.  
71FC1-95...146' above base of Rockdell. |
| 38.  | 4 | 154| Calcarenite, argillaceous, fine-grained, blue-gray, weathering yellowish-brown, thin-bedded with blocky fractures; mudstone interbeds.  
71FC1-61...uppermost foot of Unit 38. |
| 39.  | 45| 199| Calcilutite, medium- to dark-gray, weathering yellowish-brown, lower 10' thin-bedded and nodular, upper 35' thicker-bedded and coarser-grained; many shaly interbeds; many small calcite crystals; fossiliferous between 5' and 10' above base of unit.  
71FC1-114..156' above base of Rockdell.  
-115..159'  
-116..162'  
-96...164'  
-117..169'  
-118..173'  
-62...174'  
-119..179'  
-97...187'  
-120..189'  
-63...194'  
(barren). |
| 40.  | 14| 213| Calcilutite, argillaceous, and shale; lower 2' of unit is greenish-gray shale with ripple marks and thin limestone lenses; upper 12' of unit is greenish-gray calcilutite, weathering greenish-brown, medium- to thick-bedded (this unit is at the road intersection just southeast of Lay School).  
71FC1-98...203' above base of Rockdell. |
<table>
<thead>
<tr>
<th>Unit</th>
<th>T</th>
<th>CT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>41.</td>
<td>14</td>
<td>227</td>
<td>Calcilutite, medium- to dark-gray, weathering greenish-gray, thin-bedded with abundant mudstone interbeds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-121..214' above base of Rockdell (3 Kg).</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-64...219' (2 Kg).</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-122..224' (2 Kg).</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-99...226'</td>
</tr>
<tr>
<td>42.</td>
<td>26</td>
<td>253</td>
<td>Mudstone, calcareous, green and gray, a few reddish-brown beds, weathering greenish or reddish, medium-to thick-bedded; calcarenite intercalations. The upper 4&quot; of this unit is a red clay, which was sampled by Mr. Joe A. Fetzer as a possible bentonite (sample 71FC1-66, which is not included in Fig. 4). Fetzer (1973) reports that the clay is not a bentonite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-123..lowermost foot of Unit 42.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-65...236' above base of Rockdell (2 Kg).</td>
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<td></td>
<td></td>
<td></td>
<td>-124..237'</td>
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<td></td>
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<td>-100..247'</td>
</tr>
<tr>
<td>43.</td>
<td>27</td>
<td>280</td>
<td>Calcilutite, dark-gray, weathering yellowish-brown, thin-bedded with abundant shaley interbeds; some green shale in upper part of unit; thick-bedded calcilutite, 5' thick, begins 10' above base of unit.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-67...lowermost foot of unit 43.</td>
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<td></td>
<td></td>
<td></td>
<td>-101..262' above base of Rockdell (barren).</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-68..268'</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-102..274'</td>
</tr>
<tr>
<td>44.</td>
<td>18</td>
<td>298</td>
<td>Calcilutite, medium-gray, weathering yellowish-brown, thick-bedded at base of unit, becomes thin- to medium-bedded toward top of unit.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>71FC1-69...lowermost foot of Unit 44.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-103..289' above base of Rockdell.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-70..296'</td>
</tr>
<tr>
<td>45.</td>
<td>18</td>
<td>316</td>
<td>Calcilutite, dark-gray, weathering greenish-brown, thin-bedded with numerous shaley interbeds; a one-foot-thick calcarenite bed occurs 5' below the top of the unit.</td>
</tr>
<tr>
<td>Unit T CT</td>
<td>Description</td>
<td></td>
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<td>-----------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>69B3-1...lowermost foot of Unit 45. 71FC1-104...308' above base of Rockdell. 69B3-2...311' &quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46. 60 376</td>
<td>Calcilutite, argillaceous, dark-gray, weathering very light-brown, thin- to medium-bedded; a few thin, shaly interbeds.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>69B3-3...lowermost foot of Unit 46. 71FC1-71...336' above base of Rockdell. -105..344' &quot; -72..356' &quot; -73..371' &quot;</td>
<td></td>
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</tr>
</tbody>
</table>

Evans Ferry Section

The designation for this section is 72FC4.

Hidson Member.

72FC4-25..12' above base. -26..32' " -27..34' " -42..48' " -28..54' " -43..61' " -8..150' " -7..174' " -6..194' "

Hogskin Member.

72FC4-5...5' above base. -36..14' " -35..22' " -34..26' " -4..33' " -33..37' "

72FC4-31...lowermost foot. 72FC4-3...47' above base. -32..50' " -2...52' " 72FC4-5...160' above base (2 Kg). -1...2' above base (2 Kg). -9..12' " -30..17' " -9..20' " -10..41' " -11..62' " -12..78' " -13..98' " -14..118' " -15..138' " -39..156' " -16..158' " -38..160' " -37..162' " -17..168' " -40..175' " -18..180' " -19..uppermost foot. "
Benbolk Formation.

72FC4-20.5' above base.
-41.17' "
-21.37' "
-22.56' "
-23.70' "
-24.80' "

Rockdell Formation.

73CC1-10.1' above base.
-11.10' " (2 Kg).
-12.34' "
-13.60' "
-14.111' "
-15.155' "

Eidson Section

The designation for this section is 73CC1.

Marcem Formation.

73CC1-16.87' above base.
-17.97' "
-18.106' "
-19.124' "

Eidson Member.

73CC1-20. lowermost foot.
-1...75' above base (2 Kg).
-2...14' " (2 Kg).
-3...136' " (2 Kg).
-4...154' "
-5...179' " (2 Kg).
-6...213' "
-7...221' "

Hogskin Member.

73CC1-8.34' above base.
-9...52' "

Thorn Hill Section

The designation for this section is 71FC6. Samples designated as 71B25 were collected by S. M. Bergström. Unit numbers are from Hall and Amick (1934).

Mosheim Member (Units 688 through 715).

71FC6-1.10' above base (barren).

Holston Formation (Units 716 through lower 35' of Unit 744--see Rodgers and Kent, 1935).

71FC6-2. lowermost foot.
-27.17' above base.

71B25-1.22' "
71FC6-3.31' "
71B25-2.32' "
71FC6-28.34' "
-29.35' " (2 Kg).
-30.39' " (2 Kg).
71B25-4.40' " (71FC6-44 was collected at this same level--3 Kg).
71FC6-4.42' above base. (2 Kg).
-31.44' " (2 Kg).
-32.53' " (2 Kg).
-5...63' " (2 Kg).
-6...74' "
-33...76.5' " (2 Kg).
-34...79.5' " (2 Kg).
Cuba Section

The designation for this section is 73CC2.

Mosheim Member.

73CC2-1...4' above base.
-2...10' "
-3...28' "
-4...38' " (barren).

blue limestone member.

73CC2-5...16' above base.
-6...19' "
-7...25' " (3.3 Kg).
-8...38' "
-9...61' "
-10...69' "

Holston Formation.

73CC2-11...lowermost foot.
-12..4' above base.
-13..14' "
-14..21' "
-15..27' "
-25..34' "
-26..37' " (2 Kg).
-16..45' "
-17..54' " (2.7 Kg).
-18..83' "
-19..102' "

Unit 776.

71FC6-46...8' below top of Unit 776.

Unit 780.

71FC6-45...11' above base of Unit 780.

[Sample numbers omitted from this list--71FC6-13 through 71FC6-24--were used by J. A. Fetzer (1973) for a study of Middle Ordovician bentonites. These samples are from the Rockdell Formation and are not included in the present study. Conodont species represented in the Rockdell at Thorn Hill are listed in the text (p. 61-62)].
APPENDIX B

Distribution and Frequency of Conodont Elements in the Sections Investigated

Each species represented in the study area is designated by a number in Table I (p. 31). These numbers (sp.) are listed in order across the top of Tables II–VI. Sample numbers (S) are listed in stratigraphically ascending order in the left column of Tables II–VI. Sample designations are the same as in Appendix A. Samples prefixed by FC or CC in Appendix A are not prefixed in Tables II–VI. Samples prefixed by B in Appendix A are prefixed by B in Tables II–VI (in Table II, Ba=69B3, Bb=70B17). Question marks indicate that identification is probable but not certain, either because specimens are poorly preserved or fragmentary, or because diagnostic component-elements are not present.
Table II. Distribution and frequency of conodont elements in the Lay School section.

| sp. | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
| 132 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 130 | 4 |   |   | 5 |   |   | 13 |   |   | 3 |   | 2 | 4 | 12 | 1 |   | 120 |   | 2 | 38 |   | 2 | 97 | 1 | 19 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 131 |   | 3 |   | 17 |   | 4 |   |   | 12 |   |   | 2 | 65 | 19 |   |   | 184 |   | 82 |   | 3 | 2 | 65 | 3 | 7 | 30 | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 135 |   |   | 4 |   |   | 1 |   | 4 |   |   | 1 |   |   |   |   |   | 1 |   |   |   | 9 |   | 1 | 3 |   | 9 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 136 |   |   |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 137 | 3 | 1 |   | 1 | 3 | 3 | 20 |   | 4 |   | 2 | 61 | 18 |   | 6 | 228 |   | 30 |   | 3 | 4 | 5 | 1 | 3 | 29 | 4 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 138 | 2 | 4 | 10 | 14 | 7 |   | 36 |   | 18 |   | 1 | 79 | 7 |   |   | 15 |   | 86 | 16 | 2 | 9 | 44 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 139 | 1 | 4 | 3 | 3 | 1 | 12 |   | 18 |   | 34 |   | 1 | 29 |   | 17 |   | 27 | 6 | 2 | 9 | 13 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 127 |   |   |   |   | 1 | 1 |   |   |   | 3 |   |   |   | 1 |   |   |   |   |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 128 |   |   | 4 | 1 | 1 |   |   | 1 |   |   | 29 |   |   |   |   |   |   |   |   | 24 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 129 |   |   | 2 | 2 | 5 |   | 27 |   |   | 7 |   |   |   |   |   |   |   |   |   | 119 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 130 |   |   | 6 |   | 14 |   |   | 4 |   |   |   |   |   |   |   |   |   |   |   |   | 20 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 131 | 1 |   | 6 |   |   | 1 |   |   | 1 |   |   | 9 |   |   |   |   |   |   |   |   | 11 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 132 |   | 1 |   | 1 |   | 1 |   | 1 |   |   | 43 |   |   |   |   |   |   |   |   |   | 13 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 133 |   |   |   |   |   |   |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 15  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**Note:** The table continues with similar entries, but they are not fully visible in the image provided.
Table II. Distribution and frequency of conodont elements in the Lay School section, continued.

| sp. | 1 | 2 | 4 | 5 | 8 | 9 | 10 | 11 | 13 | 14 | 15 | 16 | 17 | 18 | 23 | 24 | 26 | 27 | 28 | 29 | 31 | 32 | 34 | 35 | 36 | 37 | 38 | 41 | 42 | 44 | 47 | 49 | 50 |
|-----|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| S   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 83. |   |   |   |   |   |   | 2  | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 16. |   | 1 | 1  | 3  | 2  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 17. |   |   | 1  |    | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 18. |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 84. |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 19. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 20. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 21. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 22. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 23. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 24. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 25. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 26. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 85. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 27. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 28. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 29. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 31. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 32. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 33. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 34. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 86. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 35. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 36. |   |   |   |   |   |   | 8  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 111. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 37. |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 113. |   |   |   |   |   |   | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2 |
| 38. |   | 1 | 3  | 3  | 2  | 3  | 6  | 2  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 |
| 112. | 1 | 2 | 2  | 14 | 14 | 45 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 5 |
| 39. |   | 1 | 1  | 1  | 1  | 13 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 11 |
| 40. |   |   |   |   |   | 2  | 8  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 6 |
| 106. |   |   |   |   |   | 3  | 2  |    |    |    | 1?  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 4 |
| 259 |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 259 |
Table II. Distribution and frequency of conodont elements in the Lay School section, continued.

| sp. | 1 | 2 | 4 | 5 | 8 | 9 | 10 | 11 | 13 | 14 | 16 | 17 | 18 | 19 | 23 | 24 | 26 | 27 | 28 | 29 | 32 | 34 | 35 | 36 | 37 | 38 | 41 | 42 | 44 | 47 | 49 | 50 |
|-----|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 41. |   |   |   |   | 13 |   | 8  |   | 1  | 2  | 8  |   | 17 |   | 12 |   | 1  | 10 |   |   |   |   | 26 |   |   |   |   |   |   |   |   |   |   |   |
| 107. | 1 | 4 |   | 2 | 18 | 1 | 12 | 13 | 32 |   | 8  |   | 35 |   | 37 |   | 58 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 87. |   |   |   | 4 |   | 3 | 2  | 8  |   |   |   |   |   |   |   |   |   | 6  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 108. |   |   |   | 4 |   | 1 | 6 | 1  |   |   |   | 8  |   |   |   |   |    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 42. |   |   |   |   | 1 |   | 3 |   |   |   |   |   |   |   |   |   |   | 2  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 43. |   |   |   |   | 1 |   | 3 |   |   |   |   |   |   |   |   |   |   | 4  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 109. | 2 | 2 |   | 5 |   | 1 | 7 |   | 12 |   | 1  | 10 |   |   |   |   |   |   |   |   | 4  |   |   |   |   |   |   |   |   |   |   |   |   |
| 88. | 1 | 15 | 1 | 2 |   | 2 |   | 7  |   | 21 |   | 1  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 44. |   |   | 3 |   | 2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 110. | 9 | 4 | 1 | 3 | 2 | 1 |   | 2 | 51 |   | 25 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 45. |   |   |   | 2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 46. | 13 | 18 | 3 | 4 |   | 2 |   | 57 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 47. |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | 12 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 48. | 5 | 1 | 4 | 2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 49. |   |   | 1 |   | 1 |   | 4 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 50. | 1 |   |   | 3 |   | 1 |   | 2  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 51. |   |   | 1 |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 52. |   |   |   |   |   | 2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Bb2. |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Bb3. |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Bb4. |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 53. |   | 2 |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 54. | 1 |   | 1 |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 89. |   |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 55. |   | 1 |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 56. |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 90. |   |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 91. |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 97. |   |   |   | 2 |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 94. |   |   |   | 1 |   | 1 |   | 1 |   |   |   |   |   |   |   |   |   | 4  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 58. |   |   |   | 1 |   | 2 |   |   |   |   |   |   |   |   |   |   |   |   | 1  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 59. |   |   |   |   | 1 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 60. |   |   |   |   |   | 2 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

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Table II. Distribution and frequency of conodont elements in the Lay School section, continued.

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Table IV. Distribution and frequency of conodont elements in the Eidson section.

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|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 16. | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 17. | -  | -  | -  | 1  | 2  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 18. | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 19. | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 20. | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 1.  | 10 | 15 | 4  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 2  |
| 2.  | -  | 24 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 31 |
| 3.  | -  | -  | 6  | 10 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 4.  | -  | -  | -  | 5  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 5.  | -  | -  | -  | 4  | -  | 16 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 12 |
| 6.  | -  | -  | -  | -  | -  | -  | 6  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 7.  | -  | -  | -  | -  | -  | -  | -  | 7  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 8.  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 9.  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 10. | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 11. | 6  | -  | -  | -  | -  | -  | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 12. | 1  | -  | -  | 4  | -  | -  | 22 | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 13. | -  | -  | -  | -  | -  | -  | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 14. | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 15. | -  | -  | 1  | 7  | -  | 2  | 7  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |

Table V. Distribution and frequency of conodont elements in the Thorn Hill section.

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Table V. Distribution and frequency of conodont elements in the Thorn Hill section, continued.

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|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
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| 29  |    |    |    | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
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Table VI. Distribution and frequency of conodont elements in the Cuba Section (species columns 7, 21, 33, and 46 are omitted from Table VI. The distribution and frequency of forms that these numbers designate are noted in the systematics part of this report).

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APPENDIX C

PLATES
EXPLANATION OF PLATE I

Figure

1.7. Panderodus sp. A cf. P. panderi (Stauffer).


2. Form D, lateral view of the ungrooved face, X65. Blue limestone at Cuba (73CC2-10). OSU 31796.

3. Form D, lateral view of the grooved face, X55. Blue limestone at Cuba (73CC2-10). OSU 31797.


5. Form B, lateral view, X45. Holston Formation at Cuba (73CC2-16). OSU 31794.

6. Form B, lateral view of the grooved face of a slim element, X65. Rockdell Formation at Evans Ferry (72FC4-37). OSU 31798.

7. Form B, lateral view of the ungrooved face of a slim element, X65. Holston Formation at Thorn Hill (71FC6-34). OSU 31799.


10. Asymmetrical graciliform element, lateral view, X65. Holston Formation at Cuba (73CC2-13). OSU 31784.


12. Unicostatiform element, lateral view, X60. Blue limestone at Cuba (73CC2-10). OSU 31787.

13. P-element, lateral view, X60. Holston Formation at Cuba (73CC2-13). OSU 31789.


15. Compressiform element, lateral view, X100. Rockdell Formation at Lay School (71FC1-121). OSU 31791.

17. Unicostatiform element, upper view, X90. Blue limestone at Cuba (73CC2-10). OSU 31788.

18. Robust compressiform element, lateral view, X70. Holston Formation at Cuba (73CC2-12). OSU 31792.

19, 20, 21. Symmetrical graciliform element; left side, X70; posterior view, X95; right side, X70. Blue limestone at Cuba (73CC2-10). OSU 31782.

22. Symmetrical graciliform element, transverse section near the tip of the basal cavity, X240. Blue limestone at Cuba (73CC2-10). OSU 31783.


23. Lateral view of an element with a costate cusp, X100. Holston Formation at Thorn Hill (71FC6-41). OSU 31775.


25. Lateral view of an element with a straight basal margin, X120. Blue limestone at Cuba (73CC2-10). OSU 31773.

26. Lateral view of an element with a sinuous basal margin, X65. Blue limestone at Cuba (73CC2-10). OSU 31774.
EXPLANATION OF PLATE II

Figure

1-5. *Drepanoistodus suberectus* (Branson and Mehl).

1. Homocurvatiform element, Form B, lateral view, X60. Holston Formation at Thom Hill (71FC6-30). OSU 31742.


5. Homocurvatiform element, Form C, lateral view, X45. Hogskin Member at Evans Ferry (72FC4-35). OSU 31743.

6, 7. New Genus *B n.* sp.

6. Antero-lateral view of a nearly complete specimen, X70. Blue limestone at Cuba (73CC2-10). OSU 31771.

7. Lateral view of a fragmentary specimen showing denticulate posterior margin of the cusp, X65. Blue limestone at Cuba (73CC2-10). OSU 31772.


8. Antero-lateral view of an element with two costae on one side of the base, X100. Holston Formation at Cuba (73CC2-13). OSU 31706.


10-12. *Protopanderodus varicostatus* (Sweet and Bergström).


13, 14. "Acodus" mutatus (Branson and Mehl).

13. Acodontiform element, lateral view, X120. Tumbez Formation at Lay School (71FC1-130). OSU 31702.

14. Distacodontiform element, lateral view, X100. Eidson Member at Evans Ferry (72FC4-25). OSU 31701.


15. Acodontiform element, lateral view, X60. Holston Formation at Cuba (73CC2-16). OSU 31704.


17. Paltodontiform element, Form B, lateral view, X60. Holston Formation at Cuba (73CC2-12). OSU 31778.

18. Oistodontiform element, lateral view, X60. Blue limestone at Cuba (73CC2-10). OSU 31781.

19, 22. Paltodontiform element, Form A, lateral and anterior views, X100. Blue limestone at Cuba (73CC2-10). OSU 31777.


EXPLANATION OF PLATE III

Figure

1. "Roundya" bispicata Sweet and Bergstrom, lateral view, X70. Blue limestone at Cuba (73CC2-6). OSU 31855.

2. "Phragmodus" sp., lateral view, X70. Blue limestone at Cuba (73CC2-7). OSU 31809.

3. Belodella sp. cf. B. devonica (Stauffer), lateral view, X60. Holston Formation at Cuba (73CC2-12). OSU 31726.


6-9. "Distacodus" n. sp.


7. Acodontiform element, posterior view, X70. Holston Formation at Cuba (73CC2-14). OSU 31736.


11-15. Drepanoistodus n. sp.

11. Drepanodontiform element, Form C, lateral view, X70. Holston Formation at Cuba (73CC2-12). OSU 31748.

12. Drepanodontiform element, Form A, lateral view, X60. Holston Formation at Cuba (73CC2-12). OSU 31746.


14. Drepanodontiform element, Form D, lateral view, X100. Holston Formation at Cuba (73CC2-12). OSU 31749.
15. Oistodontiform element, lateral view, X90. Holston Formation at Cuba (73CC2-12). OSU 31750.


16. Zygognathiform element with a straight posterior process, posterior view, X60. Hogs skin Member at Lay School (71FC1-38). OSU 31708.

17, 18. Neoproniodontiform element; postero-lateral view, X110; posterior view, X90. Eidson Member at Eidson (73CC1-1). OSU 31713.


20. Spathognathodontiform element, lateral view, X60. Elway-Eidson "Formation" at Lay School (71FC1-8). OSU 31712.

21. Trichonodelliform element, posterior view, X95. Eidson Member at Evans Ferry (72FC4-28). OSU 31707.

22. Zygognathiform element with a flexed posterior process, posterior view, X90. Eidson Member at Evans Ferry (72FC4-28). OSU 31709.

EXPLANATION OF PLATE IV

Figure


1. Deboltiform element, upper-lateral view, X70. Rockdell Formation at Eidson (73CC1-10). OSU 31866.

2. Dyscritiform element with weak postero-lateral costae, lateral view, X60. Holston Formation at Cuba (73CC2-16). OSU 31863.


17. Dyscritiform element with strong postero-lateral costae, lateral view, X90. Holston Formation at Cuba (73CC2-16). OSU 31864.


3-5, 10-13. **Belodella nevadensis** (Ethington and Schumacher).

3. Oepkodontiform element with denticulate upper margin, outer side, X105. Hogskin Member at Lay School (71FC1-107). OSU 31716.

4. Oepkodontiform element with denticulate upper margin, inner side, X90. Hogskin Member at Lay School (71FC1-46). OSU 31717.

5. Oepkodontiform element with adenticulate upper margin, outer side, X90. Holston Formation at Cuba (73CC2-12). OSU 31718.


11. Triangular belodelliform element, lateral view, X90. Holston Formation at Cuba (73CC2-12). OSU 31714.

12. Oistodontiform element with a nearly complete base, lateral view, X80. Hogskin Member at Lay School (71FC1-46). OSU 31719.

13. Oistodontiform element with a nearly complete cusp, lateral view, X95. Holston Formation at Cuba (73CC2-12). OSU 31720.
6-9. **Belodella n. sp. A Bergström.**

6. Oepkodontiform element, outer side, X60. Blue limestone at Cuba (73CC2-10). OSU 31724.


8. Triangular belodelliform element with discrete denticles, lateral view, X90. Blue limestone at Cuba (73CC2-6). OSU 31721.

9. Triangular belodelliform element with confluent denticles, lateral view, X95. Holston Formation at Thorn Hill (71FC6-2). OSU 31722.


20, 21. **Walliserodus tuatus** (Hamar).


21. Curvatiform element, lateral view, X120. Holston Formation at Cuba (73CC2-12). OSU 31872.
EXPLANATION OF PLATE V

Figure
1, 2, 18, 19. *Bryantodina typicalis* Stauffer.

1. Phragmodontiform element, lateral view, X70. Eidson Member at
   Eidson (73CC1-3). OSU 31732.

2. Prioniodiniform element, lateral view, X60. Tumbez Formation
   at Lay School (71FC1-137). OSU 31734.

18. Variansiform element, posterior view, X90. Holston Formation
    at Thorn Hill (71B25-6). OSU 31733.

19. Bryantodiniform element, lateral view, X70. Holston Formation
    at Thorn Hill (71FC6-30). OSU 31731.

3, 4. *Polycaulodus* sp.

3. Trucherognathiform element, lateral view, X105. Eidson Member
   at Evans Ferry (72FC4-28). OSU 31836.

4. Trucherognathiform element, upper view, X105. Eidson Member at
   Evans Ferry (72FC4-28). OSU 31837.


5. Symmetrical tuatiform element, posterior view, X130. Holston
   Formation at Thorn Hill (71FC6-41). OSU 31869.

6. Asymmetrical tuatiform element, lateral view, X90. Elway-Eidson
   "Formation" at Lay School (71FC1-74). OSU 31870.

7-10. *Belodina monitorensis* Ethington and Schumacher.

7. Juvenile monitorensiform element, lateral view, X90. Holston
   Formation at Cuba (73CC2-13). OSU 37128.

8. Monitorensiform element, lateral view, X65. Holston Formation
   at Cuba (73CC2-14). OSU 31727.

9. Eobelodiniform element, lateral view, X60. Holston Formation at
   Thorn Hill (73CC2-13). OSU 31730.

10. Marginatiform element, lateral view, X70. Holston Formation at
    Thorn Hill (73CC2-13). OSU 31729.

11. Cytoniodontiform element, lateral view, X50. Holston Formation at Thorn Hill (71FC6-2). OSU 31807.

12. Subcordyloodontiform element, lateral view, X90. Holston Formation at Thorn Hill (71FC6-2). OSU 31804.

13. Phragmodontiform element, lateral view, X95. Holston Formation at Thorn Hill (71FC6-2). OSU 31802.


15. Phragmodontiform element, lateral view, X90. Holston Formation at Thorn Hill (71FC6-2). OSU 31803.

16. Typiciform element, lateral view, X90. Eidson Member at Evans ferry (72FC4-25). OSU 31805.

17. Phragmodus inflexus Stauffer, lateral view, X125. Eidson Member at Eidson (73CC1-20). OSU 31808.


20. Dichognathiform element, lateral view, X90. Holston Formation at Thorn Hill (71FC6-2). OSU 31819.


EXPLANATION OF PLATE VI

Figure

1-7. Plectodina aculeata (Stauffer).


7. Dichognathiform element, lateral view, X60. Rockdell Formation at Lay School (69B3-2). OSU 31814.


9-18. Plectodina n. sp.

9. Palodontiform element, lateral view, X60. Eidson Member at Evans Ferry (72FC4-28). OSU 31830.


15. Zygognathiform element, posterior view, X70. Eidson Member at Evans Ferry (72FC4-28). OSU 31824.


17. Symmetrical trichonodelliform element, posterior view, X60. Eidson Member at Evans Ferry (72FC4-28). OSU 31821.

18. Symmetrical trichonodelliform element, posterior view, X60. Eidson Member at Evans Ferry (72FC4-27). OSU 31822.


19. Prioniodiniform element, lateral view, X70. Rockdell Formation at Lay School (71FC1-121). OSU 31835.

20. Eoligonodiniform element, lateral view, X70. Rockdell Formation at Lay School (71FC1-121). OSU 31834.


22. Asymmetrical trichonodelliform element, posterior view, X95. Rockdell Formation at Lay School (71FC1-121). OSU 31832.

Figure
1-6. Triangulodus sp. cf. T. brevibasis (Sergeeva).


2. Slightly asymmetrical costate element, posterior view, X35. Eidson Member at Evans Ferry (72FC4-28). OSU 31857.


4. Oistodontiform element, lateral view, inner side, X35. Edison Member at Evans Ferry (72FC4-28). OSU 31861.


7-14. Erismodus sp. 1.

7. "Modified falodontiform" element, postero-lateral view, X35. Eidson Member at Evans Ferry (72FC4-28). OSU 31761.


9. Symmetrical trichonodelliform element, posterior view, X60. Eidson Member at Eidson (73CC1-1). OSU 31755.


14. Prioniodiniform element, lateral view, inner side, X50. Eidson Member at Evans Ferry (72FC4-25). OSU 31759.

15. "Modified falodontiform" element, postero-lateral view, X60. Rockdell Formation at Lay School (71FC1-121). OSU 31769.

16. Eoligonodiniform element, lateral view, X60. Rockdell Formation at Lay School (71FC1-64). OSU 31766.

17. Prioniodiniform element, lateral view, inner side, X60. Rockdell Formation at Lay School (69B3-1). OSU 31767.

18. Oulodontiform element, lateral view, inner side, X60. Rockdell Formation at Lay School (71FC1-64). OSU 31768.


20. Asymmetrical trichonodelliform element, posterior view, X60. Rockdell Formation at Lay School (69B3-3). OSU 31764.

21. Symmetrical trichonodelliform element, posterior view, X60. Rockdell Formation at Lay School (69B3-1). OSU 31763.

EXPLANATION OF PLATE VIII

Figure

1-4. Prioniodus variabilis Bergström.

1, 3. Amorphognathiform element, typical form; lateral view, inner side, X50; upper view, X55. Holston Formation at Cuba (73CC2-12). OSU 31845.

2, 4. Amorphognathiform element, late form; lateral view, inner side, X50; upper view, X60. Holston Formation at Thorn Hill (71FC6-9). OSU 31846.

5-7. Prioniodus variabilis—Prioniodus gerdae transition forms.


6. Amorphognathiform element, Form B, upper view, X70. Holston Formation at Thorn Hill (71FC6-5). OSU 31848.


10. Ambalodontiform element, late form, upper view, X60. Holston Formation at Cuba (73CC2-16). OSU 31839.


17, 18. *Eoplacognathus elongatus* (Bergström).


19. Pygodontiform element, upper view, X120. Holston Formation at Cuba (73CC2-12). OSU 31853.
