MERAMECIAN CONODONTS AND BIOSTRATIGRAPHY OF THE (UPPER MISSISSIPPIAN) GREENBRIER LIMESTONE (HURRICANE RIDGE AND GREENDALE SYNCLINES), SOUTHWESTERN VIRGINIA AND SOUTHERN WEST VIRGINIA

by

Michael James Huggins

Thesis submitted to the Graduate Faculty of
Virginia Polytechnic Institute and State University
in Partial fulfillment of the requirements of the degree
of

MASTER OF SCIENCE

in

Geology

APPROVED:

Richard K. Bambach
R. K. Bambach, Chairman

FRead
J. F. Read

D. M. McLean
D. M. McLean

April 1983

Blacksburg, Virginia

LD
5655
V855
1983
H833
c.2

MERAMECIAN CONODONTS AND BIOSTRATIGRAPHY OF THE (UPPER MISSISSIPPIAN) GREENBRIER LIMESTONE (HURRICANE RIDGE AND GREENDALE SYNCLINES), SOUTHWESTERN VIRGINIA AND SOUTHERN WEST VIRGINIA

by

Michael James Huggins

(ABSTRACT)

This study describes the biostratigraphic distribution of Meramecian conodonts from three measured sections of the Greenbrier Limestone (Meramecian-Lower Chesterian), located in the Greendale and Hurricane Ridge Synclines of southwestern Virginia and southern West Virginia. The Little Valley Formation, Hillsdale Limestone and lower portions of the "Denmar-Gasper" and "Ste. Genevieve" Formations, consisting of rocks deposited in a variety of shallow carbonate-ramp environments, were investigated.

Two new multielement conodont apparatuses were recognized: _Kladognathus_ sp. A and _Hindeognathus_ ("_Apatognathus_") _laevipostica_. Elements of _Kladognathus_ sp. A are morphologically distinct from homologous elements of the _K_. _levis_-_K_. _tenuis_ group. Evolutionary change from _K_. _levis_ to _K_. _tenuis_ is marked by slight Sa and Sb element changes, and the addition of an X element, DE _Lambdagnathus_ _fragilidens_. Species of _Kladognathus_ are

promising Meramecian biostratigraphic markers. Also recognized in this study are species of: Cavusgnathus, Gnathodus, Hindeodus, Idioprioniodus, Lochriea, Rhachistognathus, "Spathognathodus," Synprioniodina? and Taphrognathus.

Meramecian formations in the study area can be correlated with the Mississippian stratotype (Illinois Basin) based on the following zones: Taphrognathus varians - "Apatognathus," "A." scalenus - Cavusgnathus and Gnathodus bilineatus - Cavusgnathus charactus.

Southward thickening of the "A." scalenus zone from the Hurricane Ridge Syncline (11 m) to the Greendale Syncline (180-200 m) reflects higher rates of sedimentation and subsidence in the depositional area of the latter. In addition, thinness of the zone in the Hurricane Ridge Syncline may be due to a hiatus between this zone and the younger G. bilineatus zone. This hiatus is not indicated by conodont faunas from the Greendale Syncline, which preserves a more complete Meramecian biostratigraphic record.

Conodont and lithologic evidence for a coeval hiatus exists in other areas of eastern North America: the Illinois Basin stratotype, eastern Kentucky, southern Ohio and eastern Tennessee.

ACKNOWLEDGEMENTS

This thesis is dedicated to the memory of Prof. C. G. "Jake" Tillman who suggested this project and served as my graduate advisor until his death on May 7, 1982. His common sense advice, patience and unflagging support did much to make this a successful project. I will never forget his cheerfulness, enthusiasm and love for geology. Most of all, I will always remember his extraordinary day-to-day courage.

Prof. Richard K. Bambach graciously took over as my thesis advisor upon the death of Dr. Tillman. His advice and comments on an earlier draft of the manuscript strengthened this thesis. I have greatly benefited from his paleontologic knowledge, insight and intuition. Most of all, though, I have appreciated his enthusiasm, sense of humor, encouragement and friendship.

I thank my other committee members, Profs. D. M. McLean and J. F. Read, for their excellent advice and constructive comments on the manuscript. In addition, Dr. McLean's knowledge of the philosophy and problems of biostratigraphy has been invaluable to me, and Dr. Read's expertise in all aspects of sedimentology has furthered my professional geologic development.

I also thank Dr. Carl B. Rexroad of the Indiana Geological Survey, who very kindly read an early draft of the systematic paleontology section and provided a copy of an unpublished manuscript. His comments and suggestions were very helpful.

I owe a great debt to my graduate student colleagues and friends, Roger Humphreville, Tom Rounds, Bob Sartain, Arnie Miller, Bill Seaton and John Firth. They either assisted with field work or freely shared their geologic knowledge. Llyn Sharp photographed the plates and also assisted with field work. SEM micrographs were taken by Carlile Price and Lily Fainter, using the facilities of the Department of Forestry Products and the College of Veterinary Medicine, respectively.

I could not finish this thesis without acknowledging four of the finest geology teachers and professionals that I have ever known: Anson Piper, Bill Kirchgasser, James Carl and Neal O'Brien. Their challenging and thought-provoking style of teaching made geology for me, not only an exciting subject, but a career as well.

My greatest thanks go to my parents, John and Joan Huggins, for their continued support and encouragement throughout the course of this study.

Funding for this project was provided by the Department of Geological Sciences, V.P.I. and S. U.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Byron Cooper in a summary report of the status of Mississippian stratigraphy in the central Appalachians (1948), wrote:

> Critical study of published information on the Mississippian System of the Appalachian region reveals a long and continuous neglect of some of the thickest and most varied sections of the Mississippian in North America.

And later in the same paper:

> stratigraphic work upon which the (Appalachian Mississippian) succession was divided...
> ...has been carried on in a near vacuum of systematic paleontology.

Unfortunately, for our understanding of regional geology as a whole, little has been done to remedy this situation, particularly in Virginia. Few Mississippian biostratigraphic studies have been attempted in this region, although exceptional work, for comparison, has been done in the stratotypal region of the upper Mississippi Valley in Illinois, Indiana, Iowa and Missouri. In the overthrust belt of southwestern Virginia and Tennessee the Greendale Syncline contains thick and varied sections, up to 2.1 kilometers thick, of dominantly marine, fossiliferous Mississippian sediments; few of these rocks have been studied in detail.

The Meramecian to Early Chesterian Greenbrier Limestone Group (Weller <u>et</u> <u>al</u>., 1948), because of its abundant invertebrate fossils, is perhaps the most ideal of the Mississippian units exposed in the Appalachian region for biostratigraphic study. The unit is exposed in several northeast-trending strike belts and thickens in the Appalachian Basin to the southeast. Lithologies consist mostly of fossiliferous limestones and subordinate clastic rocks deposited in varied shallow-marine environments. Brachiopods, bryozoans, crinoids and corals are abundant and have been used by others to correlate the unit with formations in the Mississippian stratotype.

Conodonts are important fossil-groups for local, regional and world-wide Paleozoic biostratigraphy. They occur in most types of marine rocks, often in in large numbers, especially in limestone. Thus, they have been used extensively in subdividing the Mississipian (Lower Carboniferous) System. In North America, Collinson et al. (1971) worked out a detailed Mississippian zonation. In their Upper Mississippian zonation scheme, Meramecian zones are distinctive and are more clearly defined than Chesterian zones based on long ranging,less distinctive taxa.

Although Mississippian conodont studies in the Appalachians are few, work by Chaplin (1971, 1974, 1977) shows that conodonts occur throughout the Greenbrier Limestone. Meramecian portions of the Greenbrier

Limestone include the Little Valley, Hillsdale, and parts of the "Denmar-Gasper" or "Ste. Genevieve" Formations. These units have distinct lithologic boundaries and are ideally suited for biostratigraphic interpretation. However, the thicker Chesterian part of the Greenbrier is lithologically monotonous and more difficult to subdivide. This, and the unchanging nature of Chesterian conodont faunas, makes the Chesterian part of the Greenbrier Limestone difficult to study.

In this study, I have investigated Meramecian conodont faunas from three measured sections in southwestern Virginia and southern West Virginia. Two sections are from the Hurricane Ridge Syncline in the Appalachian Plateau Province, marginal to the overthrust belt (Fig. 1) and the third section was located in the Greendale Syncline in the Valley and Ridge Province (Fig. 1).

The objectives of the study are:

1) _To systematically describe Meramecian conodont faunas in the study area._ Conodont elements will be described using multielement taxonomic concepts to place elements within natural genera and species. This will add important new information to our knowledge of taxonomy, phylogeny, paleoecology and paleogeographic distribution of Mississippian conodonts.

2) To correlate Meramecian rocks in the Hurricane Ridge and Greendale Synclines. Previous stratigraphic correlations in the study area have been based on lithology and poorly studied invertebrate megafossils. Correlation with conodont zones established by Collinson et al. (1971) should clarify the stratigraphic relationships of the Meramecian rocks in the study area. This work should provide new information on rates of sedimentation and subsidence in different areas of the Appalachian Basin during the Late Mississippian. With this information it should be possible to determine if Meramecian sedimentation and subsidence rates near the axis of the Appalachian Basin were affected by coeval epeirogenic tectonic activity that episodically interrupted sedimentation along the cratonic western margin of the basin, in east-central Kentucky and southern Ohio (Ettensohn, 1980, 1981). Also, local correlation will provide a time-framework for future studies of Upper Mississippian rocks in the Appalachians.

3) To correlate the study-area sections with Meramecian sections in the stratotype region and other areas of North America. This study will show how Meramecian conodont faunas from thick Appalachian foreland-basin sequences compare with those of thinner

sequences deposited in the cratonic interior of North America. In addition to the stratotypal region of the Illinois Basin, other areas of eastern North America where Meramecian conodont faunas have been studied, are: eastern Kentucky, southern Ohio, east-central Tennessee, northern Alabama, Michigan and the maritime provinces of eastern Canada.

4) To correlate with European Lower Carboniferous (Dinantian) faunas. Conodont faunas from Dinantian rocks of Europe, particularly Great Britain, have been described allowing correlation with North American faunas.

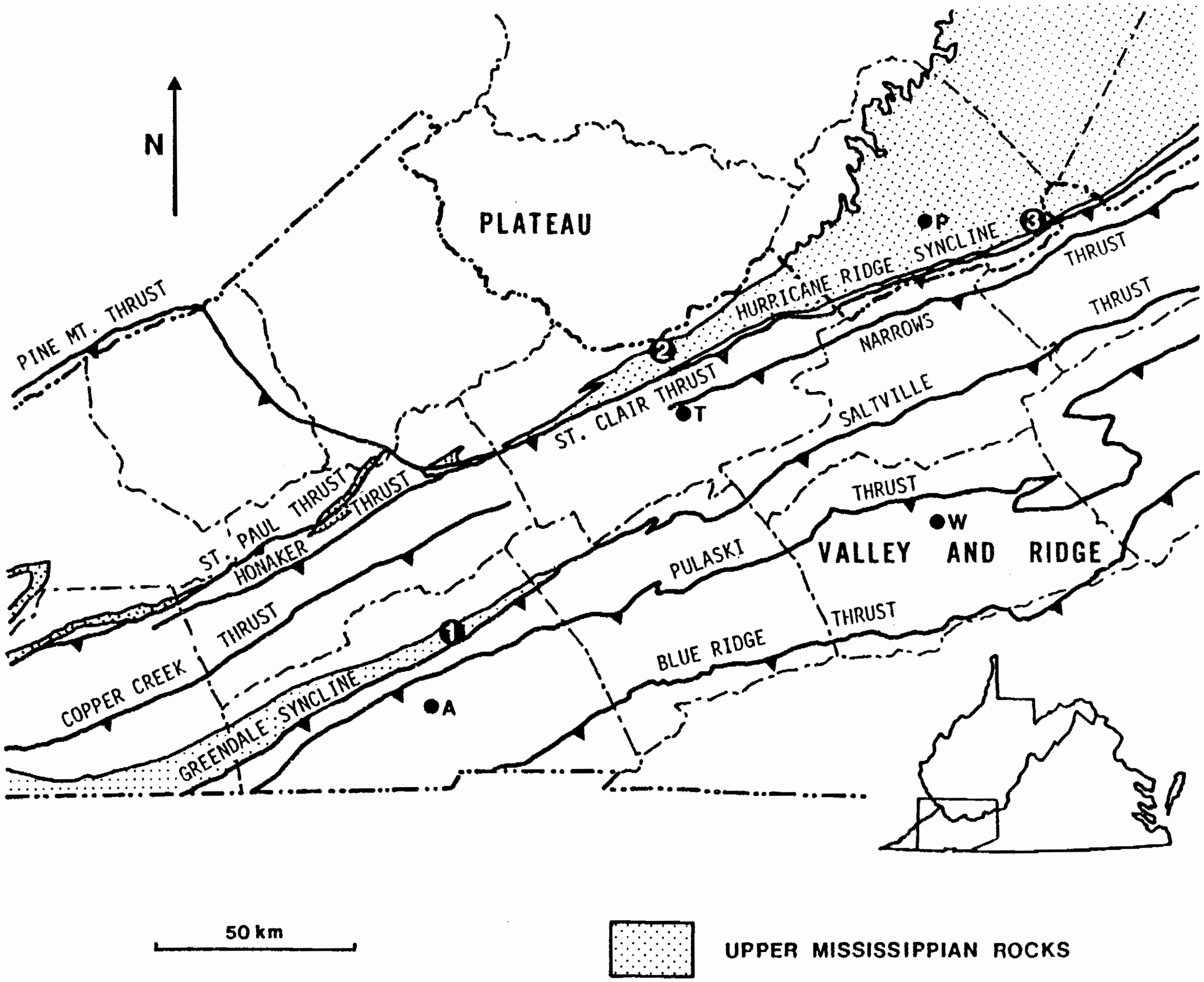
GEOLOGIC SETTING

The study area encompasses the Appalachian Valley and Ridge and Appalachian Plateau Provinces (Fig. 1). Northeast-trending folds and low-angle, imbricate thrust faults dominate the Valley and Ridge Province; the Plateau Province, to the north, consists of gently folded to nearly undeformed rocks.

Two of the sections studied (Bishop and Willowton) are located in the northeast-plunging Hurricane Ridge Syncline. The syncline, at the southern margin of the Plateau Province, is bounded on the southeast by the St. Clair Fault which thrusts Cambro-Ordovician Knox carbonates over overturned Upper Devonian rocks in the syncline, and on the northwest by the Abbs Valley Anticline, which disappears to the northeast in Mercer County, West Virginia. The St. Clair Fault is the structural front between the Valley and Ridge overthrust belt and the slightly disturbed rocks of the Appalachian Plateau.

The Willowton (Mercer Co., West Virginia) section is exposed on the overturned, southeastern limb of the Hurricane Ridge Syncline. Dip is approximately 40° to the southeast and strike is north 70° east. The Bishop section (Tazewell Co., Virginia), about 65 kilometers southeast of Willowton, is exposed along the northwestern limb of the

Figure 1 : Map showing localities of measured sections, major thrust faults and principal geopolitical features in the study area of southwestern Virginia and southern West Virginia. The stippled pattern shows the outcropping area of Upper Mississippian rocks. Measured sections are: 1) Lindell, 2) Bishop and 3) Willowton. Principal municipalities are: A) Abingdon, Va.; P) Princeton, W. Va.; T) Tazewell, Va. and W) Wytheville, Va. (See Appendix A for detailed locality maps of the measured sections.)


N
PLATEAU
PINE MT. THRUST
ST. PAUL THRUST
HONAKER THRUST
HURRICANE RIDGE SYNCLINE
ST. CLAIR THRUST
NARROWS THRUST
SALTVILLE THRUST
PULASKI THRUST
VALLEY AND RIDGE
COPPER CREEK THRUST
GREENDALE SYNCLINE
BLUE RIDGE THRUST
P
T
W
A
1
2
3
50 km
UPPER MISSISSIPPIAN ROCKS

syncline. Here dip is 20° to 30° southeasterly, and strike is north 50° to 60° east.

The third section, located between Lindell and Hayters Gap, Virginia (Washington Co.), is on the northwest limb of the Greendale Syncline, a major structural feature of the Appalachian Valley and Ridge. The easternmost belt of exposed Upper Mississippian rocks in Virginia is exposed in the Greendale Syncline; the entire System is about 1.8 to 2.1 kilometers thick. The southeastern limb of the syncline is cut off by the Saltville Fault, which, at Lindell, thrusts Cambrian Honaker Dolomite over slightly dipping rocks of the Upper Mississippian Pennington Formation; dip is 20° to 30° to the southeast and strike is north 50° to 60° east.

METHODS

Field Methods and Laboratory Procedure

The three sections were measured using a steel tape, Brunton pocket transit, Jacob's Staff and a collapsible ruler. Eighty-nine samples were taken, of which eighty-three were processed for conodonts. The sample interval was variable depending on lithology. Sample density was greatest in the Hillsdale Limestone, where samples were at 3.7, 2.7 and 2 meter intervals, at Bishop, Willowton and Lindell, respectively. Sample weights varied from 4 to 10 kilograms.

Rock samples were dissolved in 10% Glacial acetic acid; 10% formic acid was used on samples that were difficult to dissolve. After acid disolution, insoluble residues were sieved through 20, 45 and 120 mesh screens. Samples on the 45 and 120 mesh screens were saved for processing. After drying at low oven-temperature, residues were processed in tetrabromethane, to concentrate conodonts and heavy minerals. Samples were then washed with acetone, and concentrated residues were picked for conodont elements. Conodonts are stored in the micropaleontology collections of the Department of Geological Sciences, VPI and SU. Selected conodonts were photographed using JEOL35 Scanning Electron Microscopes from the Department of Forestry Products and the College of Veterinary Medicine, VPI and SU.

622 kilograms of rock samples yielded 4,329 identifiable conodont elements. Element abundances were low. The average for all eighty-three samples was about seven elements per kilogram.

Conodont Descriptive Terminology

Conodonts were enigmatic marine animals (Cambrian to Triassic), whose fossilized remains usually consist of small, phosphatic, skeletal elements. Each conodont (conodont animal or conodontophorid) contained several kinds of paired, morphologically distinct elements that together formed a multielement skeletal apparatus. Whole conodont apparatuses are only rarely preserved as natural bedding-plane assemblages or fused element-clusters. Most conodonts are represented only by their disarticulated, discrete elements (see Briggs, Clarkson and Aldridge, 1983).

Before the 1970's most conodont researchers, primarily biostratigraphers, classified discrete conodont elements via a system of "form taxonomy," based on distinctive shape-categories. Each type of morphologically distinct element was given a Linnean binomial name, as are biological species. Names of conodont "genera" and "species" thus erected are still used; many "form-taxa" are the basis for Paleozoic and Triassic zonation schemes. Continued use of "form-taxa" has hindered understanding of conodont taxonomy and phylogeny.

Recently, conodont workers have tried to group different discrete elements into multielement apparatuses of natural genera and species. Several successful methods of reconstructing apparatuses from random associations of disarticulated, discrete elements have been developed: study of bedding-plane assemblages or fused element-clusters, statistical grouping-techniques, and empirical constraints (similarity of element stratigraphic-ranges and abundances, morphological similarity of elements, and study of impoverished faunas where only one or two multielement taxa are represented).

It is now known that the basic structural plan of conodont apparatuses remained essentially unchanged during the phylogeny of the group. Although exceptions are known, many multielement apparatuses were seximembrate, consisting of six, morphologically distinct, paired element-types. Similarly shaped elements occupied analogous or homologous positions in the apparatuses of different species.

Several schemes exist for identifying different kinds of element-types in a conodont apparatus. Most widely used is the notational scheme of Sweet (1981), modified slightly from Sweet and Schonlaub, (1975). This scheme identifies three major types of element-positions within an apparatus: P, M and S positions. In the basic seximembrate apparatus there are two types of P (pectiniform) elements (Pa and Pb) and three types of S elements (Sa, Sb and Sc), the latter of which form a symmetry-transition series of morphologically similar and intergradational elements. Of these types of elements, Pa elements (often called platform elements) are the most important in the recognition of different conodont species. These elements usually underwent the greatest amount of morphological change associated with speciation and evolution. Thus, Pa elements are important biostratigraphic markers. Other element-types (Pb, M, Sa, Sb and Sc), known as ramiform elements, changed slowly during phylogeny. These elements were often shared vicariously by closely related species.

Variations from the basic seximembrate plan is common. Some apparatuses, while conforming to the basic seximembrate plan, had an element-position or positions filled by several, slightly different, element-morphotypes, all of which were present in one individual conodont. For example, some apparatuses contained three morphotypes of the Sc element: Sc_1, Sc_2 and Sc_3. Some apparatuses had more or less than six distinct element-types; unimembrate to septimembrate apparatuses have been recognized. Some element-types or positions do not appear to be analogous to any of the main types of positions in the seximembrate scheme of Sweet (1981). For these elements new letter designations have to be devised (For example, the X element in the apparatus of Kladognathus, as reconstructed herein). Although these exceptions do occur, most types of elements are assigned to one of the element-positions in this notational scheme. Until the phylogeny of different conodont groups (i.e. Families, Superfamilies, etc.) is better understood, this scheme is the best available for identifying analogous, and hopefully homologous, elements among different conodont species.

Discrete conodont elements that cannot be assigned to multielement species are herein noted by DE preceeding the commonly-used name of the element. This follows the practice of Rexroad (1981) and Horowitz and Rexroad (1982), in showing that the element is a discrete-element species. For ease in communication, elements of multielement species are often referred to by their common discrete-element name.

LITHOSTRATIGRAPHY

Introduction

The Greenbrier Limestone Group (Late Mississippian) of southwestern Virginia and southern West Virginia is a thick succession of limestone and lesser fine-grained clastic rocks deposited in shallow-marine environments in the northeast-southwest trending Appalachian foreland basin. Paleogeographic reconstructions (Scotese, et al., 1979) show that this region, during the Late Mississippian, was in a tropical setting, approximately five degrees south latitude. The actively subsiding basin was bordered on the southeast by a low-lying, tectonically quiescent, orogenic source area and on the west by a broad, cratonic carbonate platform. These rocks are Meramecian to Early Chesterian in age based on their invertebrate fossils (Weller, et al., 1948; see Fig. 2).

The Greenbrier Limestone is underlain by red mudstone and shale of the Maccrady Formation. In the Hurricane Ridge Syncline, it is overlain by shale and argillaceous limestone of the Bluefield Formation and in the Greendale Syncline, by the Fido Sandstone (Fig. 2).

The Greenbrier Limestone thickens to the southeast toward the Appalachian Basin axis. On the northwest limb of the Hurricane Ridge Syncline (in the Bandy and Bishop

Figure 2 : Chart showing previous worker's and this study's interpretations of Greenbrier Limestone lithostratigraphy. Diagram also shows Mississippian stratigraphy in the study area. (*: partial time-stratigraphic unit)

EUROPEAN SYSTEM		CARBONIFEROUS*																	
EUROPEAN SUB-SYSTEMS		SILESIAN*							DINANTIAN										
EUROPEAN SERIES		NAMURIAN*							VISEAN									TOURN.	
NORTH AMERICAN SYSTEMS		PENN.*		MISSISSIPPIAN															
NORTH AMERICAN SERIES		MORR.*	CHESTERIAN										MERAMECIAN				OSAGE		KIND.
PRESENT PAPER	GREENDALE SYNCLINE				?	Pennington Formation		Cove Creek Formation		Fido Sandstone		"Gasper" Formation	"Ste. Genevieve" Formation	Hillsdale Limestone	Little Valley Formation	Maccrady Formation	Price Formation		Big Stone Gap Sh.
	HURRICANE RIDGE SYNCLINE	Pocahontas Formation	Bluestone Formation		Princeton Sandstone		Hinton Formation	Bluefield Formation			"Denmar-Gasper" Formation			Hillsdale Limestone	Little Valley Formation	Maccrady Formation	Price Formation		Big Stone Gap Sh.
											GREENBRIER LIMESTONE								

VIRGINIA	AVERITT, 1941 COOPER, 1944	"Gasper" Limestone				"Ste. Genevieve" Limestone			Hillsdale Limestone	Little Valley Formation	Maccrady Formation
	BUTTS 1933, 1940	Gasper Limestone				Ste. Genevieve Limestone			St. Louis Limestone	Warsaw Formation	Maccrady Formation
WEST VIRGINIA	WELLS, 1950	"Gasper" Limestone				Taggard Formation	Denmar Formation		Hillsdale Limestone	Maccrady Formation	
	REGER, 1926	Alderson Limestone	Greenville Shale	Union Limestone	Pickaway Limestone	Taggard Formations	Patton Limestone	Sinks Grove Limestone	Hillsdale Limestone	Maccrady Formation	
		GREENBRIER SERIES									

areas of Tazewell County, Virginia) the Greenbrier is 250 to 260 m thick (Wilpolt and Marden, 1955, 1959). Along the southeast overturned limb, these beds thicken down the plunge of the syncline toward the northeast from 300 m in Tazewell County, Virginia (Cooper, 1944), to 335 m in the Bluefield, West Virginia area (Englund, et al., 1979), and to 355 m at Willowton, West Virginia (Appendix A). To the south, in the Greendale Syncline, the Greenbrier equivalents are 870 m to 960 m thick (Bartlett and Webb, 1971; Averitt, 1941).

Previous Work

The origin of the name Greenbrier Limestone is unknown (Reger, 1926) but the term was originally used informally in reference to Carboniferous limestones exposed along the Greenbrier River in Greenbrier County, West Virginia. Reger (1926) named these limestones the Greenbrier Series, and divided the group into many formations (Fig. 2). The type localities of these formations are scattered about a small geographic area in southern West Virginia.

Butts (1927, 1933, 1940) did not use the name Greenbrier Limestone for the equivalent section in the Virginia Valley and Ridge; he included these rocks in the Newman Limestone and used formation names from the

Mississippian stratotype area of the upper Mississippi Valley (Fig. 2). He referred these rocks to the Warsaw, St. Louis, Ste. Genevieve and Gasper Formations, using these terms in a time-stratigraphic sense. The formations were differentiated by their invertebrate fossils. For example, the "Ste. Genevieve" and "Gasper" Formations were so alike lithologically that the boundary between them was placed at a change in echinoderm faunas. The crinoid Platycrinites penicillus characterized the "Ste. Genevieve" Formation, and the crinoids Talarocrinus and Pterotocrinus the "Gasper." The boundary between the "St. Louis" and "Ste. Genevieve" formations was similarly marked.

Averitt (1941) used Butts' terminology, but renamed the "Warsaw" Formation, the Little Valley Limestone. A type-locality was designated in the Greendale Syncline.

Cooper (1944) used Reger's term Hillsdale Limestone for rocks in the Hurricane Ridge Syncline in Tazewell County, Virginia, that Butts had previously named as St. Louis Limestone (Fig. 2). He also used Averitt's term the Little Valley Formation for argillaceous limestones and shales underlying Hillsdale Limestone and overlying Maccrady Formation red-beds. He used with some reservation the terms "Ste. Genevieve" and "Gasper" in the Hurricane Ridge Syncline. He believed that the "Ste.

Genevieve" Formation was correlative with Reger's (1926) Patton and Sinks Grove Limestones, that could not be differentiated outside their type areas. He also stated that the "Ste. Genevieve" and "Gasper" Formations could not be distinquished without fossils. Cooper (1948) commented on the "trivial character of the paleontologic data" used to delimit those formations.

Wells (1950) studied the Meramecian portion of the Greenbrier Limestone throughout its exposed area in southeastern West Virginia, including the type localities of Reger. He agreed with Cooper (1944) that the Patton and Sinks Grove Limestones had identical lithologic and faunal characteristics and could not be differentiated outside their type areas. He renamed this succession the Denmar Formation, correlating it with the "Ste. Genevieve" Formation of Virginia (Fig. 2). Wells also combined Reger's formations above the Taggard Shale as equivalent to the Chesterian "Gasper" Formation of Virginia. Wells believed that Taggard red beds, which separated the Denmar and "Gasper" Formations, probably did not extend southwestward into Mercer County, West Virginia.

Bartlett and Webb (1971) mapped the Mississipian limestones in the Greendale Syncline, north of Bristol, Virginia. They retained the stratigraphic nomenclature of Cooper (1944), modified from Averitt (1941) and Butts

(1940). The stratigraphic extent of the "Ste. Genevieve" Formation was recognized in this report on paleontologic grounds as the rocks encompassing the range of abundant stem plates of Platycrinites penicillus.

Blancher (1974) used the term Greenbrier Group in the Hurricane Ridge Syncline and recognized the Little Valley Formation and the Hillsdale Limestone. He was unable to differentiate the Denmar and "Gasper" Formations because of their lithologic similarities. He also suggested that the Taggard red beds, used by Wells (1950) to separate the two units, could not be recognized with certainty in the study area.

Stratigraphic Terminology used in this Study

The Little Valley Formation and Hillsdale Limestone are clearly defined in the literature and easily recognizable in the field. However, the overlying Denmar-"Ste. Genevieve" and "Gasper" Formations, can not be distinguished from one another lithologically. The only means of differentiating them is by a perhaps unreliable change in echinoderm faunas. Thus I suggest that these units not be treated as separate formations. Like Blancher (1974) I have combined all of the Greenbrier rocks overlying the Hillsdale Limestone in the Hurricane Ridge Syncline into the "Denmar-Gasper" Formation. For correlative rocks in the Greendale Syncline, I have retained the terms "Ste. Genevieve" and "Gasper" Formations. At Lindell I studied only the lower 109 m of the Meramecian "Ste. Genevieve" Formation for conodonts. Above this interval the "Ste. Genevieve" Formation was poorly exposed.

Maccrady Formation

The Maccrady Formation underlies the Greenbrier Limestone throughout the study area. It was named by Stose (1913) for a thick sequence, in the Greendale Syncline, of of shale, sandstone and argillaceous limestone, that overlaid Price Formation sandstone and contained economic deposits of salt and gypsum. Butts (1933) later restricted the term Maccrady Formation to the lowest part of Stose's section which consisted of "red shale or mudrock with less red, argillaceous sandstone." He renamed the upper 180 meters, consisting primarily of argillaceous limestone, as "limestone of Warsaw Age." Averitt (1941) renamed these rocks as the Little Valley Formation.

According to Bartlett and Webb (1971), the rocks of the Maccrady Formation, "are characteristically composed of maroon, pink and light-green, soft micaceous shale or thin-bedded mudstone, with minor amounts of maroon siltstone and light-gray to pink, fine-grained sandstone." A few thin beds of yellowish, argillaceous limestone have also been found in the Hurricane Ridge outcrop belt (Cooper, 1944). Marine fossils are rare and may be of Osagean to Meramecian age (Weller et al. (1948).

Some workers have cited an unconformity as separating the Maccrady Formation and Greenbrier Limestone in the study area (Reger, 1926; Butts, 1940 and Englund et al., 1981). The paleontologic evidence supporting this idea is equivocal (see Weller et al., 1948). Cooper (1944) suggested that in the Burke's Garden area (Tazewell Co., Va.) the two units are conformable. This appears to be the case in the outcrop belt of the Greendale Syncline (Cooper, 1965; Bartlett and Webb, 1971).

Of the sections measured in this study, The Maccrady Formation was only exposed at Willowton where it is in fault contact with the Hillsdale Limestone.

Little Valley Formation

Name. The Little Valley Formation was named by Averitt (1941) for a thick section (195 m) of "mostly argillaceous limestone with one or more beds of fine-grained sandstone," above the Maccrady Formation and beneath the "St. Louis" (Hillsdale) Limestone, exposed in the Greendale Syncline, Little Valley (Scott County), Virginia. Stose (1913) included these rocks in the lower

Maccrady Formation. Cooper (1944) extended the use of the name to the Hurricane Ridge Syncline.

Contacts. At the Bishop and Lindell sections the lower contact is not exposed. At the Willowton section the formation is cut out by faulting. Bartlett and Webb (1971), and Blancher (1974) placed the lower contact at the base of the first argillaceous limestone above Maccrady Formation mudstone and siltstone. The upper contact is placed at the base of thick-bedded Hillsdale Limestone.

Thickness. In the Hurricane Ridge Syncline at Bishop the Little Valley Formation is 20 m thick. Blancher (1974) indicated an average thickness of 26 m in the same outcrop belt. Cooper (1944) and Wilpolt and Marden (1955) show slightly lesser thicknesses. The formation thickens rapidly to the south. In the Greendale Syncline at Lindell at least 172 m are exposed with probably another 10 m covered by the North Fork of the Holston River. Averitt (1941) assigned 195 m to the formation from exposures near Greendale, Virginia, to the southwest of Lindell, and Bartlett and Webb (1971) measured 174 m, to the southwest, near Bristol, Virginia.

Lithology. Interbedded argillaceous limestone and calcareous mudstone are the common lithofacies in the Little Valley Formation (Figs. 3, 4). At Lindell, the

Little Valley is mostly fossiliferous calcareous mudstone with some argillaceous skeletal wackestone. At Bishop, mudstones and argillaceous limestones are poorly fossiliferous and often laminated. Calcareous quartz sandstone (Fig. 3) and black shale are minor lithofacies at Lindell, and are absent at Bishop. Breccia horizons are common at Bishop, but not at Lindell. Calcareous siltstone and dolomite are rare at both sections. Lithofacies at Lindell commonly are cyclic. In a complete cycle, argillaceous limestone grades upward into calcareous mudstone, which then grades upward into calcareous siltstone and sandstone, and are overlain by argillaceous limestone.

Calcareous mudstone and argillaceous limestone at Lindell are commonly interbedded and, in part, intergradational. Calcareous mudstone is very thin-bedded to massive, and may be silty. Argillaceous limestone is thin- to thick-bedded, skeletal wackestone, with minor lime mudstone and packstone. Argillaceous limestones may be silty or sandy, and locally cherty. Mudstones and limestones contain a diverse fauna of abundant bryozoans (fenestrate, tubular and encrusting), crinoids, brachiopods and pelecypods. Gastropods, ostracodes and solitary rugose corals are less common, and _Syringopora_ corals are rare. Trace fossils are locally abundant, consisting of <u>Zoophycus</u>-like markings and various burrows, tracks and trails. Pelecypods and trace fossils are common in calcareous mudstone, whereas bryozoans, crinoids and brachiopods are more abundant in argillaceous limestone. Typical sequences consist of argillaceous limestone with diverse, marine faunas grading upward into mudstone with pelecypods and trace fossils.

At Bishop (and less commonly at Lindell) calcareous mudstone is very thin-bedded, thinly laminated, occasionally silty, rarely lenticular bedded with thin siltstone to very fine-grained sandstone stringers, and display small cut and fill structures. Argillaceous limestone is composed either of thinly laminated to burrowed lime mudstone or peloidal skeletal wackestone. Laminated lime mudstone often show thin, graded beds, ripple cross-laminations, cryptalgalaminations (rare laterally-linked hemispheroidal stromatolites), and small cut and fill structures. Fossils occur in thin shell beds and consist of a restricted fauna of brachiopods, ostracodes, pelecypods and rare echinoderms. Limestones are rarely cherty.

Pure limestone beds are rare and thin (usually less than 0.3 m thick). They may be skeletal packstone, ooid grainstone-packstone, peloidal packstone and intraclast packstone.

Calcareous quartz sandstones, at Lindell, are thin- to thick-bedded, rarely trough cross-bedded, wave ripple-laminated to plane-laminated, and dominantly fine-grained. Rare, thin sandstone beds are bar-form in shape, with a megarippled top and a flat base. Sandstones form coarsening- and thickening-upward sequences, that are underlain and overlain by fossiliferous silty mudstone and argillaceous limestone. The few fossils are pelecypods (and associated burrows), brachiopods, bryozoans, echinoderm fragments and ostracodes. Plant fragments are rare.

Black shale at Lindell is noncalcareous and very thin-bedded to fissile. It contains a distinctive fauna of pelecypods, nautiloid cephalopods, articulate and inarticulate brachiopods, ostracodes, and diarticulated fish scales. Small, carbonized plant fragments are rare.

Breccia horizons, with small blocks and pebbles of calcareous siltstone in a fine-grained calcite matrix, occur in the lower Little Valley at Bishop. Similar breccia horizons have been described from Bandy, Virginia (15 km to the southwest of Bishop) by Wilpolt and Marden (1955).

Rare dolomite occurs at both sections. Dolomite is thin- to massive-bedded and is rarely thinly laminated.

Calcareous siltstone is thin-bedded, and ripple-laminated to plane-laminated. Siltstone is usually interbedded with silty mudstone, argillaceous limestone and sandstone.

Depositional environments. At Bishop, the Little Valley Formation reflects deposition in low energy, nearshore, restricted, lagoonal and tidal-flat settings. Mudstone and argillaceous limestone exhibit low-energy sedimentary structures: thin plane-laminations, ripple cross-laminations, lenticular bedding and small scour and fill structures. Some lime mudstones are cryptalgalaminated. Thick, bioclastic or nonskeletal grainstone-packstones indicative of wave or current action are lacking. The restricted invertebrate fauna consists of brachiopods, ostracodes and rare echinoderms. Breccia horizons that occur in the lower part of the formation may be indicative of the former presence of evaporite minerals.

More open-marine settings may have prevailed in other areas of the Hurricane Ridge Syncline. Blancher (1974) noted that skeletal wackestone and packstone with a diverse fauna of crinoids, fenestrate bryozoans, brachiopods and corals were more common at other localities in the outcrop belt.

Cyclic Little Valley beds at Lindell were deposited in shallowing-upward sequences in more open marine settings than at Bishop. Calcareous mudstone and argillaceous skeletal wackestone were deposited in protected, shallow subtidal environments, as indicated by diverse marine faunas. Calcareous mudstone with a restricted fauna of pelecypods and trace fossils was deposited in more unstable, nearshore environments, with terrigenous sediment influx. Calcareous quartz sandstones were deposited as shallow, subtidal marine bars.

Some lithologies at Lindell reflect intertidal deposition. These are: thinly laminated peloidal limestone and calcareous mudstone with cut and fill structures, thinly laminated dolomite and rare stromatolitic or cryptalgalaminated limestone.

Hillsdale Limestone

Name. Reger (1926) named the Hillsdale Limestone for dark, massive limestone, which overlaid the Maccrady Formation (including beds now called the Little Valley Formation), and contained abundant nodules of black chert and the colonial coral "*Lithostrotion*." The type locality is in Monroe County, West Virginia. Cooper (1944) renamed the "St. Louis" Limestone of southwestern Virginia as the Hillsdale Limestone.

Contacts. The lower contact of the Hillsdale, at the base of the first, thick-bedded, pure limestone, is exposed at Bishop and Lindell; at Willowton, conodont data indicates that the lower portion of the formation has been cut out by faulting and the formation is in fault contact with Maccrady Formation.

The upper contact is difficult to place. The "Denmar-Gasper" or "Ste. Genevieve" Formations are variable in character and contain more abundant and thicker, calcareous siltstone and skeletal packstone beds than the Hillsdale, which is predominantly cherty skeletal wackestone. At both Bishop and Willowton the upper contact is picked at the base of a calcareous siltstone and mudstone unit that overlies thicker-bedded Hillsdale skeletal wackestones (Figs. 4, 5).

At Lindell the lower 40 meters of the "Ste. Genevieve" Formation is mostly cherty skeletal wackestone, similar to the underlying Hillsdale Limestone (Fig. 3). Here, the contact is marked at a sharp change from massive Hillsdale skeletal wackestone up into shaley calcareous mudstone and argillaceous limestone. The lower "Ste. Genevieve" Formation is more argillaceous than upper Hillsdale carbonates.

Thickness. The Hillsdale Limestone thickens to the south. In the Hurricane Ridge Syncline the formation is roughly 34 m thick at Bishop (Fig. 4) and 35 m thick between Ingleside, West Virginia and Rich Creek, Virginia

(Blancher, 1974). In the Greendale Syncline it is 73 m thick at Lindell (Fig. 3) and 80 to 84 m are exposed to the southwest (Averitt, 1941; Bartlett and Webb; 1971).

Lithology. The Hillsdale Limestone is mostly skeletal wackestone, with some ooid and skeletal packstone-grainstone, calcareous mudstone and siltstone, and silty-argillaceous limestone (Figs. 3-5). Skeletal packstone-grainstone is more abundant at Willowton (Fig. 5) than at Bishop (Fig. 4), and is rare at Lindell. Calcareous mudstone, siltstone, and silty-argillaceous limestone is also less common at Lindell than at Bishop and Willowton.

Skeletal wackestone is medium- to massive-bedded, dark gray and cherty. Beds of skeletal packstone, peloidal skeletal packstone and lime mudstone are minor. Wackestones are slightly argillaceous locally. Fossils occur as whole fossils and fragmental bioclasts. The fauna is mostly fenestrate bryozoans (lesser stick-like forms), echinoderms, brachiopods and rarer solitary rugose corals. Colonial corals Lithostrotionella and Syringopora are infrequent (although common in the Hillsdale throughout the study area). Other fossils include endothyrid foraminifera, ostracodes, trilobites, gastropods and pelecypods. Algal onkoids, up to 5 cm in diameter, are common in wackestone at Lindell but rare at Bishop or Willowton.

At Lindell rare thick- to massive-bedded skeletal wackestone beds with abundant fenestrate and stick-like bryozoans (Cistodictya?) resemble some carbonate mound or bank lithologies. In these beds bryozoans are randomly stacked to form shelter voids that contain geopetals of peloids and lime mud, and fibrous (marine?) calcite cements.

Rare, ooid grainstone and skeletal grainstone-packstone are thick-bedded and cross-stratified. Skeletal grains are dominantly coarse-grained echinoderm debris. Intraclasts are common in both lithologies. At Lindell (Fig. 3, 30 m above the formation base; see also Appendix A) thin beds of peloidal skeletal packstone, fenestral peloidal limestone, stromatolitic limestone and dolomitic breccia are interbedded in thin cycles with ooid grainstone.

Calcareous mudstone and siltstone are very thin-bedded to thin-bedded, or blocky to massive-bedded, and thinly laminated to ripple-laminated. Fossils and intraclasts are rare. Burrow structures occur locally.

Silty-argillaceous limestones are thin, unevenly bedded to massive, and may have thin, discontinuous laminations. They are mudstone and lesser peloidal and intraclast packstone. Fossils and burrows are rare but locally abundant.

Depositional environments. The Hillsdale Limestone was deposited predominantly in quiet, shallow subtidal marine settings. This is indicated by the abundance of thick-bedded skeletal wackestone with diverse marine faunas. Abundant onkoids at Lindell (Fig. 3) indicate more restricted and current-agitated settings during deposition, there. Small bryozoan mounds or banks may have formed at Lindell also.

Cross-bedded ooid grainstone and crinoidal packstone-grainstone were deposited during rare shoaling events, as subtidal sand sheets, and tidal barriers and channels. Thin peloidal packstone and peloidal skeletal packstone, associated with ooid grainstone, may have been deposited in protected, shallow lagoons behind ooid shoals. Rare episodes of shoaling to sea-level are indicated by thin fenestral peloidal limestone, stromatolitic limestone and dolomitic breccia.

Calcareous mudstone, siltstone and argillaceous limestone were deposited in nearshore, restricted settings, as indicated by thin, planar laminations and ripple laminations, peloidal and intraclastic beds, and lack of diverse marine faunas.

"Denmar-Gasper" and "Ste. Genevieve" Formations

Name. The Ste. Genevieve Formation was named by

Shumard (1860) for limestones exposed in the bluffs of the Mississippi River, near Ste. Genevieve, Missouri (Swann, 1963). Butts (1933, 1940) applied the term in Virginia for rocks, above the "St. Louis" Limestone (Hillsdale Lst.) and below the "Gasper" Formation, that contained spiny stem plates of <u>Platycrinites</u> <u>penicillus</u>.

Wells (1950) named the Denmar Formation for, "a sequence of gray, slightly cherty, calcarenite and calcilutite beds younger than the Hillsdale Limestone and older than the Taggard Formation" in Pocahontas County, West Virginia.

The "Gasper" Formation was named by Butts (1917) for a group of Mississippian limestones exposed along the banks of the Gasper River in western Kentucky. Butts (1933, 1940) applied the term in Virginia for rocks, containing the index fossil <u>Talarocrinus</u>, above the "Ste. Genevieve" Formation and below the Glen Dean, Bluefield or Fido Formations. Wells (1950) tentatively assigned the rocks of the Greenbrier Limestone above the Taggard Formation in southern West Virginia to the "Gasper" Formation.

<u>Contacts</u>. The lower contact of the "Denmar-Gasper" Formation, at both Bishop and Willowton, is placed at the change from thick-bedded cherty limestone of the Hillsdale into thin-bedded calcareous siltstone and mudstone, and

overlying skeletal packstone and ooid grainstone of the "Denmar-Gasper" Formation.

The lower contact of the "Ste. Genevieve" Formation at Lindell was placed at the base of a very thin-bedded, calcareous mudstone unit which overlies massive-bedded, onkoidal skeletal wackestone of the Hillsdale Limestone. This mudstone grades upward into cherty, nodular-bedded, argillaceous skeletal wackestone (Fig. 3) not unlike the Hillsdale Limestone. The contact is marked here although both Butts (1940) and Averitt (1941) placed the lower contact of the "Ste. Genevieve" at the top of a similar mudstone unit at a section roughly 16 km southwest of Lindell (Greendale, Virginia). Only the lower 109 m of an approximately 450 m thick "Ste. Genevieve" sequence (Butts, 1940) was measured. Overlying beds are poorly exposed and contain few relatively pure limestone units which might be good conodont-bearing beds.

Lithology. The "Denmar-Gasper" and "Ste. Genevieve" Formations mostly consist of cyclic sequences of skeletal packstone, argillaceous limestone and calcareous mudstone and siltstone. However, the lower 100 m of the "Ste. Genevieve Formation" at Lindell is noncyclic and consists of thick units of argillaceous skeletal wackestone, crinoidal grainstone and calcareous siltstone. The remainder of the formation (approximately 350 m) appears to be cyclic.

Cyclic units in the "Denmar-Gasper" Formation are a diverse assemblage of lithofacies and consist of skeletal packstone, skeletal wackestone (less abundant than in the Hillsdale), ooid grainstone, calcareous mudstone-siltstone, intraclast packstone-grainstone, peloidal skeletal packstone and silty-argillaceous limestone. Skeletal (crinoidal) packstone, calcareous mudstone-siltstone and ooid grainstone are more common at Willowton than at Bishop. However, diversely fossiliferous skeletal wackestone is more abundant at Bishop. Limestones, on average, are more argillaceous at Willlowton.

Skeletal wackestone (lesser packstone and lime mudstone) is medium- to thick-bedded, cherty and fossiliferous. Fossils include abundant echinoderms (primarily crinoids with fewer blastoids and echinoids), fenestrate bryozoans and brachiopods. Solitary rugose corals, trilobites, ostracodes, endothyrid foraminifera, gastropods and pelecypods are less common. Fossils are commonly silicified.

Calcareous siltstone and mudstone are very thin- to thin-bedded and thinly laminated. Laminations may be planar, wavy or undulose. Current and wave ripple-laminations are less common. Very fine-grained quartz sand may be admixed and, with calcareous siltstone, may form lenticular bedding or wavy bedding, locally. These rocks are poorly fossiliferous and contain scattered fenestrate bryozoans, brachiopods and echinoderm debris. Small trace fossils, primarily tracks and trails, are locally common.

Coarse-grained, skeletal (crinoidal) packstone-grainstones are thick-bedded and may have low-angle, tabular cross-bedding. Fossils are dominantly disarticulated pelmatozoan columnals (crinoids and blastoids), while brachiopods, fenestrate bryozoans and solitary rugose corals are common.

Ooid grainstone, and lesser packstone, are medium- to thick-bedded and may have low-angle, tabular cross-bedding. They consist of medium- to coarse-grained ooids, common intraclasts, and coated skeletal grains, primarily disarticulated pelmatozoan columnals.

Intraclast packstone-grainstone and peloidal skeletal packstone occur together. Intraclast packstone-grainstone is thick-bedded and contains coarse-grained to pebble-sized intraclasts, ooids and abraded skeletal grains. Peloidal skeletal packstone is thin-bedded, heavily burrowed, fine-grained and silty to argillaceous, with abundant skeletal grains.

Interbedded, silty-argillaceous limestone and calcareous mudstone are thin-bedded to shaley, finely laminated and slightly fossiliferous, containing rare brachiopods, crinoids and fenestrate bryozoans. Small burrows are common.

The lower 100 m of the "Ste. Genevieve" Formation at Lindell is noncyclic. Thick units in this sequence consist of calcareous mudstone, argillaceous skeletal wackestone, crinoidal grainstone and calcareous siltstone. The overlying rocks of the formation (approximately 350 m) appear to be in cyclic sequences like the rocks of the "Denmar-Gasper" Formation.

Calcareous mudstone is very thin-bedded or shaley, and silty. Abundant fossils include brachiopods, solitary rugose corals, bryozoans, crinoids, pelecypods and ostracodes. Argillaceous limestone is commonly interbedded.

Argillaceous skeletal wackestone is massive, nodular bedded, and cherty. Algal onkoids are common to abundant. Fossils consist dominantly of echinoderms (crinoids and blastoids) and fenestrate bryozoans. Brachiopods, solitary rugose corals and endothyrid foraminifera are common, whereas gastropods, pelecypods, ostracodes and trilobites are rare.

Crinoidal grainstone is medium- to thick-bedded and contains large-scale, low-angle, tabular cross beds. Coarse- to very coarse-grained skeletal grains consist dominantly of echinoderm (crinoid) debris, with fewer bryozoans, brachiopods, pelecypods, gastropods and solitary rugose corals. Glauconite and quartz grains are scattered throughout. Thin, argillaceous skeletal wackestone is rarely interbedded.

Calcareous siltstone, and minor, very fine-grained sandstone, is thin-bedded, flaggy, and thinly laminated to wave and current ripple-laminated. Small burrows, trails, echinoderm fragments and very small carbonaceous plant fragments are rare.

Depositional environments. Cyclic facies of the "Denmar-Gasper" Formation at Bishop and Willowton were deposited in shallow carbonate ramp settings. Open platform or protected lagoonal facies, deposited in low-energy, sub wave-base settings, are skeletal wackestone with diverse marine faunas. Crinoidal packstone-grainstone and ooid grainstone are wave-agitated skeletal shoal or channel deposits. Nearshore, restricted, lagoonal facies are peloidal skeletal packstone and intraclast grainstone-packstone (storm-generated beds); where terrigenous sediment influx was high, fossiliferous argillaceous limestone and calcareous mudstone were deposited. Poorly fossiliferous, mechanically laminated, calcareous siltstone and mudstone were deposited in nearshore, lagoonal or tidal-flat settings, also with high terrigenous sediment influx.

The abundance of calcareous siltstone and mudstone, skeletal packstone and argillaceous limestone at Willowton indicates that nearshore conditions prevailed for a longer time here, and that the area was closer to a terrigenous sediment source, than Bishop (Blancher, 1974; Chaplin, 1977). Open-marine environments were more prevalent at Bishop as indicated by the abundance of fossiliferous skeletal wackestone.

Noncyclic carbonates of the lower "Ste. Genevieve" Formation at Lindell were deposited in environments similar to cyclic carbonates, except in a single progradational sequence. Argillaceous skeletal wackestone and calcareous mudstone were deposited in shallow subtidal, open platform settings. Onkoids may have been transported from more restricted, wave-agitated settings. Overlying, cross-bedded, crinoidal grainstone was deposited as shallow subtidal sand sheets formed during upward shoaling. Mechanically laminated, calcareous siltstone and very fine-grained sandstone were deposited in nearshore, lagoonal (and tidal flat?) settings behind sand banks.

CONODONT BIOSTRATIGRAPHY

North American Meramecian Conodont Zonation

Collinson, Scott and Rexroad (1962) proposed a conodont zonation for the Mississippian System in the Mississippi Valley stratotype region. They recognized seventeen assemblage zones, three of which were Meramecian (Late Valmeyeran of the Illinois Geological Survey) in age (Fig. 7). Collinson, Rexroad and Thompson (1971) later revised these zones, with only minor changes to Meramecian zones. Meramecian zones are (from the base of the Series): 1) the *Taphrognathus varians* - "*Apatognathus*" zone, 2) the "*Apatognathus*" *scalenus* - *Cavusgnathus* zone and 3) the *Gnathodus bilineatus* - *Cavusgnathus charactus* zone (see Fig. 7).

Taphrognathus varians - "*Apatognathus*" *zone*. This zone was originally characterized by the concurrent ranges of *Taphrognathus varians* and DE "*Apatognathus*" (*Hindeognathus* new genus of this report). The base is marked by the lowest "common" occurrence of *Taphrognathus* and the lowest occurrence of DE "*Apatognathus*" in North America (DE "*Apatognathus*" has a greater range in Great Britain than North America). The upper limit is marked by the earliest "common" occurrence of *Cavusgnathus* and the earliest abundance of DE "*Apatognathus*," as well as the latest "common" occurrence of *Taphrognathus*.

As currently accepted this zone is really an acme-zone (or peak-zone) marked by the maximum development of *Taphrognathus varians*. Thus, the zonal boundaries may not be reliable biostratigraphic markers. The top of the zone is marked by the change from abundant *Taphrognathus* to abundant *Cavusgnathus*. The ranges of these genera overlap, with the amount of overlap varying from one study area to another (Compare data of Rexroad and Collinson, 1963; Thompson and Goebel, 1968; MacGill, 1973; and Ruppel, 1979). The local abundance of *Taphrognathus* or *Cavusgnathus*, or the change from a *Taphrognathus*-dominated fauna to a *Cavusgnathus*-dominated one, may not be of regional time-significance but may reflect only favorable local environmental conditions.

In the Mississippi Valley region this zone occurs in the Warsaw, Salem and lower St. Louis Formations (Fig. 7).

"*Apatognathus*" *scalenus* - *Cavusgnathus* *zone*. This is a concurrent range zone defined by the earliest common occurrence of *Cavusgnathus* at the base and the youngest common occurrence of DE "*Apatognathus*" spp. and DE *Spathognathodus scitulus* (elements of *Hindeognathus laevipostica*, herein) at the top. The base is also marked by the latest common occurrence of *Taphrognathus*. Discrete elements of *Hindeognathus laevipostica* are unique to this zone. In the Mississippi Valley region the zone includes the upper part of the St. Louis Formation (Fig. 7). The upper zonal boundary is one of the sharpest, most easily recognizable, conodont faunal breaks in the midcontinent area (Collinson *et al.*, 1971).

Gnathodus bilineatus - *Cavusgnathus charactus zone*. Work subsequent to Collinson *et al.* (1971) has made the top of this zone biostratigraphically unreliable, although the base is clearly defined. The base is marked by the youngest occurrence of DE *S. scitulus* and elements of DE "*Apatognathus*" which roughly corresponds to the first appearance of *Gnathodus bilineatus* in North America. Originally, the upper boundary was taken as the oldest occurrence of DE *Lonchodina furnishi*, DE *L. paraclarki*, DE *Roundya barnettana* and *Cavusgnathus altus*. The first three elements belong to a species (or several species) of the multielement genus *Idioprioniodus*. The range of morphological variation in elements of this genus is poorly understood and many invalid synonyms exist (see Nicoll & Rexroad, 1975; Norby, 1976 and Merrill, 1980 for further details). Perhaps these elements range throughout the entire Upper Mississippian (see Rexroad and Fraunfelter, 1977 and Horowitz and Rexroad, 1982). Although not abundant, *Cavusgnathus altus* also ranges lower than previously thought (Scatterday, 1963; Thompson

& Goebel, 1968; and herein). The conodonts of the *G. bilineatus* - *C. charactus* zone and the overlying *G. bilineatus* - *C. altus* zone are virtually identical. The differences between these two faunas in the midcontinent may be due to paleoecological factors.

Gnathodus bilineatus and *Lochriea commutatus* were cited by Collinson *et al.* (1971) as common to this zone. Also, "*Spathognathodus*" *campbelli* and *Hindeodus cristula*, although not restricted to the zone, were cited by Collinson *et al.* (1962) as important members of the assemblage. In my study, the name-giver for this zone, *Cavusgnathus charactus*, was not recognized as a separate taxon, but as a morphological variant of *Cavusgnathus unicornis*.

Previous Biostratigraphic Work in the Study Area

Little recent biostratigraphic information exists for the Greenbrier Limestone in the study area. Correlations with the Mississippian stratotype in the Illinois Basin have been based on using various invertebrate megafossil groups (Weller *et al.*, 1948).

Because of its bryozoan and brachiopod fauna, and stratigraphic position below the "St. Louis" Limestone, Butts (1933, 1940) correlated the rocks known today as the Little Valley Formation with the Warsaw Formation in the stratotype area, The Hillsdale ("St. Louis") Limestone, because of its coral fauna of *Lithostrotionella catelnaui* (Hayasaki) and *Lithostrotion proliferum* (Hall), has long been correlated with the St. Louis Limestone in the Mississippi Valley. The presence of the crinoid *Platycrinites penicillus* Meek and Worthen (*P. huntsvillae* Wachsmuth and Springer) in the "Ste. Genevieve" (or Denmar Formation of Wells, 1950) was used by Butts (1933, 1940) to indicate that these beds were equivalent to the Ste. Genevieve Formation in the stratotype area.

A study of Greenbrier Limestone conodont faunas in the Hurricane Ridge Syncline by J. R. Chaplin, was published in a series of abstracts (Chaplin, 1971, 1975, 1977). Chaplin (1971) suggested that the Hillsdale faunas, consisting of *Cavusgnathus*, *Taphrognathus*, DE "*Apatognathus*" and DE *Spathognathodus scitulus*, resemble those of the St. Louis Formation in the type area. He later stated (1975) that the Little Valley and Hillsdale Formations contain conodonts of the "*Apatognathus*" *scalenus* - *Cavusgnathus* and *Gnathodus bilineatus* - *Cavugnathus charactus* zones of Collinson *et al.* (1971). Based on this information, the boundary between the two zones occurs within the Hillsdale Limestone. Chaplin (1977) placed the Denmar Formation in the *G. bilineatus* - *C. charactus* zone.

Conodont Fauna of the Little Valley Formation

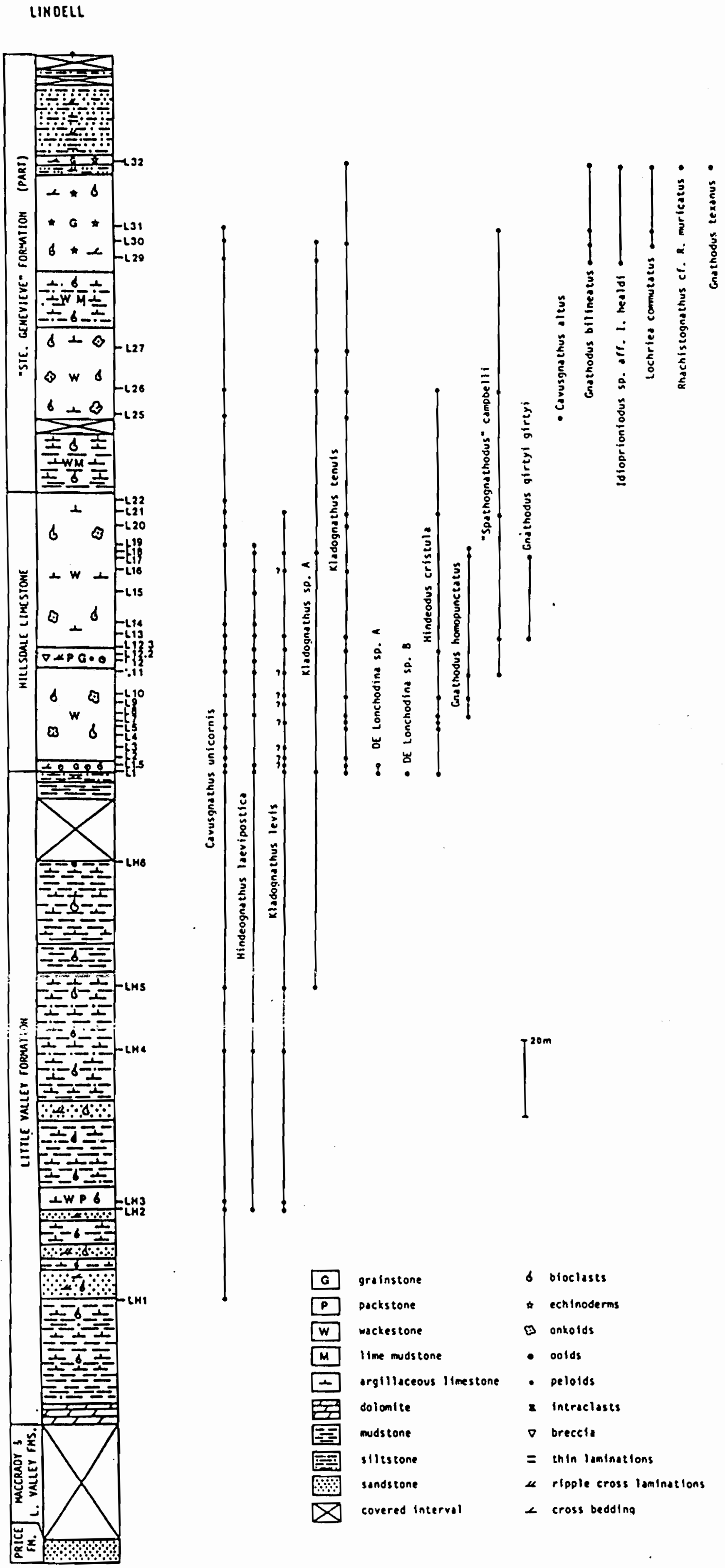
Bishop. Only two of the four samples taken at Bishop produced abundant, identifiable conodont elements (Fig. 4). Most Little Valley lithologies were unsuitable for sampling because, either the clastic content of the rock would not allow easy sample disaggregation, or the rock was unfossiliferous.

Both productive samples yielded a restricted fauna consisting almost entirely of Pa elements and rarer ramiform elements of *Taphrognathus varians*. The only other elements found in either sample were rare Pa elements of *Cavusgnathus unicornis*. No other multielement taxa were represented (see Fig. 4).

Lindell. Samples at this locality were few, widely spaced stratigraphically and confined to thin, relatively pure limestone (packstone) beds. Most of the formation consists of fossiliferous argillaceous limestone and calcareous mudstone, and was not sampled (Fig. 3).

The lowest sample (LH1; 62 m above the Price Formation and 140 m below the Hillsdale Limestone) contained only rare elements -mostly Pa elements- of *Cavusgnathus unicornis* (Fig. 3). Samples higher in the section (LH2-LH4) yielded a less restricted fauna, containing Pa elements of *Hindeognathus laevipostica* (DE *Spathognathodus scitulus*) and elements of *Kladognathus*

Figure 3 : Stratigraphic column and conodont ranges at the Lindell section. (Question marks indicate samples in which only Sc elements, but not distinctive Sa elements, of _Kladognathus levis_ were found, making the identification of this species uncertain; see Rexroad, 1981).


LINDELL
"STE. GENEVIEVE" FORMATION (PART)
HILLSDALE LIMESTONE
LITTLE VALLEY FORMATION
MACCRADY & L. VALLEY FMS.
PRICE FM.
L32
L31
L30
L29
L27
L26
L25
L22
L21
L20
L19
L18
L17
L16
L15
L14
L13
L11
L10
L5
L4
L3
L2
L1
LH6
LH5
LH4
LH3
LH2
LH1
Cavusgnathus unicornis
Hindeognathus laevipostica
Kladognathus levis
Kladognathus sp. A
Kladognathus tenuis
DE Lonchodina sp. A
DE Lonchodina sp. B
Hindeodus cristula
Gnathodus homopunctatus
"Spathognathodus" campbelli
Gnathodus girtyi girtyi
Cavusgnathus altus
Gnathodus bilineatus
Idioprioniodus sp. aff. I. healdi
Lochriea commutatus
Rhachistognathus cf. R. muricatus
Gnathodus texanus
20m
G grainstone
P packstone
W wackestone
M lime mudstone
argillaceous limestone
dolomite
mudstone
siltstone
sandstone
covered interval
bioclasts
echinoderms
onkoids
ooids
peloids
intraclasts
breccia
thin laminations
ripple cross laminations
cross bedding

levis, in addition to C. unicornis (Fig. 3). Distinctive apatognathiform elements of Hindeognathus laevipostica were not found in Lindell samples, but were found in a reference sample at an unlogged section of the formation, roughly 2.8 km (1.75 mi.) to the southwest of the Lindell section (mouth of Findley Creek, Hayter's Gap 7.5' Quad.). Kladognathus sp. A first appears about 60 m below the Hillsdale Limestone (LH5) together with C. unicornis and K. levis (Fig. 3).

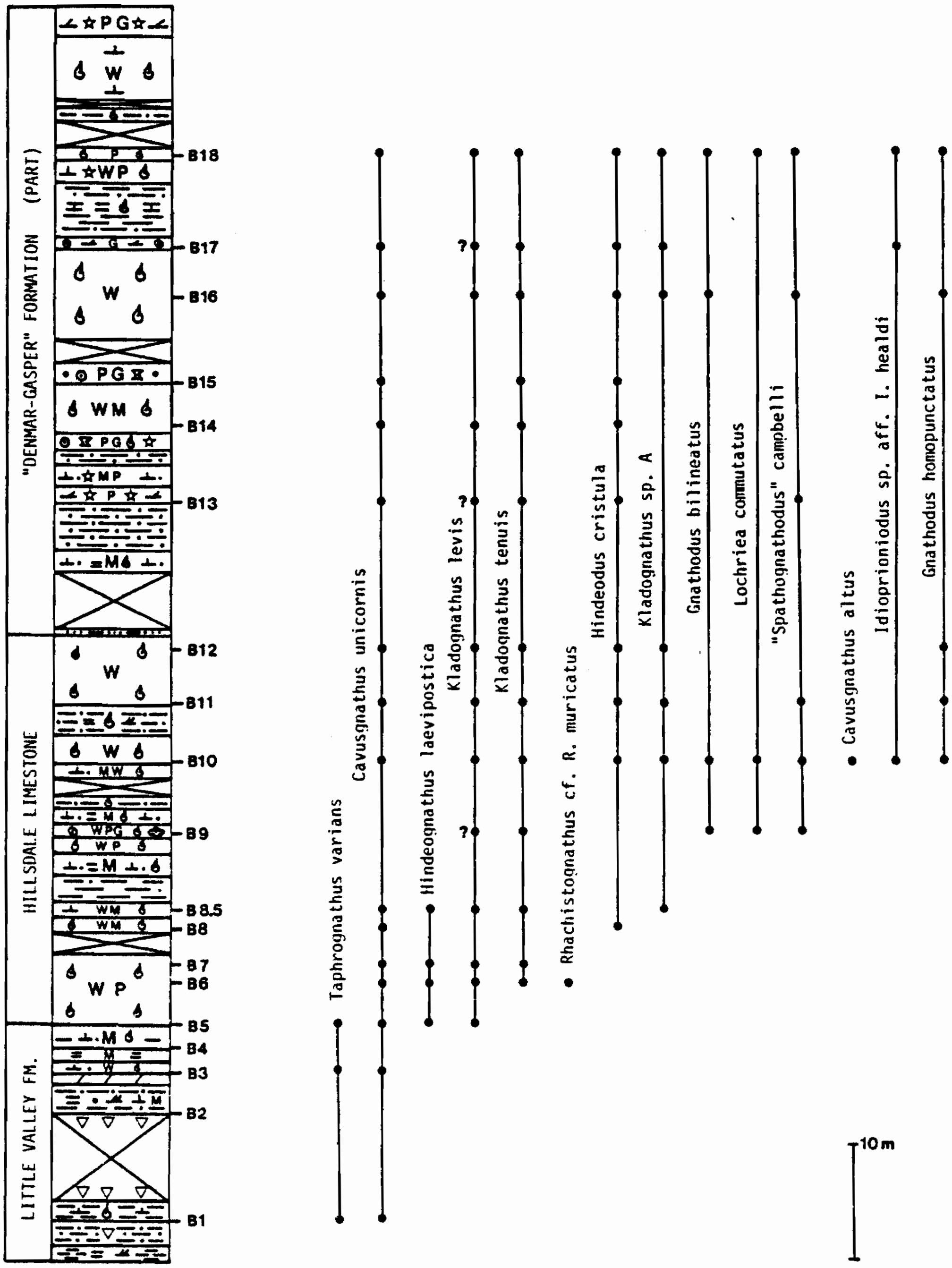
The upper 117 meters (perhaps the upper 140 meters) of the Little Valley Formation contains Cavusgnathus unicornis, Kladognathus levis and Hindeognathus laevipostica. Taphrognathus varians was not found, but may be present in the lower 40 m of the formation (part of which is covered by the North Fork of the Holston River).

Conodont Fauna of the Hillsdale Limestone

Bishop. The Hillsdale Limestone at Bishop contains two distinctive conodont faunas (Fig. 4). The basal 10.7 m is dominated by abundant elements of Hindeognathus laevipostica (DE "Apatognathus" spp. and DE Spathognathodus scitulus). Also abundant are Cavusgnathus unicornis, Kladognathus levis and Kladognathus tenuis. Rare Pa elements of Taphrognathus varians, occur only at the base of the formation, as does Rhachistognathus cf. R.

Figure 4 : Stratigraphic column and conodont ranges at the Bishop section. Legend is same as Fig. 3. (Note: Scale is twice that of Fig. 3.)

BISHOP


"DENMAR-GASPER" FORMATION (PART)
HILLSDALE LIMESTONE
LITTLE VALLEY FM.
B18
B17
B16
B15
B14
B13
B12
B11
B10
B9
B8.5
B8
B7
B6
B5
B4
B3
B2
B1
Taphrognathus varians
Cavusgnathus unicornis
Hindeognathus laevipostica
Kladognathus levis
Kladognathus tenuis
Rhachistognathus cf. R. muricatus
Hindeodus cristula
Kladognathus sp. A
Gnathodus bilineatus
Lochriea commutatus
"Spathognathodus" campbelli
Cavusgnathus altus
Idioprioniodus sp. aff. I. healdi
Gnathodus homopunctatus
?
?
?
10m
PG
W
WP
G
WM
MP
P
M
MW
WPG

muricatus. *Hindeodus cristula* appears slightly below the last occurrence of *H. laevipostica*.

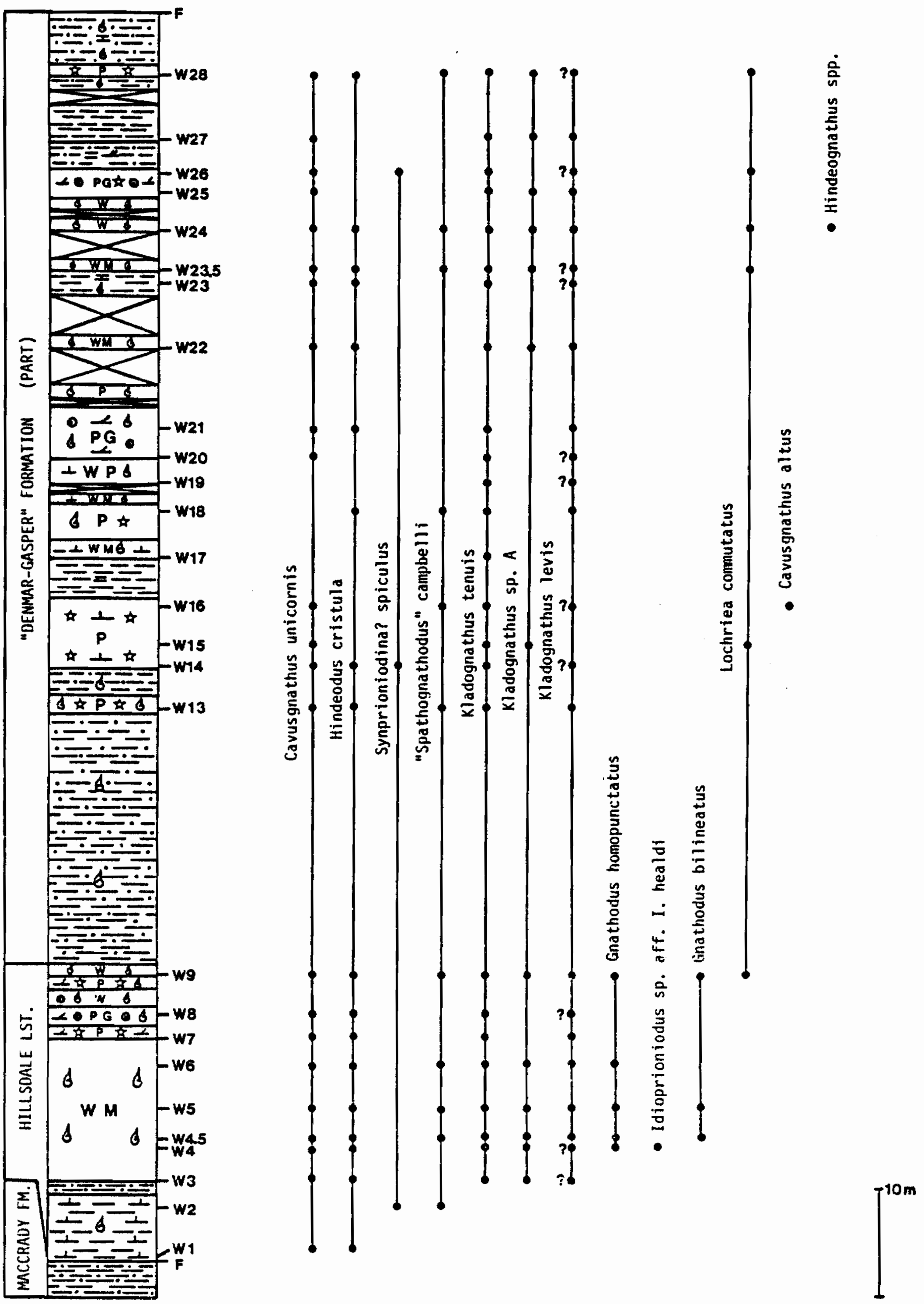
About 6 m of unsampled, dominantly argillaceous limestone overlies the last sample known to contain elements of *Hindeognathus laevipostica*. The remaining 17.3 m of the Hillsdale contains *Cavusgnathus unicornis*, *Gnathodus bilineatus*, *G. homopunctatus*, *Hindeodus cristula*, *Lochriea commutatus*, "*Spathognathodus*" *campbelli*, *Kladognathodus tenuis*, *K.* sp. A and *K. levis*. Sparsely represented in this part of the Hillsdale are *Cavusgnathus altus* and *Idioprioniodus* sp. aff. *I. healdi*.

Willowton. At Willowton, West Virginia, the Hillsdale Limestone is in fault contact with the Maccrady Formation (Fig. 5). Only 26.8 m are exposed. The uniform conodont fauna contains *Cavusgnathus unicornis*, *Hindeodus cristula*, *Kladognathus tenuis*, *K. levis*, *K.* sp. A, *Gnathodus bilineatus*, *G. homopunctatus* and "*Spathognathodus*" *campbelli*. *Lochriea commutatus* and *Synprioniodina*? *spicula* are rare. Elements of *H. laevipostica* were not found.

Lindell. Samples from the Hillsdale Limestone yielded low numbers of conodont elements (less than 4 elements per kg). dominated by *Hindeognathus laevipostica*, *Cavusgnathus unicornis*, *Kladognathus tenuis*, *K. levis* and *Hindeodus cristula* (Fig. 5). *Kladognathus* sp. A is rare,

Figure 5 : Stratigraphic column and conodont ranges at the Willowton section. Legend is that of Fig. 3. (Note: Scale is twice that of Fig. 3; F = fault.)

WILLOWTON


"DENMAR-GASPER" FORMATION (PART)
HILLSDALE LST.
MACCRADY FM.
F
W28
W27
W26
W25
W24
W23.5
W23
W22
W21
W20
W19
W18
W17
W16
W15
W14
W13
W9
W8
W7
W6
W5
W4.5
W4
W3
W2
W1
F
Cavusgnathus unicornis
Hindeodus cristula
Synprioniodina? spiculus
"Spathognathodus" campbelli
Kladognathus tenuis
Kladognathus sp. A
Kladognathus levis
Gnathodus homopunctatus
Idioprioniodus sp. aff. I. healdi
Gnathodus bilineatus
Lochriea commutatus
Cavusgnathus altus
Hindeognathus spp.
10m

but ranges throughout the formation.

Elements of *Hindeognathus laevipostica* are very common, but disappear at 13.4 m below the top of the formation (Fig. 3). *Hindeodus cristula* and *K. tenuis* appear at the base of the formation and range upward into the "Ste. Genevieve" Formation. *Gnathodus homopunctatus* and "*Spathognathodus*" *campbelli* first appear in the Hillsdale and overlap the range of *Hindeognathus laevipostica*. The stratigraphically highest occurrence of *G. homopunctatus* correlates with that of *H. laevipostica*; "*S.*" *campbelli* ranges into the "Ste. Genevieve" Formation. *Gnathodus girtyi girtyi*, (not found at either Bishop or Willowton) appears within the range of *H. laevipostica*. Two elements of uncertain affinities (DE *Lonchodina* sp. A and sp. B) are restricted to the base of the formation.

"Denmar-Gasper" and "Ste. Genevieve" Conodont Faunas

Bishop and Willowton. The lowest 41 and 82 m of the "Denmar-Gasper" Formation were sampled at Bishop and Willowton, respectively. Both localities have a fauna identical to the upper Hillsdale Limestone: *C. unicornis*, *H. cristula*, *L. commutatus*, *K. tenuis*, *K. levis*, *K.* sp. A and "*S.*" *campbelli*. *Synprioniodina*? *spicula* was found only at Willowton, and *Gnathodus bilineatus*, *G. homopunctatus* and *Idioprioniodus* sp. aff. *I. healdi* occur only at Bishop.

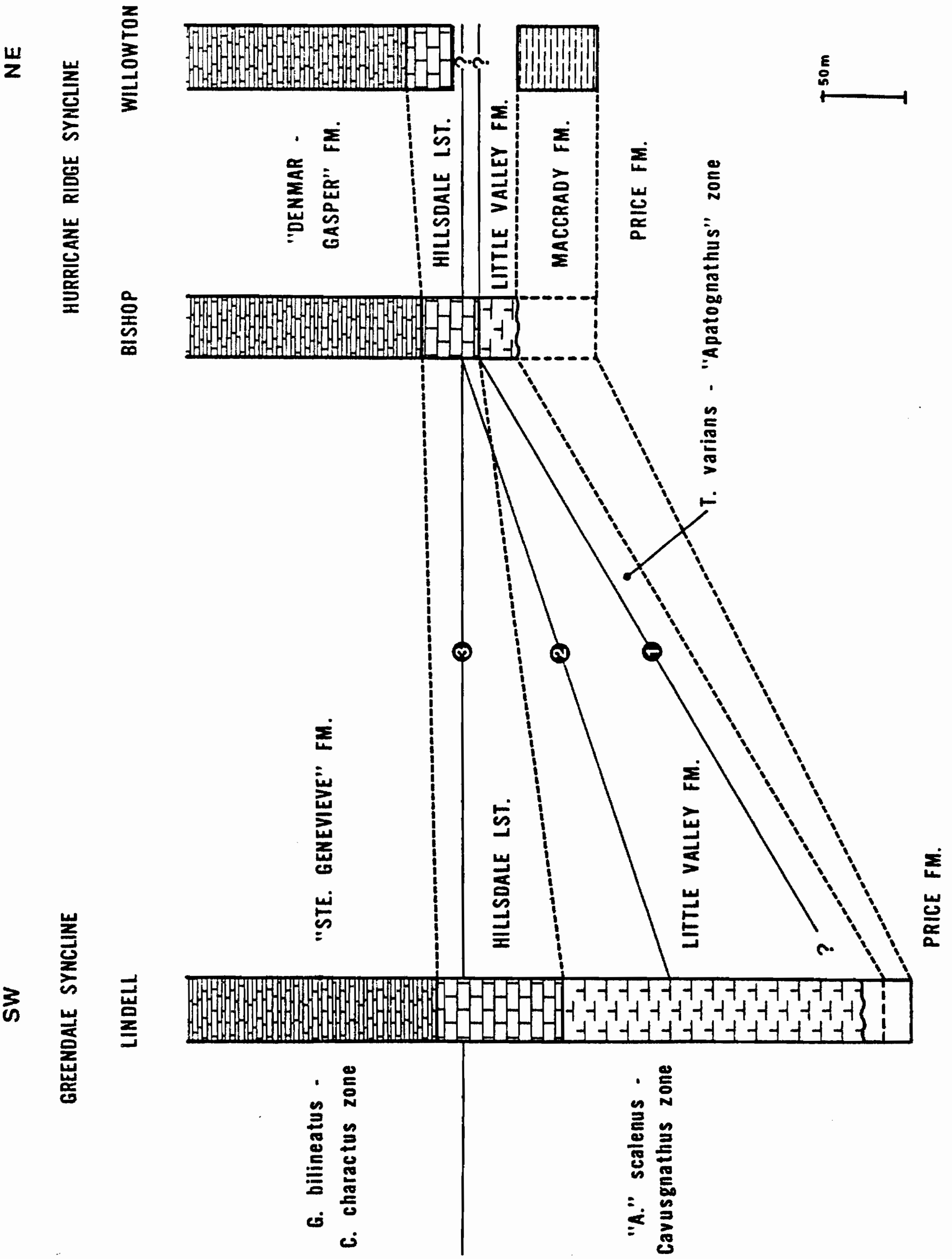
Rare apatognathiform elements were found in the "Denmar-Gasper" Formation, 67.2 m above the Hillsdale Limestone (Fig. 5). Poor preservation precluded identification. They are included in Hindeognathus spp. No characteristic Pa or Pb elements of that genus were found in this interval.

Lindell. Samples from the lower 86 m of the "Ste. Genevieve" Formation at Lindell contained few conodonts (Fig. 3). The lowest "Ste. Genevieve" has a small fauna, of forms also occurring in the uppermost Hillsdale: C. unicornis, K. tenuis, K. sp. A, H. cristula and "S." campbelli. Thick crinoidal grainstone, 57 m above the base of the formation, contains G. bilineatus, G. texanus, L. commutatus, I. sp. aff. I. healdi and Rhachistognathus cf. R. muricatus.

Local Correlation

Stratigraphic relationships are shown in Figures 6 and 7. Figure 6 is a correlation diagram of the Little Valley, Hillsdale and lower "Denmar-Gasper" or lower "Ste. Genevieve" formations at the three measured sections. It is based on my conodont data. The last occurrence of Hindeognathus laevipostica is chosen as boundary marker between the "Apatognathus" scalenus - Cavusgnathus and

Figure 6 : Diagram showing the correlation of Meramecian units in the study area. Three time lines are shown: 1) last appearance of *Taphrognathus varians*, marking the top of the *T. varians* - "*Apatognathus*" zone; 2) first appearance of *Kladognathus* sp. A.; 3) last appearance of *Hindeognathus laevipostica*, marking the top of the "*Apatognathus*" *scalenus* - *Cavusgnathus* zone and the base of the *Gnathodus bilineatus* - *Cavusgnathus charactus* zone. Thicknesses of the Maccrady Formation are taken from: (Greendale Syncline) Bartlett and Webb (1971); (Hurricane Ridge Syncline) Blancher (1974) and Englund *et al.* (1981).


SW
NE
GREENDALE SYNCLINE
HURRICANE RIDGE SYNCLINE
LINDELL
BISHOP
WILLOWTON
"STE. GENEVIEVE" FM.
"DENMAR - GASPER" FM.
HILLSDALE LST.
HILLSDALE LST.
LITTLE VALLEY FM.
LITTLE VALLEY FM.
MACCRADY FM.
PRICE FM.
PRICE FM.
?
?
?
3
2
1
T. varians - "Apatognathus" zone
G. bilineatus - C. charactus zone
"A." scalenus - Cavusgnathus zone
50m

Gnathodus bilineatus - *Cavusgnathus charactus* zones. Other important biostratigraphic markers shown on the diagram are the last occurrence of *Taphrognathus varians*, which marks the boundary between the *T. varians* - "*Apatognathus*" and "*A.*" *scalenus* - *Cavusgnathus* zones, and the first appearance of *Kladognathus* sp. A. a probable descendent of *K. levis*. Figure 7 summarizes correlation of the Meramecian rocks in the Hurricane Ridge and Greendale Synclines, and their correlation with strata in the Illinois Basin stratotype and east-central Tennessee.

Little Valley Formation. The conodont faunas from the Little Valley Formation at Bishop and Lindell are different and indicate that much of the formation at Lindell is younger than at Bishop. *C. unicornis* occurs sparingly throughout the formation at Bishop. Because of the dominance of *T. varians*, the fauna at Bishop is more indicative of the *T. varians* - "*Apatognathus*" zone as defined by Collinson, *et al* (1971), than the younger "*A.*" *scalenus* - *Cavusgnathus* zone. In contrast, at Lindell *T. varians* was not found in the upper 140 m of the formation, and the co-occurrence of *C. unicornis* and *H. laevipostica* in the upper 117 m is indicative of the "*A.*" *scalenus* - *Cavusgnathus* zone (Fig. 3).

At Lindell, it is possible that *T. varians* occurs in the lower, unsampled, 40 m of the formation that was

Figure 7 : Correlation chart showing regional correlation of Meramecian units in the study area with standard Mississippian conodont zones, and formations in east-central Tennessee and the Mississippian stratotype of the upper Mississippi River valley. Tentative correlations with Carboniferous conodont zones of Great Britain are also suggested ("Gnathodus" = Lochriea of this report, and "Apatognathus" = Hindeognathus; (*: complete time-stratigraphic unit).

SYSTEM	SUBSYS.	SERIES	SYSTEM	SERIES	SERIES	BRITISH CONODONT ZONES		NORTH AMERICAN CONODONT ZONES [3]	MISSISSIPPIAN STRATOTYPE (ILLINOIS BASIN) [3]	EAST-CENTRAL TENNESSEE [4]	HURRICANE RIDGE SYNCLINE [5]	GREENDALE SYNCLINE [5]
						CRAVEN LOWLANDS [1]	AVON GORGE [2]					
CARBONIFEROUS	DINANTIAN	VISEAN	MISSISSIPPIAN	UPPER	CHESTERIAN	*"Gnathodus" nodosus*	*Gnathodus girtyi collinsoni*	*Gnathodus bilineatus* *Cavusgnathus altus*	CHESTERIAN FORMATIONS	BANGOR LIMESTONE	BLUEFIELD FORMATION	COVE CREEK FORMATION
										HARTSELLE FM.		FIDO SANDSTONE
							"Gnathodus" mononodosus			MONTEAGLE LIMESTONE	GREENBRIER LIMESTONE "DENMAR-GASPER" FORMATION	"GASPER" FORMATION
						Gnathodus bilineatuc	*Mestognathus beckmanni* *Gnathodus bilineatus*					
					MERAMECIAN*			*Gnathodus bilineatus* *Cavusgnathus charactus*	STE. GENEVIEVE LIMESTONE			"STE. GENEVIEVE" FORMATION
											HILLSDALE LIMESTONE	
												HILLSDALE LIMESTONE
						"Gnathodus" commutatus	*Cavusgnathus* *"Apatognathus"*	*"Apatognathus" scalenus* *Cavusgnathus*	ST. LOUIS LIMESTONE	ST. LOUIS LIMESTONE		
												LITTLE VALLEY FORMATION
							NO CONODONTS	*Taphrognathus varians* *"Apatognathus"*			LITTLE VALLEY FORMATION	
									SALEM LIMESTONE WARSAW FORMATION	WARSAW FORMATION	MACCRADY FORMATION	MACCRADY FORMATION
						Gnathodus homopunctatus						
				LOWER	OSAGE.		*M. beckmanni* *Poly. bischoffi*	*Gnathodus texanus* *Taphrognathus*	KEOKUK LIMESTONE	FT. PAYNE FORMATION	PRICE FORMATION	PRICE FORMATION

1) Metcalfe, 1980; 2) Rhodes, *et al.*, 1969; Austin, 1973; 3) Collinson, *et al.*, 1971; 4) Horowitz, *et al.*, 1979; 5) Present paper.

partly covered by the flood plain of the North Fork of the Holston River. Perhaps, further study will reveal a *T. varians* - "*Apatognathus*" zone.

The difference in conodont faunas at the Bishop and Lindell sections can perhaps be explained by paleoecological factors that controlled the original distribution of *Taphrognathus* and *Cavusgnathus*. In general, the Little Valley Formation was deposited in more restricted, nearshore settings at Bishop than at other localities in the Hurricane Ridge Syncline or at Lindell (see previous chapter). During Carboniferous time, *Taphrognathus* and *Cavusgnathus* were strongly facies-controlled and were the dominant (and often only) members of conodont communities in nearshore marine environments (Merrill and von Bitter, 1975, 1976; Austin, 1976; von Bitter, 1976a; and Higgins and Varker, 1982). The abundance of *Taphrognathus* at Bishop may be due to favorable environmental conditions that lasted longer there than at other localities. Thus, *Taphrognathus* may have a higher stratigraphic range at the Bishop section than at other Little Valley sections. Because *Cavusgnathus* occurs throughout the Little Valley Formation at both Bishop and Lindell, these sections may be more correlative than as first indicated. Future study of other Little Valley sections in the Hurricane Ridge

Syncline will determine whether Taphrognathus varians is ubiquitous throughout the formation or represents only an isolated occurrence at Bishop due to favorable local environments.

Hillsdale Limestone. At Bishop the Hillsdale Limestone contains two distinctive conodont faunas. The lower 11 m contains a fauna of the "Apatognathus" scalenus - Cavusgnathus zone; the upper 17 m of the formation is typical of the Gnathodus bilineatus - Cavusgnathus charactus zone. (see Figs. 4 and 7).

Overall the fauna of the Hillsdale at Willowton is characteristic of the G. bilineatus - C. charactus zone. By correlation with Bishop, the lack of Hindeognathus laevipostica and an older Taphrognathus fauna indicates that the lower Hillsdale and the entire Little Valley Formation have been removed by faulting; the Hillsdale is in fault contact with the Maccrady Formation. Thus, the entire 26.5 m of the Hillsdale at Willowton is equivalent to the upper Hillsdale (17-23 m) at Bishop.

Much of the Hillsdale at Lindell (like the underlying Little Valley Formation) correlates with the "A" scalenus - Cavusgnathus zone. This is because of the co-occurrence of Hindeognathus laevipostica and Cavusgnathus unicornis. The upper boundary of the zone is placed at the stratigraphically highest occurrence of H. laevipostica, 13.4 m below the top of the formation (Fig. 3 and Fig. 6). Unpublished data (R. Schwind, material in the micropaleontology collections, Dept. of Geol. Sci., VPI & SU) show that H. laevipostica ranges throughout the formation at other localities in the Greendale Syncline. The total thickness of the "A." scalenus - Cavusgnathus zone at Lindell, including the upper Little Valley Formation, is at least 175 to 200 m thick. At Bishop, the zone is confined to the basal 11 to 17 m of the Hillsdale.

The change in thickness of this zone from Bishop to Lindell can be explained in part by different rates of sedimentation and basin subsidence. Thickening of Meramecian formations southeastward from the Appalachian Plateau to the Appalachian Valley and Ridge indicates that subsidence was greatest in the part of the Appalachian Basin marginal to the southeastern foreland. Sedimentation seems to have kept pace with basin subsidence because sedimentologic features indicate that shallow marine environments prevailed during the deposition of these rocks. The pronounced thickening of the "A." scalenus - Cavusgnathus zone from the Hurricane Ridge Syncline to the Greendale Syncline is further proof of the increase in sedimentation and subsidence rates to the southeast. Unfortunately, Late Carboniferous to Permian (Alleghenian) thrusting and folding, and later erosion, has destroyed evidence for the original configuration of this part of the Appalachian Basin.

Additional explanation is needed for the thinness of the zone at Bishop. The relatively abrubt appearance of *Kladognathus* sp. A, *Hindeodus cristula*, "*Spathognathodus*" *campbelli* and *Gnathodus homopunctatus*, at or shortly above the last appearance of *Hindeognathus laevipostica*, suggests that a hiatus or disconformity marks the boundary between the "*A.*" *scalenus* - *Cavusgnathus* and *G. bilineatus* - *C. charactus* zones. Although physical evidence for an unconformity is slight (Wilpolt and Marden {1955} reported a thin {1 m thick} breccia horizon in this interval - beds 10-12, Appendix A, of this report), because these species overlap the range of *H. laevipostica* at Lindell, their sudden appearance at Bishop (Fig. 4) suggests that their lower ranges have been chopped off by a hiatus or hiatuses.

Comparison of the ranges of *Kladognathus* sp. A and *H. laevipostica* at Bishop and Lindell, respectively, is striking in this respect (Fig. 6). *Kladognathus* sp. A probably evolved from *K. levis*. Because evolutionary change at the species level is rapid, the first appearance of *K.* sp. A should mark a datum that can be correlated throughout the basin. At Bishop *K.* sp. A first appears coevally with the last occurrence of *H. laevipostica* (Fig.

4). At Lindell K. sp. A appears 120 m below the last appearance of H. laevipostica (Fig. 3). If the last occurrence of H. laevipostica is accepted as a datum throughout the study area, then the magnitude of the hiatus at Bishop is indicated by the amount of range-overlap of K. sp. A and H. laevipostica at Lindell (Fig. 6).

An identical, abrupt change in Meramecian conodont faunas occurs between the St. Louis and Ste. Genevieve Limestones, or their equivalents, throughout the midcontinent stratotypal region (Collinson et al., 1971). This change has been documented from Illinois, Indiana and Kentucky (Rexroad and Collinson, 1963); central Tennessee (Horowitz et al., 1979); and southern Ohio (Scatterday, 1963). In the Illinois Basin little sedimentological evidence for an unconformity exists (Rexroad and Fraunfelter, 1977). To the east, along the western margin of the Appalachian Basin in eastern Kentucky and southern Ohio, there is physical evidence for unconformities in this stratigraphic interval (Scatterday, 1963 and Ettensohn, 1981). These unconformities resulted from epeirogenic basement-fault movements along the Waverly Arch in east-central Kentucky, contemporaneous with sedimentation (Ettensohn, 1980, 1981).

In other areas, like the Hugoton embayment of the

Anadarko Basin (Thompson and Goebel, 1968) and the eastern maritime provinces of Canada (Globensky, 1967; von Bitter, 1976a) there is overlap of conodont ranges similar to Lindell, suggesting that in those areas sedimentation was continuous throughout this time interval.

"*Denmar-Gasper*" *and* "*Ste. Genevieve*" *Formations*. The lower "Denmar-Gasper" and "Ste. Genevieve" Formations at all three study localities contain a fauna continuous with the underlying Hillsdale Limestone. This fauna is characteristic of the *G. bilineatus* - *C. charactus* zone. Both *G. bilineatus* and *L. commutatus* appear in the Lindell section, 60 m above the base of the "Ste. Genevieve"; this may be due to inadequate sampling or the effects of facies control.

Pa elements assigned to *Rhachistognathus* cf. *R. muricatus* in the "Ste. Genevieve" Formation (and in the Hillsdale Limestone at Bishop) appear anomalous, because *R. muricatus* is considered to be a Latest Mississippian - Earliest Pennsylvanian zonal species (Lane and Straka, 1974; Tynan, 1980). Other specimens (like the Pa elements recovered here) have been found in Mermecian to lower Chesterian rocks elsewhere (Thompson and Goebel, 1968; Thompson, 1972; and MacGill, 1973). These specimens may be older homeomorphs of *R. muricatus* or they may indicate that this species has a longer range than previously thought.

The occurrence of rare, unidentifiable apatognathiform elements of *Hindeognathus* spp. at Willowton is anomalous, and indicates that this genus ranges higher in the study area than in the stratotype region. Elements included in *Hindeognathus* have also been recovered in Chesterian rocks of Missouri (Thompson, 1972) and Nevada (Rice and Langenheim, 1974a). In Great Britain this genus has a greater range compared with North America (Rhodes *et al.*, 1969).

Regional Correlation

Mississippian stratotype. The conodont biostratigraphy of Meramecian rocks in the stratotype region (Illinois, Indiana, Kentucky, and Missouri) has been discussed by Rexroad and Collinson (1963, 1965), Thompson (1966) and Collinson *et al.* (1962, 1971, 1979). Abundant elements of *Taphrognathus varians* and rarer elements of *Cavusgnathus unicornis* in the Little Valley Formation at Bishop indicates that the formation in the Hurricane Ridge Syncline is in the upper part of the *T. varians* - "*Apatognathus*" zone, comparable to the lower St. Louis Formation in the stratotype area (see Fig. 7). The upper part of the St. Louis Formation is within the "*A*." *scalenus* - *Cavusgnathus* zone and correlates with the lower

Hillsdale Limestone in the Hurricane Ridge Syncline and the bulk of the Little Valley and Hillsdale Formations in the Greendale Syncline. The upper Hillsdale Limestone (above the last occurrence of _Hindeognathus laevipostica_) and the lower portions of the "Denmar-Gasper" and "Ste. Genevieve" Formations are correlated with the type-Ste. Genevieve Formation, which contains a fauna characteristic of the _G. bilineatus_ - _C. charactus_ zone.

The faunal break in the Hillsdale Limestone at Bishop, between the "_A._" _scalenus_ - _Cavusgnathus_ and _G. bilineatus_ - _C. charactus_ zones, is nearly identical to the break between the St. Louis and Ste. Genevieve Formations in the stratotypal region indicating that hiatuses of similar magnitude occur in this stratigraphic interval at both localities. A more complete conodont faunal record is preserved in the Little Valley and Hillsdale Formations of the Greendale Syncline.

Conodont evidence indicates that earlier correlations of the Little Valley and Hillsdale Formations with formations in the stratotype region (Butts, 1927, 1933, 1940), were partly inaccurate. The Little Valley Formation contains a conodont fauna characteristic of the type-St. Louis Formation, and not the Warsaw Formation as Butts suggested. At Bishop the formation contains abundant elements of _Taphrognathus varians_ as does the type-Warsaw

Formation (Rexroad and Collinson, 1965), but the presence of *Cavusgnathus unicornis* indicates that it is also probably no older than the lower St. Louis Formation.

The Hillsdale Limestone has long been correlated with the St. Louis Formation (Reger, 1926; Butts, 1940), because it contains the supposed guide fossils, *Lithostrotionella castelnaui* (Hayasaki), and *Lithostrotion proliferum* (Hall), However, conodonts indicate that the formation spans the boundary between the St. Louis and Ste. Genevieve Formations. At Bishop and Willowton, crinoid columnals of the Ste. Genevieve guide fossil, *Platycrinites penicillus* (Meek and Worthen), occur in the upper Hillsdale Limestone (see Appendix A), supporting its correlation with the Ste. Genevieve Formation.

Eastern Kentucky. Meramecian conodonts from the Borden Formation and the Newman Limestone along the western edge of the Appalachian Basin in eastern Kentucky were described by MacGill (1973), Slone (1975) and Chaplin and Mason (1979). In that region the Renfro Member of the Borden Formation contains a conodont fauna characteristic of the upper *T. varians* - "*Apatognathus*" zone, as does the Little Valley Formation at Bishop. The St. Louis Limestone Member of the Newman Formation, like the upper St. Louis Limestone in its type-area, contains a fauna completely diagnostic of the "*A.*" *scalenus* - *Cavusgnathus* zone, and is correlative with the lower Hillsdale Limestone of Virginia and West Virginia.

The top of the St. Louis Member in eastern Kentucky exhibits sedimentological evidences of subaerial exposure. A disconformity separates the member from the overlying Ste. Genevieve Member. In some areas one or both formations are cut out entirely. Ettensohn (1980, 1981) suggested that this unconformity, and others in the Newman Formation, were produced by repeated epeirogenic uplift of the Waverly Arch (a basement fault block) contemporaneous with sedimentation. Although the nature of the change in conodont faunas from the St. Louis Member to the Ste. Genevieve Member in eastern Kentucky has not been documented, the change, based on the stratigraphic position of the unconformity separating those two units, is probably similar to that seen at Bishop and in the Illinois Basin.

Southern Ohio. Scatterday (1963) and Uttley (1974) reported similar unconformities just to the north of the Mississippian outcrop belt of eastern Kentucky, in the correlative Maxville Limestone of southern Ohio. There, Scatterday's "Dillons Falls Formation," which contains a conodont fauna of _T. varians_, _C. unicornis_ and _H. laevipostica_ resembling that of the Little Valley and lower Hillsdale Formations, is thin, exhibits sedimentological evidence of subaerial exposure, and has disconformable, lower and upper boundaries. The part of the Maxville Limestone just above this interval contains a fauna characteristic of the _G. bilineatus_ - _C. charactus_ zone, like the upper Hillsdale, "Denmar-Gasper" and "Ste. Genevieve" Formations in Virginia and West Virginia. Much of this part of the Maxville Limestone, though, is probably Chesterian in age.

Tennessee. Horowitz _et al._ (1979) have done an important biostratigraphic study of a core through the Upper Mississippian of east-central Tennessee. They used several microfossil groups including conodonts to correlate their section with the composite stratotype section in the Illinois Basin and the type Lower Carboniferous of Belgium. Their study is important because their core which cut the entire Upper Mississippian sequence, offers the best available data for correlation with the thick, continuosly exposed sections in the Appalachians, unlike the geographically scattered sections in the stratotype region. Correlation of the core data with the Meramecian rocks of Virginia and West Virginia, and the Illinois Basin, is shown in Figure 7.

The sequence of conodont faunas in the St. Louis and Monteagle Formations of east-central Tennessee resembles the sequence at Bishop in the Hurricane Ridge Syncline.

The Tennessee St. Louis Limestone contains a *T. varians* - "*Apatognathus*" fauna in its lower part and a "*A.*" *scalenus* - *Cavusgnathus* fauna in its upper part, making the formation correlative with the Little Valley Formation and the lower Hillsdale Limestone. The Monteagle Limestone contains conodonts of the *G. bilineatus* - *C. charactus* zone as do the upper Hillsdale Limestone and the "Denmar-Gasper" Formation.

A conodont faunal break, nearly identical to that of the Hillsdale Limestone at Bishop occurs between the St. Louis and Monteagle Limestones in the Tennessee core. In the core the boundary between the "*A.*" *scalenus* - *Cavusgnathus* zone and the *G. bilineatus* zone is indicated by abrupt appearances of *G. bilineatus*, *G. homopunctatus*, *G. girtyi*, *L. commutatus*, and "*S.*" *campbelli*, three to four m above the last occurrence of *H. laevipostica*.

Alabama. Ruppel (1979) described a Meramecian conodont fauna from the Tuscumbia Limestone of northern Alabama. The fauna of this formation is similar to that of the stratotype-St. Louis Limestone and contains conodonts of the *T. varians* - "*Apatognathus*" and "*A.*" *scalenus* - *Cavusgnathus* zones, making it correlative with the Little Valley and lower Hillsdale Formations in Virginia.

Michigan. Conodonts of the Bayport Limestone in the Michigan Basin were described by Horowitz and Rexroad

(1972). The fauna is diagnostic of the "A." scalenus - Cavusgnathus zone, and is correlative with the Little Valley and lower Hillsdale Formations.

Eastern Canada. Globensky (1967), von Bitter (1976a) and von Bitter and Plint-Geberl (1982) described conodont faunas from the Upper Mississippian (Lower Carboniferous) Windsor and Codroy Groups of the maritime provinces of eastern Canada. They reported occurrences of: Taphrognathus, Cavusgnathus, Mestognathus, Hindeognathus, Gnathodus bilineatus, Gnathodus girtyi, Hindeodus cristula and "Spathognathodus" campbelli. These faunas indicate Meramecian age, suggesting the Windsor and Codroy Groups are roughly equivalent to the lower portion on the Greenbrier Limestone.

Although scattered exposures, structural complications, and complex facies changes all hamper biostratigraphic interpretation, von Bitter (1976a) and von Bitter and Plint-Geberl (1982) recognized stratigraphically successive Taphrognathus, Cavusgnathus and Gnathodus zones. These may be correlative with the zonal sequence in the stratotype area. The stratigraphic sequence of Meramecian conodont faunas is more complex in eastern Canada than in the North American midcontinent. There is no distinctive break in conodont faunas similar to the one seen within the Hillsdale Limestone at Bishop, or between the St. Louis and Ste. Genevieve Formations. Instead, species characteristic of this stratigraphic interval in eastern Canada show greater range overlap, indicating that the Canadian stratigraphic sequence is more complete than correlative Meramecian sequences in the midcontinent and the Hurricane Ridge Syncline. The Canadian sequence most resembles that of the Greendale Syncline.

The presence of the genus _Mestognathus_ (which is unknown elsewhere in North America) indicates affinities of Canadian faunas to those of western Europe (Rhodes and Austin, 1971).

Correlation with the Lower Carboniferous of Europe

Rhodes and Austin (1971) summarized the zonation of Lower Carboniferous (Dinantian) conodont faunas from Europe, primarily Great Britain. Other studies are by Austin (1973), Metcalfe (1980), Higgins and Varker (1982), and Higgins and Wagner-Gentis (1982). Correlation of European faunas with North American Meramecian faunas is difficult due to provinciality (Higgins, 1982) and facies differences. In Great Britain there conodont faunas show sharp division into shallow-water platform and deeper-water basinal biofacies (Austin, 1976; Austin and Davies, 1983). Meramecian conodont studies in North America have been mostly on shallow-water faunas of the midcontinent and the Appalachians, and not deeper-water faunas from the western and southwestern United States. Canadian conodont faunas compare to the shallow-water platform faunas of Great Britain.

Two zonation schemes from Great Britain are correlated with North American Mississippian conodont zones and the stratigraphic sequences in the study area (Fig. 7). The Craven Lowlands zonation (Metcalfe, 1980) is based on typical basinal faunas, and resembles Dinantian zonations from Belgium (Groessens, 1977) and Spain (Higgins and Wagner-Gentis, 1982). Conodont zones from the Avon Gorge (Rhodes _et_ _al_., 1969, and Austin, 1973) are based on typical shallow-water faunas.

Biostratigraphy _Summary_

Based on conodont biostratigraphy the Little Valley Formation appears older in the Hurricane Ridge Syncline than the Greendale Syncline. At Bishop, the Little Valley conodont fauna is characteristic of the _Taphrognathus_ _varians_ - "_Apatognathus_" zone. The upper 140 m of the Little Valley at Lindell is younger because it contains a fauna typical of the "_Apatognathus_" _scalenus_ - _Cavusgnathus_ zone. No data is yet available for the lower 40 m of the formation. Additional sampling of other

Little Valley sections in the Hurricane Ridge Syncline will determine whether the *T. varians* fauna at Bishop is time-significant or partly reflects favorable, local environmental conditions.

Most of the Hillsdale Limestone (59 m) at Lindell belongs in the "*A.*" *scalenus* - *Cavusgnathus* zone as does the upper Little Valley Formation. The zone is thickest at Lindell (up to 200 m), and thinnest at Bishop, where the zone occurs only in the lower 11 m (-17 m ?) of the formation. The upper part of the Hillsdale Limestone (13 m at Lindell; 17-23 m at Bishop; 26.8 m at Willowton) is in the *G. bilineatus* - *C. charactus* zone. At Bishop, a relatively sharp change in conodont faunas marks the boundary between the "*A.*" *scalenus* - *Cavusgnathus* and *Gnathodus bilineatus* - *Cavusgnathus charactus* zones, while at Lindell the change is gradational. This evidence suggests that a hiatus or disconformity separates the "*A.*" *scalenus* - *Cavusgnathus* and *G. bilineatus* - *C. charactus* zones, at Bishop. No major hiatus occurred during the deposition of the Little Valley and Hillsdale formations at Lindell.

The Bishop section on the northwest limb of the Hurricane Ridge Syncline occurs in a cratonic setting in the Appalachian Plateau Province. During the deposition of the Hillsdale Limestone subsidence and sedimentation rates were low. Sedimentation was affected by Meramecian epeirogenic activity, that occurred throughout the craton to the west and centered in east-central Kentucky and southern Ohio. Nondeposition, or uplift and erosion produced the hiatus between the "_A._" _scalenus_ - _Cavusgnathus_ and _G._ _bilineatus_ - _C._ _charactus_ zones. Not until later Chesterian time did the area of the Hurricane Ridge Syncline begin to subside rapidly and accumulate thick piles of terrigenous sediments of the Bluefield-Bluestone formations (Thomas, 1966).

Meramecian rocks of the Greendale Syncline were deposited in a part of the Appalachian Basin that was subsiding marginal to an eroded and tectonically quiescent, orogenic source area. Basin subsidence was initiated earlier in this part of the Appalachian Basin and shallow-marine sedimentation kept pace with subsidence, enabling a more complete Meramecian stratigraphic record to be preserved.

The upper Hillsdale Limestone, the lower "Denmar-Gasper" Formation and the lower "Ste. Genevieve" Formation at all three localities have faunas diagnostic of the _G._ _bilineatus_ - _C,_ _charactus_ zone. At Willowton, where the Hillsdale Limestone is in fault contact with the Maccrady Formation, no conodonts of the "_A._" _scalenus_ - _Cavusgnathus_ zone were found. This suggests that the lower

Hillsdale Limestone and the entire Little Valley Formation were cut out by faulting.

Regional biostratigraphic correlation of Meramecian rocks of the Greenbrier Limestone in Virginia and West Virginia with other Meramecian units throughout eastern North America, indicates that the disconformity between the St. Louis and Ste. Genevieve Formations (or their equivalents) is areally extensive across the craton. Lithologic evidence for the unconformity is found in southern Ohio and eastern Kentucky. Conodont evidence (the break between the "A." scalenus - Cavusgnathus and G. bilineatus - C. charactus zones) occurs in the Illinois Basin stratotype region, and in eastern Tennessee and southwestern Virginia (Bishop). Only in the thick Greendale Syncline of southwestern Virginia, and the maritime provinces of eastern Canada, is a complete record of sedimentation across this stratigraphic interval preserved. Continued study of Meramecian conodonts from the Greendale Syncline may yield a biostratigraphic scheme that is more complete than the midcontinent scheme devised by Collinson et al. (1962, 1971). This would allow more accurate correlation with other Meramecian sequences in western North America and correlative (Dinantian) strata in western Europe.

SYSTEMATIC PALEONTOLOGY

Introduction

The suprageneric classification for the Phylum Conodonta (Clark, 1981) is used here. Genera whose affinities have not yet been determined are listed under Superfamily and Family Unknown. Discrete-element genera are listed after biologic genera.

Synonomies of multielement species include separate listings of references to each of the disjunct, component elements, followed by a listing of multielement references. Only references with illustrations of the elements are included. Existing complete synonomy is noted after the reference to the paper which includes it. Only more recent references, previously unlisted references and the reference to the original description of each element are included here. Listings from unpublished theses and dissertations are included in synonomy lists if the reference is important for the interpretation of the apparatus.

Phylum CONODONTA Eichenberg, 1930

Class CONODONTA Eichenberg, 1930

Order CONODONTOPHORIDA Eichenberg, 1930

Superfamily HIBBARDELLACEA Muller, 1956

Family HIBBARDELLIDAE Muller, 1956

Genus IDIOPRIONIODUS Gunnell, 1933

Idioprioniodus Gunnell, 1933
Metalonchodina Branson and Mehl, 1941a
Duboisella Rhodes, 1952
Geniculatus Hass, 1953
Roundya Hass, 1953
Neoprioniodus Rhodes and Muller, 1956

Type species. *Idioprioniodus typus* Gunnell, 1933

Remarks. See Baesemann (1973), Merrill and Merrill (1974) and Clark *et al*. (1981) for descriptions and discussions of this genus.

IDIOPRIONIODUS sp. aff. I. HEALDI (Roundyi)

Remarks. A few fragmentary elements of *Idioprioniodus* were found in the Hillsdale and "Denmar-Gasper" or "Ste. Genevieve" Formations. Sc and both dimorphic Pb elements were recognized. Fragmentary nature and paucity of these elements preclude detailed discussion or illustration.

Confusion exists about which specific names are valid for Late Mississippian representatives of *Idioprioniodus*, Norby (1976) has shown that *I. healdi* has priority over other names. I have followed Rexroad (1981) in tentatively assigning these elements to *I. healdi*.

Occurrence. Hillsdale Lst. (B, W), "Denmar-Gasper" Fm. (B), "Ste. Genevieve" Fm. (L).

Material recovered. Pb , Pb , Sc (10).

Genus KLADOGNATHUS Rexroad, 1958

Kladognathus Rexroad, 1958, p. 19; *pro* *Cladognathus* Rexroad, 1957, *non* *Cladognathus* Burmeister, 1847.
Lambdagnathus Rexroad, 1958, p. 19, 20.
Magnilaterella Rexroad and Collinson, 1963, p. 11-14.

Type species. *Cladognathus prima* Rexroad, 1957.

Diagnosis. The apparatus is quinquimembrate or seximembrate and lacks a platform element. Making up the apparatus are neoprioniodiform M elements and a four element transition series, which consists of a hibbardelliform Sa element, magnilaterelliform Sb and Sd elements, and ligonodiniform Sc elements. A sixth element, the lambdagnathiform X element, is included in the apparatuses of the species, *K. tenuis* and *K.* sp. A, but not *K. levis*.

Remarks. Rexroad (1981) reconstructed this apparatus. Both von Bitter (1976a) and Norby (1976) had suggested the multielement grouping of *Kladognathus* elements. Evidence which supports this reconstruction includes the similar morphology and ranges of the constituent elements, the similar micromorphology of these elements as revealed by scanning electron microscopy (Norby, 1976) and statistical studies by Horowitz and Rexroad (1980, 1981 and 1982). The reconstruction of Rexroad (1981) is accepted with some modification; an Sd element is added to all three species of *Kladognathus* recognized herein and a lambdagnathiform X element is added to two of these species. Meramecian species recognized in this study are: *K. levis* (Branson and Mehl), *K. tenuis* (Branson and Mehl) and a new species, informally designated *K.* species A. Other valid species recognized by Rexroad (1981), *K. primus* and *K. mehli*, are found in younger Chesterian rocks.

Rexroad (1981) and Horowitz and Rexroad (1982) stated that *K. levis* and *k. tenuis* are part of an evolutionary lineage which included *K. primus* and *K. mehli*; *K. tenuis* evolved from *K. levis* during the late Meramecian. *K. tenuis* as it is reconstructed here differs from *K. levis* by having slightly different Sa and Sc elements and an additional element, the X or lamdagnathiform element. The first appearance of the Sc element, DE *Ligonodina tenuis*, marks the first appearance of *K. tenuis*. This element, along with the Sa and X elements (DE *Hibbardella milleri* and DE *Lambdagnathus fragilidens*), is generally not known from lower Meramecian rocks (Rexroad and Collinson, 1963 and 1965; Nicoll and Rexroad, 1975) in which elements of *K. levis* are common. Rare exceptions, though, have been documented (Thompson and Goebel, 1968 and Ruppel, 1979). Elements of *K. levis* occur stratigraphically below the first appearance of elements characteristic of *K. tenuis*. at Bishop and Lindell.

The fate of *K. levis* after the appearance of *K. tenuis* is difficult to determine. Distinctive Sa and Sc elements of *K. levis* are found along with the corresponding elements of *K. tenuis* throughout Chesterian-aged strata of North America. For example, DE *Ligonodina levis* (Sc) ranges into the youngest Chesterian strata of the Illinois Basin (Rexroad and Burton, 1961; Rexroad and Fraunfelter, 1977). Also, DE *Hibbardella abnormis* (Sa, *K. levis*) is known to extend into lower Chesterian rocks of north-central Tennessee (Horowitz, Mamet, Neves, Potter and Rexroad, 1979) and the similar element, DE *Hibbardella fragilis* is found in uppermost Chesterian rocks of Illinois (Rexroad and Burton, 1961; Rexroad and Fraunfelter, 1977). These elements usually can be distinguished from their counterparts in *K. tenuis* (DE *L. tenuis* and DE *H. milleri*).

Either *K. tenuis* replaced *K. levis* while retaining elements of the latter as variant morphotypes in its apparatus, or *K. levis* coexisted for some time along with

K. tenuis. Rexroad (1981) suggested that perhaps DE *L. levis* was retained as a dimorphic Sc element along with DE *L. tenuis* in the apparatus of *K. tenuis*. Sa elements typical of *K. levis* (DE *H. abnormis*) may have also been retained in *K. tenuis*. All elements of *K. tenuis* exhibit some degree of morphological variation and some of this variation is comparable to that seen in the different Sc elements.

Alternatively, the fact that the Sa and Sc elements characteristic of *K. levis* (DE *H. abnormis* and DE *L. levis*) are distinctive and different from the corresponding elements of *K. tenuis* (DE *H. milleri* and DE *L. tenuis*) may be sufficient evidence for considering *K. levis* as a contemporary of, and not just as a predecessor of *K. tenuis*. Similarly, *K. mehli* and *K. primus* have been recognized as distinct species in the later Chesterian, due to their distinctive Sc elements. Presumably, *K. levis*, *K. mehli* and *K. primus* all shared vicariously other elements with *K. tenuis* (Rexroad, 1981).

In this study, *K. levis* is treated as a distinct species which coexisted along with *K. tenuis* after the latter had originated. The Sa and Sc elements are diagnostic of *K. levis*. The decision is based on the assumption of Rexroad (1981) and Horowitz and Rexroad (1982) that *K. mehli* and *K. primus* are also valid species.

This problem will not be resolved until the stratigraphic and regional variation of the component elements of these species is better understood.

Kladognathus species A is a new multielement species described for the first time. It is recognized primarily due to the morphological similarity of its constituent elements, the similarity of these elements to corresponding elements of K. levis and K. tenuis and one natural bedding-plane assemblage described and illustrated by Norby (1976) as Hibbardella sp. (p. 285, Pl. 10, fig. 3a-b; Pl. 19, fig. 4). Another closely related species of Kladognathus is indicated by several elements, described by British workers, that are very similar to some elements of species A. This species and the elements from Great Britain probably represent a separate lineage which may have branched off from the K. levis - K. tenuis line at about the same time that K. tenuis originated. Further detailed study of the genus Kladognathus is warranted.

A clearer understanding of the evolutionary changes in the lineages of Kladognathus may be useful in biostratigraphic correlation. Elements of Kladognathus are very common in Mississippian rocks that contain a Cavusgnathus biofacies (documented by several workers, see Merrill and von Bitter, 1976; Rexroad, 1981; and Horowitz and Rexroad, 1981, 1982, for most recent discussions)

Rocks that contain this conodont biofacies were commonly deposited in near-shore, restricted environments and often lack important Carboniferous zonal forms (Gnathodus and Lochriea) due to facies control. A series of lineage zones based on evolutionary first appearances of new species of Kladognathus, in conjuction with previously established Mississippian conodont zones (Collinson et al., 1971), would be of great utility in subdividing these rocks for which few reliable biostratigraphic datums have been established.

KLADOGNATHUS LEVIS (Branson and Mehl)

Pl. 1, figs. 4, 6, 8

M element.

Prioniodus tulensis Pander, 1856 (partim), p. 30, Pl. 2a, fig 1 only; Holmes, 1928 (partim), p. 22, Pl. 3, fig. 18 only.

Neoprioniodus tulensis (Pander). Rexroad & Collinson, 1963, p. 18, Pl. 2, figs. 17, 22, 23; Rexroad & Collinson, 1965, p. 12, Pl. 1, figs. 28,29; Thompson & Goebel, 1968, p. 38-39, Pl. 3, figs. 7, 18; Pl. 4, fig. 20; Ruppel, 1979, p. 67-68, Pl. 1, fig. 15, 16.

Prioniodus casilaris Branson & Mehl, 1941b, p. 186, Pl. 6, figs. 11, 12, 15, 17.

Neoprioniodus sp. cf. N. cassilaris (Branson & Mehl). Thompson & Goebel, 1969, p. 37, Pl. 3, fig. 3.

?Prioniodus scitulus Branson & Mehl, 1941a, p. 173, Pl. 5, figs. 5, 6.

?Neoprioniodus scitulus (Branson & Mehl). Globensky, 1967, p. 443, Pl. 55, figs. 22, 26; Koike, 1967, p. 307, Pl.4, figs. 31, 32; Rhodes, Austin & Druce, 1969, p. 162, Pl. 22, figs. 9, 10, 12 (Includes complete synonomy through 1969); Webster, 1969, p. 39, Pl. 7, fig. 13; Igo, 1973, p. 195, Pl. 29, figs. 30, 31; Austin & Husri, 1974, Pl. 12, figs. 12, 13, 17; Lane & Straka, 1974, fig. 34-7; Rice & Langenheim, 1974b, p. 31, Pl. 2, fig. 12.

?Neoprioniodus sp. B Rexroad, 1957, p. 36, Pl. 2, fig.

24.

?*Neoprioniodus alytus* Stanley, 1958, p. 471, Pl. 66, fig. 1.

Sa element.

Hibbardella abnormis Branson & Mehl, 1941b, p. 184-185, Pl. 6, fig. 14; Rexroad & Collinson, 1963, p.10, Pl. 2, figs. 15, 18, 20, 21; Rexroad & Collinson, 1965, p. 9, Pl. 1, figs. 8, 9; Thompson and Goebel, 1968, p. 37, Pl. 2, figs. 11, 15; Austin, Rhodes & Druce, 1969, p. 111-112, Pl. 31, fig. 6; Nicoll & Rexroad, 1975, Pl. 5, figs. 9-11.

?*Trichonodella fragilis* Rexroad, 1957, p. 40, Pl. 4, figs. 6, 7.

?*Hibbardella fragilis* (Rexroad). Rexroad & Burton, 1961, p. 1153, Pl. 140, fig. 7; Thompson & Goebel, 1968, p. 25, Pl. 2, figs. 22, 23.

non Hibbardella fragilis Higgins, 1961, p. 213, Pl. 2, fig. 4, text-fig. 2 (=*Hibbardella acuta* Murray and Chronic, 1964).

?*Hibbardella milleri* Rexroad. Austin & Husri, 1974, Pl. 13, fig. 16.

Sb element.

Magnilaterella robusta Rexroad & Collinson, 1963, p. 14-17, Pl. 1, figs. 4, 5, 9, text-figs. 3, 4; Thompson & Goebel, 1968, p. 36, Pl. 2, figs. 13, 14; Rhodes, Austin & Druce, 1969, p. 148, Pl. 31, figs. 25, 26 (includes synonomy through 1969); Webster, 1969, p. 38, Pl. 4, fig. 12; Austin & Husri, 1974, Pl. 15, fig. 7; Lane & Straka, 1974, fig. 34-2; Rice & Langenheim, 1974b, p. 31, Pl. 2, fig. 12.

Magnilaterella spp. Rexroad & Collinson, 1963 (partim), p. 17, Pl. 2, figs. 1, 3, 10 (not fig. 6, = Sd element, *Kladognathus* sp. A.).

Magnilaterella spp. Nicoll & Rexroad, 1975, Pl. 6, figs. 10-13, 16.

?*Magnilaterella* spp. Austin, Rhodes & Husri, 1969 (partim), p. 149, Pl. 23, fig. 10 only.

Magnilaterella sp. Rexroad & Collinson, 1965, p.11, Pl. 1, fig. 7.

Magnilaterella sp. Watanabe, 1975, p. 165, Pl. 15, figs. 15, 16.

Lonchodina? recurvata Bischoff, 1957, p.34, Pl. 5, figs. 17, 18.

Sc element.

Ligonodina levis Branson & Mehl, 1941b, p. 185, Pl. 6, fig. 10; Thompson & Goebel, 1968, p. 30, Pl. 2, figs. 19, 20 (includes synonomy through 1969); Rhodes, Austin

& Druce, 1969, p. 134, Pl. 26, figs. 15, 17-19; Rice & Langenheim, 1974b, p. 29, Pl. 3, fig. 1; Nicoll & Rexroad, 1975, Pl. 6, figs. 14, 15; Ruppel, 1979, Pl. 1, fig. 2.

?Ligonodina levis Branson & Mehl. Reynolds, 1970, p. 11, Pl.5, fig. 8.

Sd element.

Ligonodina? sp. Branson & Mehl, 1941a, p. 171, Pl. 5, fig. 11.

Ligonodina sp. Bischoff, 1957, p. 32, Pl. 5, fig. 7.

New Genus and new species Rexroad & Collinson, 1963, p. 21, Pl. 3, fig. 2.

Magnilaterella robusta Rexroad & Collinson. Rexroad & Furnish, 1964 (partim), p. 673, Pl. 111, figs. 27, 30 only.

Magnilaterella contraria Rhodes, Austin & Druce, 1969, p. 147-148, Pl. 23, figs. 8, 18.

Description. The apparatus is quinquimembrate and consists of neoprioniodiform M elements and a four-element transition series: a hibbardelliform Sa element, magnilaterelliform Sb elements, ligonodiniform Sc elements, and Sd elements which are transitional between the Sb and Sc elements.

Sa element. This element conforms to the concept of DE Hibbardella abnormis. The apical cusp is large, posteriorly recurved, subcircular in cross-section and forms the anterior end of the posterior process, which is rarely well preserved. Two, identical, thin, denticulated lateral processes are attached to the antero-lower side of the apical cusp. The lateral processes are joined below the lower side of the posterior process and are directed outward, posteriorly and sharply downward. There are usually from three to four, small, thin, discrete and erect denticles on each lateral process. Each denticle is slightly curved posteriorly and has a convex, outer lateral face. The lower side of the anterior portion of the posterior process exhibits the ontogenetic changes mentioned by Rexroad and Collinson (1963).

Sc element. This element conforms to the concept of DE *Ligonodina levis*. It is nearly identical to the Sa element, but possesses only a single, inner-lateral process attached to the antero-lower side of the apical cusp. The posterior process, when well preserved, is long, thin and slightly bowed, convex, upward. It bears short, thin, uncrowded denticles that are posteriorly inclined or recurved. Larger denticles are usually separated by a single, much smaller denticle.

For a more complete description of this element, see Rhodes *et al.* (1969) under DE *Ligonodina levis* (p. 134, 135).

M, Sb and Sd elements. These elements are identical to homologous elements of *K. tenuis* and are described under that species.

Comparisons. Sa and Sc elements of *K. levis* and *K. tenuis* are different. In the apparatus of *K. levis* the inner-lateral process of the Sc element is attached to the apical cusp in an antero-lower position, lateral to the apical cusp, while in the corresponding element of *K. tenuis* the lateral process is attached at the anterior margin of the apical cusp, so that the proximal denticle of the process is directly or marginally anterior to the apical cusp. In *K. levis* the corresponding denticle is in a decidedly lateral position to the cusp. Sa elements of these two species differ in the same respect.

The Sa elements differ in other ways, too. The lateral processes of Sa elements of *K. tenuis* tend to have a greater height and a more spatulate shape than the lateral processes of Sa elements of *K. levis*. In addition, the lateral processes of the latter tend to be directed more downward and posteriorly than those of *K. tenuis*.

M elements that are solely associated with *K. levis* in the oldest beds of this study (Little Valley and lowest Hillsdale Fms.) are in general slightly different than M elements of *K. tenuis*. Most of the former M elements are more like illustrated specimens of DE *Neoprioniodus tulensis* in Rexroad and Collinson (1963, 1965) than DE *N. scitulus* by having closely spaced, crowded denticles on the posterior process. Neoprioniodiform (M) elements of *K. tenuis* tend to have uncrowded, more discrete denticles on the posterior process. This difference may not be important because intermediate M elements are known and the stratigraphic extent of this difference is undetermined. For now, no distinction is made between M elements of these two species.

Consistant, specific differences between the other respective, common elements (Sb and Sd) of K. levis and K. tenuis have not been found yet. These elements are treated as being alike in both species.

An X element, DE Lambdagnathus fragilidens, is not included in the reconstruction of K. levis because there is insufficient evidence that this element was associated with other elements of K. levis. In this study no lambdagnathiform elements were found exclusively with elements of K. levis and not K. tenuis. Rexroad and Collinson (1963) reported one or two specimens referrable to DE Lambdagnathus sp. in the St. Louis Limestone of the stratotype area, which solely contained elements of K. levis, not K. tenuis. Thompson and Goebel (1968) found DE L. fragilidens in the subsurface St. Louis Limestone of Kansas. Other studies (Scatterday, 1963; Rexroad and Collinson, 1965; MacGill, 1973; and Nicoll and Rexroad, 1975) failed to report DE Lambdagnathus occurring in lower to middle Meramecian rocks (Warsaw, Salem, St. Louis Formations and equivalents), of the Illinois and Appalachian Basins, that contained only elements of K. levis and not K. tenuis. Yet, in a summary of Mississipppian conodont biostratigraphy with information primarily from the midcontinent region, Collinson, Rexroad and Thompson (1971, p. 357, fig. 1) show the range of DE *Lambdagnathus* extending into the lower Meramecian Salem Limestone, making this element contemporaneous with other elements of *K. levis*. Until there is confirmed, illustrated evidence of this association, though, the lambdagnathiform element should not be included in the apparatus of *K. levis*.

Occurrence. Little Valley Fm. (L), Hillsdale Lst. (B, W?, L), "Denmar-Gasper" Fm.? (B?, W?).

Material recovered. Sa (39), Sc (263).

KLADOGNATHUS TENUIS (Branson & Mehl)

Pl. 1. figs. 1-3, 5, 7, 9, 10.

M element.
Prioniodus scitulus Branson & Mehl, 1941a, p. 173, Pl. 5, figs. 5, 6.
Prioniodus spp. Younquist & Miller, 1949, p. 62, Pl. 101, figs. 9, 10, 14.
Neoprioniodus scitulus (Branson & Mehl). Rexroad, 1957, p. 35, Pl. 2, figs. 22, 26; Globensky, 1967, p. 443, Pl. 55, figs. 22, 26; Koike, 1967 (partim), p. 307, Pl. 4, fig. 3 only; Rhodes, Austin & Druce, 1969, p. 162-163, Pl. 22, figs. 4, 10, 12 (includes synonomy through 1965); Webster, 1969, p. 39, Pl. 7, fig. 13; Igo, 1973, p. 195, Pl. 29, figs. 30, 31; Austin & Husri, 1974, Pl. 12, figs. 12, 13, 17; Lane & Straka, 1974, fig. 34-7; Rice & Langenheim, 1974b, p. 31, Pl. 2, fig. 12.

Sa element.
Hibbardella n. sp. Rexroad, 1957, p. 31, Pl. 1, fig. 19.
Hibbardella milleri Rexroad, 1957, p. 18, Pl. 2, figs. 13-16; Rexroad & Burton, 1961 (partim), p. 1153, Pl. 140, fig. 4 only; Globensky, 1967, p. 441, Pl. 56, fig. 11; Rhodes, Austin & Druce, 1969, p. 113, Pl. 25, figs. 23-25 (includes synonomy through 1965).

Sb element

Lonchodina sp. Branson & Mehl, 1941a, p. 171, Pl. 5, figs. 10, 12.

Lonchodina? spp. Younquist & Miller, 1949, p. 620, Pl. 101, figs. 7, 8.

Genus indeterminate Rexroad, 1957, p. 42, Pl. 4, figs. 19-22; Rexroad, 1958, p. 26, Pl. 5, figs. 1, 2.

Magnilaterella robusta Rexroad & Collinson, 1963, p. 14, Pl. 2, figs. 4, 5, 9, text-figs. 3, 4; Rexroad & Furnish, 1964 (partim), p. 673, Pl. 111, figs. 28, 29, 31, not 27, 30 (= Sd element); Rexroad & Nicoll, 1965, p. 22-23, Pl. 1, figs. 10, 11; Rhodes, Austin & Druce, 1969, p. 148, Pl. 31, figs. 25, 26; Thompson & Goebel, 1969, p. 36, Pl. 2, figs. 13, 14; Webster, 1969, p. 38, Pl. 4, fig. 12; Austin & Husri, 1974, Pl. 15, fig. 7; Lane & Straka, 1974, fig. 34-2; Rice & Langenheim, 1974b, p. 31, Pl. 2, fig. 10.

Magniraterella (sic) sp. Watanabe, 1975, p. 165, Pl. 15, figs. 15, 16.

Sc element.

Ligonodina tenuis Branson & Mehl, 1941a, p. 170, Pl. 5, figs. 13, 14; Globensky, 1967, p. 442, Pl. 56, figs. 13, 14; Rhodes, Austin & Druce, 1969, p. 138, Pl. 31, figs. 4, 16 (includes synonomy through 1965); Reynolds, 1970, p. 11, Pl. 5, figs. 6, 7; Rice & Langenheim, 1974b, p. 30, Pl. 3, fig 2; Ruppel, 1979, Pl. 1, fig. 1.

Ligonodina n. sp. Thompson & Goebel, 1969, p. 34, Pl. 2, figs. 7, 8, 18.

Ligonodina rexroadi Thompson, 1972, p. 36, Pl. 1, figs. 23-25.

Ligonodina spp. Dunn, 1970, p. 335, Pl. 64, figs. 15, 18

Sd element.

Ligonodina? sp. Branson & Mehl, 1941a, p. 171, Pl. 5, fig. 11.

Ligonodina sp. Bischoff, 1957, p. 32, Pl. 5, fig. 7.

New Genus and species Rexroad & Collinson, 1963, p. 21, Pl. 3, fig. 2.

Magnilaterella robusta Rexroad & Furnish, 1964 (partim), p. 673, Pl. 111, figs. 27, 30 only.

Magnilaterella contraria Rhodes, Austin & Druce, 1969, p. 147-148, Pl. 25, figs. 8, 18.

X element.

New Genus? Rexroad, 1957 (partim), p. 41, Pl. 4, figs. 8-11, 13, not 12 (= X element of *K*. sp. A).

Lambdagnathus fragilidens Rexroad, 1958, p. 19, Pl. 6, figs. 10-16; Rexroad & Burton, 1961, p. 1154, Pl. 141, fig. 18; Rexroad & Furnish, 1964, p. 672, Pl. 111, fig.

35; Rexroad & Nicoll, 1965, p. 21, Pl. 2, fig. 9; Thompson & Goebel, 1969, p. 28, Pl. 2, figs. 12, 16.

Multielement.
Kladognathus tenuis (Branson & Mehl). Rexroad, 1981, p. 13, Pl. 2, figs. 19-21, 24-26.

Diagnosis. The Sc element, DE *Ligonodina tenuis*, is diagnostic of this species and the Sa and X elements, DE *Hibbardella milleri* and DE *Lambdagnathus fragilidens* respectively, are also characteristic. The other elements (M, Sb and Sd) appear to be like those of *K. levis*.

Descriptions. In general, the elements, like those of *K. levis*, are robust and not greatly compressed laterally, with the denticles semi-circular in cross-section. The denticles are also discrete, posteriorly inclined or recurved, and subequal to regularly gradational in size. Alternating, smaller denticles may be present on the posterior processes of some elements, but there is usually only one smaller denticle, not several, between larger denticles. Denticles on the posterior process are also uncrowded.

M element. This neoprioniodiform element conforms to the concept of DE *Neoprioniodus scitulus*. The apical cusp is long, laterally compressed, and has a gently convex outer lateral face and a gently convex to nearly straight anterior margin. The cusp widens laterally, becomes thicker at its base and has a short to moderately long, pointed lower projection or anticusp, which has a gently convex to nearly straight lower margin. Continuous with the anticusp and the base of the cusp is a thin, short to moderately long, posterior process which is nearly perpendicular to the apical cusp. The angle formed by the posterior margin of the cusp and the lower margin of the posterior process varies from slightly acute to slightly obtuse. Along the upper edge of the posterior process are small, thin, sharply pointed, subequal denticles. The denticles are erect near the apical cusp, but become more posteriorly inclined, distally away from the cusp.

Branson and Mehl (1941a), Rexroad (1958) and Rhodes _et al._ (1969) gave more detailed descriptions of this element.

Sa element. This element conforms to the concept of DE _Hibbardella milleri._ It possesses a large, posteriorly curved, sharply pointed, semi-circular to ovoid (in cross-section) apical cusp, a short, usually broken, denticulated posterior process, and two lateral processes which are attached at the anterior-most position of the apical cusp or just anterior to the apical cusp. The lateral processes are short and are directed downward and slightly posteriorly. Each lateral process bears three to five unfused denticles which increase slightly in size, distally. The lateral processes are thin but increase in height and become spatulate in shape, also distally.

For more complete descriptions of this element, see Rexroad (1958) and Rhodes *et al.* (1969).

Sb element. This element is essentially a ligonodiniform element which has a greatly enlarged lateral process. It conforms to the concept of DE *Magnilaterella robusta*.

The posterior process is short and bears several small denticles and a larger, posteriorly recurved apical cusp, which in some specimens may be almost as large as some of the denticles of the lateral process. The lateral process is attached to the base of the apical cusp or anterior to it. It is strongly flexed downward and posteriorly, with a concave, outer lateral face. The process is massive, highest in the center and arched, with a concave lower margin. The denticles, usually up to six in number, are nearly straight or erect in lateral view and are slightly recurved posteriorly. The largest, most robust denticles are in the mid-region of the process. A few specimens have on the lateral process a small denticle anterior to the apical cusp, like the Sc element. A prominant attachment scar is found along the lower, inner side of the lateral process.

Rexroad & Collinson (1963) give a more complete description of this element.

Sc element. The element conforms to the concept of DE

Ligonodina tenuis. It has a large, posteriorly curved, sharply pointed, semi-circular (in cross-section) and slightly compressed apical cusp, which forms the anterior end of a short (due to breakage) posterior process. When complete the posterior process is thin, slightly arched, concave aborally, and bears several, short, thin, discrete, posteriorly inclined denticles. In some specimens, similar, smaller denticles occur between larger posterior process-denticles. A short, denticulated, inner-lateral process is attached at the anteriormost portion of the apical cusp. There are at least four denticles on the lateral process; the proximal denticle is directly or marginally anterior to the apical cusp. These denticles are thin, discrete and nearly subequal, although the denticles of the main portion of the process are larger than those proximal to the apical cusp. They are also erect and slightly recurved posteriorly.

See Rexroad (1957, 1958) under DE Ligonodina hamata and Rexroad and Nicoll (1965) under DE L. tenuis for more complete descriptions of this element. Rexroad (1981) and Horowitz and Rexroad (1982) believe that elements of DE L. levis may have also been present in the apparatus of K. tenuis as Sc element dimorphs.

Sd element. This element is a modified ligonodiniform element and is the fourth member of a four element transition series, intermediate in character between the Sb and Sc elements. It is like the Sc element but has a posterior process which is greatly enlarged and bears four to five, large posteriorly recurved denticles. The posterior process is gently bowed with a convex outer margin and a concave lower margin. The apical cusp may be small to equally as large as the posterior process-denticles. It is also posteriorly recurved. Attached to the apical cusp is a short, denticulated inner-lateral process which is directed posteriorly and downward. It has a concave outer margin and in most respects is like the lateral process of the Sc element, although it is usually not attached to the anterior part of the apical cusp and the denticles may be slightly larger than those of that element.

The denticle size in different specimens of this element is variable. Some specimens have small denticles, slightly smaller than those of the apical cusp, on the posterior process and are transitional in shape with the Sc element, while other specimens have very small denticles alternating with larger denticles on the posterior process. A few elements have a small, distinctive denticle anterior to the apical cusp like the Sc element.

For a more complete description of this element see Rexroad and Collinson (1963) under New Genus and new species. It has also been referred to as DE *Magnilaterella contraria* by Rhodes, *et al.* (1969).

X element. The element consists of denticulated anterior, posterior and outer-lateral processes that are joined near the center of the element. It conforms to the concept of DE *Lambdagnathus fragilidens*. The anterior process may be slightly longer than the posterior process; the outer-lateral process is usually the longest of the three. The denticles of the anterior and posterior processes are generally subequal and posteriorly inclined to semi-erect. When viewed from above, the outer-lateral process is nearly perpendicular to the posterior process, or is directed posteriorly to form an acute angle with it. The outer-lateral process is long, directed downward and bowed with a concave lower margin. The denticles on the outer-lateral process are large and subequal, although the middle denticles tend to be larger than denticles at the proximal and distal ends of the process. The basal pit at the junction of the three processes is small and triangular in lower view.

For a more detailed description of this element, see Rexroad (1958) under DE *Lambdagnathus fragilidens*. The element shows variation in the massiveness of the processes and denticles. Small, immature forms have low processes with gracile, anterior and posterior process-denticles, while larger, gerontic forms have higher processes with more robust semi-erect denticles.

Comparisons. For a comparison with elements of K. levis, see the discussion under that species.

Both K. tenuis and K. levis differ from K. sp. A primarily in the nature of the denticulation. Denticles of elements of K. tenuis are semi-circular or ovoid in cross-section and only slightly, laterally compressed. They also tend to be discrete and uncrowded, gently recurved posteriorly and nearly subequal in size, although the posterior process of most elements has a single small denticle alternating with larger denticles. Alternatively, denticles on the processes of elements of K. sp. A are thin, strongly compressed laterally and erect. Also, denticles alternate in size with one to several smaller, crowded denticles alternating with larger denticles.

In general, elements of K. tenuis are more robust and thicker than corresponding elements of K. sp. A, which are thin and strongly compressed. The lower surfaces of the respective elements show this particularly well; the elements of K. sp. A have very thin lower edges unlike elements of K. tenuis.

Remarks. The X element (DE Lambdagnathus fragilidens) is included in the apparatus of K. tenuis for several reasons. The element, particularly the denticulation, is morphologically similar to other elements of K. tenuis and unlike elements of other multielement species. Norby (1976) described the micromorphology of this element as closely similar to that of the Sb and Sc elements. Also, DE L. fragilidens has a stratigraphic range nearly alike the other elements of K. tenuis (Collinson, et al., 1971; Rexroad and Fraunfelter, 1977). Finally, a homologous lambdagnathiform element also clearly belongs in the apparatus of K. sp. A, strengthening the inclusion of DE L. fragilidens in K. tenuis.

Whether the appearance of the X element coincides with the first appearance of the characteristic Sc element (DE L. tenuis) can not be accurately determined here. At the Lindell section, both elements first occur together at the base of the Hillsdale Limestone (Fig. 3). This is not the case at the other sections. At Bishop the X element first occurs in a sample 12.1 meters above the first occurrence of the Sc element (Fig. 4). At Willowton the difference is much smaller; only 2.90 meters separate the first occurrence of these elements (Fig. 5).

Perhaps more intensive sampling of these intervals will nd extend the range of the X element downward. In any case, the first appearance of this characteristic element may more accurately mark the change from K. levis to K. tenuis. If this is true the biostratigraphic significance of this element would be much greater.

The suggestion of Rexroad (1981) that the Sc element DE Ligonodina levis may have been retained in some individuals or populations of K. tenuis after it evolved from K. levis receives some support in this study. In a few samples (notably Bishop samples, B12-B14) Sc elements of K. levis dominate over Sc elements of K. tenuis although the Sa elements (DE Hibbardella milleri) found are dominantly those of K. tenuis. This suggests that some Sc elements characteristic of K. levis also belonged in K. tenuis. At this time, though, this is probably not sufficient evidence for limiting the range of K. levis to beds below those which contain K. tenuis.

Occurrence. Hillsdale Lst. (B, W, L), "Denmar-Gasper" Fm. (B, W), "Ste. Genevieve" Fm. (L).

Material recovered. M (267), Sa (61), Sb (78), Sc (171), Sd (29), X (46).

KLADOGNATHUS SP. A

Pl. 2, figs. 1-15.

M element.

Prioniodus peracutus Hinde. Roundy, 1926 (partim), p. 10, Pl. 4, figs. 7, 8 only.

Neoprioniodus peracutus (Hinde). Scatterday, 1963, p. 104-105, Pl. 2, fig. 21.

?Neoprioniodus peracutus (Hinde). Dunn, 1970, p. 337, Pl. 64, fig. 22.

Prioniodus ligo Hass, 1953, p. 87-88, Pl. 16, figs. 1-3.
Neoprioniodus ligo (Hass). Thompson & Goebel, 1968, p. 37, Pl. 3, fig. 1.
Neoprioniodus erectus Rexroad, 1957, p. 34, Pl. 2, figs. 23, 25.
?*Neoprioniodus scitulus* (Branson & Mehl). Reynolds, 1970 (partim), p. 15, Pl. 3, fig. 14 only.

Sa element.
Hibbardella milleri Rexroad. Rexroad & Burton, 1961 (partim), p. 1153, Pl. 140, fig. 3 only; Lane & Straka, 1974, fig. 34-4.
?*Hibbardella milleri* Rexroad. Rice & Langenheim, 1974b, p. 28, Pl. 1, fig. 20.
Hibbardella fragilis (Rexroad). Scatterday, 1963 (partim), p. 72-73, Pl. 2, fig. 20 only.

Sc element.
Prioniodus peracutus Hinde, 1900 (partim), p. 343, Pl. 10, fig. 21 only.
Hindeodella undata Branson & Mehl, 1941a, p. 169-170, Pl. 5, fig. 3; Hass, 1953, p. 82, Pl. 16, figs. 5-7; Higgins, 1961, Pl. 12, figs. 10-12; Scatterday, 1963, p. 76-78, Pl. 3, fig. 4; Rhodes, Austin & Druce, 1969, p. 127, Pl. 31, fig. 1; Reynolds, 1970, p. 11, Pl. 4, fig. 7; Austin & Husri, 1974, Pl. 15, fig. 6; Metcalfe, 1980, p. 306, Pl. 37, fig. 7.
Hindeodella sp. Branson & Mehl, 1941a, p. 169-170, Pl. 5, fig. 3.
Ligonodina n. sp.? Rexroad & Burton, 1961, p. 1154, Pl. 141, figs. 2-4.
Ligonodina sp. Rexroad & Furnish, 1964, p.673, Pl. 111, fig. 39.
?*Ligonodina craigi* Clarke, 1960, p. 10, Pl. 2, figs. 1, 2.
?*Ligonodina loisae* Clarke, 1960, p. 11, Pl. 2, fig. 3.

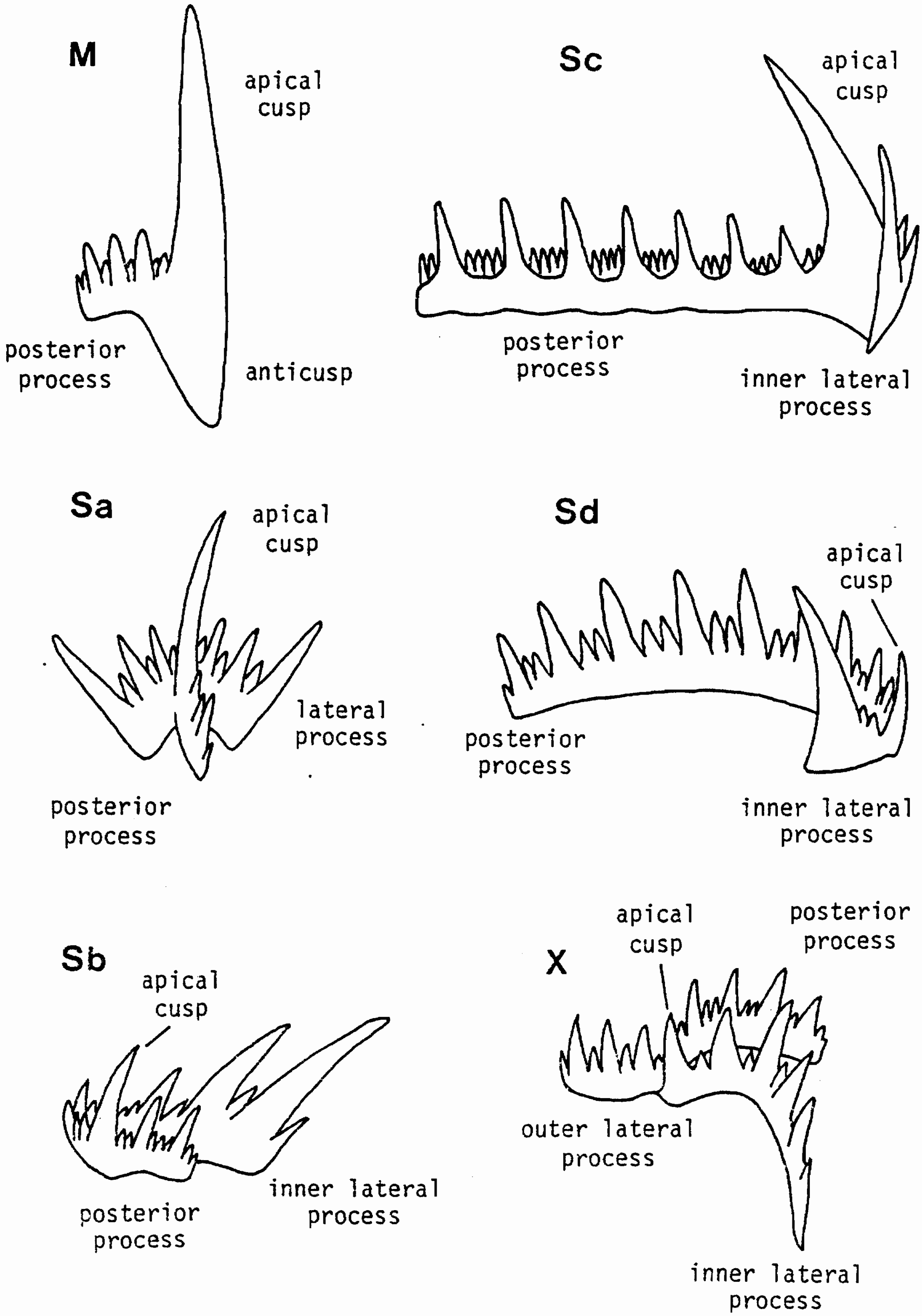
Sd element.
Magnilaterella spp. Rexroad & Collinson, 1963 (partim), p. 17, Pl. 2, fig. 6 only.
Magnilaterella altidens Scatterday, 1963, p. 93-95, Pl. 2, figs. 1-4.
?*Magnilaterella complectens* (Clarke). Higgins, 1976, p. 61-62, Pl. 1, figs. 10, 11.

Descriptions. Elements of this species are characterized by straight, alternating, hindeodellid-like denticles which are erect to slightly inclined posteriorly (see fig. 8). The denticles and processes, particularly the lower surfaces, are thin and strongly, laterally compressed. Most element have a small, subcircular basal pit.

M element. The apical cusp is long, sharply pointed distally, thin and strongly compressed laterally, with a gently concave inner face, a convex outer face and sharp, anterior and posterior margins. The anterior edge is very gently convex, while the posterior edge is gently concave to nearly straight. The apical cusp is extented downward, below the posterior process, as a long, pointed, "plough-shaped" anticusp which is slightly twisted outwards with respect to the distal end of the apical cusp. The anticusp has a gently convex, lower lateral profile and is broader than the apical cusp, where the posterior process is attached.

The posterior process is thin, moderately long in complete specimens and has a gently convex lower margin. From an upper view, the process is bowed, concave inward. Denticulation of the posterior process is hindeodellid-like with alternating tall and short denticles, that are thin, laterally compressed and erect to slighly inclined posteriorly. Proximal to the apical cusp, the denticles are crowded with one small denticle between larger denticles, while distally the denticles become more

Figure 8 : Apparatus composition of *Kladognathus* sp. A. Principal morphological features are labeled.


M
apical cusp
posterior process
anticusp
Sc
apical cusp
posterior process
inner lateral process
Sa
apical cusp
lateral process
posterior process
Sd
apical cusp
posterior process
inner lateral process
Sb
apical cusp
posterior process
inner lateral process
X
apical cusp
posterior process
outer lateral process
inner lateral process

discrete with one to two smaller denticles between larger denticles.

On the lower side of the element, a small subcircular pit is located at the junction of the posterior process and the anticusp. In lateral view the pit is conical. A basal groove extends along the lower edge of the anticusp and the posterior process. Large, gerontic forms have rounded lower edges along the anticusp, with thin, grooved attachment scars at the base.

<u>Sa element</u>. The apical cusp is tall, pointed distally, gently curved posteriorly and strongly compressed laterally. The posterior process is thin and in most specimens incomplete due to breakage. The height of the posterior process decreases markedly away from the apical cusp. The denticles on the posterior process alternate in size, one tall and one short, and are erect to slightly inclined posteriorly.

Two short lateral processes are attached at the anterior margin of the apical cusp. From an upper view the lateral processes are nearly perpendicular to the apical cusp, being directed slightly posteriorly, with very gently convex, outer lateral faces. The anterior margin is also gently convex when viewed laterally. The lateral processes are deep and have wider upper margins than lower margins. From a posterior view the outer and lower margins of the lateral processes form a W-shaped outline. The angle between the outer and lower margin of each process is sharply convex.

The denticles on each lateral process alternate in size, with the outermost denticle as the largest. In most specimens, one small denticle or an incipient denticle is directly anterior to the apical cusp. The denticles usually number from five to seven on each process, in addition to the small anterior denticle, although a few specimens only have two denticles on each process.

On the lower side the very small pit is at the junction of the lateral and posterior processes below the apical cusp. Thin basal grooves extend from the pit along the thin lower edge of each process.

The element consists of a small posterior process and a more massive, inner-lateral process which bears larger denticles. This lateral process is attached to the anterior margin of the apical cusp.

The posterior process resembles the posterior process of the Sc element, although in none of the present specimens was this process complete, due to breakage. The process is thin and bears alternating, hindeodellid-like denticles, with two to three small denticles separated by larger denticles. The apical cusp, which is situated at the anterior end of the posterior process, is long, laterally compressed, pointed and recurved.

From an upper view the inner-lateral process is recurved so that it is nearly parallel with the posterior process. In lateral view the proximal, denticulated, upper edge of the process projects farther anteriorly of the apical cusp, than the lower edge of the process.

The denticles of the proximal portion of the process, marginal to the apical cusp, are erect to slightly inclined posteriorly, crowded and short. Some of these denticles may be almost as large as the apical cusp. Distally, the denticles become larger and more inclined posteriorly. The larger denticles are broadly based with narrow tips, laterally compressed, nearly straight and posteriorly inclined. Large denticles are separated by single denticles which are noticeably shorter and narrower.

The basal pit is very small and ovoid to semicircular. Thin basal grooves extend from the pit along the lower edge of each process.

Sc element. This ligonodiniform-hindeodelliform element is commonly known as *Hindeodella undata* Branson and Mehl.

The posterior process is thin, of low height, long and has hindeodellid-like denticulation, consisting of tall, thin denticles which are slightly higher than the process, commonly separated by three to six, smaller, erect denticles. From a lower view the distal part of the process is laterally undulatory with the process crimped inward at the larger denticles and convex outward at the smaller denticles. Although the posterior process is usually broken off proximal to the cusp, the hindeodellid characteristics of the process can be seen when light is transmitted through the basal posterior part of the apical cusp, showing the white matter of the early formed denticles.

The apical cusp is long, thin and laterally compressed, distally pointed, broadly based and gently recurved posteriorly to erect. In large forms at the base of the apical cusp, lineated attachmant scars are found on both the inner- and outer-lateral sides. A short, deep inner-lateral process is attached to the anterior margin of the apical cusp. The lateral process projects inward and posteriorly, and has a convexly curved, outer-lateral surface when viewed from above. The process is wider on the upper margin than the lower margin and the basal margin extends only a short distance below the lower margin of the posterior process. The lateral process bears alternating large and small denticles, with the largest denticle at the distal end of the process. Viewed from the posterior, this large denticle forms a small acute angle with the apical cusp and posterior process.

Large denticles on the inner-lateral process are separated by one to two smaller denticles.

The basal pit is small and semicircular to trough-shaped. It may be only slightly larger than the thin basal grooves that extend along the lower edges of the posterior and inner-lateral processes.

Sd element. This element consists of a long, denticulated posterior process and a short, inner-lateral process which is dominated by a very large, laterally compressed denticle at the distal end (see Fig. 8).

The posterior process is thin and very long, although in most specimens, recovered herein, this process is incomplete due to breakage. Anteriorly, proximal to the apical cusp, the outer margin of the posterior process is convex, but distally the process becomes straighter. Denticles on the posterior process are erect to slightly inclined posteriorly. These denticles alternate in size with large denticles separated by two to three, smaller denticles. All denticles are laterally compressed.

The apical cusp is slightly taller than the larger denticles of the posterior process. It is curved posteriorly but not in the same plane as the posterior process. Instead, it is directed toward the space between the posterior and lateral processes.

Attached to the apical cusp is a short inner-lateral process which is directed inward, posteriorly and slightly downward. The lateral process is dominated by a large, strongly compressed cusp-like denticle which is at the distal end of the process. This denticle is broadly based with a pointed tip which is twisted slightly, so that its inner surface faces more posteriorly than the base of the denticle. In cross-section this denticle is lens-like with a convex, outer-lateral surface and a concave to nearly flat, inner-lateral surface. Grooved atachment surfaces are found at the base of the denticle on the inner- and outer-lateral sides. One or two tiny denticles are found between the apical cusp and the large denticle on the inner-lateral process.

The basal pit is small and subcircular to fusiform in shape. Thin basal grooves extend from the pit to the distal ends of the posterior and lateral processes. Below the large denticle on the inner-lateral process, the groove may be slightly expanded.

X element. This element is lambdagnathiform in character and consists of three centrally attached processes, one posterior and two lateral.

The posterior process is thin, but tall. In larger elements it is more massive. The outer-lateral margin is strongly laterally recurved at the anterior end but distally it is straighter. Denticles are straight, erect to slightly inclined posteriorly, crowded and hindeodellid-like, with larger denticles separated by one to two smaller denticles. In larger, more massive elements the larger denticles often crowd out and overgrow smaller denticles. In some large elements the posterior process is laterally undulatory like the posterior process of the Sc element, with the larger denticles crimped inward with respect to the smaller denticles.

The outer-lateral process is shorter than the posterior process and bears hindeodellid-like denticles. The orientation of the outer-lateral process, with respect to the posterior process varies. It may be directed partially anteriorly, or outwardly, perpendicular to the posterior process, or it may be curved posteriorly, essentially parallel to the posterior process. In small immature elements the outer-lateral process is attached to the lateral edge of the apical cusp, while in larger, mature specimens the process is attached along the posterior margin of the apical cusp. In these specimens a small, triangular denticle is situated just posterior to the apical cusp, close to this junction.

The apical cusp is compressed, slightly recurved posteriorly and may be as tall as the larger process-denticles. It is usually larger than the denticles proximal to it. Although compressed, it has a convex outer face and a flat inner face.

The inner-lateral process is attached along the anterior margin of the apical cusp. The outer-lateral surface of this process is gently convex outward, proximal to the apical cusp, but the main part of the process is concave outward. The process may be nearly perpendicular to, or recurved posteriorly so that it is nearly parallel to, the posterior process. The inner-lateral process tends to be slightly more massive than the other processes and bears larger denticles. It is usually directed slightly downward with respect to the posterior process. The denticles are erect, broad-based and triangular in profile with pointed tips. On most specimens the denticles follow the hindeodellid pattern, but on larger specimens, denticles are subequal in size. The denticles usually are slightly recurved posteriorly so that their outer faces are gently convex.

The basal pit is semi-circular and slightly expanded and is larger than the pits of the other elements of this species. Thin basal grooves extend from the pit to the distal ends of each process.

Comparisons. Elements of *K.* sp. A have several similar morphological characters that distinquish them from similar elements of the *K.* *levis* - *K.* *tenuis* group. Elements of *K.* sp. A are characterized by thin, laterally compressed processes and denticles, unlike elements of *K. levis* and *K. tenuis* in which these features are broader and more robust. In particular, the lower attachment surfaces of elements of *K.* sp. A are very thin. The denticles of *K.* sp. A, particularly those on the posterior process, are crowded, straight, erect to slightly inclined posteriorly, and alternate in size with large denticles regularly separated by one or several smaller denticles. Alternatively, denticles on the posterior processes of homologous elements of *K. levis* and *K. tenuis* are uncrowded, and inclined or recurved posteriorly. Denticles on the lateral processes of these elements are subequal to regularly increasing in size, not regularly alternating in size. Denticles on the posterior processes of *levis*-*tenuis* elements usually do alternate in size, but have only one very small denticle between larger denticles. Another feature distinctive to the Sc and X elements of *K.* sp. A (possibly the Sa and Sb elements as well, although present specimens of these elements are too incomplete to show this feature), is the posterior process which becomes laterally undulatory, distally away from the apical cusp. The Sa and Sc elements of *K.* sp. A also have much shorter and deeper lateral processes than the corresponding elements of *K. levis* or K. tenuis.

M elements of *K.* sp. A and *K. levis*-*tenuis* (DE

Neoprioniodus scitulus) are similar and may be easily confused, particularly if the specimens are poorly preserved. In addition to the differences in denticulation and element thickness, there are several other distinquishing features of these elements. The posterior process of the M element of *K.* sp. A is usually more strongly curved laterally than the posterior process of the M element of *K. levis* or *K. tenuis*, which tends to be straighter or only slightly curved laterally. Also, the anticusp in M elements of *K.* sp. A tends to be longer than the anticusp of M elements of the latter group.

The lambdagnathiform X element also exhibits several major differences from the homologous X element *K. tenuis*. Instead of bearing an anterior process which is continuously in line with the posterior process as in the X element of *K. tenuis*, this element has an outer-lateral process which, in only a few specimens, is directed anteriorly in line with the posterior process. Usually this process is directed outwardly, nearly perpendicular to the anterior part of the posterior process, or posteriorly, parallel to the posterior process. Also the basal pit is subcircular while X elements of *K. tenuis* exhibit triangular pits.

Additional discrete elements such as DE *Neoprioniodus peracutus*, DE *Kladognathus clarensis*, DE *Kladognathus* macrodentatus and DE Magnilaterella complectens have been described from Upper Mississippian rocks (Upper Dinantian-Namurian) of the British Isles and are similar to the M and Sd elements of K. sp. A as described herein. These British elements probably belonged to one or more different, although closely related, species of Kladognathus, which inhabited a different Carboniferous conodont province similar to that suggested by Higgins1(1981a).

DE Neoprioniodus peracutus is very similar the M element of K. sp. A. The two element are nearly identical except that the denticles on the posterior process of illustrated specimens of DE N. peracutus are subequal and do not regularly alternate in size (see Hinde, 1900; Clarke, 1960; Rhodes et al., 1969; and Higgins, 1975). Some discrete elements illustrated North American workers as DE Neoprioniodus peracutus (Scatterday, 1963 and Dunn, 1970) do appear to have hindeodellid-style denticulation on the posterior process. These elements are probably synonomous with the M element of K. sp. A.

Two discrete elements, DE Kladognathus clarensis and DE Kladognathus macrodentatus, described by British workers are similar to the Sd element. K. clarensis Collinson and Druce (Rhodes et al., 1969, nom. nud.) posseses a hindeodellid-style posterior process and a short, inner-lateral process with a large cusp-like denticle like that element, but it also has a short anterior process not found on any Sd element of *K.* sp. A. Elements of DE *Kladognathus macrodentatus* (Higgins, 1961) illustrated by Rhodes *et al.* (1969) bear a close resemblence to DE *K. clarensis* and the Sd element. This element also has a short anterior process. Specimens of DE *K. macrodentatus* illustrated by Higgins (1961, 1975), though, differ from those of Rhodes *et al.* (1969), by having a longer, inner-lateral process which is not dominated by a large cusp-like denticle, but which does have several, smaller hindeodellid-like denticles.

DE *Magnilaterella complectens* as originally described and illustrated by Clarke (1960) and later by Rhodes *et al.* (1969), is also similar to the Sd element, but it is probably a different element. This element posseses several, small denticles posterior to the massive denticle on the inner-lateral process, while no denticles are found in this position on the Sd element of *K.* sp. A. This large cusp-like denticle of DE *M. complectens* also tends to be more robust and not as laterally compressed as the corresponding denticle of the Sb element of *K.* sp. A. Overall, DE *M. complectens* appears closer in morphological affinities to elements of *K. tenuis* than elements of *K.* sp. A.

Remarks. Although the reconstruction of this apparatus was based primarily on the morphological similarities between the component elements, and the similarities of these elements to homologous elements of K. levis and K. tenuis, there is other evidence to support the reconstruction presented here. Norby (1976) illustrated (Pl. 10, figs. 3a,b; Pl. 19, fig. 4) a natural conodont assemblage from the Late Chesterian Tyler Formation of central Montana, which may be this species or a closely related one. He tentatively identified the assemblage as Hibbardella? sp. (Appendix A, p. 285). Clearly visible in a X-ray radiograph of the assemblage (Pl. 10, fig. 3a) are the anterior portions of several Sc elements nearly identical in profile to the Sc elements of this species. Also seen, more clearly in a photograph of the same assemblage (Pl. 19, fig. 4), are several, long, laterally undulatory, hindeodellid-like, distal ends of posterior processes of this element. Another element, seen in the radiograph, is clearly an M element, which Norby refers to DE Neoprioniodus peracutus. It bears thin, erect denticles on the posterior process and has a long anticusp like the M element of K. sp. A. Finally, two elements that Norby believed were DE Magnilaterella are unclearly seen in the photograph and the radiograph. One of these, seen in the radiograph, is similar to the Sd element in possessing a long process which has a concave lower margin and tall, thin hindeodellid-like denticles.

At this time, the name of this species of Kladognathus is left in open nomenclature. The Sc element, DE Hindeodella undata, was the first element included in this species to be described (Branson and Mehl, 1941a); K. undata may be the valid name. Unfortunately none of the other elements were found or described from the Caney Shale type-material. In Great Britain, DE H. undata is associated with elements (DE N. peracutus and DE K. macrodentatus) which are slightly different from other elements included in K. sp. A, indicating that the Sc element was probably shared vicariously by several closely related species. Because of this likelihood, until the Caney Shale conodont fauna is reinvestigated and redescribed, a specific name is not chosen.

Occurrence. Little Valley Fm. (L), Hillsdale Lst. (B, W, L), "Denmar-Gasper" Fm. (B, W) and "Ste. Genevieve" Fm. (L).

Material recovered. M (128), Sa (19), Sb (11), Sc (111), Sd (20), X (43).

Superfamily POLYGNATHACEA Bassler, 1925

Family ANCHIGNATHODONTIDAE Clarke, 1972

Genus HINDEODUS Rexroad and Furnish, 1964

Hindeodus Rexroad & Furnish, 1964, p. 671.
Anchignathodus Sweet, 1970, p. 221.

Type species. *Spathognathodus cristula* Youngquist & Miller, 1949.

Remarks. *Hindeodus* is a long ranging genus known from rocks of Late Mississippian to Triassic age. For further discussion, see Clark (1981), Merrill (1973), Rexroad and Thompson (1979) and Sweet (1976, 1977).

HINDEODUS CRISTULA (Youngquist & Miller)

Pl. 3, figs. 1, 2, 4-8.

Pa element.

Spathognathodus cristula Youngquist & Miller, 1949, p. 621, Pl. 101, figs. 1-3; Rexroad, 1957, p. 38, Pl. 3, figs. 16, 17; Rexroad, 1958, p. 25, Pl. 6, figs. 3, 4; Rexroad & Burton, 1961, p. 1156, Pl. 141, fig. 9; Rexroad & Furnish, 1964, p. 674, Pl. 111, fig. 15, Rexroad & Nicoll, 1965, p. 26, Pl. 1, figs. 1, 2; Globensky, 1967, p. 447, Pl. 57, figs. 15, 16; Thompson & Goebel, 1968, p. 42, pl. 4, figs. 13, 15.

Spathognathodus cristulus Youngquist & Miller. Rhodes, Austin & Druce, 1969, p. 227-228, Pl. 8, figs. 14-18; Dunn, 1970, p. 339, Pl. 64, fig. 30; Reynolds, 1970, Pl. 3, fig. 7; Rhodes & Austin, 1971, Pl. 2, fig. 12; Merrill, 1973, p. 304-305, Pl. 3, fig. 62; Austin & Husri, 1974, Pl. 5, fig. 6; Pl. 8, fig. 1; Ruppel, 1979, Pl. 2, figs. 17, 18.

?*Spathognathodus* cf. *S. cristulus* Youngquist & Miller. Rhodes *et al.*, 1969, p. 233-234, Pl. 8, figs. 7, 8, 12, 13; Austin & Husri, 1974, Pl. 8, fig. 2.

Spathognathodus minutus? (Ellison). Clarke, 1960, p. 20, Pl. 3, figs. 14, 15.

?*Spathognathodus* sp. A Rexroad, 1957, p. 38-39, Pl. 3, fig. 25.

?*Spathognathodus* n. sp.? Thompson & Goebel, 1968, p. 43-44, Pl. 4, figs. 24, 28.

Anchignathodus cristulus (Youngquist & Miller). Tynan, 1980, p. 1300, Pl. 2, fig. 10.

Pb element.

Ozarkodina curvata Rexroad, 1958, p. 24, Pl. 4, figs. 1-3; Rexroad & Burton, 1961, p. 1156, Pl. 141, figs. 13, 14; Rexroad & Collinson, 1963, p. 19, Pl. 2, fig. 11; Rexroad & Furnish, 1964, p. 674, Pl. 111, figs. 10, 11; Rexroad & Nicoll, 1965, p. 25, Pl. 2, figs. 1, 2; Globensky, 1967, p. 446, Pl. 56, fig. 20; Rhodes *et al.*, 1969, p. 168, Pl. 127, fig. 6; Webster, 1969, p. 42, Pl. 7, fig. 10; Tynan, 1980, Pl. 2, fig. 16.

?*Ozarkodina curvata* Rexroad. Rice & Langenheim, 1974b, p. 32, Pl. 2, fig. 16.

Hindeodus sp. Rhodes, Austin and Druce, 1969, p. 130, Pl. 22, figs. 17-20.

M element.

Neoprioniodus camurus Rexroad, 1957, p. 33, Pl. 2, figs. 18-20; Rexroad, 1958, p. 2, Pl. 5, figs. 5, 6; Rexroad & Burton, 1961, p. 1155, Pl. 140, fig. 11; Rexroad & Furnish, 1964, p. 674, Pl. 111, fig. 34; Rexroad & Nicoll, 1965, p. 23, Pl. 2, figs. 19, 20; Globensky, 1967, p. 443, Pl. 55, fig. 19; Thompson & Goebel, 1968, p. 37, Pl. 3, fig. 8, 14; Austin & Husri, 1974, Pl. 15, fig. 15.

Neoprioniodus cf. *camurus* Rexroad. Rhodes, Austin & Druce, 1969, p. 167, Pl. 22, figs. 1-4.

?*Neoprioniodus* cf. *N. camurus* Rexroad. Webster, 1969, p. 9, Pl. 8, fig. 13.

Synprioniodina denticamura Rexroad & Liebe, 1962, p. 513, text-fig. 2; Rexroad & Furnish, 1964, p. 675, Pl. 111, fig. 34; Rexroad & Nicoll, 1965, p. 27, Pl. 2, figs. 16, 17.

?*Synprioniodina denticamura* Rexroad & Liebe. Webster, 1969, p. 50, Pl. 8, fig. 16.

Sa element.

Trichonodella imperfecta Rexroad, 1957, p. 41, Pl. 4, figs. 4, 5; Rexroad, 1958, p. 26, Pl. 4, fig. 6.

Elsonella? imperfecta (Rexroad). Rexroad & Burton, 1961, p. 1152, Pl. 141, fig. 1.

Hindeodus imperfectus (Rexroad). Rexroad & Furnish, 1964, p. 672, Pl. 111, figs. 13, 14; Rexroad & Nicoll, 1965, p. 20, Pl. 2, fig. 11; Rhodes, Austin and Druce, 1969, p. 129, Pl. 31, fig. 8; Rice & Langenheim, 1974b, p. 29, Pl. 2, fig. 4.

Sb element.

Falcodus? alatoides Rexroad & Burton, 1961, p. 1152, Pl. 140, fig. 8.

Hindeodus alatoides (Rexroad & Burton). Rexroad & Furnish, 1964, p. 672, Pl. 111, figs. 18, 19: Rexroad & Nicoll, 1969, p. 20, Pl. 2, fig. 10; Globensky, 1967, p. 442, Pl. 55, fig. 8, Rice & Langenheim, 1974b, p. 29, Pl. 2, fig. 1.

Sc element.
Hindeodella spp. Rexroad, 1957 (partim), p. 32, Pl. 3, fig. 2 only.
Hindeodella spp. Rexroad & Furnish, 1964, p. 671, Pl. 111, fig. 12.
Hindeodus alatoides (Rexroad & Burton). Rhodes, Austin and Druce, 1969, p. 129, Pl. 31, figs. 7, 10.

Multielement.
Ozarkodina cristula (Youngquist & Miller). Norby, 1976, p. 158-168, Pl. 15, figs. 1-4, 9-12; Pl. 16, figs. 1-8.
Hindeodus cristula (Youngquist & Miller). Rexroad, 1981, p. 10, Pl. 2, figs. 1, 2.
Hindeodus cristulus (Youngquist & Miller). Sweet, 1977, p. 209-214, Pl. 1, figs. 1-6; von Bitter & Plint-Geberl, 1982, p. 200, Pl. 5, fig. 12; Pl. 6, figs. 12, 17; Pl. 7, fig. 21.

Diagnosis. The apparatus is seximembrate and consists of spathognathodiform Pa elements, ozarkodiniform Pb elements, neoprioniodiform or synprioniodiform M elements and a three element, symmetry-transition series of hindeodiform Sa and Sb elements and hindeodelliform Sc elements.

The diagnostic Pa element (DE *Spathognathodus cristula*) is characterized by a prominant, large anterior denticle with an undenticulated anterior margin, and a slightly asymmetrical basal cavity which takes up the posterior two-thirds of the length of the lower surface. The angulate Pb element (DE *Ozarkodina curvata*) is strongly arched, flexed inward and has a large, laterally compressed apical cusp. The M element (DE *Neoprioniodus* *camurus* or *Synprioniodina denticamura*) is usually delicate and is characterized by a long, straight apical cusp (which may have several small notches or denticles on the anterior edge) with a corresponding, straight lower projection and a thin, denticulated process which joins the apical cusp at a large obtuse angle. The symmetry-transition series of elements consists of: 1) a symmetrical, alate Sa element (DE *Hindeodus imperfectus*) that lacks a posterior process and has a short apical cusp at midlength; 2) a bipennate Sc element with a short, downcurved, denticulated anterior process, a posteriorly inclined apical cusp and a long, denticulated posterior process; and 3) an asymmetrical, digyrate Sb element (DE *Hindeodus alatoides*), transitional in form between the Sa and Sc elements.

Descriptions. See Norby (1976) and Sweet (1977) for more detailed descriptions of the elements that make up this apparatus.

Comparisons and Remarks. Elements of *H. cristula*, found in this study, differ little from previously described elements, except for the differences cited below.

One Pa element (Pl. 3, fig. 2) from the Hillsdale Limestone (Bishop, B10) has minor denticulation anterior to the apical cusp, much like the Pa elements of the younger (Latest Mississippian to Pennsylvanian) species, H. minutus (Ellison). Rexroad (1981) recently reported similar elements from mid-Chesterian rocks of the Illinois Basin.

A few Pb elements exhibit variation from previously described specimens by having a very short, downcurved anterior process and a longer, straight posterior process, like the specimens described and illustrated by Rhodes et al. (1969, p. 130, Pl. 22, figs. 17-20) as Hindeodus sp. In this respect, these Pb elements appear transitional with Sc elements and may represent a fourth member of the symmetry-transition series.

Only a few M elements have minor denticles anterior of the apical cusp in the form of DE Synprioniodina denticamura.

Sa, Sb and Sc elements are like those of previous workers, but included with Sc elements, herein, are small forms which resemble elements included by Norby (1976) in the Sc element-position of his Pandorinellina (="Spathognathodus") campbelli. In samples which contain both H. cristula and "S." campbelli, elements which fit Norby's description for Sc elements of the latter could not be distinguished from juvenile Sc elements of the former. For this reason these elements were all treated as Sc elements of H. cristula.

The Pa element is closely similar to The Pa element of _Hindeognathus laevipostica_, but the two elements can be easily distinquished by differences in the respective basal cavities. The basal cavity of the latter is distinctive because of its widely flaring, outer-lateral margin and its restriction to the medial portion of the lower surface. The basal cavity of the former is only slightly asymmetrical and extends to the posterior tip of the lower surface.

Occurrence. Hillsdale Lst. (B, W, L), "Denmar-Gasper" Fm. (B, W) and "Ste. Genevieve" Fm. (L).

Material recovered. Pa (125), Pb (26), M (38), Sa (8), Sb (21), Sc (50).

Genus HINDEOGNATHUS n. gen.

Type species. _Polygnathus scitulus_ Hinde, 1900.

Diagnosis. The skeletal apparatus is septimembrate (it may have fewer elements) and consists of Pa, Pb, Sa and Sb -Sb elements. The Pa element is scaphate and spathognathodiform. Traditionally, this element is of the form of DE _Spathognathodus scitulus_ or DE _S. penescitulus_. The Pb element is angulate, ozarkodiniform and in discrete element taxonomy is comparable to _Ozarkodina laevipostica_ The Sa and Sb elements are all apatognathiform; the Sa element is symmetrical while the four distinctive Sb elements are all asymmetrical and differ from one another in the nature of their process denticulation.

Derivation of name. The genus is named for Dr. George Jennings Hinde who originated the multielement concept of conodont species and initially described elements of the type species of *Hindeognathus*.

Remarks. Rexroad and Thompson (1979) suggested the grouping of elements, under the multielement genus *Apatognathus*, which form the basis of this apparatus reconstruction. The lines of evidence used, herein, to reconstruct the apparatus of *Hindeognathus* are as follows: 1) a fused assemblage from the Lower Carboniferous (Dinantian) of Great Britain, as reported by Rhodes and Austin (1969); 2) the mutual occurrence and similar ranges of the described discrete elements, as reported from published and unpublished sources, and herein; 3) elimination of co-occurring elements which belong to different multielement taxa; and 4) morphological similarities of the component elements.

Fused assemblage. Rhodes and Austin (1969) reported the occurrence of a fused conodont assemblage which consisted of DE *Spathognathodus scitulus* and apatognathiform elements. The assemblage was recovered from a limestone bed of the Avonian (Dinantian) D zone at the Avon Gorge, Bristol, England. The unit is shown by Rhodes *et al.*, (1969) to be correlative with the upper St. Louis

Limestone of the Mississippi Valley region. One element of DE S. scitulus and four apatognathiform elements make up the assemblage. In addition, several isolated apatognathiform elements and an unidentifiable hindeodelliform element were found in the same sample. No other isolated elements were found. The apatognathiform elements are not readily identifiable although two resemble DE Apatognathus chaulioda Varker and DE Apatognathus cuspidata Varker, respectively. The authors interpret this assemblage as a natural one and not an artifact of preservation.

Mutual occurrence and similar ranges of the component elements. A consistant association of the elements, DE Spathognathodus scitulus, DE Ozarkodina laevipostica and DE Apatognathus spp. from rocks of early Late Mississippian age is well documented, as noted by Rexroad and Thompson (1979). These elements have closely similar, startigraphic ranges and often occur together, in abundance, in the same samples.

In North America these elements are the basis for recognizing the Meramecian "Apatognathus" scalenus - Cavusgnathus zone (Collinson, Rexroad and Thompson, 1971). The same assemblage has also been documented by Scatterday (1963) from southwestern Ohio; Thompson and Goebel (1968) from Kansas; MacGill (1973) from east-central Kentucky;

Horowitz, Mamet, Neves, Potter and Rexroad (1977) from central Tennessee; and von Bitter and Plint-Geberl (1982) from southwestern Newfoundland.

The association is also documented from correlative rocks elsewhere. From Great Britain, Rhodes and Austin (1969) note in their discussion of the fused assemblage that in areas where these elements are found (localities of Rhodes *et al.*, 1969) DE *S. scitulus* and DE *Apatognathus* spp. have similar ranges and occur frequently together in the same samples. The range charts of Rhodes *et al.* also show that the stratigraphic range of DE *Ozarkodina laevipostica*, although shorter than the other associated elements, always occurs within the range of these elements. The association is also supported by the range data of Aldridge, Austin and Husri (1969) from North Wales. In addition, Nicoll (1980), in a study of the Late Devonian *Apatognathus*, implied that this association also occurred in Lower Carboniferous (Visean) rocks of Western Australia.

From the present study area, the assemblage is found at Bishop and Lindell. The correlation is especially strong at the Bishop section where the elements, DE *S. scitulus*, DE *O. laevipostica* and DE *Apatognathus* spp. have nearly identical ranges and occur in abundance together (see Appendix B, Table 3). At the Lindell section the occurrences are less frequent, but again the stratigraphic range and the respective maximum abundance of each element are very similar. Alternatively, at the Willowton section only conodonts younger than those of the "Apatognathus" scalenus - Cavusgnathus zone have been found except for several unidentifiable apatognathiform elements (see Hindeognathus spp. below) that occur in one sample (W24) high in the "Denmar-Gasper" Formation. In this sample no Pa or Pb elements were found.

Elimination of co-occurring elements of other well documented multielement taxa. If co-occurring elements which belong to well established multielement genera are removed from consideration, then the reconstruction of the apparatus of Hindeognathus is greatly strengthened. In samples that contain the assemblage under consideration, most other elements can be confidantly assigned to different multielement genera: Cavusgnathus (von Bitter, 1972; Norby, 1974, 1976; Rexroad, 1981; see also Baesemann, 1973, under Adetognathus), Taphrognathus (Rexroad and Collinson, 1963; Austin, 1974; and von Bitter and Plint-Geberl, 1982), Gnathodus (Schmidt and Muller, 1964; Norby, 1974, 1976; and Higgins, 1982), Hindeodus (Sweet, 1977; Rexroad, 1981; and Horowitz and Rexroad, 1982) and Kladognathus (Rexroad, 1981; Horowitz and Rexroad, 1982).

Discrete elements, recovered herein, that have unknown apparatus affinities are Pa elements of *Rhachistognathus* cf. *R. muricatus* and the new discrete element taxa, DE *Lonchodina* sp. A and DE *Lonchodina* sp. B. The first elements are rare in this study and probably range from Meramecian to uppermost Chesterian strata (Lane and Straka, 1974; Tynan, 1980), far above reported North American occurrences of elements assigned to *Hindeognathus*. DE *Lonchodina* sp. A and sp. B have been found only at the Lindell section, restricted to the basal two meters of the Hillsdale Limestone (samples L1 and L1.5). Since these elements are rare, have very limited stratigraphic ranges and have not been reported elsewhere, except by Rexroad and Collinson (1963, see their *Lonchodina* sp.), I believe they do not belong to an apparatus which contains any elements assigned here to *Hindeognathus*.

Morphological similarities. Further evidence in reconstructing this apparatus are morphogical similarities between the component elements. All of the apatognathiform elements are similar in the degree of arching of processes, the size of minor denticles and the nature of the basal pit. In addition, the Pb element is apatognathiform-like; strongly arched, with a strongly downturned anterior process, and a large, costate apical cusp. The outer-lateral lip of the basal pit is slightly expanded much like the corresponding structure of the Pa element, although the latter structure is much expanded. Large, gerontic Pa elements are often strongly arched or bowed with a concave aboral margin, much like the Pb element.

This multielement apparatus is given a new name, Hindeognathus, in honor of Dr. George Jennings Hinde who first described elements of the type species (Hinde, 1900). A new generic name is chosen because at present there are no other available names for the apparatus. The names of the discrete element genera found in the apparatus, Ozarkodina, Spathognathodus and Apatognathus, are all preoccupied.

Rexroad and Thompson (1979) discussed this problem and believed that because Ozarkodina and its junior synonym Spathognathodus belonged to an earlier, Silurian apparatus with a different element composition, Apatognathus was the only logical generic name. Unfortunately, as they recognized, the type species DE Apatognathus varians Branson and Mehl, which is Late Devonian in age, could not be related phylogenetically to younger Late Mississippian apatognathids. The record of Early Mississippian apatognathiform elements is skimpy (Nicoll, 1980), and most workers have suggested that

Mississippian forms were homeomorphs of older, Late Devonian elements (Scott and Collinson, 1961; Collinson, Scott and Rexroad, 1962; Rexroad and Collinson, 1963; and Varker, 1967).

Nicoll (1981) recently reconstructed the multielement species *Apatognathus varians* Branson and Mehl (with two subspecies) from Upper Devonian rocks of Western Australia. He believed that Devonian and Mississippian forms were unrelated. Apatognathiform elements of the Devonian genus differ from their younger counterparts by having cyclical en echelon denticulation patterns. Also, Pa and Pb elements of the Devonian apparatus are considerably different from the spathognathodiform Pa and ozarkodiniform Pb elements of *Hindeognathus*. The poor stratigraphic record of Lower Mississippian apatognathids and the differences in these apparatuses seems to preclude a phylogenetic relationship between *Apatognathus* and this new genus. Thus, *Apatognathus* is inappropriate as the name of this new apparatus and *Hindeognathus* is chosen in its place.

A recently described, Osagean conodont species, *Cudotaxis priceslingi* Chauff (1981), has an apparatus similar to *Hindeognathus* and may be an ancestor of this genus. *Cudotaxis* has Pa and Pb elements of a similar form to Pa and Pb elements of *Hindeognathus* and, also, apatognathiform Sa and Sb elements.

HINDEOGNATHUS LAEVIPOSTICA (Rexroad & Collinson)

Pl. 4, figs. 1-10, 12, 13.

Pa element.

Polygnathus scitulus Hinde, 1900 (partim), p. 343, Pl. 9, figs. 9, 11 only.

Panderodella scitula (Hinde). Holmes, 1928 (partim), p. 16, Pl. 6, figs. 26, 28 only.

Spathognathodus scitulus (Hinde). Clarke, 1960, p. 21, Pl. 3, figs. 12, 13; Rexroad & Collinson, 1963, p. 20, Pl. 2, figs. 14, 19, 29-31; Scatterday, 1963, p. 112-113, Pl. 1, fig. 19; Globensky, 1967, p. 447,Pl. 56, figs. 7, 17, 21; Thompson & Goebel, 1968, p. 43, Pl. 4, figs. 26, 27; Rhodes, Austin & Druce, 1969, p. 232, Pl.8, figs. 9-11; Reynolds, 1970, p. 15, Pl. 3, fig. 8; MacGill, 1973, p. 45-46, Pl. 2, figs. 8-10; Austin & Husri, 1974, Pl. 8, fig. 6; Rice & Langenheim, 1974b, p. 34, Pl. 3, figs. 9-11; Austin & Mitchell, 1975, p. 53, Pl. 2, fig. 26; Ruppel, 1979, Pl. 2, figs. 15, 16; Metcalfe, 1980, Pl. 38, fig. 7; Higgins & Varker, 1982, p. 164-165, Pl. 19, fig. 14; von Bitter & Plint-Geberl, 1982, p.200, Pl. 6, figs. 1-3.

Pb element.

Ozarkodina laevipostica Rexroad & Collinson, 1963, p. 19, Pl. 1, figs. 1-6; Scatterday, 1963, p. 110, Pl. 4, fig. 6; Globensky, 1967, p. 446, Pl. 56, figs. 1, 2; MacGill, 1973, p. 43, Pl. 1, fig. 23, von Bitter & Geberl, 1982, p. 202, Pl. 6, fig. 4.

?Ozarkodina cf. O. laevipostica Rexroad & Collinson. Rexroad & Collinson, 1965, p. 13, Pl. 1, fig. 12; Thompson & Goebel, 1968, p. 40-41, Pl. 3, figs. 21, 24.

Prioniodina laevipostica (Rexroad & Collinson). Rhodes, Austin & Druce, 1969, p. 195, Pl.28, figs. 11, 12.

?Apatognathus minutus Austin & Husri, 1974, p. 51, Pl. 10, figs. 1, 2, 5, 9.

Sa element.

Apatognathus? porcata (Hinde). Globensky, 1967 (partim), p. 438, Pl. 56, fig. 24 only.

?Apatognathus sp. nov.? Reynolds, 1970, p. 4, Pl. 3, fig. 1.

Apatognathus symmetricus MacGill, 1973, p. 28, 29, Pl. 1, figs. 1-3.

Synclydognathus symmetrica Scaterday, 1963, p. 123-124, Pl. 3, figs. 6, 7, 14.

Sb$_1$ *element.*

Apatognathus? *porcata* (Hinde). Rexroad & Collinson, 1963 (partim), p. 8, Pl. 1, figs. 7-9 only.

Apatognathus porcatus (Hinde). Rice & Langenheim, 1974b, p. 19, Pl. 1, fig. 3.

Apatognathus altus MacGill, 1973, p. 25-26, Pl. 1, figs. 6-11.

?*Apatognathus petilus* Varker. Austin & Husri, 1974, Pl. 10, fig. 2.

?*Apatognathus geminus* (Hinde). Rice & Langenheim, 1974b, p. 19, Pl. 1, fig. 2.

Apatognathus asymmetricus Higgins, 1982, p. 157, Pl. 19, figs. 7, 9.

Apatognathus sp. von Bitter and Plint-Geberl, 1982 (partim), p. 202, Pl. 6, fig. 19 only.

Synclydognathus markae Scatterday, 1963, p. 119-120, Pl. 3, figs. 15, 16.

Sb$_2$ *element.*

Apatognathus porcata (Hinde). Rexroad & Collinson, 1963 (partim), p. 8, Pl. 1, figs. 10, 11 only; Globensky, 1967 (partim), p. 438, Pl. 56, fig. 12 only; Thompson & Goebel, 1968 (partim), p. 21, Pl. 2, fig. 1 only.

Apatognathus porcatus (Hinde). MacGill, 1973, p. 27-28, Pl. 1, figs. 4, 5; Ruppel, 1979, Pl. 1, fig. 12.

Synclydognathus porcata (Hinde). Scatterday, 1963, p. 120-121, Pl. 3, figs. 8, 9.

Sb$_3$ *element.*

Apatognathus? *gemina* (Hinde). Rexroad & Collinson, 1963, p. 7-8, Pl. 1, figs. 12-17; Globensky, 1967, p. 438, Pl. 56, fig. 3-5.

Apatognathus? *scalena* Varker, 1967, p. 136, Pl. 18, figs. 1, 2, 4, 5.

Apatognathus? *scalenus* Varker. Rhodes, Austin and Druce, 1969, p. 74, Pl. 20, figs. 9-11; Reynolds, 1970, p. 7, Pl. 3, fig. 6,; MacGill, 1973, p. 28, Pl. 1, figs. 9, 10; Austin & Husri, 1974, Pl. 10, fig. 12.

Synclydognathus hastata Scatterday, 1963, p. 116-118, Pl. 3, figs. 10, 11, 13, 17.

Sb$_4$ *element.*

? *Apatognathus gemina* (Hinde). Thompson & Goebel, 1968 (partim), p. 21, Pl. 2, fig. 2 only.

Apatognathus cf. *A. chaulioda* Varker. Rice & Langenheim, 1974b, p. 19, Pl. 1, fig. 1.

Apatognathus scalenus Varker. Rice & Langenheim, 1974b, p. 19, 26, Pl. 1, fig. 4.

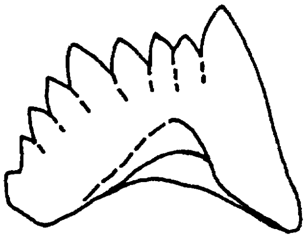
Apatognathus tricuspis MacGill, 1973, p. 29-30, Pl. 1,

figs. 7, 8.
?*Apatognathus* sp. von Bitter & Plint-Geberl, 1982 (partim), Pl. 6, fig. 16.
Synclydognathus spinifera Scatterday, 1963, p. 122-123, Pl. 3, figs. 12, 18-20.

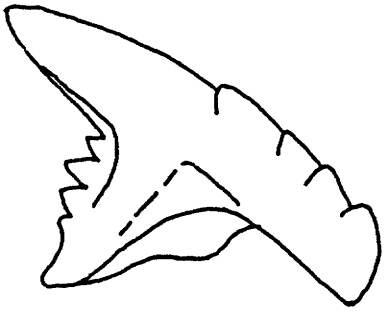
Diagnosis. This species has a septimembrate apparatus consisting of Pa, Pb, Sa and four distinctive Sb elements (Fig. 9). The Sa and Sb elements are apatognathiform and are diagnostic of the species. In general, these elements are characterized by small, thin, subequal denticles on each process and basal cavities that in lateral view are triangular and open to the inner side of the element. The Sa element is bilaterally symmetrical, while the Sb elements are all asymmetrical and differ in the nature of the denticulation on each process. The Sb_1 element has longer and thinner denticles on the anterior process, proximal to the apical cusp, than the posterior process. The denticles of the Sb_2 element are subequal but the element is slightly twisted with the long apical cusp directed posteriorly. The Sb_3 element is like the Sb_2 element but has a large denticle developed near midlength on the posterior process, while the Sb_4 element has a large denticle on the anterior process proximal to the apical cusp, in addition to a similar, large denticle on the posterior process. The Pa element is spathognathodiform and is characterized by a large, asymmetrical basal cavity that is flared on the outer-

Figure 9 : Apparatus composition of *Hindeognathus laevipostica*.

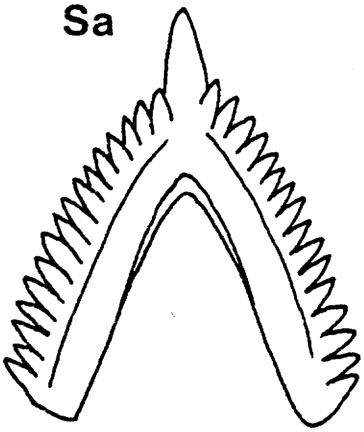
Pa



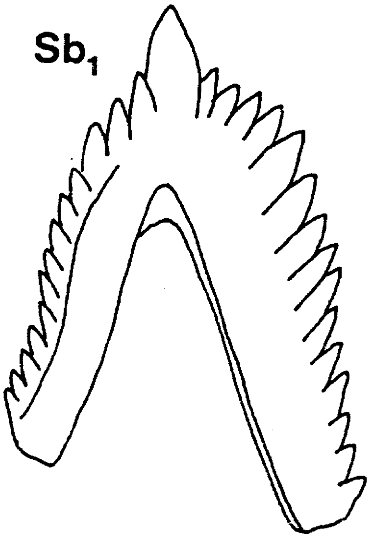
Pb



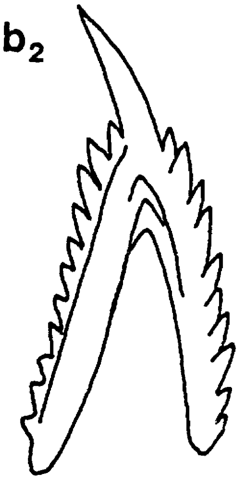
Sa



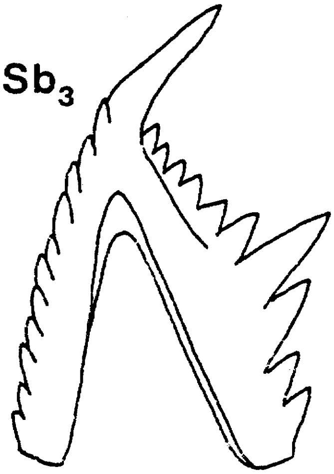
Sb$_1$



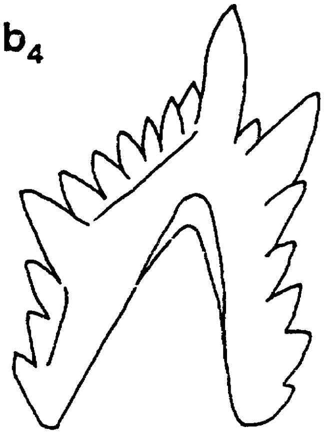
Sb$_2$



Sb$_3$



Sb$_4$



lateral side of the element. The Pb element is small and delicate, strongly arched and has a large, laterally costate apical cusp.

Descriptions.

Pa element. The Pa element is characteristically a blade-like spathognathodiform element with a large, asymmetrical basal cavity which is widely flared on the outer-lateral side of the element. Developed on the upper margin of the element are up to nine, bluntly pointed, fused denticles, of which the anterior-most is the largest. The element, especially large, gerontic forms, may be moderately arched about the basal cavity.

For a more complete description of this element see DE *Spathognathodus scitulus* in Rhodes, *et al*. (1969).

Pb element. The angulate ozarkodiniform Pb element is small and strongly arched. The denticulated anterior and posterior processes are short and small compared to the large, laterally compressed apical cusp. The anterior process is directed strongly downward. The basal cavity is asymmetrical and slightly flared on the outer side of the element.

For a more complete description, see Rexroad and Collinson (1963) under DE *Ozarkodina laevipostica*.

Sa element. The element is a bilaterally symmetrical apatognathiform element with the two processes separated by a 40° to 50° arch. The processes are bowed slightly inward and may be slightly twisted at the arch. They are also of equal length and are narrow, thin and compressed. The height of each process remains constant except at the arch where they may be slightly narrower.

The apical cusp is two to three times the length of the process-denticles. It is also thin and laterally compressed with sharp, costate edges and a pointed tip. The cusp inclines slightly inward and has no lateral or posterior recurvature.

Denticles on each process are subequal, thin and slender, and roughly equal in height to the process. They may number from seven to eighteen in complete specimens. Except in small juvenile specimens, the denticles are thinner than the processes. They are fused for at least two-thirds of their length, except in some specimens where they may become more discrete, adapically. For most of the length of the process the denticles are perpendicular to the process, but proximal to the apical cusp the denticles become inclined toward the cusp.

The basal pit is small, cone-shaped, but triangular in lateral view, and open to the inner side of the element. Thin-lipped grooves extend adapically along the basal margin of each process.

Sb$_1$ *element*. The element is asymmetrical with the processes of unequal size, and slightly twisted so that the posterior process is more inwardly directed than the anterior process. An angle of 30° to 50° separates the two processes.

The apical cusp is broad, laterally compressed with costate edges and pointed. The cusp is one and a half to two times as high as the anterior process-denticles and two to three times as high as the posterior process-denticles. The cusp is slightly offset anteriorly from the basal cavity and may be slightly twisted so that the inner face faces the anterior process. In most specimens the apical cusp is an extension of the anterior process.

The anterior process is thin and strongly compressed, slightly concave inward and is deeper than the posterior process. The process is usually straight with the distal end only slightly twisted with respect to the proximal end. The denticles on the anterior process are long, thin, fused nearly to their apices and inclined apically with the angle of inclination usually increasing apically. The denticles are highest proximal to the apical cusp and decrease in height distally; the one or two denticles closest to the apical cusp are slightly smaller than the highest denticles. The highest denticles are the same thickness as the anterior process, and in transmitted light the white matter of these denticles can be seen to extend deep into the process. The anterior process may bear from twelve to twenty-three denticles.

Although usually equal in length to the anterior process, the posterior process is thicker, subrounded in cross-section and not laterally compressed. Near the apical cusp the posterior process is curved inward, while for the rest of its length the process may be straight or curved slightly outward, distally. The denticles on the posterior process are short, subequal in height, discrete to fused for half of their length and inclined slightly, apically. The denticles are one-half to equal to the height of the posterior process but thinner. The number of denticles on the posterior process usually equals the number of denticles on the anterior process.

The basal cavity is small, triangular and opens to the inner side of the element. Thin-lipped basal grooves extend distally along the basal margin of each process.

<u>Sb_2 element</u>. The apical cusp is long, slender, sharply pointed and only slightly compressed with costate edges. In length it is usually slightly less than one-half the length of the anterior process, but it may be up to two-thirds as long as that process. It is usually four to five times as long as the process-denticles. The cusp is recurved strongly posteriorly and inclined inwardly. In most specimens the apical cusp is an extension of the

anterior process.

The element is slightly twisted so that the posterior process is more inwardly directed than the anterior process. The anterior and posterior processes diverge at angles of 25° to 35°. Both processes are of nearly equal length and height, with the height of each process remaining constant for the length of that process. In cross-section the processes are subrounded to subrectangular. The thickness of each process also is constant for the length of the process except in a few, large elements which show gradual thickening of the anterior process apically.

There is a nearly equal number of denticles on each process, numbering from seven to eighteen in complete specimens. On some specimens the anterior process will have a few more denticles than the posterior process. The denticles on each process are one-half to equal to the height of the process and subequal in height, although there may be some variation in height along the length of the process. In a few specimens the denticles gradually increase in height apically. The denticles are discrete to fused for one-half of their length and have subrounded cross-sections, a triangular profile and pointed tips. They are inclined apically, with those on the anterior process slightly more inclined.

The basal pit is small and triangular. It is also asymmetrical, with the anterior, inner margin longer than the posterior margin, and slightly offset posteriorly with respect to the apical cusp. The pit opens to the inner side of the element and is extended to the distal end of each process as thin-lipped basal grooves.

$\underline{Sb_3}$ element. This element is like the Sb element except that it has a large cusp-like denticle, equalling the size of the apical cusp, situated nearly at midlength on the posterior process. Here the posterior process is slightly higher than it is at the proximal or distal ends. The denticles adjacent to the large cusp-like denticle are ususally larger than the other denticles. For a more complete description of this element see Scatterday (1963) under DE *Synclydognathus hastata*.

$\underline{Sb_4}$ element. The anterior and posterior processes of this element are short, thin and strongly compressed, and form an arch of about 40° to 50° at their junction. Distally the processes are very slightly twisted outward.

The apical cusp is of moderate length, two to three times the length of the average, smaller process-denticles. It is pointed, slightly compressed laterally, has costate edges, and is curved inwardly and inclined, slightly posteriorly. It is also twisted so that its inner face partially faces the anterior process.

The anterior process is slightly curved concave inward. Six to seven denticles are on the anterior process, one of which approaches the apical cusp in size. This cusp-like denticle is separated from the apical cusp by one or rarely two smaller fused denticles. The denticle is triangular in lateral view, has a broader base than the apical cusp, and is two-thirds to equal to the height of the apical cusp. The other smaller denticles on the anterior process are short, rounded in cross-section, discrete to fused for one-half of their length and one-half to equal the height of the process. The denticles are inclined apically, but become more erect toward the distal end of the process.

The posterior process is straighter and longer than the anterior process. It bears seven to ten denticles, one of which, situated at midlength of the process, approaches the apical cusp in size. This cusp-like denticle is two-thirds to equal to the height of the apical cusp but is broader based. The denticles adjacent on either side of the large denticle are usually slightly shorter and almost as wide. Four to six smaller denticles which are fused for one-half to two-thirds of their length are between the large denticle and the apical cusp. These denticles are slightly inclined apically. The denticles on the distal side of the cusp-like denticle number from two to four and are discrete and usually slightly larger than the smaller denticles on the apical side of this denticle. The smaller denticles on either side of the large denticle are roughly one-third to equal to the height of the posterior process, which is highest at the large denticle. This denticle is the same thickness as the process, while the smaller denticles are thinner. The denticles on the posterior process are less inclined apically than those on the anterior process.

The basal pit is triangular, opens to the inner side of the element and and is slightly offset anteriorly from the apical cusp. Thin-lipped, basal grooves extend to the distal ends of each process.

Comparisons. In general, the Pa and Pb elements compare favorably with previously described elements from both North America and Great Britain. Sa and Sb apatognathiform elements from this study are also like others described from North America by previous workers but differ from apatognathiform elements described from Great Britain. The evidence suggests that most British apatognathiform elements belong to a species of Hindeognathus different from the North American H. laeviipostica. This would support the conclusion of Higgins (1981) that some Upper Mississippian (Visean-Namurian) conodonts were provincially distributed, with

British (European) faunas geographically separated from North American faunas.

Pa element. Present specimens are like those described by previous workers. Variation is expressed primarily by the degree of arching of the lower margin. Large, gerontic elements are usually more arched, with a concave lower margin, than smaller, juvenile elements. The degree of arching and the asymmetric, flared basal cavity of this element distinquishes it from Pa elements of *Hindeodus cristula*.

Pb element. The majority of Pb elements agree with the descriptions of Rexroad and Collinson (1963) for DE *Ozarkodina laevipostica*, but differ in that they usually have completely denticulated posterior processes similar to specimens described by Rhodes , *et al*. (1969). Occasional elements have strongly denticulated posterior processes with denticles that are more robust and discrete than denticles on the anterior process (see Pl. 4, fig. 6).

Also included as Pb elements of this species are elements that are like those forms described as DE *Ozarkodina* cf. *O. laevipostica* by Rexroad and Collinson (1965; also Thompson & Goebel, 1968). These forms are similar to typical Pb elements but differ in having larger, unfused denticles on the anterior process and a larger basal cavity (see Pl. 4, fig. 3). In general, they are also larger and less arched than typical Pb elements. Although they do form a morphologically distinct group, they may be gerontic forms and, thus, are included with other Pb elements.

Rare Pb elements are like apatognathiform Sb elements in having a longer than usual apical cusp and longer anterior and posterior processes which are strongly arched. These are similar to elements described by Austin and Husri (1974) as DE *Apatognathus minutus*.

Sa element. Although not reported as a distinctive element in published studies, this symmetrical apatognathiform element was described in unpublished works by Scatterday (1963) and MacGill (1973) from southeastern Ohio and east-central Kentucky, respectively. In addition, Globensky (1967) illustrated a symmetrical apatognathiform element as DE *Apatognathus porcata* (Pl. 56, fig. 24) which is probably the same element.

DE *Apatognathus libratus*, originally described by Varker (1967) and common in Dinantian strata of Great Britain, is a bilaterally symmetrical apatognathiform element that resembles the Sa element of this species. It differs, though, from this element by having more massive, thicker and broader-based denticles on each process and a smaller basal pit which does not open to the inner side of the element. DE A. libratus is probably a homologous Sa element in a different species of Hindeognathus.

Reynolds (1970) illustrated a symmetrical apatognathiform element, DE Apatognathus? sp. nov. from Dinantian strata in North Wales that, unlike DE A. libratus, is not a robust element and has numerous, small denticles on each process. In this sense it is closer in morphology to the Sa element of H. laevipostica.

Sb_1 element. Rexroad and Collinson (1963; Pl. 1, figs. 7-9) illustrated this element, from the St. Louis Limestone of Illinois and Missouri, as a gerontic form of DE Apatognathus porcatus. Subsequent, unpublished studies by Scatterday (1963) and MacGill (1973) further documented the existence of this distinctive element in correlative rocks from southeastern Ohio and east-central Kentucky. In addition, specimens illustrated by Rice and Langenheim (1974b; Pl.1, figs. 2, 3), from Nevada, appear to fit the description of this element, suggesting that the element was widespread throughout North America during early Late Mississippian time.

Two apatognathiform elements described from Great Britain, DE Apatognathus bladus Rhodes, Austin and Druce (1969) and DE A. petila Varker (1967) are similar to this element. DE A. bladus, like the Sb element, has a tall, blade-like anterior process with tall, thin, laterally compressed denticles and a thicker, but lower, posterior process, which is subquadrate in cross-section and has very short, sharply pointed denticles. DE *A. bladus* differs because it has wider, more robust denticles on the anterior process and a tiny denticle separating the apical cusp from the largest denticles on the anterior process, unlike the Sb_1 element of this species. DE *A. petila* which also has tall, thin denticles on the anterior process, was noted by Varker (1967) to be similar to those elements that Rexroad and Collinson (1963) believed to be large, gerontic forms of DE *A. porcatus*. Unlike those latter elements, DE *A. petila* lacks a distinctive apical cusp. Instead, all of the denticles on the anterior process near the the apex of the arch are large and subequal. In addition, these denticles are usually highly inclined inward and often posteriorly. The basal pits of the respective elements are different, too. Varker (1967) stated that the basal pit of DE *A. petila* was "large and spindle-shaped" unlike the small basal pit of the Sb element of *H. laevipostica* which is triangular and opens inwardly.

Both DE *A. bladus* and DE *A. petila* appear to be so similar that I believe they are just slightly different morphotypes of the same element. These elements, though, are more similar to other British Carboniferous apatognathiform elements than the typically North American Sb_1 elements of this species, and so they probably occupied a homologous Sb_1 position in a different species, possibly _H. scitulus_.

Higgins and Varker (1982) recently described a new apatognathiform element, DE _A. asymmetricus_, from northwestern England which does have very close similarities to this element. One process of DE _A. asymmetricus_ (posterior in paper, but more likely it is the anterior process) is blade-like, with high, fused denticles proximal to the apical cusp, a laterally thickened opposing (posterior?) process and a triangular basal pit situated on the inner face of the element. The element appears nearly identical to the Sb_1 element of _H. laevipostica_ and is good evidence that this species was also present in Great Britain during the Early Carboniferous.

_Sb_2 element_. Previous workers have often referred North American specimens of this form to DE _A. porcatus_ (Hinde). Unfortunately, the holotype of DE _A. porcatus_ from Lower Carboniferous rocks of Scotland is an incomplete specimen, with the anterior process missing. Clarke (1960) redescribed Hinde's (1900) holotypes of both DE _A. porcatus_ and the co-occurring DE _A. geminus_. He believed that the former element could be distinquished from the latter element by its uniform subequal denticulation and the greater swelling or thickening of the posterior process proximal to the apical cusp. DE *A. geminus* has denticles on the anterior process which are larger apically, but both specimens illustrated by Clarke (1960; Pl. 1, figs. 1, 2) appear to have short, subequal denticles on the posterior process like DE *A. porcata*. Because the anterior process of the holotype of DE *A. porcata* is missing, it can not be determined whether denticulation on this process was uniformly subequal or like that of DE *A. geminus*, increasingly larger toward the apical cusp. It appears to that these elements are not fundamentally different and may be synonomous.

Sb_2 elements of *H. laevipostica* are similar to both DE *A. geminus* and DE *A. porcatus*, but differ from them by having uniform, subequal denticulation on both anterior and posterior processes. Most specimens, except a few, large, gerontic forms, also do not show any thickening of the posterior process proximal to the apical cusp. Also, British specimens of DE *A. geminus*, as illustrated by Varker (1967) and Rhodes, *et al.* (1969), have larger process-denticles than this element and do not have triangular basal pits which open to the inner side of the element. Because of these differences, I do not believe that either DE *A. porcatus* or DE *A. geminus* should be placed in synonomy with this element.

Varker (1967) described a new element, DE *A. cuspidata* from the Upper Visean (Dinantian) Yoredale Series of northern England which is similar to both DE *A. geminus* and DE *A. porcatus*. Like DE *A. porcatus*, the denticulation on the posterior process of this element is uniform and subequal, but the posterior process is not thickened as it is in the former. DE *A. cuspidata* was distinquished from DE *A. geminus* because it, the former, has regular, subequal denticulation on both processes, and larger denticles on the posterior process than the anterior process, while lacking any lateral thickening of the posterior process. Several of Varker's specimens, though, do show an increase in denticle size apically, particularly the denticles on the anterior process, similar to DE *A. geminus*. Also, at least one specimen illustrated by Rhodes *et al*. (1969) as DE *A. geminus* fits more closely the description of DE *A. cuspidata* by having larger, subequal denticles on the posterior process than on the anterior process. These similarities suggest that perhaps DE *A. cuspidata*, like DE *A. geminus* and DE *A. porcatus*, is yet another morphotype of the same element.

Of all the apatognathiform elements described from Great Britain, DE *A. cuspidata* is the morphotype closest to the Sb_2 element of *H. laeviipostica*. Varker (1967) noted the similarity of DE A. cuspidata to what Rexroad and Collinson (1963) referred to as juvenile elements of DE A. porcata, herein referred to this Sb_2 element. Both elements have a long posteriorly curved apical cusp, an inwardly directed or twisted posterior process and uniform, subequal denticles on both processes. DE A. cuspidata, like most British Carboniferous apatognathiform elements, differs from this element because its denticles are fewer and larger or more robust and it has a small, circular basal pit unlike the triangular basal pits of homologous North American apatognathiform elements (Varker stated only that the basal pit was "circular." Presumably this was in lower view. His photographs of DE A. cuspidata (Pl. 17, figs. 4, 6-8, 10) do not show the basal pit clearly, but a line drawing of the elment (text-fig. 2c,d) show the pit is small and not triangular or open to inner side of the element.).

Rare elements recovered herein (Pl. 4, fig. 9) are like DE A. cuspidata because they have large, robust denticles on the anterior and posterior processes, which are also massive. The basal pits of these elements, though, are like those of the other Sb elements of H. laevipostica. Although the differences between DE A. cuspidata and the Sb_2 may appear to be slight, I believe that the former is truly more similar to other British apatognathiform elements than North American elements. DE A. cuspidata probably did occupy a homologous Sb_2 position in another species of Hindeognathus, probably H. laevipostica.

Sb_3 element. This element is very similar to DE A. scalena Varker (1967)from Great Britain. The Sb_3 element of H. laevipostica differs from that element in the following ways: 1) The prominant cusp-like denticle on the posterior process is usually not wider than the height of the process; 2) This large denticle and its adjacent denticles, especially those adapical of it are not as large or massive as the corresponding denticles of DE A. scalena; 3) the apical cusps of mature specimens are long rather than "only slightly larger than the adjacent denticles of the anterior process" as is the case with DE A. scalena (Varker, 1967); and 4) the basal pit is triangular and opens to the inner side of the element, while the basal pit of DE A. scalena is spindle-shaped or slit-like (Varker, 1967; Rhodes, et al., 1969).

In all other aspects these elements are very similar, and because of this, the two may represent an element vicariously shared between H. laevipostica and another species, perhaps H. scitulus.

Sb_4 element. This distinctive element although not reported in any published accounts of North American

Mississippian conodonts was extensively described and illustrated by both Scatterday (1963) and MacGill (1973). Also some workers have illustrated in published reports apatognathiform elements which are probably this element, further documenting its widespread occurrence. Thompson and Goebel (1968) illustrated an element (Pl. 2, fig. 2) which they referred to DE *A. gemina*, but which is closer in apppearance to this element. The specimen appears to have a large broken denticle at midlength on what may be the posterior process and another large, also broken, denticle on the opposite (anterior?) process, separated from the apical cusp by one smaller denticle. Rice and Langenheim (1974b) also illustrated two, three-cusped, forms (Pl. 1, figs. 1, 4) which they referred to as DE *A.* cf. *A. chauliodus* Varker and DE *A. scalenus* Varker. Both of these are closely similar to this element. Finally, von Bitter and Plint-Geberl (1982) recently illustrated (Pl. 6, fig. 16) what appears to be another three-cusped element like this element. similar to this Sb element.

The British counterpart to this element is DE *A. chaulioda* Varker (1967), which is ubiquitous in correlative Dinantian strata of Great Britain and Ireland (Varker, 1967; Aldridge, Austin and Husri, 1968; Rhodes, Austin and Druce, 1969; and Austin and Husri, 1974). It also has large cusp-like denticles on the anterior and posterior processes. The main difference between these elements is that on elements of DE _A. chaulioda_ the large denticles are symmetrically opposed with the cusp-like denticle on the anterior process separated from the apical cusp by almost as many smaller denticles as there are between the cusp-like denticle on the posterior process and the apical cusp, instead of one, or rarely two, smaller denticles as in the Sb_4 element of _H. laevipostica_. The basal pit of DE _A. chaulioda_ also is not triangular and open to the inner side of the element as it is in the Sb_4 element of _H. laevipostica_.

Remarks. Evidence cited above suggests that elements of _Hindeognathus_ from the study area and other regions of North America are different enough from contemporary British counterparts to belong to a different species. Although the Pa and Pb elements appear to be identical from the two areas, the apatognathiform (Sa and Sb) elements exhibit consistant differences. North American apatognathiform elements are characterized by numerous, small denticles on each process and triangular basal pits that open to the inner side of the element. Most British apatognathiform elements are characterized by larger, more robust denticles and basal pits that are not open to the inner side of the element. British elements which are probably homologous with the North American Sb_1 and Sb_4

elements have slightly different denticle arrangements as well.

Although a recent study by Higgins and Varker (1982) documented the occurrence of at least one typical "North American" element (DE *Apatognathus asymmetricus*) from Great Britain, indicating that under certain conditions the two species may have coexisted, unequivocal "British" elements of *Hindeognathus* (*Apatognathus* sensu Varker, 1967 and Rhodes, *et al.*, 1969) have yet to be found in North America. This evidence suggests that the two different, yet contemporaneous, species of *Hindeognathus* were distributed into two, geographically separate, Lower Carboniferous conodont provinces, Midcontinent and Eurasian, as Higgins (1981a) has proposed.

The choice for a trivial name for this North American species of *Hindeognathus* is difficult. Presumably British representatives would be named *H. scitulus* (Hinde, 1960) after the Pa element, originally the first element of the species to be described. Of the names available for this species, *scitulus* has page preference over both *geminus* and *porcatus* (contrary to what Rexroad and Thompson {1979} stated), although *geminus* may be preferable because it comes from the apatognathiform (S) elements which are diagnostic of the species. Preferably, the trivial name for the North American species should, if possible, emphasize the differences between the North American and British species. Unfortunately, the diagnostic North American apatognathiform elements have only been formally described under the British names, geminus and porcatus. The only element of this species originally described from North America is the Pb element, DE Ozarkodina laevipostica Rexroad and Collinson (1963). Although this element may not be the best choice as the name-provider for the species, because it also, along with the Pa element, is common to both Great Britain and North America, it is the only valid name for the North American species.

Occurrence. Little Valley Fm. (L), Hillsdale Lst. (B, L).

Material recovered. Pa (123), Pb (27), Sa (34), Sb (109), Sb (116), Sb (40), Sb (26).

HINDEOGNATHUS spp.

Pl. 4, fig. 11.

Remarks. Several unidentifiable and broken apatognathiform (S) elements were found in the "Denmar-Gasper" Formation, 67.20 meters above the Hillsdale Limestone, at the Willowton section (W24). Because the specimens are few, poorly preserved and do not co-occur with Pa and Pb elements, they are not identified and are included under Hindeognathus sp. Of the general element types for this genus the elements most closely resemble Sb_1 and Sb_2 elements.

The fauna which these elements are associated with, including Hindeodus cristula, Lochriea commutatus and "Spathognathodus" campbelli, is characteristic of the Gnathodus bilineatus - Cavusgnathus zone rather than the older "Apatognathus" scalenus - Cavusgnathus zone of Collinson, Rexroad and Thompson (1971). The occurrence of these Hindeognathus elements, within the "Denmar-Gasper" Formation, is the youngest in the study area. Elsewhere in North America, elements of Hindeognathus are not known to range this high stratigraphically, although in Great Britain they have been reported as high as strata that are correlative with Chesterian strata in North America. Thompson (1972), though, reported the occurrence of an isolated apatognathiform element in the Chesterian Hindsville Limestone of Missouri.

Occurrence. "Denmar-Gasper" Fm. (W24).

Material recovered. 3 elements.

Genus SYNPRIONIODINA? Ulrich & Bassler, 1925

Type species. Synprioniodina alternata Bassler, 1925.

SYNPRIONIODINA? SPICULA (Youngquist & Miller)

Pl. 3, fig. 3

Pa element.
Spathognathodus spiculus Youngquist & Miller, 1949, p.

622, Pl. 101, fig. 4; Merrill, 1973, p. 309-310, Pl. 3, fig. 61 (includes synonomy through 1973); Rice & Langenheim, 1974, p. 34, Pl. 3, fig. 9; Norby, 1976, p. 198-200, Pl. 15, figs. 5-8.

Multielement.
Synprioniodina? *spicula* (Youngquist & Miller). Rexroad, 1981, p. 14, Pl. 2, fig. 3.

Remarks. The discrete element DE *Spathognathodus spiculus* was tentatively assigned to *Synprioniodina* by Rexroad and Thompson (1979) and Horowitz and Rexroad (1982). I have followed their assignment because no further evidence of the apparatus affinities of this species were found in the course of this study. At present *Synprioniodina*? *spicula* is thought to have been monoelemental.

Occurrence. Hillsdale Lst. (W2) and "Denmar-Gasper" Fm. (W26).

Material recovered. Pa (6).

Family CAVUSGNATHIDAE Austin & Rhodes, 1981

Genus CAVUSGNATHUS Harris & Hollingsworth, 1933

Cavusgnathus Harris & Hollingsworth, 1933
Lewistownella Scott, 1942

Type species. *Cavusgnathus alta* Harris & Hollingsworth, 1933

Diagnosis. Dextral, cavusgnathiform Pa elements are diagnostic of this multielement genus. Other elements in this seximembrate apparatus are ozarkodiniform (Pb), neoprioniodiform (M), hibbardelliform (Sa), angulodiform (Sb) and hindeodelliform (Sc).

Remarks. There is now strong agreement among conodont workers about the nature of the Cavusgnathus apparatus based on several lines of investigation. Scott (1934, 1942) discovered and described natural bedding-plane assemblages of Cavusgnathus, which were later confirmed by Norby (1974, 1976). Confirming multivariate statistical analysis has been carried out by von Bitter (1972) who reconstructed the apparatus of Late Pennsylvanian (Virgilian) species of Cavusgnathus (=Adetognathus Lane, 1967), and Horowitz and Rexroad (1980, 1982), who worked with Late Mississippian (Chesterian) species. Rexroad (1981) also described two Chesterian species which also occur in the rocks of this study. Additional studies that deal with multielement Cavusgnathus are those of Baesemann (1973, Adetognathus) and von Bitter and Plint-Geberl (1982).

Different species are recognized by differences in the respective platform elements. Although the ramiform elements appear to be morphologically stable, the range of interspecific and intraspecific variation is not well known. For this reason ramiform elements are treated, herein, as if they were shared vicariosly by different species.

Morphologic variation of the platform elements complicates species recognition. Rexroad (1981) discussed the taxonomic problems of *C. altus* and *C. unicornis*, in a study of conodonts from the Chesterian Vienna Limestone of the Illinois Basin. He recognized Pa elements which were intermediate between those of *C. altus* and *C. unicornis*. These elements exhibited the main platform characteristics of the former combined with the blade characteristics of the latter. He believed that these intermediate (not intergradational) forms were "hybrids" produced when the two species, which were normally isolated geographically, overlapped in their geographic ranges. Although considering alternative possibilities, he believed that *C. altus* and *C. unicornis* were still distinct species.

Intermediate Pa elements, like those described by Rexroad (1981) were found in this study, in a Bishop sample (B10) which contained abundant Pa elements of both *C. altus* and *C. unicornis*. These elements show a more complicated picture than those of Rexroad and appear to be more clearly intergradational in form between the two species. A further complication is the fact that only Pa elements of *C. unicornis* show a full size-range from small juvenile elements to large gerontic forms. Pa elements of _C._ _altus_, in other samples as well, and the "hybrids" are large and are probably only gerontic forms; few, small juvenile elements have been found. Merrill (personal communication, 1982) reports a similar situation with elements from the Chesterian Barnett Formation of Texas. Interestingly, a few specimens from other samples in this study are intermediate in the opposite respect. These elements exhibit the main platform characteristics of _C._ _unicornis_ while having blade configurations similar to _C._ _altus_.

This may be further evidence as Rexroad (1981) suggested, that the differences between _C._ _altus_ and _C._ _unicornis_ are more of an ecological nature than a phylogenetic one; these morphotypes may be subspecies which had different ecological tolerances related to different geographic settings. In any case, because the two forms are well documented in the literature as two different species and the intermediate forms occur only in a narrow stratigraphic interval, they are treated as such. Herein, intermediate "hybrids" are listed separately (Appendix B) under _C._ _altus_ X _C._ _unicornis_ (see Plate 5, fig. 12).

CAVUSGNATHUS ALTUS Harris and Hollingsworth

Pl. 5, fig. 11.

Pa element.
Cavusgnathus alta Harris & Hollingsworth, 1933, p. 201, Pl. 1, figs. 10a-b; Thompson & Goebel, 1968, p. 21, Pl. 1, figs. 19, 22 (includes synonomy through 1968).
Cavusgnathus altus Harris & Hollingsworth. Tynan, 1980, Pl. 2, fig. 26.
Cavusgnathus cristatus Branson & Mehl, 1941a, p. 177, Pl. 5, figs. 26-31.

Ramiform elements.
See synonomies under Cavusgnathus unicornis.

Multielement.
Cavusgnathus altus Harris & Hollingsworth. Rexroad, 1981, p. 7-8, Pl. 1, figs. 28-34.

Diagnosis. The Pa element is diagnostic of this species. The distinguishing characteristics of this element are the irregular upper outline of the blade as viewed laterally, the straight outer edge of the parapet, a posterior median carina and a basal cavity that does not extend to the posterior end of the platform.

Remarks. As mentioned above, the characteristic Pa elements found in this study are almost entirely large, gerontic forms. Smaller, more juvenile-like Pa elements are very uncommon. Instead, smaller Pa elements, when identifiable, are usually referable to C. unicornis.

Rexroad (1981) assigned DE Neoprioniodus varians as the M element of C. altus. In this study, Pa elements of C. altus are rare, but DE N. varians is relatively common and often occurs in samples that lack the former. For this reason, M elements of both *C. altus* and *C. unicornis* are undifferentiated and treated as if they were vicariously shared by the two species.

C. altus was found only rarely in the study. Only one sample from each of the three sections studied yielded Pa elements of this species. At the Bishop section elements are common in a sample (B10) in the upper part of the Hillsdale Limestone. Single elements were found at both Willowton and Lindell sections, in the "Denmar-Gasper" and "Ste. Genevieve" Formations, respectively.

Occurence. Hillsdale Lst. (B10), "Denmar-Gasper" Fm. (W16), "Ste. Genevieve" Lst. (L25).

Material recovered. Pa (18).

CAVUSGNATHUS UNICORNIS Youngquist & Miller

Pl. 5, figs. 6-10, 13-18.

Pa element, α morphotype.

Cavusgnathus unicornis Youngquist & Miller, 1949, p. 619, Pl. 101, figs. 18-23; Austin & Husri, 1974, Pl. 1, fig. 8 (figs. 2, 3); Rice & Langenheim, 1974b, p. 27, Pl. 1, fig. 10; Watanabe, 1975, p. 163, Pl. 15, figs. 1, 2, 4-6; Ruppel, 1979, Pl. 2, fig. 14; Skompski & Sobon-Podgorska, 1980, Pl. 5, figs. 9, 10, 12; Tynan, 1980, Pl. 2, figs. 25, 27, 28; Higgins, 1982, p. 160, Pl. 18, fig. 14.

?*Cavusgnathus unicornis* Youngquist & Miller. Reynolds, 1970, p. 7, Pl. 2, fig. 5.

(see Lane and Straka, 1974, p. 70 for synonomy through 1970)

Pa element, β morphotype.

Cavusgnathus regularis Youngquist & Miller, 1949, p. 619, Pl. 101, figs. 24, 25; Thompson & Goebel, 1968, p. 22, Pl. 1. figs. 3, 12; Rice & Langenheim, 1974b, p. 26-27, Pl. 1, fig. 9 (includes synonomy through 1970); Higgins, 1975, p. 27, Pl. 8, figs. 1,2; Ruppel, 1979, Pl. 2, fig. 8; Higgins, 1982, p. 158-159, Pl. 18, figs. 12, 13.

?*Cavusgnathus regularis* Youngquist & Miller. Igo, 1974, p. 419, Pl. 56, figs. 4, 5.

Pa element, γ morphotype.

Cavusgnathus convexa Rexroad, 1957, p. 17, Pl. 1, figs. 3-6; Thompson & Goebel, 1968, p. 22, Pl. 1, figs. 14, 18, 20, 21 (includes synonomy through 1965).

Cavusgnathus convexus Rexroad. Dunn, 1970, p. 329, Pl. 61, figs. 18, 19; Austin & Husri, 1974, Pl. 1, fig. 1, Rice & Langenheim, 1974b, p. 26, Pl. 1, fig. 7; Tynan, 1980, Pl. 2, fig. 24.

?*Cavusgnathus convexus* Rexroad. Webster, 1969, p. 26, Pl. 4, fig. 10.

non Cavusgnathus convexus Rexroad. Rhodes, Austin and Druce, 1969, p. 80, Pl. 14, fig. 2; Reynolds, 1970, p. 7, Pl. 2, fig. 4.

Pb element.

Ozarkodina compressa Rexroad, 1957, p. 36, Pl. 2, figs. 1, 2; Globensky, 1967, p. 446, Pl. 56, figs. 18, 22; Thompson & Goebel, 1968, p. 40, Pl. 3, figs. 17, 20; Rhodes, Austin & Druce, 1969, p. 169, Pl. 27, fig. 23 (includes synonomy through 1965); Thompson & Goebel, 1969, p. 40, Pl. 3, figs. 17, 20; Dunn, 1970, p. 337, Pl. 62, fig. 32.

Ozarkodina cf. *O. compressa* Rexroad. Rice & Langenheim, 1974b, p. 31, Pl. 2, fig. 15.

?*Ozarkodina mutabilis* Branson & Mehl, 1941a, p. 177, Pl. 5, fig. 16.

?*Ozarkodina recta* Rexroad, 1957, p. 36-37, Pl. 2, figs. 5, 6; Rexroad & Furnish, 1964, p. 674, Pl. 111, fig. 8; Thompson & Goebel, 1968, p. 41, Pl. 3, fig. 22.

?*Ozarkodina hindei* Clarke, 1960, p. 18, Pl. 3, figs. 1, 6; Rhodes, Austin & Druce, 1969, p. 171, PL. 27, figs. 16, 17, 22.

non Ozarkodina compressa Rexroad. Reynolds, 1970, p. 15, Pl. 2, fig. 13; Austin & Husri, 1974, Pl. 12, fig. 5, 6, 25.

M element.

Prioniodus varians Branson & Mehl, 1941a, p. 174, Pl. 5, figs. 7, 8.

Neoprioniodus varians (Branson & Mehl). Thompson & Goebel, 1968, p.39, Pl. 3, fig. 6 (includes synonomy through 1965); Rhodes, Austin & Druce, 1969, p. 165, Pl. 21, fig. 18; Reynolds, 1970, p. 15, Pl. 3, fig. 10; Austin & Husri, 1974, Pl. 15, figs. 2, 17; Rice & Langenheim, 1974b, p. 31, Pl. 2, fig. 14.

Neoprioniodus tenuis Rexroad, 1957, p. 35, Pl. 2, figs. 13, 16.

Neoprioniodus loxus Rexroad, 1957, p. 34, Pl. 2, figs. 15, 21; Dunn, 1970, p. 337, Pl. 64, figs. 23, 26-28; Rice & Langenheim, 1974b, p.31, Pl. 2, fig. 11; Watanabe, 1975, p. 166, Pl. 14, fig. 19 (includes synonomy through 1969).

?*Neoprioniodus loxus* Rexroad. Rexroad & Collinson, 1963, p. 18, Pl. 2, fig. 28.

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

Neoprioniodus sp. A Rexroad, 1957, p. 36, Pl. 2, fig. 17.

Neoprioniodus brevis Clarke, 1960, p. 13, Pl. 2, fig. 7.

Sa element.

Prioniodus angulatus Hinde, 1900 (partim), p. 343, Pl. 10, fig. 18 only, *non* fig. 19.

Hibbardella angulata (Hinde). Holmes, 1928 (partim), p. 11, Pl. 4, fig. 32 only.

Hibbardella ortha Rexroad, 1958, p. 18, Pl. 2, figs. 9-12; Rhodes, Austin & Druce, 1969, p. 113, Pl. 25, fig. 22 (includes synonomy through 1965); Webster, 1969, p. 34, Pl. 5, fig. 22; Austin & Husri, 1974, Pl. 13, figs. 6, 7.

non Hibbardella ortha Rexroad. Thompson & Goebel, 1969, p. 25, Pl. 2, figs. 5, 6.

?*Hibbardella* spp. Koike, 1967, p. 303, Pl. 4, figs. 13, 14.

Hibbardella geniculata Higgins, 1975, p. 35, Pl. 6, figs. 11, 12, 14; Metcalfe, 1980, p. 305, Pl. 37, fig. 17.

Sc element.

?*Ctenognathus obliquus* Pander. Hinde, 1900, p. 334, Pl. 10, fig. 28.

?*Ctenognathus* sp. A Roundy, 1926, p. 16, Pl. 2, fig. 3.

Hindeodella obliqua Holmes, 1928, p. 12, Pl. 5, fig. 5.

Hindeodella sp. Branson & Mehl, 1941a, p. 170, Pl. 5, fig. 1.

Hindeodella ensis Hass, 1953, p. 81, Pl. 16, figs. 19-21.

Hindeodella sp. Rexroad, 1957, p. 32, Pl. 3, figs. 4(=Sb?),8; Rexroad, 1958, p. 19, Pl. 2, figs. 2, 3.

Hindeodella pachymandala Stanley, 1958, p. 466, Pl. 63, fig. 5.

Hindeodella tenuis Clarke, 1960, p. 8, Pl. 1, figs. 10, 11; Rhodes, Austin & Druce, 1969, p. 126-127, Pl. 28, fig. 27.

Multielement.

?*Lewistownella agnewi* Scott, 1942, p. 300, Pl. 39, figs. 10-13; Pl. 40, figs. 1, 6, 7, 17, 20, 21.

Cavusgnathus unicornis Youngquist & Miller. Rexroad, 1981, p. 8-9, Pl. 1, figs. 7, 8, 17-23, 26, 27.
Cavusgnathus regularis "type" Youngquist & Miller. von Bitter & Plint-Geberl, 1982, p. 197, pl. 3, figs. 9-14, 17, 18; Pl. 7, figs. 9, 20, 22.

Diagnosis. Rexroad (1981) states that:

> This species has polymorphic Pa elements characterized by a broadly expanded basal cavity that extends to the posterior tip of the platform, a platform on which the parapets are convex outward, especially the outer one, and a blade that in lateral view has: (1) a large and high posterior denticle with anterior denticles decreasing regularly in size and height anteriorly [α morphotype] (DE *C. unicornis*); (2) denticles of nearly uniform height and size, although they may decrease slightly anteriorly [β morphotype] (DE *C. regularis*); or (3) a blade whose outline is regularly convex upward [γ morphotype] (DE *C. convexus*).

The other elements are ozarkodiniform (Pb), neoprioniodiform (M), hibbardelliform (Sa), angulodiform (Sb) and hindeodelliform (Sc). Evidence presented by Norby (1976) and Rexroad (1981) suggests that two morphotypes of the Sc element exist, but due to poor preservation of the elements, no distinction of this kind is made, herein.

Remarks. Rexroad (1981) discussed the differences between Pa elements of *C. altus* and *C. unicornis* (and see above). As noted above, a very few cavusgnathiform Pa elements which have the platform characteristics (parapets and basal cavity) of *C. unicornis* have blades with irregular upper outlines, in lateral view, like Pa elements of C. altus. Pa elements like this and C. altus-"hybrids" indicate intergradation between C. altus and C. unicornis.

Among Pa elements assigned to C. unicornis, herein, are infrequent specimens which have a notch between the outer parapet and fixed blade, a distinctive characteristic of DE C. charactus. Rexroad (1981) and Horowitz and Rexroad (1982) consider Cavusgnathus charactus to be a distinct multielement species. However, specimens of this type, from this study, are intergradational with more common Pa elements of C. unicornis. These elements exhibit blade configurations and platform characteristics like Pa elements of C. unicornis (see Pl. 3, fig. 4), while the notch is usually developed to varying degrees. Based on the specimens studied, I believe that no species distinction need to be made; the specimens exhibit normal intraspecific variability. This morphologic feature of is important stratigraphically, though, because DE C. charactus is limited to rocks of the G. bilineatus - C. charactus zone and the older "A." scalenus - Cavusgnathus zone of Collinson, et al, (1971). Because of their biostratigraphic importance, perhaps in the future Pa elements that exhibit the characteristics of DE C. charactus should be designated as subspecies of C. unicornis.

Ramiform elements of *C. unicornis* exhibit a wide range of morphological variation as noted by Norby (1976) and Rexroad (1981). Interspecific variation between elements of different species of *Cavusgnathus*, along with intraspecific variability, is poorly understood now, and so, the ramiforms are treated here as if they had been vicariously shared by different species. There also appears to be no great difference between ramiforms of *Taphrognathus varians* and *C. unicornis*, and no distinction is made between these, either.

The Pb element conforms well to the discrete element concept of DE *Ozarkodina compressa*. Also included, though, are elements like DE *O. recta*. Although Norby (1976) included this element in the apparatus of *Lochriea commutatus*, I believe, based on the illustrations of Scott (1942) and specimens recovered during this study, that elements of the form of DE *Subbryantodus subaequalis* are more likely the Pb elements of that species, while specimens like DE *O. recta* belong to *Cavusgnathus*, probably *C. unicornis*. Scatterday (1963) believed that the holotype of DE *O. recta* was closely similar to DE *O. compressa* and Horowitz and Rexroad (1982) expressed doubts about including DE *O. recta* with *L. commutatus*. Present specimens which look like the illustrated type specimens of DE *O. recta* (Rexroad, 1957; Pl. 2, figs. 5, 6) have closely appressed denticles on the anterior process which are erect to slightly inclined posteriorly, unlike Pb elements of *L. commutatus* which have discrete denticles on the anterior process. In general, the overall form of these elements (DE *O. recta*) is more closely similar to DE *O. compressa*.

Following the usage of Norby (1976), the M element includes both DE *Neoprioniodus loxus* and *N. varians*, which were previously separated taxonomically based on the size of the obtuse angle between the apical cusp and the posterior process. The former has an angle close to 135° while the latter, more typically, has an angle closer to 100°. Both forms are recognized in this study, as are intermediate forms, but the differences between these elements are probably not significant at the specific level, although they may be ecologically important. Rexroad (1981) limited DE *N. varians* to the apparatus of *C. altus*, but, in this study, this element is common along with DE *N. loxus* in samples which contain Pa elements solely of *C. unicornis*. Perhaps DE *N. varians* was shared by both species while the *loxus* morphotype was restricted to *C. unicornis*.

Sb elements are recognized in this study. Until now, Sb and Sc elements were not differentiated morphologically, although both Norby (1981) and Rexroad

(1981) believed that at least three morphotypes of the Sc element were associated with C. unicornis. Sb elements are very similar to Sc elements but lack a large apical cusp. Instead, the apical cusp is small and more inclined, posteriorly, and the element is arched with an downwardly directed anterior process.

Sc elements are not differentiated into separate morphotypes, herein.

Occurrence. Little Valley Fm. (B, L), Hillsdale Lst. (B, W, L), "Denmar-Gasper" Fm. (B, W), "Ste. Genevieve" Fm. (L).

Material recovered. aPa (590), bPa (187), cPa (99), Pb (139), M (95), Sa (10), Sb (19), Sc (141).

Genus TAPHROGNATHUS Branson & Mehl

Type species. Taphrognathus varians Branson & Mehl, 1941b.

Remarks. Branson and Mehl (1941b) and Rexroad and Collinson (1963) believed that Taphrognathus and Cavusgnathus were closely related, with Cavusgnathus as the lineal descendent of Taphrognathus, based on Pa elements which appear to be transitional between the two genera. Evidence from other published studies and this work supports a close phylogenetic relationship between the two genera. There is little morphological change in the ramiform elements from Taphrognathus to Cavusgnathus.

Von Bitter and Plint-Geberl (1982) reconstructed the apparatus of *Taphrognathus* (*Taphrognathus* n. sp. A von Bitter & Plint-Geberl) based on low diversity faunas from the Lower Codroy Group of Newfoundland and the Lower Windsor Group of Nova Scotia. In that study distinctive ramiform elements much like those of *Cavusgnathus* were consistantly associated with Pa elements of *Taphrognathus* in samples that contained a very restricted conodont fauna. Similarly, samples of low conodont diversity from the Little Valley Formation at the Bishop section (B1 & B3) show the same relationship. Again, ramiform elements morphologically like those of *Cavusgnathus* are associated with abundant *Taphrognathus* Pa elements which greatly outnumber rare Pa elements of *Cavusgnathus* (Appendix B, Table 3). Elements of other multielement genera are not present in these samples. Finally, published studies that report faunas which contain only Pa elements of *Taphrognathus* and not *Cavusgnathus* (Rexroad & Collinson, 1963; Nicoll & Rexroad, 1975) show that the ramiform elements: DE *Neoprioniodus loxus*, DE *Hibbardella ortha* and DE *Ozarkodina* sp. (like DE *O. compressa*) are consistantly associated with *Taphrognathus*.

TAPHROGNATHUS VARIANS Branson & Mehl

Pl. 5, figs. 3, 4, 5.

Pa element.

Taphrognathus _varians_ Branson & Mehl, 1941b, p. 182, Pl. 6, figs. 27-41; Rexroad & Collinson, 1963, p. 21, Pl. 1, figs. 18-20, 22; Rexroad & Collinson, 1965, p. 24, Pl. 1, figs. 30-32; Thompson & Goebel, 1968, p. 44-45, Pl. 5, figs. 1-9, 12-15; Rhodes, Austin and Druce, 1969, p. 241-242, Pl. 13, figs. 4, 5; Nicoll & Rexroad, 1975, p. 27, Pl. 4, figs. 7-16; Ruppel, 1979, Pl. 2, figs. 1-3, 10; Higgins, 1982, p.165, Pl. 18, figs. 5, 6.

?_Taphrognathus_ _varians_ Branson & Mehl. Pierce & Langenheim, 1974, p. 168- 169, Pl. 1, figs. 1-7; Austin & Mitchell, 1975, p. 53, Pl. 1, figs. 5, 6, 18, 19, 30.

?_Taphrognathus_ sp. Thompson & Goebel, 1968, p. 45, Pl. 5, figs. 10, 11.

?_Taphrognathus_-_Cavusgnathus_ transitions Rexroad & Collinson,1963, Pl. 1, figs. 21,23-25.

?_Taphrognathus_-_Cavusgnathus_ transition Ruppel, 1979, Pl. 2, figs. 4, 5.

_Pb_ _element_.

Ozarkodina sp. Nicoll & Rexroad, 1975, p. 26-27, Pl. 5, figs. 4-6.

_M_ _element_.

?_Prioniodus_ sp. indet. Branson & Mehl, 1941b, p. 186, Pl. 6, figs. 8, 9.

?_Neoprioniodus_ _insolitus_ Hass. Rexroad & Collinson, 1965, p. 11-12, Pl. 1, fig. 18.

Neoprioniodus _loxus_ Rexroad. Rexroad & Collinson, 1965, p. 12, Pl. 1, figs. 11, 19; Nicoll & Rexroad, 1975, Pl. 5, figs. 12-14.

_Sa_ _element_.

Hibbardella _ortha_ Rexroad. Rexroad & Collinson, 1965, p. 10, Pl. 1, fig. 10; Nicoll & Rexroad, 1975, Pl. 5, figs. 7, 8.

_Sb_ _element_.

Hindeodella sp. Nicoll & Rexroad, 1975 (partim), Pl. 6, fig. 8.

_Sc_ _element_.

Hindeodella sp. Nicoll & Rexroad, 1975 (partim), Pl. 6, figs. 4, 9 (fig. 5 = Sc element of _Gnathodus_ _texanus_.).

Diagnosis. The Pa element, DE _Taphrognathus_ _varians_, is diagnostic of the species. The other elements are like those of _Cavusgnathus_.

Description. Only Pa elements are described here.

These elements conform in most respects with the original description given by Branson and Mehl (1941b, p. 182, Pl. 6, figs. 27-41) but show a greater degree of morphological variation in the nature of the blade attachment to the platform.

In present specimens the platform is high, nearly as high as as the upper edge of the free blade, and has a deep, narrow, medial trough which is bounded on either side by high parapets, which are faintly ornamented with slight transverse ridges or, on some specimens, smooth and unornamented. The denticulated free blade in lateral view has a regular upper outline with denticles which may increase slightly in size anteriorly. The blade usually does not extend onto the platform as a carina, although a very short carina is usually developed at the posterior end of the platform.

Upon close scrutiny most Pa elements recovered herein show either a left- or right-sided development of the free blade. In only a few specimens is the blade attached to the platform in a medial position. In left- or right-sided individuals the blade is usually separated from the outer parapet by a small notch, whereas the inner parapet extends slightly farther anteriorly. In a few elements the blade is continuous with the outer parapet and the element is cavusgnathiform.

Comparisons. Left- and right-sided Pa elements recovered in this study are very similar to left- and right-sided elements identified by Rexroad and Collinson (1963) and Ruppel (1979) as *Taphrognathus* - *Cavusgnathus* transitions. These latter forms were found in stratigraphic intervals where *Cavusgnathus* began to replace *Taphrognathus* as a dominant member of the conodont fauna. The migration of the blade to a lateral position, from a medial one was seen as marking the phyletic, evolutionary change to *Cavusgnathus*, although Upper Mississippian Pa elements of that genus are all known to be left-sided.

In comparison, Pa elements of *T. varians* which exhibit varying degrees of asymmetry have been found by several workers (Branson and Mehl, 1941b, p. 183, Pl. 6, figs. 3, 4; Thompson and Goebel, 1968, Pl. 5, figs. 9, 12; Nicoll and Rexroad, 1975, p. 27) throughout Lower Meramecian strata and not just in intervals where *Cavusgnathus* becomes important. Thus, the degree of asymmetry, i.e. the development of left- and right-sided Pa elements, may be due to factors other than evolutionary ones, perhaps paleoecolgical ones instead.

The above workers stated that Pa elements of *T. varians* exhibit a wide range of morphological variation. I believe that the variation exhibited by Pa elements of

Taphrognathus recovered herein, including left- and right-sided forms, is well within that range. For this reason all of these elements are included in one species, T. varians.

Elements identified as Taphrognathus - Cavusgnathus transitions by Rexroad and Collinson (1963) were recently included in a new genus, Cloghergnathus, by Austin and Mitchell (1975). Pa elements of Cloghergnathus illustrated by them and Higgins and Varker (1982) have platforms which are strongly transversely ridged or nodose, unlike the specimens of Rexroad and Collinson, that I include in Taphrognathus varians.

Results. Only ramiform elements which in other studies were solely associated with Pa elements of Taphrognathus and not Cavusgnathus are included in the synonomy lists above, although these ramiform elements are not differentiated in this study from those of Cavugnathus.

Occurrence. Little Valley Fm. (B1, B3) and base of Hillsdale Lst. (B5).

Material recovered. Pa (102)

Family IDIOGNATHODONTIDAE Harris & Hollingsworth, 1933

Genus GNATHODUS Pander, 1856

Gnathodus Pander, 1856
Dryphenotus Cooper, 1939

Type species. *Gnathodus mosquiensis* Pander, 1856

Diagnosis. This multielement genus consists of gnathodiform Pa elements, ozarkodiniform Pb elements, synprioniodiniform M elements, a hibbardelliform Sa element, angulodiform Sb elements and hindeodelliform Sc elements; of the latter there are three morphotypes, designated Sc , Sc and Sc . Different species are identified by the diagnostic Pa elements (see Ziegler, 1981).

Remarks. Following Lane, Sandberg and Ziegler (1980), the generic name *Gnathodus* is retained, although Barskov, Alekseev and Goreva (1977) have shown that the type species, *Gnathodus mosquiensis* Pander, is lost and could not have come from Lower Carboniferous aged-strata. The synonym *Dryphenotus* Cooper may be the taxonomically correct name. For a further discussion see Lane *et al*. (1980) and Ziegler (1981).

The apparatus of *Gnathodus* is well understood through studies of natural bedding-plane assemblages by Schmidt and Muller (1964) and Norby (1974, 1976). Examination of *Gnathodus* shows that it is closely related to other genera of the family Idiognathodontidae, *Idiognathodus* and *Streptognathodus* (von Bitter, 1972 and Baesemann, 1973) *Idiognathoides* (Higgins, 1981) and *Neognathodus* (Merrill and von Bitter, 1977). Ramiform elements of all these genera appear to be nearly identical.

Herein, ramiform elements are listed together under Gnathodus spp. because these elements can not be assigned with certainty to a given species. Although the degree of interspecific variation is not well known, evidence suggests that ramiform elements were vicariously shared by different species.

GNATHODUS BILINEATUS (Roundy)

Pl. 6, figs. 1-3.

Pa element.

?Polygnathus (Gnathodus) mosquiensis Pander. Hinde, 1900, p. 342, Pl. 9, figs. 2-4.

Polygnathus bilineatus Roundy, 1926, p. 13, Pl. 3, fig. 10.

Gnathodus bilineatus (Roundy). Igo, 1973, p. 193, Pl. 29, figs. 1-6; Austin & Husri, 1974, Pl. 2, figs. 4, 5, 7, 8, 13; Lane,& Straka, 1974, p. 72-77, fig. 32: 1-5, 7, 9, 11-13; fig. 33: 11-13, 19-23,25, 28-32; fig. 34: 13-26; fig. 40: 27; Rice & Langenheim, 1974b, p. 27, Pl. 1, fig. 11; Matthews & Thomas, 1974, Pl. 50, fig. 19, Pl. 51, figs. 12-15, 20-24; Igo & Kobayashi, 1974, p. 418, 420, Pl. 56, figs. 1-3; Watanabe, 1975, p. 163, Pl. 14, figs. 1-5; Metcalfe, 1980, p. 302, Pl. 38, figs. 5, 8, 9; Tynan, 1980, Pl. 1, fig. 19.

Gnathodus bilineatus bilineatus (Roundy). Higgins, 1975, p. 28-29, Pl. 11, figs. 1-4, 6, 7 (includes synonomy of G. bilineatus through 1970); Skompski & Sobon-Podgorska, 1980, Pl. 5, fig. 4.

?Gnathodus bilineatus bollandensis Higgins & Bouckaert. Higgins, 1975, p. 29, Pl. 11, figs. 5, 8-13 (includes synonomy of this subspecies).

Gnathodus sp. Matthews & Thomas, 1974, Pl. 50, figs. 20, 22.

Multielement.

Gruppe mit Gnathodus bilineatus (Roundy). Schmidt & Muller, 1964, p. 114-116, figs. 7, 8.

Gnathodus bilineatus (Roundy). Norby, 1976, p. 102-122,

Pl. 4, fig. 1a-d; Pl. 5, figs. 1-16b, Pl. 10, fig. 5, text-fig. 20.
Gnathodus bilineatus bilineatus (Roundy). Higgins & Wagner-Gentis, 1982, p. 328-330, Pl. 34, figs. 1, 3, 19, 20, 22, 24-26.

Remarks. Most Pa elements, studied herein, conform to the descriptions of previous workers (see Rhodes, Austin and Druce, 1969). Specimens, though, from the "Ste. Genevieve" Formation, exposed at the Lindell section, are atypical in possessing narrow, weakly ornamented outer platforms (Pl. 6, fig. 3) much like smaller, juvenile forms of more typical Pa elements (see Pl. 6, fig. 2).

Occurrence. Hillsdale Lst. (B, W), "Denmar-Gasper" Fm. (B), "Ste. Genevieve" Fm. (L).

Material recovered. Pa (158).

GNATHODUS GIRTYI GIRTYI Hass

Pl. 6, fig. 5

Pa element.
Gnathodus girtyi Hass, 1953, p. 80, Pl. 14, figs. 22-24.
Gnathodus girtyi girtyi Hass. Rhodes, Austin & Druce, 1969 (partim), p. 98-99, Pl. 17, figs. 9, 10 only; Rice & Langenheim, 1974b, p. 28, Pl. 1, figs. 15, 16; Skompski & Sobon-Podgorska, 1980, Pl. 5, figs. 2, 3, 8; Tynan, 1980, p. 1302, Pl. 1, figs. 9, 16-18 (includes synonomy through 1976); Higgins & Wagner-Gentis, 1982, p. 334, Pl. 34, fig. 9.

Diagnosis. The Pa element is diagnostic of this species. The description of Hass (1953) for G. girtyi is the same for this subspecies. Higgins (1975) and Tynan (1980) explain how this subspecies may be differentiated from others.

Occurrence. Hillsdale Limestone (L13, L18).

Material recovered. Pa (30).

GNATHODUS HOMOPUNCTATUS Ziegler

Pl. 6, figs. 4, 8.

Pa element.
Gnathodus commutatus punctatus Bischoff, 1957, p. 24, Pl. 4, figs. 7-11, 14.
Gnathodus commutatus homopunctatus Ziegler, 1960, p. 39, Pl. 4, fig. 3; Matthews & Thomas, 1974, Pl. 51, fig. 6.
Gnathodus homopunctatus Ziegler. Rhodes, Austin & Druce, 1969, p. 103, Pl. 19, figs. 5-8; Higgins, 1975, p. 33-34, Pl. 7, figs. 1-6; Pl. 10, fig. 7 (includes synonomy through 1969); Tynan, 1980, Pl. 1, figs. 1, 2.
Gnathodus symmutatus Rhodes, Austin & Druce. Skompski & Sobon-Podgorska, 1980, Pl. 5, fig. 1.
Gnathodus symmutatus homopunctatus Ziegler. Austin & Husri, 1974, Pl. 4, figs. 1, 9, 12.
Gnathodus symmutatus mermaidus Austin & Husri, 1974, p. 54-55, Pl. 3, fig. 11; Pl. 4, fig. 10.
Gnathodus commutatus lineatus Austin & Husri, 1974, p. 52-53, Pl. 3, fig. 9,; Pl. 4, fig. 11.
Gnathodus sp. Matthews & Thomas, 1974, Pl. 51, figs. 4, 8, 9.

?Pb element.
Ozarkodina plumula Collinson & Druce, in Rhodes, Austin & Druce, 1969 (nom. nud.), p. 175-176, Pl. 27, figs. 4, 5.
Ozarkodina collinsoni Higgins, 1975, p. 68-69, Pl. 5, figs. 4, 8, 9; Tynan, 1980, Pl. 2, fig. 6.

Diagnosis. The Pa element is diagnostic of the species. For a description of this element see Rhodes, et al. (1969, p. 103). Aside from the designated Pb element, ramiform elements are shared vicariously by other species of Gnathodus.

Remarks. Previously, some workers have treated G.

homopunctatus as a subspecies of "Gnathodus" (=Lochriea) commutatus. This can be discounted because Scott (1942) and Norby (1974, 1976) have shown that Lochriea commutatus has distinctly different ramiforms than species of Gnathodus or any members of the Family Idiognathodontidae. In this study some samples from the Hillsdale Limestone at the Bishop section (B11, B12), that contained Gnathodus ramiform elements (DE Hindeodella ibergensis, DE H. uncata and DE H. simplex, for example) were associated with common elements of DE Gnathodus homopunctatus. No other Gnathodus Pa elements or any elements of Lochriea were found in these samples.

Lane, et al. (1980) and Ziegler (1981) restricted the concept of Gnathodus to include only Pa elements that have asymmetric posterior cups; the inner side of each element is developed as a high, narrow parapet. If one accepts this limitation, G. homopunctatus would have to be transferred to a new genus because the Pa elements have very nearly symmetrical platforms. For the present, though, I have retained G. homopunctatus as a valid species of Gnathodus.

Small Pa elements closely resemble DE G. symmutatus Rhodes, Austin and Druce, in having platforms which are unornamented except for one or two small incipient nodes developed on either side of the median carina. These elements do not belong to a separate species, but are part of a continuously gradational ontogenetic series. Progressively larger Pa elements exhibit more pronounced platform denticulation.

DE _Ozarkodina collinsoni_ is tentatively assigned as the Pb element because of its close association with Pa elements. Previous studies (Rhodes, _et al._, 1969; Higgins, 1975; and Tynan, 1980) show this relationship and in this study these Pb elements were only found in samples that contained Pa elements of _G. homopunctatus_. DE _Ozarkodina collinsoni_ is also very similar morphologically to Pb elements of other species of _Gnathodus_ (DE _Ozarkodina roundyi_ and DE _O. delicatula_).

Occurrence. Hillsdale Lst. (B, W, L) and "Denmar-Gasper" Fm. (B).

Material recovered. Pa (146), Pb (4).

GNATHODUS TEXANUS Roundy

Pl. 6, fig. 6.

Pa element.

Gnathodus texanus Roundy, 1926, p. 12, Pl. 2, figs. 7, 8; Dunn, 1970, p. 332, Pl. 62, fig. 21; Rice & Langenheim, 1974b, p. 28, Pl. 1, fig. 19; Nicoll & Rexroad, 1975, p. 20, Pl. 4, figs. 1-6; Ruppel, 1979, p. 67, Pl. 1, figs. 7-10; Lane, Sandberg and Ziegler, 1980, p. 133, Pl. 6, figs. 8, 9, 11, 12, 16; Tynan, 1980, Pl. 1, figs. 14, 15; Ziegler, 1981, p. 149-152, Pl. 3, figs. 5-10 (includes synonomy through 1970).

?_Gnathodus texanus_ Roundy. Koike, 1967, p. 300, Pl. 1, fig. 26; Austin & Husri, 1974, Pl. 4, figs. 2, 8 (= _G. pseudosemiglaber_?).

?_Gnathodus_ aff. _texanus_ Roundy. Igo, 1973, p. 194, Pl. 29, fig. 7.

Diagnosis. The Pa element is diagnostic of the species. For a description of this element see Ziegler (1981; p. 143). Ramiform elements were vicariously shared with other species of *Gnathodus* (see Nicoll and Rexroad, 1975, for an association of ramiform elements with Pa elements of *G. texanus*).

Remarks. One Pa element was recovered from the "Ste. Genevieve" Formation at the Lindell section in the Greendale Syncline.

Occurrence. "Ste. Genevieve" Fm. (L32).

Material recovered. Pa (1).

GNATHODUS spp.

Pl. 6, figs. 7, 9-14.

Pb element.

Ctenognathus sp. B Roundy, 1926, p. 16, Pl. 2, figs. 4, 5.

Subbryantodus roundyi Hass, 1953, p. 89, Pl. 14, figs. 3-6.

Ozarkodina roundyi (Hass). Bischoff, 1957, p. 40, Pl. 1, figs. 29-32; Pl. 2, figs. 1-3; Rexroad, 1957, p. 37, Pl. 2, fig. 7; Dunn, 1965, p. 1149, Pl. 140, figs. 19, 20; Webster, 1969, p. 43, Pl. 7, fig. 8; Marks & Wensink, 1970, p. 267, Pl. 1, fig. 11; Rice & Langenheim, 1974b, p. 32, Pl. 2, fig. 19; Nicoll & Rexroad, 1975, p. 26, Pl. 5, figs. 1-3.

non *Ozarkodina roundyi* (Hass). Reynolds, 1970, p. 15, Pl. 2, fig. 11 (= Pb element of *Lochriea*).

Ozarkodina delicatula (Stauffer & Plummer). Bischoff, 1957, p. 39, Pl. 1, figs. 25-28; Higgins, 1961, p. 220, Pl. 12, fig. 13; Rexroad & Burton, 1961, p. 1156, Pl. 141, fig. 12; Globensky, 1967, p. 446, Pl. 56, fig. 19; Higgins & Bouckaert, 1968, p. 45, Pl. 3, fig. 3; Rhodes, Austin & Druce, 1969, p. 170-171, Pl. 27, figs. 15, 19; Webster, 1969, p. 42-43, Pl. 7, fig. 11; Reynolds, 1970,

p. 15, Pl. 2, fig. 14; Igo, 1973, p. 195, Pl. 29, fig. 29; Rice & Langenheim, 1974b, p. 32, Pl. 2, fig. 17; Austin & Husri, 1974, Pl. 12, fig. 5; Higgins, 1975, Pl. 5, figs. 9, 11, 16; Metcalfe, 1980, p. 308, Pl. 37, fig. 22.

Ozarkodina compressa Rexroad. Reynolds, 1970, Pl. 2, fig. 13; Austin & Husri, 1974, Pl. 12, figs. 6, 25.

Ozarkodina sp. Igo & Koike, 1968 (partim), Pl. 3, fig. 4 only.

Subbryantodus stipans Rexroad, 1957, p. 39, Pl. 4, fig. 1; Higgins, 1961, p. 219, Pl. 12, fig. 14; Higgins, 1962, p. 13, Pl. 1, fig. 9; Higgins, 1975, p. 74, Pl. 5, figs. 14, 15.

Prioniodina stipans (Rexroad). Rhodes, Austin & Druce, 1969, p. 198, Pl. 28, figs. 7-10; Austin & Husri, 1974, Pl. 12, figs. 4, 7, 8.

Subbryantodus subaequalis Higgins. Reynolds, 1970, Pl. 2, fig. 10.

?*Subbryantodus planidorsalis* Clarke, 1960, p. 22, Pl. 3, fig. 18.

M element.

Synprioniodina sp. Gunnell, 1933, p. 264, Pl. 31, fig.6.

?*Synprioniodina microdentata* Ellison, 1941, p. 119, Pl. 120, figs. 43-46 (= M element of *Gondolella*, see von Bitter, 1976).

Synprioniodina microdentata Ellison. Webster, 1969, p. 50, Pl. 8, fig. 15; Higgins, 1975, p. 75, Pl. 3, figs. 10, 15, 16 (includes synonomy through 1970); Metcalfe, 1980, p. 307, Pl. 37, fig. 16; Tynan, 1980, Pl. 2, fig. 11.

Euprioniodina microdentata (Ellison). Austin & Husri, 1974, Pl. 13, figs. 19, 20.

Synprioniodina laxilabrum Rexroad & Collinson, 1965, p. 23, Pl. 1, figs. 3-5; Thompson & Goebel, 1968, p. 44, Pl. 3, fig. 10, Nicoll & Rexroad, 1975, Pl. 6, figs. 1-3.

Synprioniodina denticamera Rexroad & Liebe. Dunn, 1970, p. 340, Pl. 62, figs. 33, 34.

Synprioniodina sp. Lane,& Straka, 1974, fig. 44: 45.

Euprioniodina caverna (Collinson & Druce), (*nom. nud.*) Rhodes, Austin & Druce, 1969, p. 90, Pl. 22, fig. 11; Austin & Husri, 1974, Pl. 12, figs. 20, 23.

Sa element.

Hibbardella acuta Murray & Chronic, 1965, p. 598, Pl. 73, figs. 3-5; Austin & Husri, 1974, Pl. 13, figs. 10, 12; Higgins, 1975, p. 34, Pl. 1, figs. 7, 9 (includes synonomy through 1970); Metcalfe, 1980, p. 304, Pl. 37, fig. 3; Tynan, 1980, Pl. 2, fig. 7.

Sb element.
Angulodus walrathi (Hibbard). Bischoff, 1957, p. 17, Pl. 5, figs. 44, 45.
Hindeodella paradelicatula Igo & Koike, 1964, p. 183, Pl. 27, figs.3, 4; Koike, 1967, Pl. 4, fig. 3.
Hindeodella simplex (Higgins & Bouckaert). Higgins, 1975, p. 42-43, Pl. 5, figs. 10, 12, 13 (includes synonomy through 1970).
Hindeodella hibbardi Collinson & Druce (nom. nud.). Austin & Husri, 1974, Pl. 15, figs. 9, 10.
Hindeodella spp. Murray & Chronic, 1965 (partim), p. 600, Pl. 72, fig. 20 only.

Sc_1 element.
Hindeodella ibergensis Bischoff, 1957 (partim), p. 28, Pl. 6, fig. 33 only; Austin & Husri, 1974 (partim), Pl. 15, fig. 18 only; Higgins, 1975 (partim), p. 38-40, Pl. 4, figs. 11, 14 only.
(see Norby, 1976, under Gnathodus bilineatus, A a element, for a complete synonomy).

Sc_2 element.
Hindeodella sp. Ellison, 1941 (partim), p. 118, Pl. 20, fig. 18 only.
Hindeodella sp. Ellison & Graves, 1941 (partim), p. 2, Pl. 1, fig. 6 only.
Hindeodella ibergensis Bischoff, 1957 (partim), p. 28, Pl. 6, figs. 37, 39 only; Austin & Husri, 1974, Pl. 12, fig. 26; Higgins, 1975 (partim), p. 38-40, Pl. 4, figs. 10, 15 only; Metcalfe, 1980, p. 305, Pl. 37, fig. 10; Tynan, 1980, Pl. 2, fig. 3.
Hindeodella spp. Nicoll & Rexroad, 1975 (partim), Pl. 6, fig. 5 only.
see Norby (1976) under Gnathodus bilineatus, A b element, for further synonomy.

Sc_3 element.
Hindeodella parva Ellison, 1941, p. 117, Pl. 20, fig. 29.
Hindeodella brevis Branson & Mehl. Bischoff, 1957, p. 26, Pl. 6, fig. 24.
Hindeodella uncata (Hass). Austin & Husri, 1974, Pl. 15, fig. 13; Higgins, 1975, p. 44, Pl. 4, figs. 1-3 (includes synonomy through 1970); Metcalfe, 1980, p. 305, Pl. 37, fig. 9.

Remarks. Pb elements of Gnathodus are undifferentiated herein, but could be assigned to either

DE *Ozarkodina delicatula* or DE *O. roundyi*. These two forms, along with DE *Subbryantodus stipans*, are very similar morphologically and appear to be intergradational, based on previous reports.

The concept of DE *O. delicatula* is morphologically very broad and has been used to embrace Upper Mississippian (Visean - Lower Namurian) forms along with strictly Pennsylvanian Pb elements of the related genera, *Streptognathodus*, *Idiognathodus* and *Idiognathoides*. Norby (1976) restricted DE *O. delicatula* to the Pennsylvanian and made Pb elements of *Gnathodus bilineatus* synonomous with DE *O. roundyi*. However, Pb elements that he illustrated (Pl. 6, figs. 6, 8; Pl. 8, figs. 3, 5, 6, 9) might be easily taken for DE *O. delicatula*, and DE *S. stipans* as well, if not for the relatively small basal cavity of that element. Schmidt and Muller (1964) and Higgins and Wagner-Gentis (1982) referred Pb elements of *G. bilineatus* to DE *O. delicatula*. Indeed, specimens recovered in this study, which are probably Pb elements of *G. bilineatus*, appear most similar to DE *O. delicatula*.

Perhaps different Pb morphotypes are associated with particular species, yet at present this can not be determined. Alternatively, different morphotypes may be more indicative of different ecological tolerances or geographic distributions.

Material recovered. Pb (11), M (2), Sa (2), Sb (6), Sc (12), Sc (2), Sc (14).

Family UNKNOWN

Genus LOCHRIEA Scott, 1942

Lochriea Scott, 1942, p. 298
Paragnathodus Meischner, 1970 (*nom. nud.*). p. 1173.
Paragnathodus Higgins, 1975, p.70.

Type species. *Spathognathodus commutatus* Branson & Mehl, 1941

Diagnosis. The apparatus consists of spathognathodiform Pa elements, ozarkodiniform Pb elements, neoprioniodiform M elements, a hibbardelliform Sa element and hindeodelliform Sc and Sc elements. No Sb (angulodiform) elements have yet been distinguished. The Pa element is diagnostic of the respective species and is characterized by a low, simple, unornamented or ornamented (nodose), cup-like platform.

Remarks. The multielement reconstruction of *Lochriea* is based primarily upon natural bedding-plane assemblages studied by Scott (1942) and Norby (1976). Horowitz and Rexroad (1982) statistically confirmed a partial reconstruction of the apparatus. Although Pa elements exhibit similarities to Pa elements of species of multielement *Gnathodus*, the element composition of *Lochriea* is different from genera of the family

Idiognathodontidae, which all show a striking degree of conformity of ramiform elements. Elements of Lochriea also exhibit different ultrastucture than elements of that group (Norby, 1976).

LOCHRIEA COMMUTATUS (Branson & Mehl)

Pl. 7, figs. 1-7.

Pa element.
Spathognathodus commutatus Branson & Mehl, 1941c, p. 98, Pl. 19, figs. 1-4.
Spathognathodus pellaensis Youngquist & Miller, 1949, p. 622, Pl. 101, fig. 6.
Gnathodus inornatus Hass, 1953, p. 80, Pl. 14, figs. 9-11.
Gnathodus commutatus commutatus (Branson & Mehl). Bischoff, 1957, p. 23, Pl. 4, figs. 2-6, 15; Austin & Husri, 1974, Pl. 3, figs. 1-3, 12.
Gnathodus commutatus (Branson & Mehl). Rexroad & Burton, 1961, p. 1153, Pl. 139, figs. 1-3; Rice & Langenheim, 1974b, p. 27, Pl. 1, fig. 13, 14; Igo & Kobayashi, 1974, p. 420-421, Pl. 56, figs. 6, 7; Watanabe, 1975, p. 164, Pl. 14, figs. 8-11; Metcalfe, 1980, p. 304, Pl. 38, figs. 3, 4.
Paragnathodus commutatus (Branson & Mehl). Higgins, 1975, p. 70-71, Pl. 7, figs. 7-9, 11, 13, 16, 20, 21; Skompski & Sobon-Podgorska, 1980, Pl. 5, fig. 5.
non Paragnathodus commutatus (Branson & Mehl). Tynan, 1980, Pl. 1, figs. 3, 4 (= Gnathodus symmutatus Rhodes, Austin & Druce or Gnathodus homopunctatus Ziegler).
(See Norby ,1976, p. 146-149, for a more detailed synonomy.)

Pb element.
Prioniodina montanaensis (Scott). Stanley, 1958, p. 474, Pl. 64, fig. 5, Pl. 65, fig. 1.
Prioniodina sp. B Stanley, 1958, p. 474, Pl. 65, fig. 7.
Prioniodina sp. C Stanley, 1958, p. 474, Pl. 65, fig. 2.
Ozarkodina deflecta Stanley, 1958, p. 472, Pl. 65, figs. 4, 5.
Subbryantodus subaequalis Higgins, 1961, p. 218-219, Pl. 12, fig. 15, text-fig. 6; Higgins & Bouckaert, 1968, p. 47, Pl. 3, figs. 1, 2; Higgins, 1975, p. 74, Pl. 5, fig. 17.
?Subryantodus subaequalis Higgins. Metcalfe, 1980, p. 309,

Pl. 37, fig. 20.
non *Subbryantodus subaequalis* (Higgins). Reynolds, 1970, p. 18, Pl. 2, fig. 10 (= DE ?*S. stipans*).
Prioniodina subaequalis (Higgins). Rhodes, Austin and Druce, 1969, p. 198, Pl. 28, figs. 1-4; Rice & Langenheim, 1974b, p. 32-33, Pl. 3, fig. 3; Austin & Husri, 1974, Pl. 12, figs. 1-3, 9.
Ozarkodina subaequalis (Higgins). Marks & Wensink, 1970, p. 267, Pl. 1, fig. 13; Watanabe, 1975, p. 166, Pl. 14, figs. 22, 23.
Ozarkodina sp. A Globensky, 1967 (partim), p. 446, Pl. 55, fig. 5 only.
Ozarkodina cf. *O. recta* Rexroad. Dunn, 1970, p. 338, Pl. 62, figs. 25, 26.
Ozarkodina sp. nov. Reynolds, 1970, p. 15, Pl. 2, fig. 15.
?*Ozarkodina roundyi* (Hass). Reynolds, 1970, p. 15, Pl. 2, fig. 11.
?*Ozarkodina plana* (Huddle). Reynolds, 1970, p. 15, Pl. 2, fig. 12.

M element.
Prioniodus singularis Hass, 1953, p. 88, Pl. 16, fig. 4.
Neoprioniodus singularis (Hass). Stanley, 1958, p. 471, Pl. 66, figs. 2, 3; Rice & Langenheim, 1974b, p. 31, Pl. 2, fig. 13; Higgins, 1975, p. 68, Pl. 3, fig. 11; Metcalfe, 1980, p. 307, Pl. 37, fig. 15.
Neoprioniodus montanaensis (Scott). Rhodes, Austin & Druce, 1969, p. 160, Pl. 22, figs. 5-8; Austin & Husri, 1974, Pl.12, figs. 11, 16, 18.
(see Norby, 1976, p. 153,154, for a more complete synonomy through 1975)

Sa element.
Hibbardella pennata Higgins, 1961, p. 213, Pl. 13, figs. 5, 6; Higgins & Bouckaert, 1968, p. 36, Pl. 1, fig. 10; Reynolds, 1970, p. 10, Pl. 2, figs. 8, 9; Metcalfe, 1980, p. 305, Pl. 37, fig. 11.
Hibbardella (*Hibbardella*) *parva* Rhodes, Austin & Druce, 1969, p. 114-115, Pl. 25, fig. 21; Austin & Husri, 1974, Pl. 13, figs. 1, 2.

Sc$_1$ element.
Hindeodella mehli Elias, 1956, p. 108, Pl. 1, figs. 22-24.
Hindeodella montanaensis Scott. Stanley, 1958 (partim), p. 465, Pl. 64, figs. 1-4, 5; Metcalfe, 1980, p. 305, Pl. 37, fig. 8 (includes complete synonmy).

Multielement.
Lochriea montanaensis Scott, 1942, p. 298-299, Pl. 37, figs. 1-7; Pl. 38, figs. 1-4, 6, 7, 10, 12; Pl. 39,

figs. 1, 4, 7, 9; Pl. 40, figs. 2-5, 9, 10, 12, 13, 15, 18, 19; text-fig. 1.
Lochriea bigsnowyensis Scott, 1942 (partim), p. 299, Pl. 40, figs. 3-5 only.
Lochriea commutatus (Branson & Mehl). Norby, 1976, p. 143-157, Pls. 11-13, Pl. 14, figs. 1, 3-9, text-fig. 21.

Diagnosis. The Pa element is diagnostic of this species while the ramiform elements were vicariously shared by other species. The Pa element is characterized by a low, unornamented, cup-like platform and a denticulated blade which extends onto the platform as a high carina and is rectangular in lateral view. The Pb element is relatively unarched and is characterized by tall, thin, discrete denticles. The M element has a large, compressed apical cusp and a short, laterally incurved posterior process with denticles that decrease regularly in height, posteriorly. The hibbardelliform Sa element is small and delicate. The Sc elements consist of two variant morphotypes: one, the Sc_1 element, has a short, inwardly curved, denticulated, antero-lateral process and the other, the Sc_3 element, has a longer, denticulated antero-lateral process, nearly perpendicular to the posterior process. No angulodiform Sb elements have yet been distinguished.

Descriptions. All of the component elements, except for the Pb element, have been well described in previous reports and the reader is referred to those works for details. An emended description (from that of Norby, 1976) of the Pb element is given below.

Pb element. The element has a nearly straight, thin, anterior process of uniform height. The lower, lateral profile is straight to slightly convex. The denticles of the anterior process are thin, usually erect to slightly inclined posteriorly and characteristically discrete except in gerontic forms in which they may partially fused for one-half to two-thirds of their length.

The apical denticle is often the same size or only slightly larger than the other denticles and is slightly more inclined posteriorly than the anterior process-denticles.

The posterior process is strongly arched, with a concave, lower lateral profile. The denticles exhibit a pronounced posterior inclination, with the first denticle posterior to apical denticle noticeably inclined with respect to that denticle. The other denticles are progressively more inclined distally. These denticles are discrete and may alternate in size, unlike denticles on the anterior process.

Remarks. The Pb element is restricted from the sense of Norby (1976). He included as Pb elements, DE Ozarkodina recta Rexroad and DE Subbryantodus stipans Rexroad (sense of Higgins, 1961, 1962; and Rhodes et al., 1969).

Elements that resemble the holotype of DE _O._ _recta_ are probably Pb elements of the multielement genus _Cavusgnathus_ (see discussion under Pb elements of that genus). DE _S._ _stipans_, as understood by British workers, differs from Pb elements of this species by having short, closely appressed, posteriorly inclined denticles and arched anterior and posterior processes. In all DE _S._ _stipans_ is closest in morphology to DE _O._ _roundyi_ (Hass) which is included by Norby (1976) and herein as a Pb element of multielement _Gnathodus_.

Occurrence. Hillsdale Lst. (B, W), "Denmar-Gasper" Fm. (B, W) and "Ste. Genevieve" Fm. (L).

Material recovered. Pa (155), Pb (27), M (66), Sa (9), Sc (31).

Genus RHACHISTOGNATHUS Dunn, 1966

Type species. _Rhachistognathus primus_ Dunn, 1966

RHACHISTOGNATHUS cf. R. MURICATUS (Dunn)

Pl. 5, figs. 1, 2.

Pa element.
?_Cavusgnathus muricata_ Dunn, 1965, p. 1147, Pl. 140, figs. 1, 4.
?_Rhachistognathus muricatus_ (Dunn). Metcalfe, 1980, p. 308, Pl. 38, figs. 24, 25; Tynan, 1980, p. 1303-1304, Pl. 1, fig. 27 (includes synonomy through 1974).
Spathognathodus muricatus (Dunn). Thompson, 1972, p. 39, Pl. 1, figs. 8-19; MacGill, 1973, p. 44-45, Pl. 2, figs. 12, 14.
?_Rhachistognathus_ sp. A Tynan, 1980, p. 1304-1305, Pl. 1, figs. 21-23.
Spathognathodus n. sp. Thompson & Goebel, 1968, p. 43, Pl.

1, figs. 9, 15-17.

Diagnosis. Only the Pa element of this species is known. The element is left-sided and has a narrow platform ornamented by two parallel rows of nodes. The left-sided row of nodes is continuous with the blade and at the posterior end of the platform is deflected to form a short medial carina. Several nodes on the left side are fused at the anterior end of the platform.

Rhachistognathus _muricatus_ is commonly believed to be restricted to rocks of the uppermost Chesterian and Morrowan (Lower Pennslyvanian) Series (Lane and Straka, 1974; Tynan, 1980), although nearly identical forms have been reported from Meramecian and lower Chesterian rocks. DE _Spathognathodus_ n. sp. (Thompson and Goebel, 1968) recovered from the Meramecian St. Louis Limestone of Kansas is identical in form with Pa elements of _R_. _muricatus_. Elements assigned to DE _Spathognathodus_ _muricatus_ have been recovered by MacGill (1973) from the St. Louis Limestone Member of the Newman Formation of eastern Kentucky and by Thompson (1972) from the lower Chesterian Hindsville Limestone of southwestern Missouri. Lane and Straka (1974) and Tynan (1980) believed that these older forms were probably early homeomorphs of _R_. _muricatus_.

Given the number of occurrences of these forms throughout the Late Mississippian and the paucity of knowledge of the evolution of *R. muricatus*, it seems reasonable to postulate that Latest Mississippian forms are just an extention of an older lineage, and not unrelated to older elements. Further study may close the evolutionary gaps between Latest Mississippian *R. muricatus* and earlier element.

Occurrence. Hillsdale Lst. (B6) and "Ste. Genevieve" Fm. (L32).

Material recovered. Pa (9).

Genus "SPATHOGNATHODUS" Branson & Mehl, 1941c

"SPATHOGNATHODUS" CAMPBELLI Rexroad

Pl. 7, figs. 9-15.

Pa element.
Spathognathodus campbelli Rexroad, 1957, p. 37-38, Pl. 3, figs. 13-15; Merrill, 1973,p. 303-304, Pl. 3, fig. 60 (includes synonomy through 1970); Igo, 1973, p. 195-196, Pl. 29, fig. 23; Austin & Husri, 1974, Pl. 9, figs. 1, 5, 6; Rice & Langenheim, 1974b, p. 33, Pl.3, fig. 4; Higgins, 1975, p. 73, Pl. 10, fig. 11; Watanabe, 1975, p. 166-167, Pl. 15, figs. 11-14; Metcalfe, 1980, p. 308-309, Pl. 38, fig. 13; von Bitter & Plint-Geberl, 1982, p. 200, Pl. 5, figs. 10, 11, 20, 21.

M element.
Neoprioniodus sp. nov. A Rhodes, Austin & Druce, 1969, p. 166-167, Pl. 22, fig. 14.
Neoprioniodus parvus Higgins, 1975, p. 67, Pl. 3, fig. 8.

Sa element.
Hibbardella higginsi Scatterday, 1963, p. 74-75, Pl. 4, figs. 3, 4.
Sb_2 element.
Plectospathodus? sp. nov. B. Rhodes, Austin & Druce, 1969, p. 181, 189, Pl. 25, figs. 10-12.

Hindeodella? macrodentata Higgins, 1975, p. 42, Pl. 6, figs. 7, 8.

Multielement.
Pandorinellina campbelli (Rexroad). Norby, 1976, p. 170-183, Pls. 17; 18; 19, figs. 1a-e.

Diagnosis. The apparatus may be seximembrate or septimembrate. The Pa element is diagnostic of the species and is spathognathodiform. Also included are ozarkodiniform Pb elements, neoprioniodiform M elements, a hibbardelliform Sa element, dimorphic, angulodiform Sb_1 and plectospathodiform Sb_2 elements and (probably) hindeodelliform Sc elements. The plectospathodiform Sb element had not been recognized until this study.

Description. All elements are thin and laterally compressed. The ramiform elements are particularly small and delicate. Although Norby (1976) originally described most of the elements of this species in detail, shorter descriptions are given here, too.

Pa element. The element is a relatively high blade which does not show platform development. The blade is slightly bowed laterally, particularly the posterior end, making the outer-lateral face gently convex. The upper margin is denticulated and the denticles are short, bluntly pointed and laterally compressed. Along the anterior half of the blade the denticles are subequal and erect, but toward the posterior end they become shorter and slightly inclined posteriorly. At midlength of the blade one denticle is usually slightly higher than the others.

The lower margin is straight along the anterior half of the element, but posteriorly it is slightly concave along the margin of the basal cavity. The lower part of the blade below a thin line which parallels the lower margin is thinner than the main portion of the blade. The line is most noticeable in the anterior half of the element.

The basal cavity is narrow, elongate, slightly flared and fusiform in shape. It is slightly more open to the inner side of the element. The small nodes or spikes along the anterior, lateral sides of the element observed by Norby (1976) could not be resolved in the present specimens.

Pb element. The element is characterized by a large, broadly based, sharply pointed apical cusp. The anterior edge of the cusp in lateral view is gently convex, while the posterior edge is straight to gently concave. The outer-lateral face is more convex than the inner-lateral face which may be flat or slightly concave at the base of the cusp. A short posterior process bears one to two, small, short denticles. An anterior process is slightly developed and has one or two small denticles which appear as small notches along the anterior margin of the cusp.

The shortness of the anterior and posterior processes may be due to poor preservation of the recovered specimens. The small basal cavity is more flared along the outer side of the element than the inner side.

<u>M element</u>. The posterior process forms an obtuse angle with the apical cusp and is bowed inward giving it a gently convex outer-lateral face. It bears short, slender denticles which alternate in size, two or three denticles separated by slightly larger denticles. The apical cusp is not quite as wide as the posterior process is high and has a short anticusp. The apical cusp is bowed slightly inward and is slightly curved posteriorly, which produces a gently convex anterior margin. Along the anterior margin of the anticusp are developed several, very small, thin, compressed and fused denticles. The basal cavity is small and flared along the inner side of the element. In transmitted light the cavity is cone-shaped with the tip of the cone directed anteriorly.

<u>Sa element</u>. The short posterior process has a concave lower margin and a concave upper outline. The upper margin bears thin, delicate, posteriorly inclined denticles which are partially fused. The denticles are slightly larger toward the posterior end of the process, which is terminated by a large, posteriorly inclined denticle. This denticle is longer, wider and more

compressed than the apical cusp. Along the lower posterior edge of this denticle are small, thin, fused and subhorizontal denticles.

The apical cusp has a triangular base; its anterior face is confluent with the lateral processes. At its distal end, the apical cusp is rounded in cross-section. The apical cusp is nearly straight but is slightly inclined posteriorly.

The lateral processes are short, but higher than the posterior process and are spatulate in shape. Each process has a slightly convex anterior face and bears seven to ten, very small, thin denticles.

A small, triangular pit is present at the base of the apical cusp.

$\underline{Sb_1}$ element. This angulodiform element is arched at roughly midlength, and the moderately long anterior process is directed downward. The anterior process is bowed inward and has a gently convex, outer-lateral surface. The lower surface is slightly concave; the upper surface is denticulated with one to three, small, slender denticles alternating with slightly larger denticles. The denticles are strongly inclined posteriorly.

The apical cusp is situated at the point of flexure between the anterior and posterior processes. It is long, three to four times the length of the anterior process-denticles, slender, sharply pointed and posteriorly inclined. It is curved slightly inward and has a convex, outer-lateral face.

The posterior process is short and slightly higher than the anterior process. It has a nearly straight lower margin. Along the upper margin the denticles adjacent to the apical cusp are like those on the anterior process, alternating in size, but posteriorly the denticles are larger. Here, there is a large, posteriorly inclined denticle, which may be as large or larger than the apical cusp. Along the posterior edge of this large denticle are found up to nine or ten, tiny, closely packed, subhorizontal denticles.

The small basal cavity is triangular and flared on the inner side of the element. Viewed in transmitted light, the cavity is cone-shaped and inclined posteriorly in-line with the apical cusp.

Sb$_2$ *element*. This plectospathodiform element is characterized by a short, inwardly curved anterior process, a posteriorly inclined apical cusp and a posterior process, slightly longer than the anterior process, which is twisted so that its upper margin is directed outward. The lower margin is straight.

The distal end of the anterior process is curved inward and the outer face is gently convex. The denticles along the upper margin increase in size anteriorly, with the anteriormost denticle nearly as large as the apical cusp. This denticle is slightly inclined inward and is nearly erect.

The apical cusp is long, slender and sharply pointed. It is inclined strongly posteriorly and slightly inward.

The distal end of the posterior process is twisted with respect to the apical cusp so that the upper, denticulated margin is directed outward with respect to the lower margin. The denticles adjacent to the apical cusp alternate in size, but posteriorly they become larger and progressively more inclined. The distal denticle is larger than the apical cusp.

The asymmetrical basal cavity is small and is slightly anterior to the apical cusp. The opening is triangular in shape and is more open to the inner side of the element. Seen in transmitted light the basal cavity is cone-shaped and inclined posteriorly in line with the apical cusp.

<u>Sc element</u>. No unequivocal Sc elements have been found in this study. See Norby (1976) for a description of this element.

<u>Remarks</u>. Norby (1976) based the reconstruction of this apparatus on a single, natural bedding-plane assemblage and the morphological similarity of the

component elements. He tentatively assigned this species to the common, Devonian mutielement genus Pandorinellina Muller and Muller. Horowitz and Rexroad (1982) disagreed with this assignment due to the lack of continuity between Pandorinellina and this Late Mississippian species; no Early Mississipian representatives are known. They assigned the species to an unnamed new genus. Because no new generic name has yet been proposed, for ease of recognition, I have retained the name of the Pa element, "Spathognathodus," in quotation marks as a temporary name, until a new generic name can be published.

I have followed Norby's reconstruction with the following exceptions: Sc elements could not be distinquished from juvenile Sc elements in the apparatus of Hindeodus cristula and an additional Sb element has been added to the apparatus. The Sc elements included by Norby in the apparatus of "S." campbelli are very close morphologically to small, juvenile Sc elements of Hindeodus cristula and, in this study, samples which contained the uncommon ramiform elements of "S." campbelli also contained common elements of H. cristula. In these samples (Bishop section: B10, B11), Sc elements which fit the description given by Norby for "S." campbelli could not be differentiated from small Sc elements of H. cristula. Thus, no Sc elements are listed for "S."

campbelli.

A plectospathodiform Sb element is added to this apparatus. The element commonly occurs with the other rare ramiform elements of the apparatus and its delicate form is similar to theirs. It also is unlike any other element of other species found in this study. These facts favor its inclusion in the apparatus. At first, I thought that this element might be a Sc element, unlike those described by Norby which may have been juvenile elements belonging to *H. cristula*. Recently, though, Sparling (1981) illustrated Middle Devonian apparatuses of the genus *Polygnathus* which contained two, dimorphic Sb elements. The plectospathodiform element of that apparatus is very similar to the analogous element, included herein, of "*S.*" *campbelli* and the same can be said of the angulodiform Sb element.

Occurrence. Hillsdale Lst. (B, W, L), "Denmar-Gasper" Fm. (B, W) and "Ste. Genevieve" Fm. (L).

Material recovered. Pa (138), Pb (3), M (3), Sa (3), Sb (9), Sb (6).

Superfamily UNKNOWN

Family UNKNOWN

Genus DE LONCHODINA Bassler, 1925

Type species. *Lonchodina typicalis* Bassler, 1925

Remarks. Two, distinctive, lonchodiniform elements of unknown affinities were found in the basal Hillsdale Limestone at the Lindell section (L1 and L1.5) and are referred to this discrete element genus. These elements are similar to Pb elements of Idioprioniodus, but the lack of other associated elements of that genus in the same samples makes a relationship unlikely.

DE LONCHODINA sp. A

Pl. 3, fig. 10

Description. The element is bipennate and arched. Both processes are massive, but relatively thin. The posterior process is long, twice as long as the anterior process, and nearly straight, with a slightly concave lower margin. The height of the posterior process increases slightly distally and reaches a maximum height at the midportion of the process. Toward the distal end the height decreases. The denticles on the posterior process are generally robust, broad-based, triangular in lateral view and discrete. They are arranged perpendicular to the process and are gently curved inward. Proximal to the apical cusp the denticles are short, thinner than the processes and may be fused. Distally, the denticles are larger and discrete, with the largest denticles situated at the midportion of the process. At the distal end they are slightly smaller. In all, seven to eight denticles are usually present on the posterior process in mature specimens. The anterior process is much like the posterior process, only shorter and with up to four similar denticles.

The apical cusp is large and robust. It is curved gently inward and slightly posteriorly. It is not strongly compressed laterally and the inner face is more strongly convex than the outer face, as viewed in cross-section. The apical cusp is costate along the anterior and posterior edges and the costae merge with the small, fused denticles proximal to the cusp on both processes.

The basal cavity is moderately large and wide. It is slightly flared on the inner side and extends farther along the lower margin of the posterior process than the anterior process.

Comparisons. DE *Lonchodina* sp. A is closely similar to DE *L.* sp. B. Both elements are robust, have a massive apical cusp and have processes that bear large, triangular-shaped, discrete denticles. DE *L.* sp. A, though, tends to be more massive than sp. B and has a wider basal cavity. The denticles of sp. A also tend to be erect and not inclined laterally as denticles of sp. B are.

DE *Lonchodina* sp. A is closest morphologically to Pb elements of Idioprioniodus, DE Lonchodina paraclaviger or DE L. ponderosa. Those elements, though, unlike DE L. sp. A, have anterior processes which are longer than posterior processes and long, partially fused denticles.

Remarks. The apparatus of this element is unknown, although it may have contained the element, DE L. sp. B as well, based on the morphological similarity of these elements and their close association. No other elements of Idioprioniodus have been found in association with these elements, and this fact along with the morphological differences cited above would not support inclusion of this element in that genus.

Occurrence. Hillsdale Lst. (L1 and L1.5).

Material recovered. 6

DE LONCHODINA sp. B

Pl. 3, figs. 9, 11.

?Lonchodina sp. Rexroad & Collinson, 1963, p. 11, Pl. 2, fig. 27.

Description. The element is bipennate and arched. The anterior process is shorter than the posterior process, roughly two-thirds the length of that process. It is also directed sharply downward with respect to the apical cusp and is curved slightly inward. It bears three to four, triangular, sharply pointed denticles that are slightly inclined posteriorly toward the apical cusp. The denticles are discrete and widely separated by U-shaped spaces. The largest of the denticles at the midportion of the process are the same thickness as the process. The larger posterior process may bear as many as three to four small, discrete denticles proximal to the apical cusp. One or more large, slender, sharply pointed denticles like the denticles on the anterior process are situated at the distal end of the process.

The apical cusp is very long, nearly as long as the posterior process, slender, laterally compressed, costate, and sharply pointed. The cusp is generally erect but is slightly curved inward and recurved posteriorly. In cross-section the outer face of the cusp is slightly more convex than the inner face.

The basal cavity is large, but thin and not flared on either side of the element. It extends farther along the lower margin of the posterior process, proximal to the apical cusp , than along the anterior process.

Remarks. DE Lonchodina sp. B is only known in this study from the basal Hillsdale Limestone at the Lindell section (L1) where it occurs with DE Lonchodina sp. A. As noted above, the morphological similarity and co-ocurrence of these elements suggests that they belonged to the same, unknown apparatus.

A specimen illustrated by Rexroad and Collinson

(1963; Pl. 2, fig. 27) as *Lonchodina* sp. is closely similar to this element. Both have a long, slender, sharply pointed apical cusp and the denticles on the posterior process of their specimen proximal to the apical cusp appear to be minute compared to the more distal denticles on the same process.

Occurrence. Hillsdale Lst. (L1).

Material recovered. 10

Conclusions

A total of 17 multielement species and two discrete-element species were recognized in this study. Two of the multielement apparatuses are new: *Kladognathus* sp. A and *Hindeognathus laevipostica*.

There are several lines of evidence that support the apparatus reconstruction of *Kladognathus* sp. A. Elements of this species are all similar to homologous elements of *K. levis* and *K. tenuis*, and share thin, hindeodellid-like denticles and similar basal cavitites. The apparatus is also similar to a bedding-plane assemblage illustrated by Norby (1976).

DE *Lambdagnathus fragilidens* is included as the enigmatic X element of *Kladognathus tenuis*, based on its morphological similarity to the other elements in that species. The idea had been suggested by Rexroad (1981) and Horowitz and Rexroad (1982). A homologous lambdagnathiform X element is also present in the apparatus of *Kladognathus* sp. A, but has yet to be found with elements of *K. levis*. *K. tenuis* evolved from *K. levis*, and the change is marked not only by changes in the Sa and Sc elements, but by the addition of the X element as well.

Recognition of the morphological changes exhibited by elements of the *Kladognathus* lineage during the group's phylogeny will be of important use in Carboniferous biostratigraphy. *Kladognathus* is common in Upper Mississippian rocks of North America and is often associated with *Cavusgnathus* in rocks that were deposited in restricted, nearshore settings (Rexroad, 1981 and Horowitz and Rexroad, 1982). Important Carboniferous zonal conodonts, (*Gnathodus* and *Lochriea*) are often lacking in these same rocks. Recognition of speciation events within the *Kladognathus* lineage will help to correlate Mississippan rocks that contain restricted faunas of nearshore biofacies and lack zonal forms.

Hindeognathus is a new multielement genus named herein. Its reconstruction is based on a previously reported fused-element cluster (Rhodes and Austin, 1969), and the common co-occurrence of the element-types that are assigned to the apparatus. This septimembrate apparatus is unusual and unlike other Carboniferous apparatuses because it consists of five slightly different, apatognathiform elements that replace the normal M-Sa-Sb-Sc series of elements. One species, *Hindeognathus laevipostica*, was recovered in this study. Typical, British apatognathiform elements reported by Varker (1967) and Rhodes *et al*. (1969) are slightly different from North American counterparts, and probably belonged to a different species, endemic to Great Britain during the Early Carboniferous.

Other conodont apparatuses described herein conform to those described by Norby (1976), Rexroad (1981), Horowitz and Rexroad (1982) and others. An additional element, though, is added to the apparatus of "Spathognathodus" campbelli, originally reconstructed by Norby (1976). This element is plectospathodiform, and it accompanies the typical angulodiform element in an Sb position. Although no other elements similar to this additional element are known from other Carboniferous apparatuses, Sparling (1981) showed that an analogous element was present in some Middle Devonian Polygnathacean apparatuses.

REFERENCES CITED

Aldridge, R. J., R. L. Austin and S. Husri. 1968. Visean conodonts from North Wales and Ireland. Nature 219: 255-258.

Austin, R. L. 1973a. Phylogeny and homeomorphy of conodonts in the Lower Carboniferous, p. 105-116. In F. H. T. Rhodes (ed.), Conodont Paleozoology, Geol. Soc. Am. Spec. Pap. 141.

----. 1973b. Modification of the British Avonian conodont zonation and a reappraisal of European Dinantian conodont zonation and correlation. Ann. Soc. geol. Belg. 96:523-532.

----. 1974. The biostratigraphic distribution of conodonts in Great Britain and the republic of Ireland, p. 1-17, In J. Bouckaert and M. Streel (eds.), Int. Symp. on Belg. Micropal. Limits, Namur, 1974, Belg. Geol. Surv., Publ. 3.

----. 1976. Evidence from Great Britain and Ireland concerning West European Dinantian conodont paleoecology. Geol. Soc. Can. Spec. Pap. 15:202-224.

---- and R. B. Davies. 1983. The recognition and implications of Dinantian conodont biofacies in the British Isles. Geol. Soc. Am. Abst. with Prog. 15:221.

----. and S. Husri. 1974. Dinantian conodont faunas of County Clare , County Limerick and County Leitrim. An appendix, p. 18-69. In J. Bouckaert and M. Streel (eds.), Int. Symp. on Belg. Micropal. Limits, Namur 1974, Belg. Geol. Surv., Publ. 3.

----. and M. Mitchell. 1975. Middle Dinantian platform conodonts from County Fermanagh and County Tyrone, Northern Ireland. Bull. Geol. Surv. Gr. Brit. 55:43-54.

----. and F. H. T. Rhodes. 1969. A conodont assemblage from the Carboniferous of the Avon Gorge, Bristol. Palaeontol. 12: 400-405.

Averitt, P. 1941. The Early Grove gas field, Scott and Washington Counties, Virginia. Va. Geol. Surv. Bull. 56, 50 p.

Baesemann, J. F. 1973. Missourian (Upper Pennsylvanian) conodonts of northeastern Kansas. J. Paleontol. 47:689-710.

Barskov, I. S., A. S. Alexseyev and N. V. Goreva. 1977. Taksonomichki i nomenclaturny status konodontov roda Gnathodus Pander, 1856. Paleontol. Zh., no. 4, p. 131-134.

Bartlett, C. S., Jr. and H. W. Webb. 1971. Geology of the Bristol and Wallace quadrangles, Virginia. Va. Div. Min. Resources, Rept. of Invest. 25, 93 p.

Bassler, R. S. 1925. Classification and stratigraphic use of the conodonts. Geol. Soc. Am. Bull. 36: 218-220.

Bischoff, G. 1957. Die Conodonten-Stratigraphie des rhenoherzynischen Unterkarbons mit Berucksichtigung der Wocklumeria-Stufe und der Devon/Karbon-Grenze. Abh. hess Landesamt Bodenforsch 19:1-64.

Blancher, D. W., Jr. 1974. Sediments and depositional environments of the Maccrady Formation and the Greenbrier Group (Mississippian) of the Hurricane Ridge syncline of southwestern Virginia and West Virginia. unpubl. Ph.D. dissert. Va. Poly. Inst. and S.U., Blacksburg, 228 p.

Branson, E. B. and M. G. Mehl. 1934. Conodonts from the Grassy Creek Shale of Missouri. Univ. Mo. Stud. 8:171-259.

---- and ----. 1941a. Caney conodonts of Upper Mississippian age. Bull. Dennison Univ. 40: 179-188.

---- and ----. 1941b. Conodonts from the Keokuk Formation. Bull. Dennison Univ. 40:179-188.

---- and ----. 1941c. New and little known Carboniferous conodont genera. J. Paleontol. 15: 97-106.

Briggs, D. G., E. N. K. Clarkson and R. J. Aldridge. 1983. The conodont animal. Lethaia 16:1-14.

Butts, C. 1927. Oil and gas possibilities at Early Grove, Scott County, Virginia. Va. Geol. Surv. Bull. 27, 18 p.

----. 1933. Geologic map of the Appalachian Valley of Virginia with explanatory text. Va. Geol. Surv. Bull.

42, 56 p.

----. 1940. Geology of the Appalachian Valley in Virginia. Va. Geol. Surv. Bull. 52, pt. 1, 568 p.

Chaplin, J. R. 1971. Conodonts of Mississippian age from the Hurricane Ridge Syncline in southwestern Virginia and adjacent West Virginia. Geol. Soc. Am. Abst. with Progr. 3:302-303.

----. 1975. Factors controlling the distribution and abundance of Mississippian conodonts from the Little Valley Formation and Hillsdale Limestone in the Hurricane Ridge Syncline of southwestern Virginia and West Virginia. Geol. Soc. Am. Abst. with Progr. 7:733.

----. 1977. Environmental interpretation of conodont distribution in the Denmar Formation (Early Chesterian) in the Hurricane Ridge Syncline of southwestern Virginia and West Virginia. Geol. Soc. Am. Abst. with Progr. 9:582.

---- and C. E. Mason. 1979. Upper part of the Borden Formation and the lower Newman Limestone, p. 152-162, <u>in</u>. Ettensohn, F. R. and G. R. Dever, Jr., eds., Carboniferous geology from the Appalachian Basin to the Illinois Basin through eastern Ohio and Kentucky. Field Trip Gdbk. 4, Ninth Int. Cong. Carbon. Strat. Geol., Univ. of Ky., Lexington, 293 p.

Chauff, K. M. 1981. Multielement conodont species from the Osageian (Lower Carboniferous) in midcontinent North America and Texas. Palaeontographica Abt. A. 175: 140-169.

Clark, D. L. 1981. Early Permian crisis and its bearing on Permo-Triassic conodont taxonomy. Geol. Palaeontol. SB 1:147-158.

----. 1981. Classification. p. W102-W103, <u>In</u> Robison, R. A. (ed.). Treatise on Invertebrate Paleontology, Pt. W, Miscellanea, Supplement 2, Conodonta. Geol. Soc. Am. and Univ. Kans. Press, Boulder and Lawrence.

Clarke, W. J. 1960. Scottish Carboniferous conodonts. Trans. Edinburg Geol. Soc. 18:1-31.

Collinson C. W., A. J. Scott and C. B. Rexroad. 1962. Six charts showing biostratigraphic zones and correlations based on conodonts from the Devonian and Mississippian rocks of the Upper Mississippi Valley. Ill. St. Geol. Surv., Circ. 328, 32 p.

----, C. B. Rexroad and T. L. Thompson. 1971. Conodont zonation of the North American Mississippian. Mem. Geol. Soc. Am. 127:353-394.

----, R. D. Norby, T. L. Thompson, and J. W. Baxter. 1979. Stratigraphy of the Mississippian stratotype: upper Mississippi Valley, U.S.A. Field Trip no. 8, Gdbk., Ninth Int. Congr. Carb. Strat. and Geol., Ill. Geol. Surv. 109 p.

Cooper, B. N. 1944. Geology and Mineral Resources of the Burkes Garden Quadrangle, Virginia. Va. Geol. Surv. Bull. 60, 299 p.

----. 1948. Status of Mississippian stratigraphy in the central and northern Appalachian region. J. Geol. 56: 255-263.

----. 1965. Geology of the salt and gypsum deposits in the Saltville area Smyth and Washington Counties, Virginia. Second Ann. Symp. on Salt, v. 1, N. Ohio. Geol. Soc. p. 11-34.

Cooper, C. L. 1939. Conodonts from a Bushberg-Hannibal horizon in Oklahoma. J. Paleontol. 13:379-422.

Dunn, D. L. 1965. Late Mississippian conodonts from the Bird Spring Formation in Nevada. J. Paleontol. 39:1145-1150.

----. 1966. New Pennsylvanian conodonts from southwestern United States. J. Paleontol. 40:1294-1303.

_____. 1970. Middle Carboniferous conodonts from western United States and phylogeny of the platform group. J. Paleontol. 44:312-342.

Eichenberg, W. 1930. Conodonten aus dem Culm des Harzes. Paleontol. Z. 12:177-182.

Elias, M. K. 1956. Upper Mississippian and Lower Pennsylvanian formations of south-central Oklahoma. Am. Assoc. Pet. Geol. Bull. 40:56-134.

Ellison, S. P., Jr. 1941. Revision of the Pennsylvanian conodonts. J. Paleontol. 15: 107-143.

Englund, K. J., H. H. Arndt and T. W. Henry, eds. 1979. Proposed Pennsylvanian System stratotype, Virginia and West Virginia. AGI Sel. Gdbk. Ser. 1, IX Int. Congr. Carbon. Strat. Geol., Gdbk. Field Trip 1, 138 p.

----, T. W. Henry, and others. 1981. Mississippian-Pennsylvanian boundary in the central part of the Appalachian basin (Field Trip No. 4), Part 1: southwestern Virginia and southern West Virginia, p. 153-194. in T. G. Roberts (ed.). GSA Cincinnati '81 Field Trip Guidebooks, Vol. 1: stratigraphy, sedimentology. Amer. Geol., Inst. Falls Church, Va. 258 p.

Ettensohn, F. R. 1980. An alternative to the barrier-shoreline model for deposition of Mississippian and Pennsylvanian rocks in northeastern Kentucky: summary. Geol. Soc. Am. Bull. Pt. I. 91:130-135 (complete article in Pt II. Card 3. 91:1057-1090).

----. 1981. Mississippian-Pennsylvanian boundary in the central part of the Appalachian Basin, Part 2: northeastern Kentucky. GSA Ann. Mtg., Field Trip 4, p. 195-257.

Globensky, Y. 1967. Middle and Upper Mississippian conodonts from the Windsor Group of the Atlantic Provinces of Canada. J. Paleontol. 41: 432-448.

Groessens, E. 1977. Distribution de conodontes dans le Dinantien de la Belgique. Int. Symp. on Belg. Micropal. Limits, Namur 1974, Belg. Geol. Surv. Publ. 17: 1-193.

Gunnell, F. H. 1933. Conodonts and fish remains from the Cherokee, Kansas City and Waubaunsee Groups of Missouri and Kansas. J. Paleontol. 7: 261-297.

Harris, R. W. and R. V. Hollingsworth. 1933. New Pennsylvanian conodonts from Oklahoma. Am. J. Sci. 25: 193-204.

Hass, W. H. 1953. Conodonts of the Barnett Formation of Texas. U.S. Geol. Surv. Prof. Pap. 243-F, p. 69-94.

Higgins, A. C. 1961. Some Namurian conodonts from North Staffordshire. Geol. Mag. 97: 210-224.

----. 1962. Conodonts from the Griotte Limestone of North West Spain. Notas y Communs. Inst. Geol. Min. Espana. 65: 5-22.

----. 1975. Conodont zonation of the late Visean - early Westphalian strata of the south and central Pennines of northern England. Bull. Geol. Surv. Gt. Brit. 53, 90 p.

----. 1981a. The distribution of conodonts in relation to the paleogeography of late Visean-Namurian time, p. 37-51. In J. W. Neale and M. D. Brasier (eds.), Microfossils from Recent and Fossil Shelf Seas. Ellis Horwood Ltd., Chichester.

----. 1981b. Coprolitic conodont assemblages from the Lower Westphalian of North Staffordshire. Palaeont. 24: 437-441.

---- and J. Bouckaert. 1968. Conodont stratigraphy and paleontology of the Namurian of Belgium. Mem. Expl. Cartes Geol. et Minieres de la Belg. 10:1-64.

---- and W. J. Varker. 1982. Lower Carboniferous conodont faunas from Ravenstonedale, Cumbria. Palaeont. 25: 145-166.

---- and C. H. T. Wagner-Gentis. 1982. Conodonts, goniatites and biostratigraphy of the earlier Carboniferous from the Cantabrian Mountains, Spain. Palaeont. 25: 313-350.

Hinde, G. J. 1900. Notes and descriptions of new species of Scottish Carboniferous conodonts. Trans. Nat. Hist. Soc. Glasg. 5:338-345.

Holmes, G. B. 1926. A bibliography of the conodonts with description of early Mississippian species. Proc. U.S. Nat. Mus. 72:1-38.

Horowitz, A. S., B. L. Mamet, R. Neves, P. E. Potter and C. B. Rexroad. 1979. Carboniferous paleontological zonation and intercontinental correlation of the Fowler No. 1 Traders Core, Scott County, Tennessee, U.S.A. Southeastern Geol. 20: 205-228.

---- and C. B. Rexroad. 1972. Conodont biostratigraphy of some United States Mississippian sites. J. Paleontol. 6: 884-891.

---- and ----. 1980. A summary of Chesterian (Carboniferous) conodonts from the Illinois Basin, U.S.A. (abs.). Geol. Bundesanst. Abh. 35, p. 197, 199.

---- and ----. 1981. Statistical evaluation of Middle Chesterian (Carboniferous) conodonts from southern Indiana. Geol. Soc. Am. Abst. with Progr. 13:281

---- and ----. 1982. An evaluation of statistical reconstructions of multielement conodont taxa from Middle Chesterian rocks (Carboniferous) in southern Indiana. J. Paleontol. 56:959-969.

Igo, H. 1973. Lower Carboniferous conodonts from the Akiyoshi Limestone Group, southwest Japan. Trans. Proc. Palaeont. Soc. Japan, N.S., no. 92, p. 185-199.

---- and F. Kobayashi. 1974. Carboniferous conodonts from the Itsukaichi district, Tokyo, Japan. Trans. Proc. Palaeont. Soc. Japan, N.S., no. 96. p. 411-426.

---- and T. Koike. 1968. Carboniferous conodonts from Kuantan, Malaya. Geol. Paleontol. S.E. Asia 5:26-30.

Koike, T. 1967. A Carboniferous succession of conodont faunas from the Atetsu Limestone in southwest Japan. Tokyo Kyoiku Daigaku Sci. Rep., Sec. C, 93:279- 318.

Lane, H. R. 1967. Uppermost Mississippian and Lower Pennsylvanian conodonts from the type Morrowan region, Arkansas. J. Paleontol. 41:920-942.

----, C. A. Sandberg and W. Ziegler. 1980. Taxonomy and phylogeny of some Lower Carboniferous conodonts and preliminary standard post-<u>Siphonodella</u> zonation. Geol. Palaeontol. 14:117-164.

---- and J. J. Straka, II. 1974. Late Mississippian and Early Pennsylvanian conodonts, Arkansas and Oklahoma. Geol. Soc. Am. Spec. Pap. 152, 144 p.

MacGill, R. A. 1973. Conodonts from the St. Louis Member of the Newman Formation of east-central Kentucky. unpubl. M.S. thesis, Eastern Kentucky University, Richmond, 48 p.

Marks, P. and H. Wensink. 1970. Conodonts and the age of the "Griotte" Limestone Formation in the Upper Aragon

Valley (Huesca, Spain).I. Konickl. Nederl. Akad. van Wettenschappen, Ser. B, 3:238-261.

Matthews, S. C., P. M. Sadler and E. B. Sellwood. 1972. A Lower Carboniferous conodont fauna from Chillaton, southwest Devonshire. Paleontol. 15:550-568.

---- and J. M. Thomas. 1974. Lower Carboniferous conodont faunas from northeast Devonshire. Palaeontol. 17:371-385.

Merrill, G. K. 1973. Pennsylvanian nonplatform conodont genera, I: Spathognathodus. J. Paleontol. 47: 289-314.

----. 1980. Preliminary report on the restudy of conodonts from the Barnett Formation, p. 103-107. in D. L. Windle, Jr. (ed.). Geology of the LLano region, central Texas. W. Texas Geol. Soc. Pub. 80-73:103-107.

---- and S. M. Merrill. 1974. Pennsylvanian nonplatform conodonts, IIa: the dimorphic apparatus of Idioprioniodus. Geol. Palaeontol. 8:119-130.

---- and P. H. von Bitter. 1975. Evolution of Carboniferous conodont communities through time. VIII Int. Carb. Cong., Compte Rendu 3:222-229.

---- and ----. 1976. Revision of conodont biofacies nomenclature and interpretations of environmental controls in Pennsylvanian rocks of eastern and central North America. R. Ont. Mus. Life Sci. Contrib. 108:1-46.

Metcalfe, I. 1980a. Upper Carboniferous conodont faunas of the Panching Limestone, Pahang, West Malaysia. Palaeontol. 23:297-314.

----. 1980b. Conodont zonation and correlation of the Dinantian and early Namurian strata of the Craven Lowlands of northern England. Rep. Inst. Geol. Sci. 80-10:1-70.

Muller, K. J. 1956. Triassic conodonts from Nevada. J. Paleontol. 30: 818-830.

Murray, F. N. and J. Chronic. 1965. Pennsylvanian conodonts and other fossils from insoluble residue of the Minturn Formation (DesMoinesian), Colorado. J.

Paleontol. 39: 594-610.

Nicoll, R. S. 1980. The multielement genus Apatognathus from the Late Devonian of the Canning Basin, Western Australia. Alcheringia 4:133-152.

---- and C. B. Rexroad. 1975. Stratigraphy and conodont paleontology of the Sanders Group (Mississippian) in Indiana and adjacent Kentucky. Ind. Geol. Surv. Bull. 51, 36 p.

Norby, R. D. 1974. Conodont apparatuses of the Heath Shale (Chesterian) of central Montana. Geol. Soc. Am. Abst. with Prog. 6:535.

----. 1976. Conodont apparatuses from Chesterian (Mississippian) strata of Montana and Illinois. unpubl. Ph.D. dissert. Univ. Illinois, Urbana-Champaign, 295 p.

Pander, C. H. 1856. Monographie der fossilen Fische des silurischen Systems der russichbaltischen Gouvernements. Akad. Wiss., St. Petersburg, 91 p.

Pierce, R. W. and R. L. Langenheim, Jr. 1974. Platform conodonts of the Monte Cristo Group, Mississippian, Arrow Canyon Range, Clark County, Nevada. J. Paleontol. 48:149-169.

Reger, D. B. 1926. Mercer, Monroe, and Summers Counties. West Va. Geol. Surv. Co. Rept., 926 p.

Rexroad, C. B. 1957. Conodonts from the Chester Series in the type area of southwstern Illinois. Ill. Geol. Surv., Rept. of Invest. 199:1-43.

----. 1958. Conodonts from the Glen Dean Formation (Chester) of the Illinois Basin. Ill. Geol. Surv., Rept. of Invest. 209:1-27.

----. 1981. Conodonts from the Vienna Limestone member of the Branchville Formation. Ind. Geol. Surv. Occ. Pap. 34:1-16.

---- and R. C. Burton. 1961. Conodonts from the Kinkaid Formation (Chester) in Illinois. J. Paleontol. 35:1143-1158.

---- and C. E. Clarke. 1960. Conodonts from the Glen Dean Formation of Kentucky and equivalent formations of

Virginia and West Virginia. J. Paleontol. 34:1202-1206.

---- and C. Collinson. 1963. Conodonts from the St. Louis Formation (Valmeyeran Series) of Illinois, Indiana, and Missouri. Ill. Geol. Surv. Circ. 355:1-28.

---- and ----. 1965. Conodonts from the Keokuk, Warsaw, and Salem Formations (Mississippian) of Illinois. Ill. Geol. Surv. Circ. 388:1-26.

---- and G. H. Fraunfelter. 1977. Upper Mississippian conodonts and boundary relations in southern Illinois, p. 80-103. In C. O. Frank (ed.), Guidebook for Field Trips, V. 2, 11th Annual Meeting, North-central Section, Geol. Soc. Am. Southern Ill. Univ., Carbondale.

---- and W. M. Furnish. 1964. Conodonts from the Pella Formation (Mississippian), south-central Iowa. J. Paleontol. 38:667-676.

---- and H. R. Lane. 1966. Clarification of Cavusgnathus altus, type species of the conodont genus Cavusgnathus. J. Paleontol. 40:1391-1392.

---- and R. M. Liebe. 1962. Conodonts from the Paoli and equivalent formations in the Illinois Basin. Micropaleontol. 8:509-514.

---- and R. S. Nicoll. 1965. Conodonts from the Menard Formation (Chester Series) of the Illinois Basin. Ind. Geol. Surv. Bull. 35:1-28.

---- and T. L. Thompson. 1979. A spathognathodont lineage of Mississippian conodonts. Lethaia. 12:235-243.

Reynolds, M. J. 1970. A Lower Carboniferous conodont fauna from Flintshire, North Wales. Bull. Geol. Surv. Gt. Brit. 32:1-19.

Rhodes. F. H. T. 1952. A classification of Pennsylvanian conodont assemblages. J. Paleontol. 226:886-901.

----, R. L. Austin and E. C. Druce. 1969. British Avonian (Carboniferous) conodont faunas, and their value in local and intercontinental correlation. Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 5, 313 p.

---- and Muller, K. J. 1956. The conodont genus Prioniodus and related forms. J. Paleontol. 30:695-699.

Rice, W. D. and R. L. Langenheim, Jr. 1974a. Conodont zonation of the Battleship Wash Formation, Late Mississippian, Arrow Canyon Range, Clark County, Nevada. Wy. Geol. Assoc., Earth Sci. Bull. 7:3-13.

---- and ----. 1974b. Conodonts of the Battleship Wash Formation, Late Mississippian, Arrow Canyon Range, Clark County, Nevada. Wy. Geol. Assoc., Earth Sci. Bull. 7:19-36.

Ruppel, S. C. 1979. Conodonts from the Lower Mississippian Fort Payne and Tuscumbia Formations of northern Alabama. J. Paleontol. 53:55-70.

Scatterday, J. W. 1963. Stratigraphy and conodont faunas of the Maxville Group (Middle and Upper Mississippian) of Ohio. unpubl. Ph.D. dissert., Ohio St. Univ., Columbus, 162 p.

Scotese, C. R., R. K. Bambach, C. Barton, R. Van der Voo and A. M. Ziegler. 1979. Paleozoic base maps. Jour. Geol. 87:217-268.

Scott, A. J. and C. W. Collinson. 1961. Conodont faunas from the Louisiana and Mc Graney Formations of Illinois, Iowa, and Missouri. Fld. Conf. Gdbk., Kansas Geol. Soc. 26:110-142.

Scott, H. W. 1942. Conodont assemblages from the Heath Formation, Montana. J. Paleontol. 16:293-300.

Skompski, S. and J. Sobon-Podgorska. 1980. Foraminifera and conodonts in the Visean deposits of the Lublin Upland. Acta. Geol. Pol. 30:87-96.

Slone. G. T. 1975. Conodont paleoecology of the Renfro Member of the Borden Formation and Newman Limestone of eastern Kentucky. unpubl. M.S. thesis, East. Ky. Univ., Richmond, 54 p.

Sparling, D. R. 1981. Middle Devonian conodont apparatuses with seven types of elements. J. Paleontol. 55:295-316.

Stanley, E. A. 1958. Some Mississippian conodonts from the High Resistivity Shale of the Nancy Watson no. 1 well in northeastern Mississippi. J. Paleontol. 32:459-476.

Stauffer, C. R. and H. J. Plummer. 1932. Texas Pennsylvanian conodonts and their stratigraphic relations. Texas Univ. Bull. 3201:13-58.

Stose, G. W. 1913. Geology of the salt and gypsum deposits of southwestern Virginia. Va Geol. Surv. Bull. 8:51-60.

Swann, D. H. 1963. Classification of Genevievian and Chesterian (Late Mississippian) rocks of Illinois. Ill. Geol. Surv. Rept. Inv. 216:1-91.

Sweet, W. C. 1977. <u>Hindeodus</u> <u>cristulus</u>, p. 209-214. <u>In</u> W. Ziegler (ed.) Catalogue of Conodonts 3.

Sweet, W. C. 1981. Macromorphology of elements and apparatuses, p. W5- W20. <u>In</u> R. A. Robison (ed.). Treatise on Invertebrate Paleontology, Part W, Miscellanea, Supplement 2, Conodonta. Geol. Soc. Am. and Univ. Kans. Press, Boulder and Lawrence.

---- and H. P. Schonlaub. 1975. Conodonts of the genus <u>Oulodus</u> Branson and Mehl, 1933. Geol. Palaeontol. 9:41-59.

Thomas. W. A. 1966. Late Mississippian folding of a syncline in the western Appalachians, West Virginia and Virginia. Geol. Soc. Am. Bull. 77:473-494.

Thompson, T. L. 1966. Conodont faunas from the Fort Bellafontaine and Vigus North Quarries, St. Louis County, Missouri. Miss. Geol. Surv. and Water Res. Rept. of Invest. 34:42-48.

---- and E. D. Goebel. 1968. Conodonts and stratigraphy of the Meramecian Stage (Upper Mississippian) in Kansas. Kan. Geol. Surv. Bull. 192:1-56.

Tynan, M. C. 1980. Conodont biostratigraphy of the Mississippian Chainman Formation, western Millard County, Utah: J. Paleontol. 54:1282-1309.

Ulrich, E. O. and R. S. Bassler. 1926. A classification of the toothlike fossils, conodonts, with descriptions of American Devonian and Mississippian species. U. S. Nat. Mus. Proc. 68:1-63.

Uttley, J. S. 1974. The stratigraphy of the Maxville Group of Ohio and correlative strata in adjacent areas.

unpubl. Ph.D. dissert., Ohio St. Univ., Columbus, 252 p.

Varker, W. J. 1967. Conodonts of the genus Apatognathus Branson and Mehl from the Yoredale Series of the North of England. Palaeontol. 10:124-141.

von Bitter, P. H. 1972. Environmental control of conodont distribution in the Shawnee Group (Upper Pennsylvanian) of eastern Kansas. Univ. Kans. Paleontol. Contrib. 59:1-105.

----. 1976a. Paleoecology and distribution of Windsor Group (Visean - ?Early Namurian) conodonts, Port Hood Island, Nova Scotia, Canada. Geol. Assoc. Can. Spec. Pap. 15:226-241.

----. 1976b. The apparatus of Gondolella sublanceolata Gunnell (Conodontophorida, Upper Pennsylvanian) and its relationship to Illinella typica Rhodes. R. Ont. Mus. Life. Sci. Contrib. 109:1-44.

---- and H. A. Plint-Geberl. 1982. Conodont biostratigraphy of the Codroy Group (Lower Carboniferous), southwestern Newfoundland, Canada. Can. J. Earth Sci. 19:193-221.

Watanabe, K. 1975. Mississippian conodonts from the Omni Limestone, Niigata Prefecture, central Japan. Trans. Proc. Palaeontol. Soc. Japan N. S. 99: 156-171.

Webster, G. D. 1969. Chester through Derry conodonts and stratigraphy of northern and southern Lincoln Counties, Nevada. Univ. Calif. Publ. Geol. Sci. 79:1-105.

Weller, J. M. 1948. Correlation of the Mississippian formations of North America. Geol. Soc. Am. Bull. 59:91-106.

Wells, D. 1950. Lower Middle Mississippian of southwestern West Virginia. Amer. Assoc. Pet. Geol. Bull. 34:882-923.

Wilpolt, R. H. and D. W. Marden, 1955. Descriptions of fourteen measured sections in southwest Virginia and eastern Kentucky. U. S. Geol. Surv. Open File Rept. 55-200.

---- and ----. 1959. Geology and oil and gas possibilities of Upper Mississippian rocks of southwestern Virginia, southern West Virginia, and eastern Kentucky . U. S. Geol. Surv. Bull. 1072-K:587-656.

Youngquist, W. and A. K. Miller. 1949. Conodonts from the Late Mississippian Pella beds of south-central Iowa. J. Paleontol. 23:617-622.

Ziegler, W. 1960. Die conodonten aus den Gerollen des Zechsteinkonglomerates von Rossensay (sudwestlich Rheinberg/Neiderlein). Fortschr. Geol. Rheinld. Westf. 6:391-405.

----. 1981. <u>Gnathodus</u>, p. 119-155. <u>In</u> W. Ziegler (ed.), Catalogue of Conodonts 4.

PLATES

PLATE 1

Figs. 1-3, 5 7, 9, 10	*Kladognathus tenuis* (Branson and Mehl)
1	M element, outer lateral view, W18, 48X.
2, 3	Sa element, posterior and antero-lateral views, respectively, W28, 72X.
5	Sb element, inner-lateral view, B17, 48X.
7	Sd element, inner-lateral view, B16, 72X.
9	Sc element, inner-lateral view, L26, 40X
10	X element, (DE *Lambdagnathus fragildens*), inner-lateral view, W7, 60X.
Figs. 4, 6, 8	*Kladognathus levis* (Branson and Mehl).
4	Sc element, inner-lateral view, W18, 54X.
6, 8	Sa element, antero-aboral view, 60X; lateral view, 50X; W5.

1

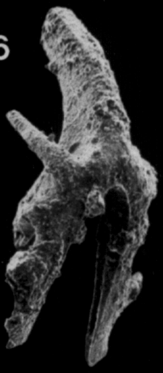
2

3

4

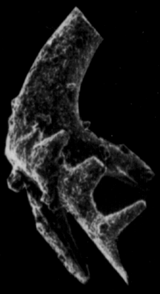
5

6



7

8



9

10

PLATE 2

Figs. 1-15 *Kladognathus* sp. A

1 M element, outer-lateral view, B12, 60X.
2 M element, inner-lateral view, W23.5, 72X.
3 Sc element, inner-lateral view, B10, 60X.
4 Sc element, inner-lateral view, B16, 72X.
5 Sc element, outer-lateral view, B10, 72X.
6 Sc element, outer-lateral view, B10, 78X.
7 Sa element, posterior view, B10, 78X.
8 Sb element, outer-lateral view, B10, 72X.
9 Sb element, outer-lateral view, B10, 72X.
10 Sc element, outer-lateral view, B10, 78X.
11 Sd element, inner-lateral view, W23.5, 86X.
12 Sd element, outer-lateral view, B10, 72X.
13 X element, posterior view (inner-lateral process on left, posterior process is short in center, outer-lateral process on right) W23.5, 40X.
14 X element, posterior view, B12, 100X.
15 X element, inner-lateral view (inner-lateral process in foreground, posterior process in background, outer-lateral process is broken off), B18, 72X.

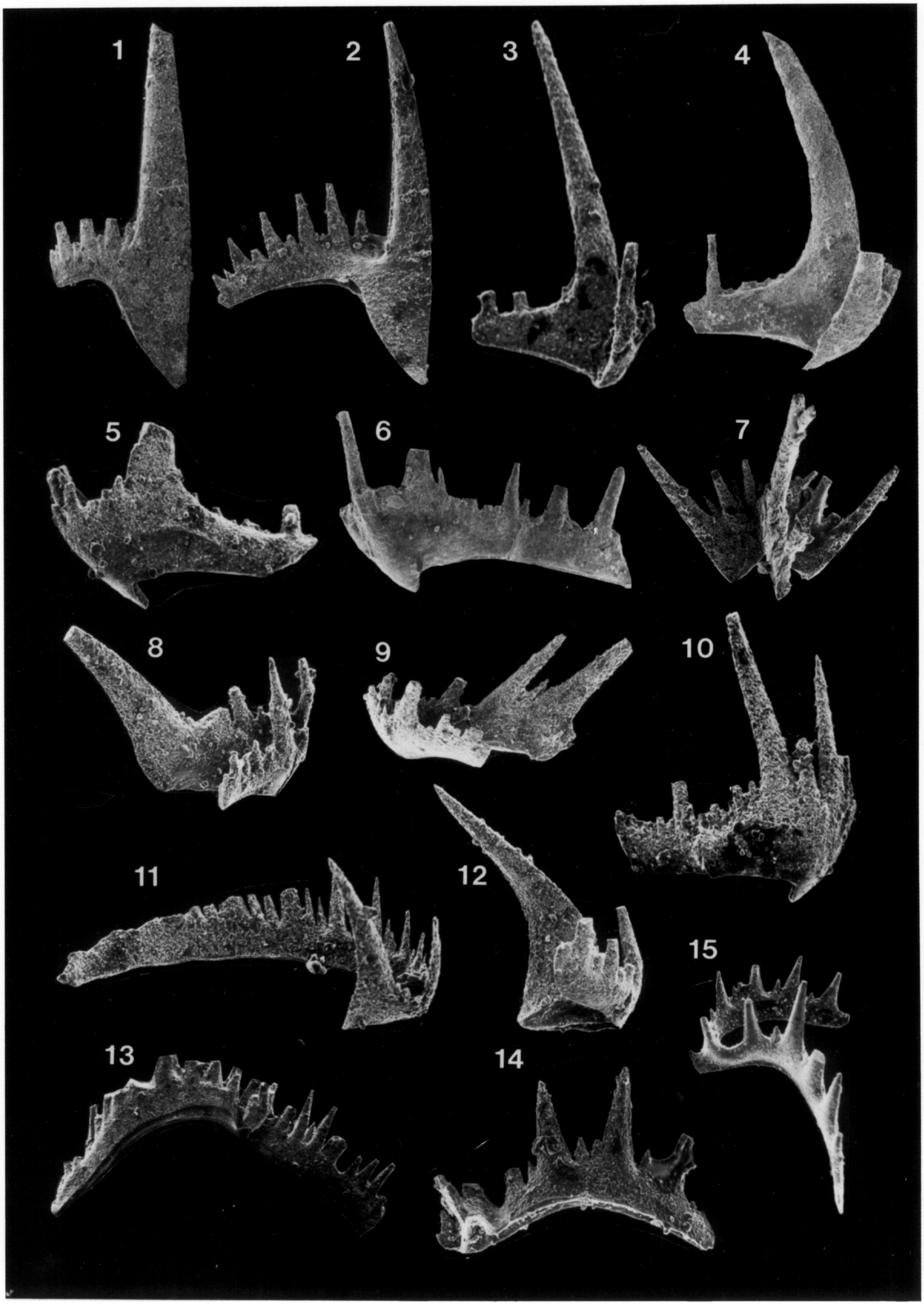

1
2
3
4
5
6
7
8
9
10
11
12
15
13
14

PLATE 3

Figs. 4-8 *Hindeodus cristula* (Youngquist and Miller)

1 Pa element, lateral view, B17, 40X.
2 Pa element, deviant morphotype, like Pa, *H. minutus* (Ellison), B10, 40X.
4 M element, inner-lateral view, B10, 72X.
6 Sa element, B14, 60X.
7 Sc element, inner-lateral view, B15, 60X.
8 Sb element, inner-lateral view, B15, 60X.

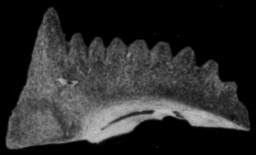
Fig. 3 *Synprionidina*? *spiculus* (Youngquist and Miller), Pa element, lateral view, W26, 60X.

Fig. 10 DE *Lonchodina* sp. A, inner-lateral view, L1, 55X.

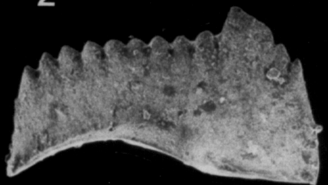
Figs. 9, 11 DE *Lonchodina* sp. B

9 inner-lateral view, L1, 55X.
11 inner-lateral view, L1, 40X.

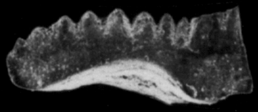
1



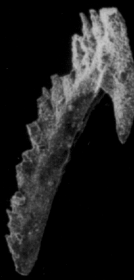
2



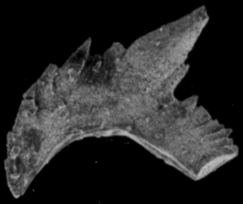
3



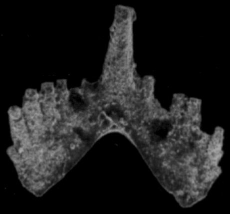
4



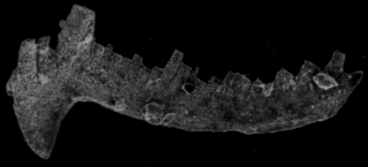
5



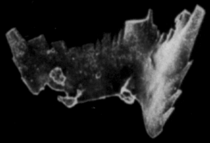
6



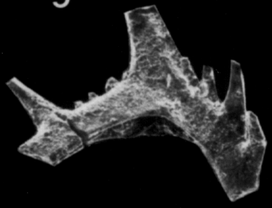
7



8



9



10

11

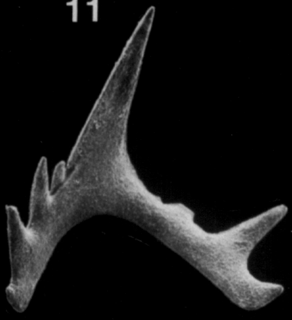
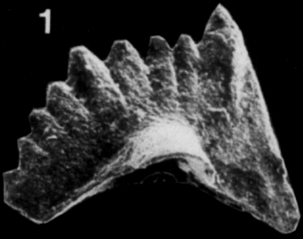


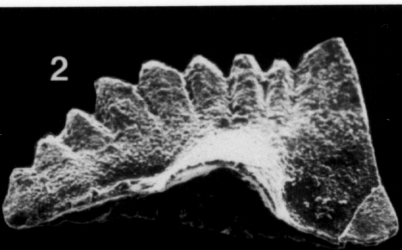
PLATE 4

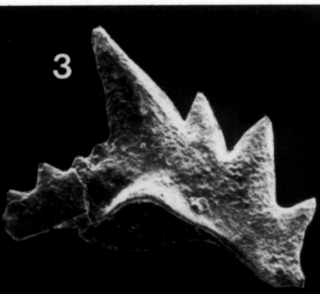
Figs. 1-10, 12, 13 *Hindeognathus* *laevipostica* (Rexroad and Collinson)

1 Pa element, outer-lateral view, L1, 75X.
2 Pa element, outer-lateral view, L1, 100X.
3 Pb element, gerontic morphotype?, outer-lateral view, L1, 100X.
4 Sa element, L1, 72X.
5 Sb_1 element, L1, 100X.
6 Pb element, inner-lateral view, L1, 100X.
7 Sb_1 element, L1, 78X.
8 Sb_2 element, L12.3, 50X.
9 Sb_2 element, L1, 78X.
10 Sb_2 element, L12.3, 72X.
12 Sb_3 element, L12.3, 72X.
13 Sb_4 element, L12.3, 100X.

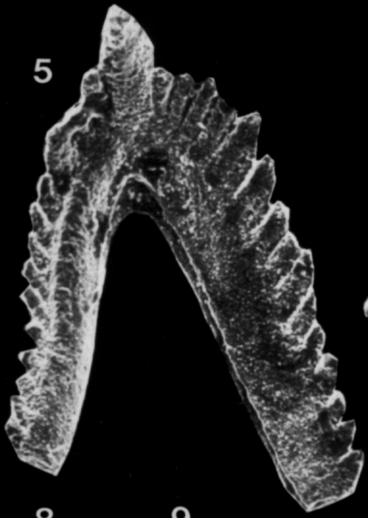
Fig. 11 *Hindeognathus* sp. unidentified Sb element, W24, 50X.


1


2


3

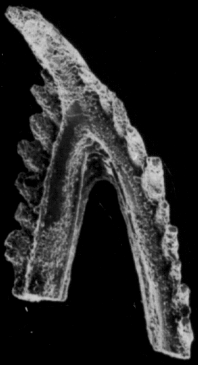

4

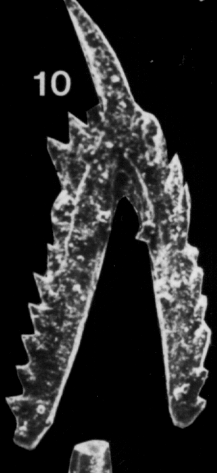

5

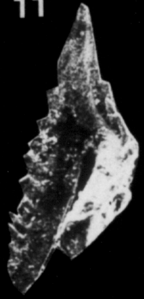

6


7


8


9


10


11


12

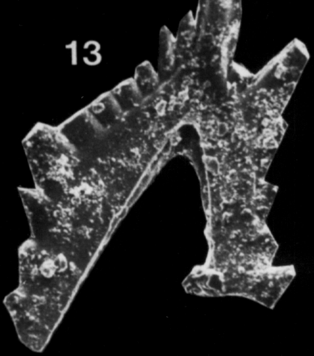

13

PLATE 5

Figs. 1, 2 *Rhachistognathus*? cf. *R. muricatus* (Dunn)

1 Pa element, L32, upper view, L32, 54X
2 Pa element, L32, upper view, L32, 75X.

Figs. 3-5 *Taphrognathus varians* Branson and Mehl

3 Pa element, right-sided morphotype, upper view, B5, 72X.
4 Pa element, upper view, B1, 78X.
5 Pa element, upper view, B1, 50X.

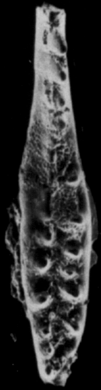
Figs. 6-10, 13-18 *Cavusgnathus unicornis* Youngquist and Miller

6 αPa element, inner-lateral view, W7, 50X.
7 αPa element, *C. charactus*-like morphotype, outer-lateral view, L1, 75X.
8 βPa element, inner-lateral view, LH5, 50X.
9 αPa element, upper view, L1, 50X.
10 γPa element, inner-lateral view, B16, 40X
13 M element, probably of *T. varians*, not *C. unicornis*, lateral view, B1, 78X.
14 Pb element, lateral view, L1, 60X.
15 M element, lateral view, L1, 60X.
16 Sa element, antero-lateral view, B10, 72X.
17 Sb element, lateral view, W13, 78X.
18 Sc element, lateral view, W13, 78X.

Fig. 11 *Cavusgnathus altus* Harris and Hollingsworth, Pa element, inner-lateral view, B10, 39X.

Fig. 12 *Cavusgnathus altus* X *C. unicornis* "Hybrid" Pa element, inner-lateral view, B10, 28X.

1

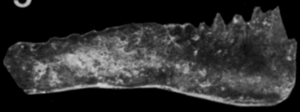


2

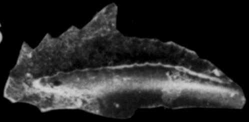
3

4

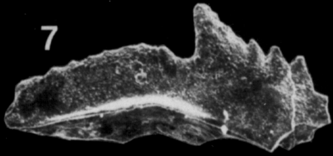
5



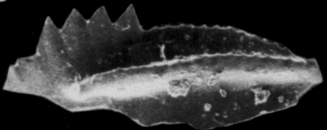
6



7

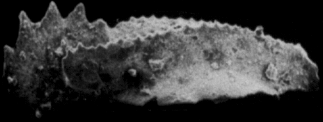


8



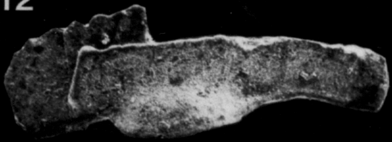
9

10

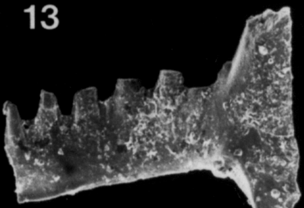


11

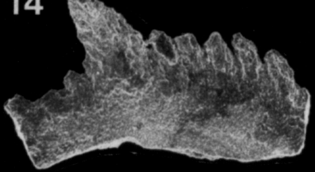
12



13

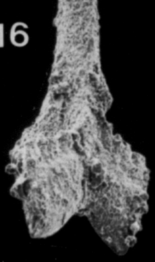


14

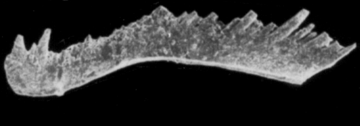


15

16



17



18

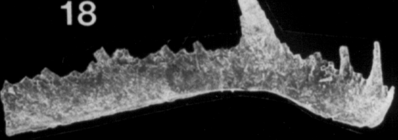


PLATE 6

Fig. 1-3 *Gnathodus bilineatus* (Roundy)

1 Pa element, gerontic form, upper view, B18, 40X.
2 Pa element, juvenile form, upper view, B10, 100X.
3 Pa element, deviant morphotype, upper view, L29, 60X.

Figs. 4, 8 *Gnathodus homopunctatus* Ziegler

4 Pa element, upper view, B16, 100X.
8 Pb element(?), lateral view, B10, 60X.

Fig. 5 *Gnathodus girtyi girtyi* Hass
Pa element, upper view, L13, 60X.

Fig. 6 *Gnathodus texanus* Roundy
Pa element, upper view, L32, 72X.

Figs. 7, 9-14 *Gnathodus* spp. (vicarious elements)

7 Pb element, lateral view, B10, 60X.
9 M element, lateral view, B11, 86X.
10 Sa element, posterior view, B10, 86X.
11 Sb element, lateral view, B11, 72X.
12 Sc_2 element, lateral view, B11, 86X.
13 Sc_1 element, lateral view, B11, 86X.
14 Sc_3 element, lateral view, B11, 72X.

1

2

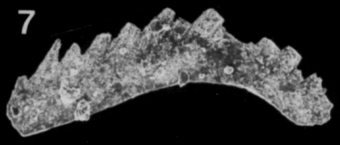
3

4

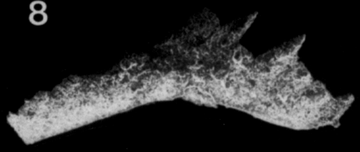
5

6

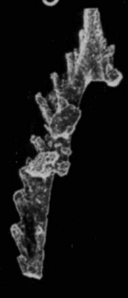
7



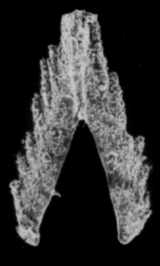
8



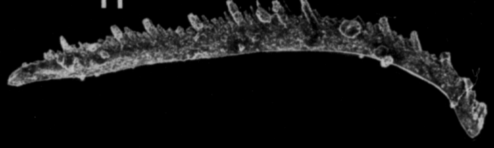
9



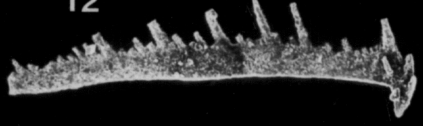
10



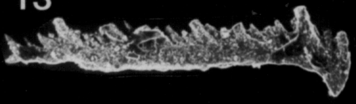
11



12



13



14

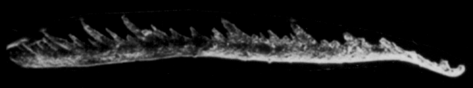


PLATE 7

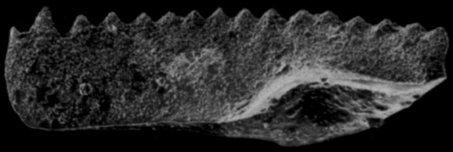
Figs. 1-7 *Lochriea commutatus* (Branson and Mehl)

1 Pa element, lateral view, B10, 72X.
2 Pa element, upper-lateral view, B10, 66X.
3 M element, inner-lateral view, B10, 48X.
4 Pb element, lateral view, B10, 78X.
5 Sa element, posterior view, B10, 72X.
6 Sc element, inner-lateral view, B10, 72X.
7 Sc element, inner-lateral view, B10, 72X.

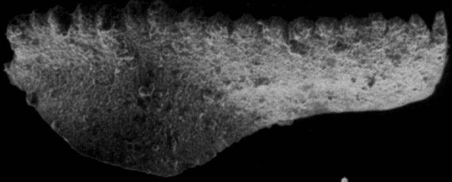
Figs. 8-14 "*Spathognathodus*" *campbelli* Rexroad

8 Pa element, inner-lateral view, B10, 78X.
9 Pb element, outer-lateral view, B10, 100X.
10 Pb element, inner-lateral view, B10, 100X.
11 Sb_1 element, inner-lateral view, B10, 100X.
12 Sb_2 element, inner-lateral view, B11, 100X.
13 Sa element, antero-lateral view, B10, 120X.
14 M element, inner-lateral view, B11, 100X.

1

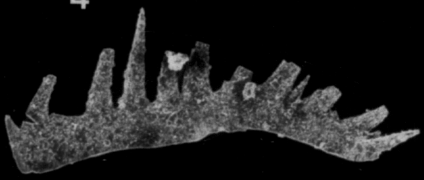


2

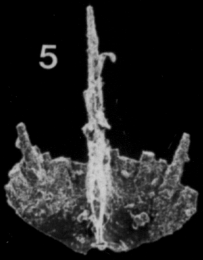


3

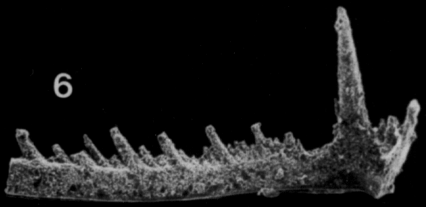
4



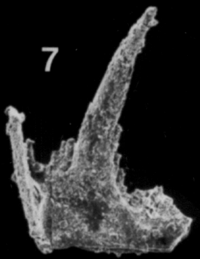
5



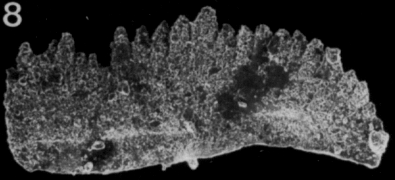
6



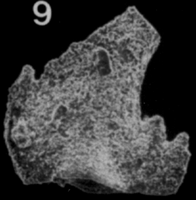
7



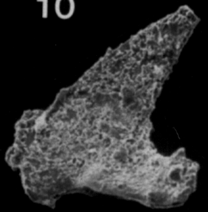
8



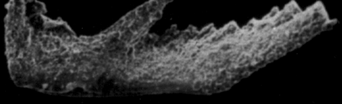
9



10

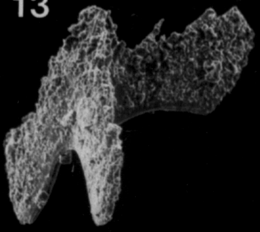


11

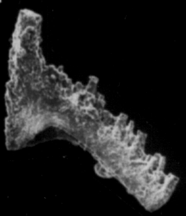


12

13



14



APPENDIX A

Measured Sections

Figure 10 : Locality map of the Lindell section (Hayter's Gap 7.5' Quad.). Hachured line shows location of section (L).


2000
1900
Branch
Creek
VALLEY
Lindell
BM LHT 278
1893
NORTH
1528
River Bridge
1525
Turkey
Hollow
Branch
Brandy
Morrison
BM LHT 275
BM LHT 276
1540
1800
1700

LINDELL - HAYTER'S GAP

This section was measured at the Route 80 bridge, across the North Fork of the Holston River, between the communities of Lindell and Hayter's Gap (Washington Co.), Virginia (Hayter's Gap 7.5' Quad.). It is located along the south side of the river, just to the southwest of the bridge and on both sides of Rte. 80, south of the bridge. The rocks are exposed on the northwest limb of the Greendale Syncline and strike N 48-58° E, with dips of 25° to 31° south.

Unit	Lithology	Bed Thickness (meters)	Total Thickness (meters)
	"Ste. Genevieve" Formation: Only the lower 108.80 m. (357 ft.) were measured. Above this, the rocks are mostly covered. Averitt (1941) measured the total "Ste. Genevieve-Gasper" interval as 740 m. (2429 ft.) thick, 16 km. to the southwest along strike.		
20.	Covered; with sporadic exposures of calcareous mudstone-siltstone and argillaceous limestone; no good exposures until "Gasper" Fm.		
19.	Calcareous sandstone; thin-bedded; very fine-grained.	0.15	108.80
18.	Calcareous silty mudstone; medium gray; bioturbated.	0.90	108.65
17.	Calcareous sandstone-siltstone; like unit 15.	0.30	107.75
16.	Covered.	2.15	107.45
15.	Calcareous sandstone-siltstone; thin-bedded, thinly laminated, small-scale current ripple-laminations (lenticular bedded, with thin, graded beds); medium gray, weathers light brown; small carbonaceous plant fragments; burrowed, occasional trails.	18.90	105.30
14.	Limestone, crinoidal grainstone;	2.00	86.40

	thick-bedded, trough cross-bedded, with megarippled top; quartzose; medium-light gray; skeletal grains are echinoderms (crinoids and echinoids) and bryozoans (fenestrate and tubular), common brachiopods, few ostracodes, gastropods, and endothyrid foraminifera; insoluble residue contains conodonts and fish teeth and scales; conodont sample L32.		
14.	Covered.	0.90	84.40
13.	Calcareous sandstone-siltstone; thin-bedded, flaggy; very thinly laminated, slightly rippled; very fine-grained sand, hematitic; olive olive gray to medium gray; coarse-grained echinderm plates; small carbonaceous plant fragments.	1.70	83.30
12.	Limestone, crinoidal grainstone; wave ripple-laminated; with thin siltstone drapes; quartzose; medium gray; abundant echinoderm plates.	0.15	81.80
11.	Limestone, crinoidal grainstone; medium- to thick-bedded (fewer thin beds); large-scale, low-angle, tabular cross-bedding, top 1.0 m. is quartzose; occasional glauconite grains; light gray; fossiliferous, with coarse to very coarse skeletal grains, grains are predominantly echinoderm (crinoid) plates, with lesser brachiopods and bryozoans, scarse pelecypods, gastropods and solitary rugose corals; insoluble residue contains conodonts, fish teeth and scales, ostracodes and inarticulate brachiopods; occasional black chert nodules; conodont samples, L30 at 64.50 m. and L31 at 68.75 m.	18.45	81.65
10.	Argillaceous limestone, lime mudstone to skeletal wackestone; thick-bedded; medium gray; echinoderm plates; occasional black chert	1.20	63.20

nodules.

9.	Limestone, crinoidal grainstone to packstone, occasional thin beds of calcareous silty mudstone; medium bedded, with large-scale, low-angle, tabular cross-bedding; light gray; very coarse to coarse echinoderm grains, predominantly crinoids, also brachiopods and bryozoans; occasional black chert nodules; few glauconite grains; conodont sample L29 at 60.20 m.	5.50	62.00
8.	Very argillaceous limestone (skeletal wackestone and lime mudstone) and calcareous silty mudstone, undifferentiated; massive-bedded; medium gray; fossiliferous, with abundant fenestrate bryozoans and crinoids (including <u>Platycrinites penicillus</u>), common blastoids, solitary rugose corals and brachiopods, few ostracodes and sponge spicules; conodont sample L28 (unprocessed) at 50.40 m.	14.45	56.50
7.	Calcareous siltstone; very thin-bedded; dark brownish-gray; crinoid columnals.	0.15	42.05
6.	Silty-argillaceous limestone skeletal wackestone, like 5. below, but onkoids poorly developed; massive to thick-bedded, not nodular; medium-dark gray; abundantly fossiliferous, with abundant fenestrate bryozoans and echinoderms (crinoids, blastoids and echinoids), common tubular to encrusting bryozoans, other fossils of unit 5. less common; becomes siltier up-section; conodont sample L27 at 37.05 m.	5.15	41.90
5.	Argillaceous limestone, onkoidal skeletal wackestone; massive to nodular-bedded, pod-like limestone masses surrounded by thin anastomosing stylolitic-argillaceous layers; dark-medium gray, weathers	18.30	36.75

	light gray; very fossiliferous, with abundant echinoderms (crinoids, including <u>Platycrinites</u> <u>penicillus</u>, blastoids and echinoids) and fenestrate bryozoans, common brachiopods, solitary rugose corals and foraminifera, lesser gastropods, pelecypods, ostracodes, trilobites, sponge spicules and calcispheres; insoluble residue contains conodonts and fish teeth and scales; abundant onkoids, up to 2 cm. in diameter; abundant black chert nodules; conodont samples, L25 at 20.00 m. and L26 at 26.70 m.		
4.	Covered.	3.65	18.45
3.	Argillaceous limestone, skeletal wackestone; thin, nodular-bedded, thin argillaceous-stylolitic seams; medium-dark gray, weathers light gray; fossiliferous, with abundant fenestrate bryozoans, brachiopods echinoderms; occasional onkoids (up to 1 cm. in diameter); black chert nodules.	3.95	14.80
2.	Argillaceous limestone and calcareous mudstone, interbedded and undifferentiated; "marlstone", thin, unevenly bedded to massive appearing, becomes more calcareous upward; dark-medium gray; abundantly fossiliferous, with abundant brachiopods (several genera), bryozoans (fenestrate and tubular) and solitary rugose corals, common echinoderms, rare pelecypods; onkoids appear at 9.00 m.; conodont sample L24 (unprocessed) at 2.30 m.	9.15	10.85
1.	Calcareous silty mudstone; very thin-bedded, shaley, friable; earthy brownish-gray; very fossiliferous, with abundant brachiopods, common solitary rugose corals and tubular bryozoans, lesser crinoids, ostracodes and pelecypods; gradational into unit 2 above, units	1.70	1.70

1-3 are part of a continuous gradational sequence which shows decrease in clastics upward; conodont sample L23 (unprocessed).

Hillsdale Limestone: Total thickness = 72.60 m. (238 ft.)

34.	Limestone, onkoidal skeletal wackestone, lesser packstone; massive-bedded; argillaceous in part; medium gray; abundant onkoids (grain-supported in part); fossiliferous, with abundant echinoderms (crinoids, blastoids and echinoids) and fenestrate bryozoans (also encrusting and tubular bryozoans), common endothyrid foraminifera and brachiopods, lesser solitary rugose corals, pelecypods, gastropods, ostracodes, sponge spicules and calcispheres; insoluble residue contains some conodonts, and fish teeth and scales burrows; occasional white chert nodules; conodont samples, L21 at 67.85 m. and L22 at 70.45 m.	5.50	72.60
33.	Limestone, oolitic skeletal wackestone and lime mudstone; medium-bedded; thinly laminated, with ooids, skeletal fragments and quartz grains in lags; medium gray; quartz sand, dispersed, coarse- to fine-grained; intraclasts of skeletal wackestone and algal limestone; abraded skeletal grains include echinoderms, brachiopods, foraminifera, fenestrate bryozoans, ostracodes, gastropods and pelecypods.	0.95	67.10
32.	Interbedded calcareous silty mudstone and silty lime mudstone; very thin- to thin-bedded, thinly laminated; brown to dark gray.	1.15	66.15
31.	Limestone, skeletal wackestone; thick-bedded; medium gray; fossiliferous, with abundant pelecypods, gastropods and echinoid spines, also	1.05	65.00

	lesser crinoids, corals, brachiopods, fenestrate bryozoans, ostracodes and trilobites; conodont sample L20.		
30.	Limestone, lime mudstone; thin-bedded and thinly laminated, graded beds; peloidal; medium brownish-gray.	0.45	63.95
29.	Calcareous silty mudstone; very thin-bedded to laminated; medium brownish-gray; burrowed.	0.55	63.50
28.	Limestone, sandy intraclast packstone; scoured (undulose) base; thin-bedded, laminated, with graded beds; medium gray; intraclasts of peloidal grainstone and algal limestone, some blackened and encrusted by algae; peloids and ooids; skeletal grains include common echinoderms, ostracodes, fenestrate bryozoans and sponge spicules, lesser brachiopods, corals and foraminifera; small amounts of coarse sand- to silt-sized quartz grains.	0.25	62.95
27.	Calcareous silty mudstone; very thin-bedded, shaley, friable; earthy brown; brachiopods.	0.15	62.70
26.	Silty limestone, skeletal wackestone; medium-dark gray; fossiliferous, with abundant ostracodes and brachiopods, lesser crinoids, pelecypods and gastropods; abundant burrows.	0.80	62.55
25.	Silty limestone, lime mudstone; finely laminated; light gray; dispersed ooids; ostracodes, top 8 cm. is shaley-silty mudstone, earthy brown.	0.60	61.75
24.	Silty dolomite; thinly laminated, wavy to undulose; light tan-gray; abundant, angular dolomite intraclasts; peloids; quartz silt.	0.35	61.15
23.	Argillaceous limestone, onkoidal	4.90	60.80

	skeletal wackestone, lesser packstone; thick-bedded; medium-dark gray; abundant onkoids, up to 5 cm. in diameter, form grain-supported fabric in some places, large and abundant from 57.4 to 58.1 m.; very fosiliferous, with abundant echinoderms (crinoids and echinoids), endothyrid foraminifera and bryozoans (including *Septopora*, *Cystodictya*, *Dichotrypa* and *Hemitrypa*), common brachiopods, lesser pelecypods, gastropods, corals, ostracodes, trilobites, sponge spicules and calcispheres; insoluble residue contains conodonts and fish teeth and scales; occasional black chert nodules; conodont samples, L17 at 56.0 m., L18 at 57.5 m. and L19 at 59.2 m.		
22.	Limestone, skeletal wackestone-packstone; thick- to massive-bedded, medium gray; peloidal; very fossiliferous, with abundant fenestrate and stick-like bryozoans (including (*Cystodictya*), crinoids and endothyrid foraminifera, with brachiopods, ostracodes and calcispheres; onkoids abundant in lower 75 cm.; rock may be biohermal, noticeable "potato-chip" effect of stacked bryozoans in thin-section, with shelter-voids, geopetals, fibrous calcite cement in void spaces between bryozoans, conodont sample L16 at 52.75 m.	3.20	55.90
21.	Argillaceous limestone, skeletal wackestone-packstone; thick-bedded, lower 15 cm. is shaley; medium gray, weathers light gray; peloidal; very fossiliferous, with echinoderms, brachiopods, fenestrate bryozoans and solitary rugose corals; burrows; occasional white chert nodules.	1.70	52.70
20.	Argillaceous limestone, skeletal wackestone; thinly laminated, wispy; dark brownish-gray, weathers light	0.60	51.00

	gray; fossiliferous, with brachiopods and tubular bryozoans; burrowed; top 15 cm. is shaley.		
19.	Calcareous silty mudstone; very thin-bedded; dark brownish-gray, heavily weathered; fenestrate bryozoans.	0.60	50.40
18.	Covered.	2.00	49.80
17.	Argillaceous limestone, skeletal wackestone; thick- to massive-bedded, shaley in part; lower 30 cm. may be dolomitic; dark brownish-gray, weathers light gray; fossiliferous, with abundant echinoderms and lesser fenestrate bryozoans, brachiopods, foraminifera, ostracodes, sponge spicules, pelecypods calcispheres, burrowed; conodont sample L15 at 47.40 m.	4.85	47.80
16.	Covered.	1.55	42.95
15.	Limestone, lime mudstone; finely laminated, undulose in part; light gray; intraclasts of lime mudstone and peloidal limestone; peloids; fossiliferous, with occasional brachiopods, bryozoans and echinoderm plates; top 15 cm. is shaley.	0.75	41.40
14.	Argillaceous limestone, lime mudstone; thin unevenly bedded, shaley in part; silty; medium-dark gray.	0.30	40.65
13.	Argillaceous limestone, skeletal packstone-wackestone and skeletal peloidal packstone-wackestone; thick-bedded; medium-dark gray, weathers light gray; peloids and intraclasts; fossiliferous, with fine- to medium-grained fossil fragments, common echinoderms, fenestrate bryozoans (lesser tubular forms) and brachiopods, lesser pelecypods, gastropods, foraminifera, ostracodes and calcispheres; insoluble residue contains cono-	7.60	40.35

	donts and fish teeth and scales; burrowed; common calcite-filled vugs (up to 0.5 cm. in diam.) from 39.95 m. up; conodont samples, L12.3 at 32.70 m., L13 at 36.25 m. and L14 at 39.35 m.		
12.	Limestone; at base of unit 12., at 32.35 m.(32.30 - 32.40 m.), is a scalloped, irregular hardground or erosion surface upon the underlying fenestral peloidal limestone; this surface is encrusted by vermiform gastropods, *Girvanella*-like algae, orange, fibrous calcite cement and, along upper surfaces, digitate stromatolites (with internal peloidal fabric) about 2.5 cm. high; hardground(?) is overlain by fenestral peloidal packstone and laminated calcareous siltstone (with admixed fine sand) which fills in lows on underlying hardground; several, thin, irregular hardgrounds occur throughout this thin interval; between 32.50 and 32.70 m. are prominant digitate stromatolite heads (up to 8 cm. in height); these are initiated on hardground encrusted by *Girvanella*-like algae, vermiform gastropods and fibrous calcite cement; heads have spongiostrome (laminated, peloidal) structure; undersides of heads are coated by pendant, laminated calcite cement; heads are bored and overlain by a thin layer of vermiform gastropods and orange, crustose (marine?) calcite cement; heads are surrounded by skeletal wackestone-packstone of overlying unit 13.	0.30	32.75
11.	Limestone, fenestral peloidal-intraclast wackestone to packstone; light gray; irregular fenestrae; abundant peloids and intraclasts; slightly fossiliferous, with common ostracodes and brachiopods, occasional pelecypods and echinoderm fragments.	0.15	32.45

10.	Limestone, ooid grainstone; gradational with unit 9 below, very low-angle cross-bedding; ooids are coarse- to very coarse-grained, poorly sorted; occasional peloids; medium-dark gray.	0.30	32.30
9.	Limestone, peloidal skeletal packstone; thick-bedded; medium-dark gray, weathers light gray; peloids abundant; small rounded intraclasts; abraded skeletal grains, including abundant echinoderm fragments, lesser brachiopods, pelecypods, fenestrate bryozoans and ostracodes; ooids appear upsection, gradational into overlying ooid grainstone.	1.20	32.00
8.	Calcareous siltstone; shaley, very thin-bedded; dark brown; skeletal debris in upper 2 cm.	0.15	30.80
7.	Limestone; sharp contact with underlying beds; basal 5 cm. is thick-laminated (0.5 - 2 cm. thick, graded laminae) peloidal grainstone; this grades up into burrowed, argillaceous peloidal-skeletal wackestone-packstone, which in turn becomes oolitic at top of unit; medium-dark gray, weathers light gray; conodont sample L12.2 at base.	0.30	30.65
6.	Dolomite; sharp, irregular contact with underlying beds; basal 10 cm. is breccia of angular, light tan, very finely crystalline dolomite clasts (up to 2.5 cm. wide), surrounded by very silty, earthy dolomitic matrix; this grades up into earthy, light tan, very finely crystalline dolomite.	0.25	30.35
5.	Limestone; sharp, scoured contact with below; ooid grainstone at base, with ooids dropping out upward with increase in ostracodes; basal 15 cm. are ooid grainstone, coarse-grained, well-sorted, with occasional peloids,	0.45	30.10

	much grain-to-grain pressure solution; upper 30 cm. is ostracode packstone, strongly compacted with loss of skeletal material, intraparticle and fenestral porosity, fibrous calcite cement; top 10 cm. is vuggy and fenestral (cavities in part, anhydrite[?] filled), with abundant intraclasts and peloids, thin (1-2 cm.) calcrete(?) zone; irregular contact with overlying breccia.		
4.	Limestone, skeletal peloidal packstone; medium-bedded; current ripple-laminated; fine-grained; dark gray; peloids abundant, few ooids; skeletal grains common, including abundant echinoderms (crinoids and echinoids) and endothyrid foraminifera, occasional pelecypods, brachiopods, fenestrate bryozoans, ostracodes, calcispheres and conodonts; conodont sample L12 at base.	0.65	29.65
3.	Limestone, ooid grainstone; thick-bedded; medium gray, coarse-grained; occasional peloids; skeletal grains in ooid nuclei: endothyrid foraminifera, echinoderm plates, bryozoans, brachiopods and pelecypods.	1.70	29.00
2.	Limestone, skeletal wackestone with lesser, skeletal packstone and peloidal skeletal packstone (associated with corals); thick- to massive-bedded; in part argillaceous, dark gray; weathers medium gray; fossiliferous with abundant echinoderms (crinoids, blastoids), common brachiopods, fenestrate bryozoans (fewer tubular forms), endothyrid foraminifera and tabulate corals (<u>Syringopora</u>), lesser pelecypods and ostracodes; occasional algal onkoids (up to 5 5 cm. in diameter in lower 3 m.; common calcispheres; insoluble residue contains scarse conodonts and	24.40	27.30

	fish teeth and scales, stylolitic and argillaceous; many small high-angle faults and calcite veins; conodont samples, L2 (3.50 m.), L3 (6.55 m.), L4 (9.30 m.), L5 (12.05 m.), L6 not taken, L7 (12.95 m.), L8 (15.10 m.), L9 (18.15 m.), L10 (20.25 m.) and L11 (26.35 m.).		
1.	Limestone, oolitic skeletal grainstone; thick- to massive-bedded; laminated (cross-bedding); medium gray, weathers light gray; fine- to medium-grained; grains are ooids and coated skeletal grains, occasional peloids and rounded intraclasts; skeletal grains include abundant echinoderms (crinoids and echinoids) and endothyrid foraminifera, lesser brachiopods, fenestrate bryozoans and ostracodes; insoluble residue contains fish teeth and scales, insoluble residue contains abundant conodonts; small faults; abundant calcite veins; conodont samples, L1 at base and L1.5 at 1.70 m.	2.90	2.90

Little Valley Formation: total exposure = 172.25 m. (565 ft.) The contact with the overlying Hillsdale Limestone is exposed near the south end of the Rt. 80 bridge, continuously on the east side of the bridge, and with a small exposure on the west side of the bridge. The contact is sharp, due to the color change from light tan siltstone of the Little Valley Formation to light-gray, oolitic limestone of the Hillsdale, and slightly undulose.

79.	Calcareous-dolomitic siltstone; gradational contact with below; medium- to thin-bedded; faintly laminated; light gray, weathers light tan; occasional echinoderm plates; bioturbated, burrows and horizontal trails on bedding planes.	2.30	172.25
78.	Calcareous shale; like unit 77,	4.45	169.95

	but with calcite pseudomorphs (rhombs, several mm. in diameter) after evaporites (gypsum?); few brachiopods; fecal pellets; Zoophycus(?) markings.		
77.	Calcareous shale; very thin-bedded; medium gray; vugs, calcite-filled or open; no body fossils seen; burrowed; gradational with unit 76.	3.05	165.50
76.	Calcareous mudstone; like unit 71.	1.50	162.45
75.	Covered.	3.50	160.95
74.	Calcareous mudstone, minor argillaceous limestone; like unit 71.	1.70	157.45
73.	Covered.	10.65	155.75
72.	Limestone, ooid grainstone-packstone; thin- to medium-bedded; medium- to coarse-grained; medium-dark gray; some skeletal grains include pelecypods and ostracodes; slightly hematitic; conodont sample H6.	0.55	144.40
71.	Calcareous mudstone, minor argillaceous limstone; thin-bedded, shaley to blocky-massive; medium-gray; fossiliferous, with brachiopods, bryozoans (fenestrate, tubular and encrusting), echinoderms, pelecypods and vertebrate (fish?) fragments; occasional, thin (2 cm.) skeletal lags; two covered intervals, 3.65 m. covered starting at 128.45 m. and 1.90 m. covered starting at 141.30 m.	20.55	144.55
70.	Very argillaceous limestone, lime mudstone to skeletal wackestone; light, earthy gray; fossiliferous, with brachiopods and echinoderm fragments.	0.30	124.00
69.	Shale (noncalcareous); like unit 67, but more fissile, with faunal differences; same fauna as below,	2.00	123.70

	but nautiloids replace pelecypods as most dominant faunal element, also with brachiopods, ostracodes as below, common fish scales and fragments, few plant fragments.		
68.	Very argillaceous limestone, skeletal wackestone; thick marker-bed; light gray; fossiliferous, with abundant tubular bryozoans, productid brachiopods and echinoderm fragments.	0.30	121.70
67.	Black shale (noncalcareous); very thin-bedded to nonbedded, very friable, crumbly, many joints perpendicular to bedding; very fossiliferous in spots, with dominantly pelecypods (*Aviculopecten*, *Phestia* and *Sedgwickia*?), lesser brachiopods (*Tetracamera*, *Lingula* and productids), nautiloid cephalopods and ostracodes.	3.60	121.40
66.	Covered.	1.45	117.80
65.	Shale (noncalcareous); very thin-bedded; very dark, earthy gray to black; fossiliferous, with abundant brachiopods (*Tetracamera* and productids); strong petroliferous odor.	0.20	116.35
64.	Interbedded calcareous mudstone and argillaceous limestone (skeletal wackestone-packstone); thin-bedded; dark, earthy gray; very fossiliferous, with abundant bryozoans (fenestrate and tubular), brachiopods, echinoderms, pelecypods (clams and *Aviculopecten*) and lesser gastropods and ostracodes; burrows and abundant *Zoophycus* markings; conodont sample, H5 at 112.50 m.	3.90	116.15
63.	Sandy-argillaceous limestone; basal 5 cm. is intraclast packstone-wackestone, with rounded, coarse- to granule-sized intraclasts, abundant skeletal grains	0.30	112.25

	(gastropods, pelecypods, brachiopods, echinoderms and ostracodes), bioturbated; grades into silty lime mudstone; light gray; quartzose; chert nodules.		
62.	Argillaceous limestone, lime mudstone; thin- (undulatory) bedded; very finely laminated, maybe cryptalgal.	1.15	111.95
61.	Silty mudstone, grading up into argillaceous limestone; very thin- to thin-bedded; limestone, more blocky-massive; light to dark olive-gray; occasional pelecypods (*Edmondia*-*Wilkingia*-like clams).	3.35	110.80
60.	Calcareous siltstone, grading upward to very fine-grained sandstone; thin-bedded, flaggy; wave ripple-laminated; light tan-gray, weathers tan-orange; ostracodes.	1.20	107.45
59.	Argillaceous-silty limestone, lime mudstone; thin-bedded; dark gray; abundant ostracodes; wave-rippled top.	0.60	106.25
58.	Calcareous siltstone, lesser mudstone, with a few, thin, argillaceous limestone and very fine-grained sandstone beds; thin-bedded, flaggy; wave ripple-laminated in part, other parts homogenized by burrowing; slightly fossiliferous, with occasional pelecypods, ostracodes and echinoderm plates; burrows and trails.	2.50	105.65
57.	Calcareous mudstone; thin- (rubbly-uneven) bedded; admixed silt and very fine sand; earthy, medium gray; fossiliferous, with fenestrate bryozoans, echinoderms, brachiopods and pelecypods (clams and *Aviculopecten*); plant fragments; burrowed and with abundant *Zoophycus* trails; in part covered.	5.95	103.15

56.	Argillaceous-sandy limestone, skeletal packstone-wackestone; medium- to thick-bedded; very fine- to fine-grained quartz sand; earthy-dark gray; very fossiliferous, with common fenestrate bryozoans, brachiopods, echinoderms (crinoids and echinoids) and pelecypods, lesser gastropods and ostracodes; gradational into unit 57; conodont sample H4 at base.	1.15	97.20
55.	Argillaceous-silty limestone and calcareous mudstone, basal 10 cm. is silty skeletal packstone, with brachiopods and echinoderms; very thin- to thin- (rubbly) bedded, shaley; medium-dark gray; very fossiliferous, with echinoderms, brachiopods (several orders), pelecypods (clams and *Aviculopecten*), bryozoans and ostracodes; burrowed; *Zoophycus* trails; body fossils drop out upward, except for occasional pelecypods and abundant *Zoophycus* markings; shalier upward.	2.80	96.05
54.	Calcareous sandstone; thin-bedded; wave ripple-laminated; very fine-grained; olive gray, weathers orange; fossiliferous, with crinoid columnals and fenestrate bryozoan fragments; burrowed.	1.00	93.25
53.	Calcareous siltstone; thin-bedded; fossiliferous, with abundant echinoderms, few ostracodes and pelecypods; plant fragments; burrowed.	0.45	92.25
52.	Interbedded silty-argillaceous limestone and calcareous shale; very thin-bedded, rubbly-uneven; earthy, light gray; pelecypods; burrowed; with thin (2-5 cm. thick) skeletal packstone beds; units 52-54 form a continuous coarsening-upward sequence.	0.90	91.80
51.	Argillaceous-silty limestone,	1.40	90.90

	skeletal wackestone; very thin- to thin-bedded, shaley; medium gray; fossiliferous, with fossils increasing in abundance upward; echinoderms, brachiopods and corals (<u>Syringopora</u>); burrowed.		
50.	Covered.	1.00	89.50
49.	Calcareous siltstone and argillaceous-silty limestone; very thin-bedded; laminated; dark, earthy gray.	0.50	88.50
48.	Sandy-argillaceous limestone, ooid packstone-grainstone; fine- to medium-grained; medium gray; skeletal grains (ooid nuclei) are bryozoans, echinoderms, pelecypods and ostracodes.	0.15	88.00
47.	Calcareous quartz sandstone; mostly covered; trough cross-bedded; coarse- to medium-grained; micaceous; light gray, weathers orange.	1.30	87.85
46.	Calcareous silty mudstone; thin-bedded; ripple cross-laminated; medium gray; burrowed.	0.90	86.55
45.	Calcareous quartz sandstone; bar-form shape, with flat base and undulose, rippled top; ripple cross-laminated; medium- to fine-grained; abundant pelecypods in basal 15 cm.	0.25	85.65
44.	Calcareous silty mudstone; thin-bedded; faintly laminated; light-medium gray; pelecypods; burrows.	2.05	85.40
43.	Calcareous sandstone, with lesser siltstone; thin-bedded, with lesser medium beds; wave ripple-laminated in part; very fine-grained sand; slightly fossiliferous, with dominantly pelecypods (clams) and associated burrows, some clams in life-position, few brachiopods and bryozoans.	5.45	83.35

42.	Calcareous mudstone; like unit 40, but siltier; gradational into unit 43.	0.45	77.90
41.	Covered.	0.45	77.45
40.	Calcareous mudstone; thin-bedded; very fossiliferous, with brachiopods (*Orthotetes* and *Tetracamera* included), pelecypods (*Wilkingia* and *Aviculopecten*), fenestrate and encrusting bryozoans and echinoderms.	0.75	77.00
39.	Covered.	1.50	76.25
38.	Calcareous mudstone; thin- to very thin-bedded; very fossiliferous; beds are alternating: 1.) thin, blocky (calcareous) beds of abundant, large brachiopods (*Orthotetes*), other brachiopods and bryozoans, and 2.) very thin, shaley beds dominated by pelecypods (*Phestia*, *Wilkingia* and *Aviculopecten*?) and some brachiopods; upward the beds become shalier, pelecypod-dominated, and more bioturbated, with burrows and *Zoophycus* markings.	1.85	74.75
37.	Covered.	0.40	72.90
36.	Calcareous siltstone and silty mudstone, with minor, very thin limestone beds; thin- to very thin-bedded; very fossiliferous, with abundant bryozoans, common brachiopods, echinoderms and pelecypods, lesser ostracodes and trilobites; burrows.	1.00	72.50
35.	Covered.	0.65	71.50
34.	Argillaceous limestone, skeletal wackestone; earthy, medium to dark gray; very fossiliferous, with echinoderms (large crinoid columnals, up to 1 cm. in diameter), brachiopods and bryozoans.	0.30	70.85
33.	Covered.	0.60	70.55

32.	Interbedded calcareous siltstone, silty shale and silty-argillaceous limestone; very thin- to thin-bedded; medium gray; fossiliferous, with brachiopods, echinoderms and pelecypods.	2.75	69.95
31.	Calcareous mudstone and very argillaceous limestone; very thin- to thin-bedded, in part, massive to poorly bedded; earthy, medium gray; fossiliferous, with abundant brachiopods, bryozoans and echinoderms, lesser pelecypods; burrowed.	3.80	67.20
30.	Covered.	2.35	63.40
29.	Argillaceous limestone, skeletal wackestone-packstone; thin- to massive-bedded, shaley in part; earthy, dark to medium gray; very fossiliferous, with abundant brachiopods and echinoderms, common bryozoans (fenestrate, tubular and encrusting), lesser pelecypods, gastropods, solitary rugose corals and ostracodes; occasional chert nodules; conodont samples, H2 at 55.30 m. and H3 at 56.90 m.	5.75	61.05
28.	Calcareous quartz sandstone; thin- to medium-bedded; plane to wave ripple-laminated; light gray; occasional burrows.	2.65	55.30
27.	Calcareous silty mudstone; gnarly, poorly bedded to very thin-bedded, shaley; light gray; very fossiliferous, with abundant brachiopods and fenestrate bryozoans, some pelecypods; burrowed; gradational into unit 28.	0.30	52.65
26.	Covered.	0.45	52.35
25.	Silty-argillaceous limestone; very thin-bedded, shaley, to poorly or massive-bedded (depends on weathering); medium to dark gray; thin	4.75	51.90

	(up to 15 cm. thick) interbeds of calcareous quartz sandstone, very fine- to fine-grained, light-medium gray; unfossiliferous, except for upper 75 cm., brachiopods (including <u>Orthotetes</u>), echinoderms and bryozoans (fenestrate and tubular); burrowed throughout.		
24.	Silty limestone; very thin-bedded, wave ripple-laminated, grades upward into undulose, cryptalgalaminations which form low, laterally-linked hemispheroidal stromatolites; light gray.	0.75	47.15
23.	Calcareous quartz sandstone; thin- to thick-bedded, more thick-bedded upward; plane-laminated in part, becomes wave ripple-laminated at 45.95 m.; very fine- to fine-grained, becomes medium-grained upward; well-rounded quartz grains; light-medium gray; fossiliferous, with occasional brachiopods and lesser bryozoans, pelecypods, ostracodes and echinoderm plates.	3.80	46.40
22.	Argillaceous-silty limestone and calcareous mudstone; heavily weathered; blocky, massive- or poorly bedded to very thin-bedded; earthy, medium to light gray; basal, fine-grained, oolitic, peloidal packstone-grainstone (15. cm. thick), overlain by lenticular-bedded (current-ripple laminated), silty, peloidal limestone (15-20 cm. thick); occasional pelecypods (<u>Wilkingia</u>?) and echinoderm plates; burrowed throughout; gradational over 15 cm. into unit 23.	2.45	42.60
21.	Covered.	0.15	40.15
20.	Calcareous quartz sandstone; like unit 19, but thick-bedded; trough cross-bedded, sets up to 50 cm. thick, dips variable, 10-20°; like unit 19 in other aspects.	1.50	40.00

19.	Calcareous quartz sandstone (Quartz arenite); medium- to thick-bedded; plane laminated; medium- to coarse-grained; light gray; quartz grains are well-rounded, moderate- to well-sorted; some ooids and skeletal grains; skeletal grains are echinoderm plates, brachiopods, bryozoans, gastropods, pelecypods and ostracodes; basal 12 cm. is conglomeratic, with siltstone and and very fine-grained sandstone clasts, up to 1 cm. in diameter.	1.85	38.50
18.	Calcareous quartz sandstone, lesser siltstone; thin-bedded; plane to wave ripple-laminated; very fine- to fine-grained; fossiliferous, with brachiopods, fenestrate and tubular bryozoans (*Rhombopora*?), echinoderm plates and occasional ostracodes; few burrows.	4.25	36.65
17.	Calcareous silty shale, with a few, thin, wave ripple-laminated, ooid packstone lenses.	0.15	32.40
16.	Limestone, oolitic skeletal packstone-grainstone; ripple laminated; light gray; oolitic grains are medium- to coarse-grained, well-sorted; some intraclasts; skeletal grains include brachiopods, bryozoans, echinoderms, pelecypods, gastropods and ostracodes; minor amounts of quartz silt; conodont sample, H1.	0.10	32.25
15.	Calcareous silty mudstone; dark, earthy-gray; fossiliferous, with brachiopods and pelecypods; burrowed; up-section, the rock grades from very thin- to blocky, poorly bedded, body fossils decrease and burrows increase in abundance.	1.85	32.15
14.	Silty-argillaceous limestone; dark earthy-gray; basal 10 cm. is silty oolitic packstone; ooids are	0.55	30.30

	hematitic, fine- to medium-grained, well-sorted; skeletal grains (ooid nuclei) include brachiopods, fenestrate bryozoans, echinoderm plates, pelecypods, gastropods and ostracodes; gradational into unit 15.		
13.	Calcareous silty mudstone; like unit 11.	0.75	29.75
12.	Covered.	2.25	29.00
11.	Calcareous silty mudstone; poorly bedded, gnarly to thin-bedded; earthy brownish-gray; very fossiliferous, fossils increase in abundance upward, with abundant pelecypods, fewer brachiopods, ostracodes and hyolithids(?); burrowed.	1.65	26.75
10.	Covered.	3.05	25.10
9.	Calcareous shale; very thin-bedded, fissile; light olive-gray; rare, very small brachiopods; trace fossils, small tracks and trails; thin (up to 5 cm. thick), lens-shaped limestone beds (argillaceous-silty peloidal limestone), ripple cross-laminated, channel-shaped, scoured bases, light-medium gray; some shale beds are tectonically fractured, with thin calcite veins.	2.20	22.05
8.	Argillaceous-silty limestone, skeletal wackestone; quartz silt; earthy gray; fossiliferous, with fenestrate and tubular bryozoans, pelecypods and gastropods; burrowed.	0.40	19.85
7.	Calcareous shale; like below; very thin-bedded; silty; light olive-brown; with a few thin (up to 10 cm. thick) beds of argillaceous lime mudstone; few trace fossils, millimeter-sized trails and bumps; occasional, thin calcite veins.	4.20	19.45

6.	Covered.	1.80	15.25
5.	Calcareous mudstone and shale, interbedded; calcareous mudstone is poorly bedded to thin-bedded, faintly laminated, light olive-brown to light brownish-gray, calcareous shale is very thin-bedded, finely laminated, light brownish-gray, many areas are tectonically brecciated, with many thin, calcite veins perpendicular to bedding; occasional pelecypods (<u>Phestia</u>?).	6.55	13.45
4.	Covered.	1.45	6.90
3.	Calcareous quartz sandstone; fine-grained; light tan.	0.25	5.45
2.	Dolomitic limestone, lime mudstone; poorly bedded, weathered, crumbly; faintly laminated; brecciated, with many thin, calcite veins, light brownish-gray.	0.30	5.20
1.	Dolomite; medium- to thin-bedded; faintly laminated; very finely crystalline, mudstone-like texture; light tan-brown to light brownish-gray; no fossils observed; some thin, calcite veins, parallel to bedding.	4.90	4.90

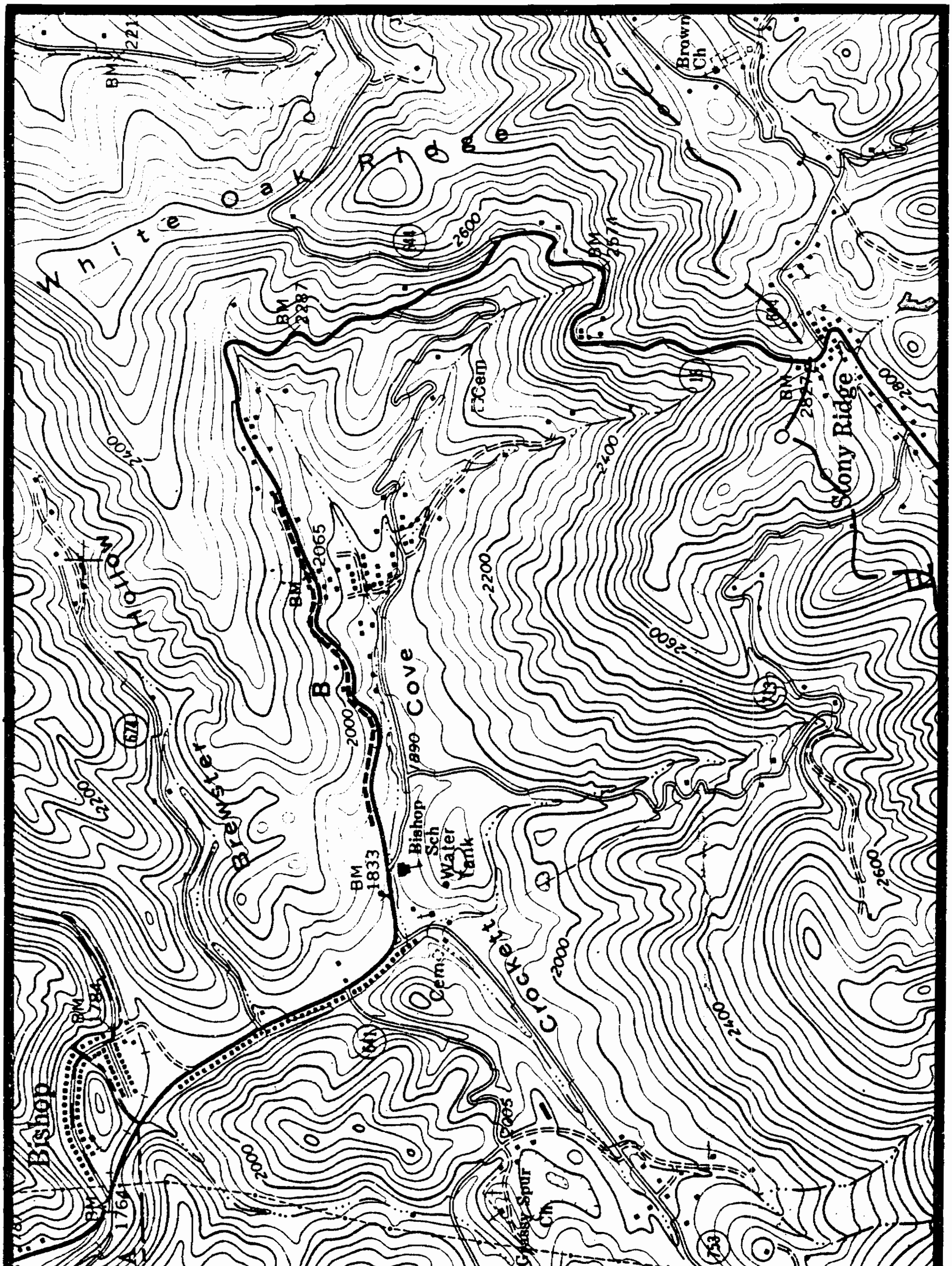
Price(?), Maccrady and Little Valley Formations

1.	Covered; in the lower 3 m. are exposed a few, thin-bedded, fine-grained, lithic sandstone and silty sandstone beds in the river bed; the remainder of this interval is covered by the meander bend and the dirt road.	29.90	--.--

Price Formation (not measured).

1. Lithic sandstone; (bed exposed in the North Fork of the Holston River); thin-bedded; fine- to medium-grained; light gray; occasional small plant fragments; the rest of the Price Fm. is exposed along the hillside (Little Mt.) to the north.	1.50	--.--

Figure 11 : Locality map of the Bishop section (Tazewell North 7.5' Quad.). Hachured line shows location of measured section (B).


White Oak Ridge
Brown Ch
Stony Ridge
Brewster Hollow
Cove
Crockett
Bishop
Bishop Sch
Water Tank
Cem
Cem
Grassy Spur Ch
BM 2287
BM 2671
BM 2827
BM 2065
BM 1833
BM 1784
BM 1764
674
661
753
2000
2200
2400
2600
2800
1890

BISHOP

This section is located along the northern side of Va. Route 16, between Stony Ridge, Virginia (Tazewell Co.) and Bishop, West Virginia, roughly 0.8 km. south of Bishop Village (Tazewell North 7.5' Quad.). The rocks are exposed along the northwest limb of the Hurricane Ridge Syncline and strike N 50-60° E, with dips of 20-30° south.

Greenbrier Limestone: Total thickness = 259 m. (850 ft.)

"Denmar-Gasper" Formation: partial section; only the lower 54.1 m. (178 ft.) were measured. The total "Denmar-Gasper" interval at Bishop has been measured at 205 m. (673 ft.) by Wilpolt and Marden (1955, 1959).

Unit	Lithology	Bed Thickness (meters)	Total Thickness (meters)
37.	Argillaceous limestone, skeletal wackestone to packstone; with crinoids and brachiopods.	0.30	54.10
36.	Limestone, crinoidal packstone; thick-bedded; coarse-grained; light gray; crinoids and brachiopods.	0.90	53.80
35.	Argillaceous limestone, echinoderm packstone-wackestone; thin-bedded; light-medium gray; crinoids and brachiopods.	0.15	52.90
34.	Limestone, crinoidal grainstone; massive; very low angle (10°);tabular cross-bedding; light gray; medium grained; few oolitic grains; crinoids and brachiopods.	1.20	52.75
33.	Argillaceous limestone, skeletal wackestone, minor packstone; medium-bedded; medium gray; very fossiliferous, with abundant crinoids, brachiopods, fenestrate and tubular bryozoans and solitary rugose corals; abundant black chert nodules.	3.85	51.55
32.	Covered.	0.60	47.70
31.	Very argillaceous limestone, skel-	1.05	47.10

	etal wackestone; uneven, thin- to medium-bedded, shaley; medium gray, weathers tan-gray; very fossiliferous, like unit 27 below, very cherty, with abundant lenticular, black chert nodules.		
30.	Covered.	0.90	46.05
29.	Calcareous siltstone-shale, with lesser argillaceous limestone; thin- to very thin-bedded; tan-brown; very fossiliferous, like unit 27.	0.95	45.15
28.	Covered.	2.35	44.20
27.	Limestone, skeletal packstone, and lesser wackestone; thin-bedded; interbedded with thin beds of calcareous shale to argillaceous limestone, which drop out upward; medium gray; very fossiliferous, with brachiopods (*Composita*, *Orthotetes*, *Dictyoclostus*, *Cliothyridina*, *Anthracospirifer*, *Punctospirifer*, *Reticulariina*), blastoids, (*Pentremites*), fenestrate bryozoans, trilobites (*Kaskia*), lesser ostracodes and pelecypods (*Aviculopecten*); fossils heavily silicified; abundant black chert nodules; conodont sample B18.	1.20	41.85
26.	Argillaceous-silty limestone, skeletal packstone-wackestone; thin- to medium-bedded; very fossiliferous, with abundant echinoderms, brachiopods and fenestrate bryozoans.	0.65	40.65
25.	Limestone, crinoidal packstone; slightly argillaceous; some thin shaley beds; basal 15 cm. with abundant coarse- to very coarse-grained echinoderm fragments, most grains are fine to medium; with brachiopods.	0.55	40.00
24.	Covered.	0.15	39.45
23.	Limestone, skeletal wackestone to packstone; massive; fine-grained;	0.30	39.30

	medium gray; with echinoderms and brachiopods.		
22.	Covered.	0.30	39.00
21.	Calcareous siltstone-shale, with minor argillaceous limestone; very thin- to thin-bedded (even to uneven, rubbly); brownish-dark gray; with occasional crinoids and brachiopods.	2.60	38.80
20.	Interbedded calcareous shale and silty limestone; calcareous shale is very thinly laminated, wavy to undulose; with only occasional burrows; silty peloidal limestone is lensing (fairly continuous) to nodular (discontinuous, pod-shaped), finely laminated, laminae pass continuously from shale into limestone, contains silt to very fine sand; very few fossil fragments, all small echinoderms and brachiopods; limestone contains many small burrows.	1.35	36.10
19.	Calcareous siltstone; very thin-bedded (uneven, rubbbly); brownish-dark gray; scattered echinoderm fragments and brachiopods; horizontal tracks and trails; gradational into unit 20.	0.50	34.75
18.	Limestone, ooid grainstone; medium- to thick-bedded, with low-angle tabular cross-bedding (10-15° dips); ooids, medium- to coarse-grained, well-sorted; skeletal grains abundant, most are echinoderm plates, also brachiopods, fenestrate bryozoans, solitary rugose corals; very light gray, weathers white; conodont sample B17.	0.60	34.25
17.	Limestone, skeletal wackestone; medium- to thick-bedded; light gray; abundant echinoderms (crinoids and echinoids), brachiopods and fenestrate bryozoans; occasional ostracodes, gastropods and trilobites; conodont sample B16 at 29.25 m.	8.15	33.65

16.	Covered.	2.20	25.50
15.	Limestone, silty peloidal skeletal packstone; thin-bedded; fine- to medium-grained; light olive-gray; dispersed silt to fine sand; common peloids, well-sorted, fine- to medium-grained; fine skeletal grains, mostly echinoderms, also brachiopods, fenestrate bryozoans, foraminifera, ostracodes and pelecypods; heavily bioturbated.	0.75	23.30
14.	Limestone, interbedded intraclast packstone (like 13.) and silty, skeletal peloidal packstone; thin-bedded; light olive-gray; peloidal packstone contains silt to very fine quartz sand, abundant peloids and skeletal fragments, mostly echinoderms, with lesser brachiopods, fenestrate bryozoans, ostracodes, pelecypods and foraminifera; heavily burrowed; gradational into unit 15.	0.30	22.55
13.	Limestone, oolitic intraclast grainstone; thick-bedded; medium gray; abundant intraclasts, very coarse sand to pebble size (up to 6 cm. long), intraclasts of lime mudstone, fenestral lime mudstone, oolitic skeletal wackestone-packstone, oolitic packstone, and intraclast packstone-grainstone; other grains are ooids and coated intraclasts and skeletal grains; skeletal fragments include echinoderms (mostly crinoids), brachiopods, bryozoans; top 15 cm. is shaley, conodont sample B15 at base.	0.65	22.25
12.	Limestone, skeletal wackestone to lime mudstone, basal 15 cm. is skeletal packstone; most is thick- to massive-bedded, basal 75 cm. is thin- to medium-bedded; light gray; fossiliferous, with common echinoderms,	4.35	21.60

	brachiopods, fenestrate bryozoans, lesser ostracodes, solitary rugose corals, pelecypods, trilobites and foraminifera; abundant burrows; conodont sample B14 at 18.00 m.		
11.	Limestone, intraclast skeletal grainstone; scoured into unit 10; intraclasts of lime mudstone are up to 2 cm. in length, most smaller; infrequent ooids; skeletal fragments include echinoderms, brachiopods,and trilobites.	0.15	17.25
10.	Limestone, ooid skeletal grainstone; medium-bedded; light gray; ooids are medium-grained; some coated skeletal grains, echinoderms and brachiopods.	0.75	17.10
9.	Argillaceous limestone, crinoidal packstone; light-medium gray; echinoderms and brachiopods, slumping in this interval (across the road from the Stony Ridge Store).	0.45	16.35
8.	Calcareous siltstone; very thin-(evenly) bedded, shaley; very thinly laminated; dispersed very fine quartz sand; yellow-tan; occasional echinoderm plates; horizontal tracks and trails	1.05	15.90
7.	Limestone, crinoidal packstone; thick-bedded; light gray; abundant echinoderm fragments, crinoids and blastoids; brachiopods and solitary rugose corals.	0.50	14.85
6.	Silty-argillaceous limestone; thin- to medium-bedded, appears massive; light brownish-gray, scarse echinoderm plates.	1.55	14.35
5.	Limestone, crinoidal packstone; thick-bedded, partly cross-stratified; light gray; intraclasts common, most are rounded, coarse sand- to pebble-sized, some multi-generation clasts; some ooids; skeletal grains	1.45	12.80

	most common; abundant echinoderms, crinoids, blastoids and echinoids; also common solitary rugose corals, brachiopods, fenestrate bryozoans, gastropods; lesser pelecypods, foraminifera and trilobites; insoluble residue contains conodonts, ostracodes, sponge spicules and fish teeth and scales; conodont sample B13.		
4.	Calcareous shaley siltstone; very thin- to thin-bedded, tan-brown.	4.05	11.35
3.	Silty-argillaceous limestone; very thin- to thin-bedded, alternating thin, shaley layers with thicker, limey beds; shaley beds are thinly-laminated, slight ledge-formers; limey beds are recessive; silt and very fine sand dispersed throughout; medium gray, earthy; fossiliferous, with occasional brachiopods and crinoids.	1.80	7.30
2.	Covered.	5.20	5.50
1.	Calcareous siltstone-sandstone; very thin-bedded; sand is very fine-grained; yellow-tan; basal 3 cm. has skeletal lag, dominantly of echinoderm plates, with lesser brachiopods and solitary rugose corals, skeletal fragments die out upward.	0.30	0.30

Hillsdale Limestone: Total thickness = 33.70 m. (110.6 ft.)

23.	Limestone, skeletal wackestone; medium- to thick-bedded; light-medium gray; fossiliferous, with abundant brachiopods, crinoids, solitary rugose corals and fenestrate bryozoans, lesser ostracodes, trilobites, foraminifera and pelecypods; insoluble residue contains conodonts, inarticulate brachiopods and fish teeth and scales; black chert nod-	5.50	33.70

	ules; conodont samples, B11 at 27.80 m. and B12 at 32.35 m.		
22.	Silty-argillaceous limestone, skeletal wackestone; very thin-(unevenly) bedded; light-medium gray; fossiliferous, with numerous echinoderm plates and brachiopods.	0.75	28.20
21.	Covered.	0.45	27.45
20.	Silty Limestone, intraclast skeletal packstone; intraclasts are large, flat-pebbles, up to 10 cm. long; skeletal fragments, mostly echinoderms, also brachiopods.	0.15	27.00
19.	Calcareous siltstone; very thin-bedded, flaggy; very thinly laminated, top is wave-rippled; light yellow-tan; basal 15 cm. contains abundant, large, platey intraclasts (up to 5 cm. long) of underlying limestone and echinoderm plates; in part fossiliferous, with brachiopods, crinoids and fenestrate bryozoans, some coquinoid lags; occasional tracks and trails; most of this interval is only partially exposed, but interval is lumped as one unit.	1.85	26.85
18.	Limestone, skeletal wackestone; thick- to medium-bedded; light gray; fossiliferous, with echinoderms (crinoids, including the St. Genevieve guide fossil, *Platycrinites penicillus*), brachiopods, fenestrate bryozoans, ostracodes and gastropods; insoluble residue contains abundant conodonts, inarticulate brachiopods and fish teeth and scales; occasional black chert nodules; conodont sample B10 at base.	2.60	25.00
17.	Silty-argillaceous limestone, lime mudstone to skeletal wackestone; light gray; crinoids and brachiopods.	1.05	22.40

16.	Covered.	1.45	21.35
15.	Calcareous siltstone; thin- to very thin-bedded; light brownish-gray; brachiopods; burrowed; partially covered interval.	1.00	19.90
14.	Silty-argillaceous limestone; thin- to very thin-bedded; faintly laminated; top 30 cm. is shaley; occasional brachiopods and crinoids.	1.75	18.90
13.	Limestone, ooid grainstone; light gray; onkoidal; small intraclasts; skeletal grains include echinoderms and brachiopods.	0.25	17.15
12.	Limestone, onkoidal skeletal wackestone to packstone; with intraclasts, ooids and skeletal grains; light gray; echinoderms and brachiopods; onkoids up to 2.5 cm. in diameter; noticeable moldic and vuggy porosity; conodont sample B9.	0.45	16.90
11.	Covered.	0.25	16.45
10.	Limestone, undifferentiated skeletal wackestone and packstone (poor exposure); thick-bedded; light-medium gray; fossilferous, with abundant echinoderms, brachiopods and fenestrate bryozoans; several thin (?) oolitic zones; some vuggy to moldic porosity; slumping here obscures detail.	1.45	16.20
9.	Silty-argillaceous limestone; massive to unbedded; some fine laminations; occasional intraclasts at base; medium gray; poorly fossiliferous except for top 15 cm., with abundant crinoids, brachiopods and occasional solitary rugose corals; common ostracodes; occasional burrows.	1.85	14.75
8.	Calcareous mudstone-siltstone; weathers massively, with thin, wispy, discontinuous laminations,	2.10	12.90

	some thin shaley beds; poorly fossiliferous, with occasional brachiopods and ostracodes; few horizontal trails; basal 0.3 m. is peloidal siltstone, with abundant ostracodes and evaporite crystals (calcite pseudomorphs after gypsum, small lath- and needle-like, radiating crystals).		
7.	Silty limestone, peloidal packstone; thick-laminated (several mm. to 2 cm. thick), some laminae are graded (peloidal packstone-mudstone couplets), wave-rippled; abundant peloids; silt and very fine-grained sand; light-medium gray; rare skeletal grains, gastropods, foraminifera and ostracodes.	0.15	10.80
6.	Limestone, lime mudstone to skeletal wackestone; massive; light-medium gray; echinoderms and brachiopods; conodont sample B8.5.	1.05	10.65
5.	Calcareous mudstone; blocky; light tan to light brownish-gray; slightly fossiliferous, with scattered brachiopods and echinoderm plates; basal 8 cm. is yellow, calcareous siltstone with abundant skeletal debris, including echinoderms (crinoids and echinoids), brachiopods, endothyrid foraminifera, ostracodes and tubular bryozoans.	0.40	9.60
4.	Limestone, coral boundstone and lime mudstone/skeletal wackestone; thick-bedded; dark-medium gray; fossiliferous, with abundant corals, <u>Lithostrotionella</u> and <u>Syringopora</u>, also echinoderms, brachiopods, fenestrate bryozoans, endothyrid foraminifera and ostracodes; occasional black chert nodules, conodont sample B8.	0.90	9.20
3.	Covered.	2.20	8.30

2.	Limestone, interbedded skeletal wackestone and packstone, lesser lime mudstone; thick- to medium-bedded; light gray; fossiliferous, with abundant brachiopods, fenestrate bryozoans and echinoderms, lesser pelecypods, gastropods, ostracodes and endothyrid foraminifera; insoluble residue contains conodonts, orbiculoid brachiopods and fish fragments; conodont samples, B6 at 3.90 m. and B7 at 5.20 m.	4.10	6.10
1.	Limestone, brachiopod wackestone to packstone (mostly mud-supported with coquinoid lags); thin- to medium-bedded; light-medium gray; abundantly fossiliferous, with many silicified fossils; abundant brachiopods (common <u>Orthotetes</u>) bryozoans fenestrate, tubular and encrusting) and echinoderms, lesser ostracodes and pelecypods; insoluble residues contain conodonts and fish teeth and scales occasional black chert nodules; conodont sample B5 at base.	2.00	2.00

Little Valley Formation: Total Thickness = 20.35 m. (66.8 ft.)

18.	Argillaceous-silty limestone, lime mudstone; thin (8, 10 and 15 cm.) beds alternating with very thin (2 cm.) beds of silty mudstone; occasional echinoderm plates.	1.30	20.35
17.	Calcareous silty mudstone; very thin- (unevenly) bedded; brownish-dark gray; abundant echinoderm plates with fewer brachiopods; black chert nodules.	0.30	19.05
16.	Limestone, peloidal wackestone-packstone; slightly argillaceous; blocky; heavily burrowed to burrow-homogenized; medium gray; slightly	0.25	18.75

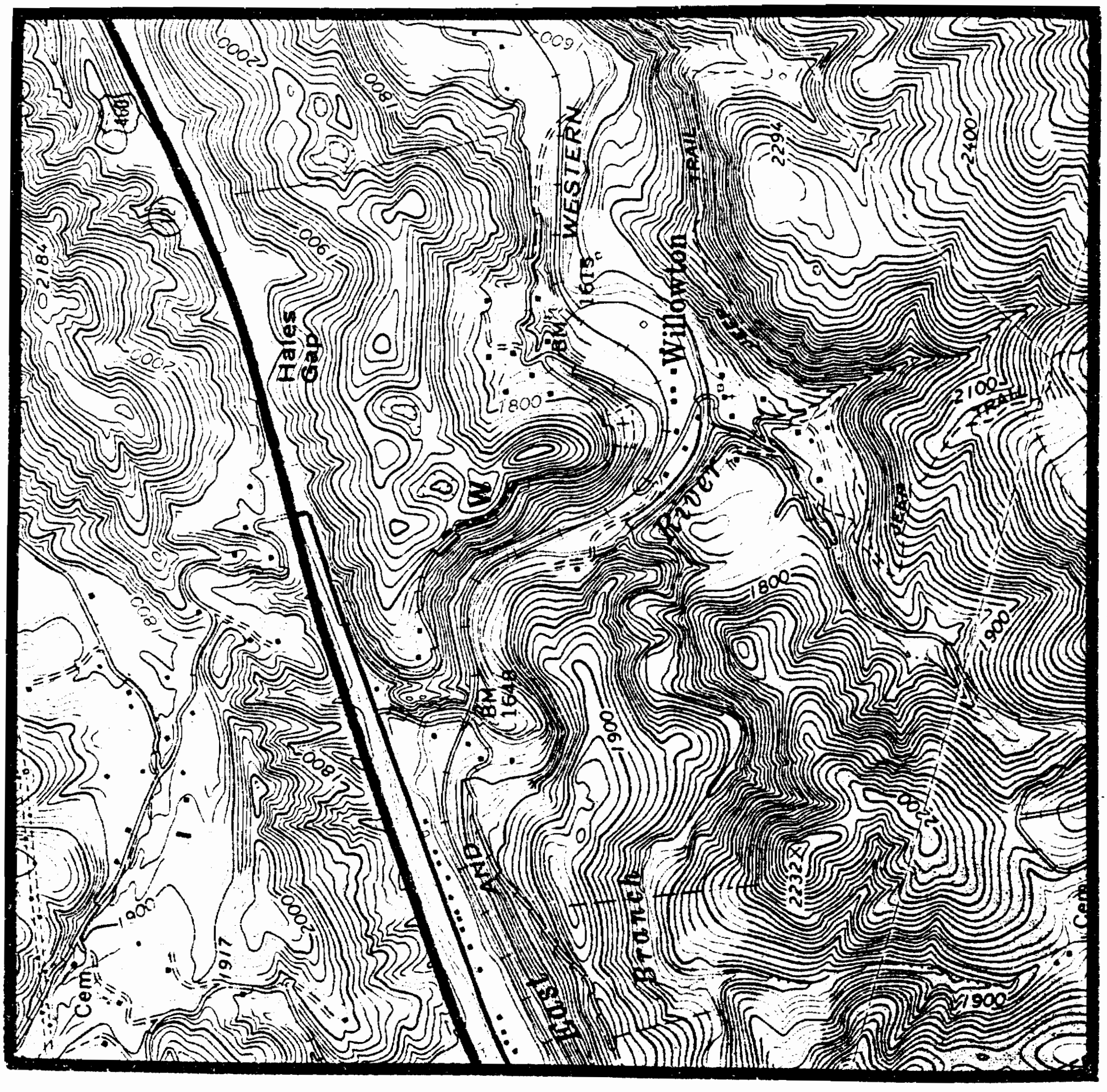
	fossiliferous, with common ostracodes, scattered echinoderm plates, fish(?) teeth in insoluble residue; conodont sample B4.		
15.	Calcareous shale, thinly laminated, fissile, laminations are wavy-undulose; medium gray; burrowed.	0.30	18.50
14.	Limestone, lime mudstone; slightly argillaceous, very thinly laminated (even to wavy), may be cryptalgal in part; black chert nodules; no fossils seen.	1.35	18.20
13.	Argillaceous limestone, argillaceous peloidal wackestone, basal 7.0 cm. are oolitic peloidal packstone, with intraclasts, medium-grained, heavily burrowed, small skeletal grains include echinoderms, brachiopods and ostracodes; rest of unit 13 is blocky, shaley in part; medium gray; fossiliferous, with ostracodes, echinoderms and pelecypods; insoluble residue contains conodonts and fish teeth; black chert nodules; conodont sample B3.	0.90	16.85
12.	Dolomite; massive and blocky; finely crystalline, evenly textured; light gray; top 15 cm. is shaley.	0.80	15.95
11.	Interbedded calcareous silty mudstone and argillaceous limestone; silty mudstone, very thin-bedded, thinly laminated, some small scour and fill structures; limestone, mostly argillaceous lime mudstone, lesser peloidal limestone, thick-laminated (1-2.5 cm.), graded beds and very low-angle, current-ripple cross-laminations, some scour and fill structures; light gray; conodont sample B2 at 12.55 m.	2.95	15.15
10.	Breccia; like unit 3.	0.15	12.20

9.	Covered; mostly covered, but contains large, displaced blocks of underlying breccia; some siltstone-shale clasts are up to 15 cm. in diameter.	5.95	12.05
8.	Breccia; like unit 3., but with larger clasts (up to 4 cm. in diameter).	0.30	6.10
7.	Covered.	0.30	5.80
6.	Interbedded silty limestone and calcareous shale; limestone, thin-bedded, tan-gray; shale, very thin-bedded, thinly-laminated, silty, yellow-tan; fossiliferous, with thin coquinoid lags, abundant brachiopods (*Camarotoechia*), and lesser ostracodes; some burrows and horizontal trails (Note: where these beds nearly intersect the road there is a fault and an associated, small drag fold. A small tree is at the trace of the fault. There is also a small wedge fault here.); insoluble residue contains conodonts and fish teeth and scales; conodont sample B1 at base.	2.00	5.50
5.	Calcareous siltstone-mudstone; thin- (unevenly) bedded; yellow-tan; basal 0.15 m. is brecciated with finely crystalline calcite veinlets and calcitic matrix, vuggy.	0.60	3.50
4.	Covered.	0.35	2.90
3.	Breccia; angular to subrounded clasts of yellow-tan siltstone in matrix of finely crystalline, limestone-dolomite; clasts vary in size from 0.5 to 1 cm. in diameter, some up to 2 cm.; much vuggy porosity.	0.30	2.55
2.	Calcareous siltstone; gradational from below; thin- (unevenly)	1.05	2.25

bedded; light tan-yellow; poorly exposed.

1. Calcareous shale; platey; very thinly laminated, in part lenticular-bedded, with thin (1-2 mm.) siltstone to very fine sandstone stringers; small cut and fill structures; light tan-gray; with a thin (10 cm.) argillaceous, dolomitic lime mudstone bed; Covered below here.	1.20	1.20

Figure 12 : Locality map of the Willowton section (Oakvale 7.5' Quad.). Hachured line shows locality of measured section (W).


460
Hales Gap
WESTERN
Willowton
TRAIL
2294
2400
2100
TRAIL
River
1800
BM 1648
1900
AND
Lost
Branch
2232
Cem
1917
2000
1900
2184

WILLOWTON

This section is exposed along the Willowton Road, just south of Route 460, near Willowton, West Virginia (Mercer Co., Oakvale 7.5' Quad). The rocks are exposed on the overturned, southeast limb of the Hurricane Ridge Syncline, adjacent to the St. Clair Fault. The rocks strike N 70-80° E, with dips of 40-50° south.

Lithology	Bed Thickness (meters)	Total Thickness (meters)
Greenbrier Limestone: total thickness = 355 m. (1166 ft.)		
"Denmar-Gasper" Formation (undifferentiated): partial section, only the lower 87.45 m. (287 ft.) were described. Total thickness = 328 m. (1076 ft.), measured using a steel tape to the base of the Bluefield Formation.		
49. Calcareous shaley siltstone; very thin-bedded; light gray; fossiliferous, with scattered crinoid columnals and brachiopods, sometimes in skeletal lags; with a few, thin (2-5 cm., up to 20 cm. thick) argillaceous limestone (wackestone-packstone) interbeds; limestone, medium-dark gray, with echinoderms and brachiopods. Note: This section ends at a high-angle reverse fault, with at least 3 m. of displacement(See light gray, very thin-bedded, cryptalgalaminated limestone above the fault).	4.90	87.45
48. Limestone, skeletal (echinoderm) packstone; thick-bedded; coarse-grained; slightly argillaceous, top 8 cm. is argillaceous limestone; medium gray, weathers olive-brown to light gray; fossiliferous, with abundant echinoderms, common brachiopods; insoluble residue contains echinoid spines, conodonts and fish teeth and scales; conodont sample W28 at 81.05 m.	1.35	82.55

47.	Dolomitic silty mudstone; massive-bedded, spheroidally weathered; light-medium gray, weathers tan; fossiliferous above 80.45 m., fossils increase in abundance upward, echinoderms and brachiopods.	0.75	81.20
46.	Covered.	1.25	80.45
45.	Calcareous mudstone; shaley, very thin-, platey-bedded; medium gray; infrequent brachiopods.	0.30	79.20
44.	Calcareous mudstone; very thin-bedded; thinly laminated; may be slightly dolomitic; tan, weathers yellow-tan.	2.90	78.90
43.	Argillaceous limestone, skeletal packstone; massive-bedded; light gray, weathers light olive-tan; fossiliferous, some skeletal grains are coated (partial ooids), with echinoderms, brachiopods and fenestrate bryozoans; conodont sample W27 at base.	0.45	76.00

Note: Units 39-42 may be the Taggard Red Member (sense of Wilpolt and Marden, 1959), used by Wells (1950) to separate the Denmar and Gasper Formations.

42.	Calcareous silty mudstone; blocky, poorly bedded; with thin, wispy, discontinuous laminations; light gray, weathers light olive-tan; large calcite-filled vugs, up to 8 cm. in diameter.	0.30	75.55
41.	Calcareous red mudstone; spheroidally weathered.	0.15	75.25
40.	Calcareous silty mudstone; thin-, lenticular-bedded, current ripple-laminated siltstone to very fine-grained sandstone stringers within laminated calcareous mudstone; light olive-tan; common calcite-filled vugs, up to 2.5 cm. in diameter;	1.20	75.10

	abundant high-angle joints; possible faults(?).		
39.	Calcareous silty mudstone, interbedded calcareous siltstone - calcisiltite (limestone) with calcareous mudstone; thin-, wavy-bedded; wave and current ripple-laminated up to 1 cm. thick ripples) calcareous siltstone and calcisiltite (limestone with skeletal fragments and/or peloids?), with very fine-grained quartz grains, medium-light gray; mudstone, light olive-tan; siltstone drops out gradually upward as rock becomes muddier; gradational into unit 40.	0.65	73.90
38.	Limestone, skeletal packstone; low-angle tabular cross-beds; medium-grained; medium gray; occasional intraclasts (up to 0.5 cm. wide); some coated skeletal grains; abraded skeletal grains include echinoderms and brachiopods.	0.60	73.25
37.	Limestone, oolitic skeletal grainstone; thick-bedded; ripple-laminated; medium-grained; medium gray; occasional small intraclasts; coated skeletal grains, abundant echinoderms; conodont sample W26.	0.75	72.65
36.	Limestone, ooid grainstone; thick-bedded, tabular cross-bedded; medium- to coarse-grained; light gray; echinoderm fragments; insoluble residue contains conodonts, fish teeth and scales, and abundant garnet crystals; conodont sample W25 at 70.25 m.	1.50	71.90
35.	Limestone, skeletal wackestone, like unit 33.	1.10	70.40
34.	Covered.	1.05	69.30
33.	Limestone, skeletal wackestone; thick-bedded; medium gray, weathers light gray; fossiliferous, with	0.90	68.25

	abundant echinoderms, common brachiopods, fenestrate bryozoans and solitary rugose corals; insoluble residue contains ostracodes, sponge spicules, gastropods, endothyrid foraminifera, pelecypods, inarticulate brachiopods, conodonts and fish teeth and scales; black chert nodules; conodont sample W24 at 67.20 m.		
32.	Covered.	3.05	67.35
31.	Limestone, lime mudstone to skeletal wackestone; medium-bedded; light gray, weathers white; fossiliferous, with many fine-grained skeletal fragments, most are echinoderms; insoluble residue contains conodonts, fish teeth and scales, and glauconite; conodont sample W23.5.	0.70	64.30
30.	Limestone, 0.15 m. thick bed overlain by calcareous silty mudstone, skeletal (echinoderm) packstone; coarse-grained; medium gray, weathers light gray; scoured basal contact, fossiliferous, with abundant echinoderms (crinoids and blastoids), lesser brachiopods and fenestrate bryozoans; gradational into mudstone like unit 29; conodont sample W23 at base.	1.05	63.60
29.	Calcareous silty mudstone; thin-, unevenly bedded; brown-tan; poor exposure.	1.15	62.55
28.	Covered.	4.00	61.40
27.	Limestone, skeletal wackestone to lime mudstone; medium-bedded; dark gray, weathers light gray; fossiliferous, with crinoids and brachiopods; insoluble residue contains echinoid spines, conodonts and fish teeth and scales; conodont sample W22 at 56.50 m.	0.60	57.40

26.	Covered.	3.95	56.80
25.	Limestone, skeletal packstone; thick-bedded; coarse-grained; medium gray; fossiliferous, with abundant echinoderms (crinoids), brachiopods and fenestrate bryozoans.	0.60	52.85
24.	Covered.	0.70	52.25
23.	Limestone, oolitic skeletal packstone-grainstone; thick- to massive-bedded, tabular cross-bedded; coarse-grained; light-medium gray; fossiliferous, with abundant echinoderms (crinoids and blastoids); conodont sample W21 at 49.50 m.	3.40	51.55
22.	Argillaceous limestone to calcareous mudstone; very thin- to thin-bedded, shaley; finely laminated; light brownish gray; crinoid columnals; top 8 cm. is very thin, shaley laminated, broadly undulose laminations (3 cm. amplitude), may be low stromatolitic domes(?).	0.65	48.15
21.	Limestone, oolitic skeletal grainstone, lesser packstone; medium- to thick-bedded, tabular cross-bedded; coarse-grained; light-medium gray; ooids and coated skeletal grains; echinoderms most abundant of skeletal grains (crinoids, blastoids and echinoids), with brachiopods, fenestrate bryozoans and gastropods; conodont sample W20 at 46.80 m.	0.90	47.50
20.	Calcareous mudstone; very thin-bedded, shaley; light brown; brachiopods.	0.15	46.60
19.	Argillaceous limestone, skeletal packstone; thick-bedded; light, brownish gray; fossiliferous, with echinoderms and brachiopods.	0.45	46.45
18.	Argillaceous limestone, skeletal wackestone-packstone; thin-bedded;	1.40	46.00

	brownish gray; fossiliferous, with echinoderms, brachiopods and fenestrate bryozoans.		
17.	Limestone, skeletal packstone; thick-bedded, with thin shale (up to 5 cm. thick) interbeds; fine-grained; medium-gray; fossiliferous, with echinoderms, brachiopods and bryozoans; insoluble residue contains inarticulate brachiopods, conodonts and fish teeth and scales; conodont sample W19.	0.30	44.60
16.	Covered.	0.80	44.30
15.	Argillaceous limestone (skeletal wackestone and lime mudstone) to calcareous mudstone; blocky, poorly bedded; light brownish-gray, weathers light brown; fossiliferous, with crinoids, brachiopods, solitary rugose corals and colonial tabulate corals (*Syringopora*).	0.85	43.50
14.	Limestone, skeletal (echinoderm) packstone; thick-bedded, with thin (up to 10 cm. thick) shale interbeds; medium-grained; medium gray; occasional intraclasts (up to 3 cm. long); fossiliferous, with abundant echinoderms (crinoids and blastoids), common brachiopods, fenestrate bryozoans and solitary rugose corals; conodont sample W18 at 41.95 m.	3.50	42.65
13.	Argillaceous limestone (lime mudstone) to calcareous mudstone; medium-bedded; thinly laminated; light brownish-gray; scattered fossils, not abundant, including crinoids, brachiopods and fenestrate bryozoans.	1.00	39.15
12.	Argillaceous limestone, skeletal wackestone; medium-bedded; light brownish gray; fossiliferous, with echinoderms, brachiopods, fenestrate bryozoans and solitary rugose cor-	0.55	38.15

	als, few trilobites; thin (5 cm. thick) skeletal (packstone) lag at base, with abundant crinoid columnals; abundant calcite-filled vugs (0.5 to 1.0 cm. diameter); gradational into unit 13; conodont sample W17.		
11.	Calcareous shale; very thin-bedded; very thinly laminated, laminations are broadly undulose (1-2 mm. amplitude); top 8 cm., laminations are wavy-undulose (2.5 cm. amplitude) in form of low domes, may be algal stromatolitic domes; light olive-tan; no body fossils; possible trace fossils (tracks).	3.75	37.60
10.	Argillaceous limestone, skeletal (echinoderm) packstone, like unit 8, below; conodont sample W16 at 33.20 m.	2.90	33.85
9.	Covered.	0.30	30.95
8.	Argillaceous limestone, skeletal (echinoderm) packstone; thick-bedded, maybe cross-bedded; coarse- to very coarse-grained; medium gray, weathers brownish gray; fossiliferous, with abundant echinoderms (crinoids, including *P. penicillus*, and blastoids), common brachiopods, fenestrate bryozoans and solitary rugose corals; occasional black chert nodules; conodont samples, W14 at 27.45 m. and W15 at 29.60 m.	3.50	30.65
7.	Covered.	0.45	27.15
6.	Calcareous mudstone, lesser siltstone; very thin-bedded; very finely laminated (wavy to planar); light, brownish gray; partly fossiliferous, with skeletal lag at base, brachiopods and crinoid columnals.	1.55	26.70
5.	Covered.	0.30	25.15
4.	Limestone, skeletal (echinoderm)	1.05	24.85

	packstone; massive- to thick-bedded; coarse- to very coarse-grained; medium gray; fossiliferous, with abundant crinoid columnals, (including <u>Platycrinites penicillus</u>), common blastoids, brachiopods and fenestrate bryozoans; conodont sample W13 at base.		
3.	Calcareous shaley siltstone, like unit 1, below.	3.80	23.80
2.	Calcareous mudstone; very thin-bedded to blocky; light olive-green; fossiliferous, with abundant tubular bryozoans, common echinoderms, brachiopods and fenestrate bryozoans; bed is a ledge-former; conodont sample (unprocessed) W12.	0.15	20.00
1.	Calcareous shaley siltstone, with lesser mudstone; very thin-bedded, occasionally thin-bedded; occasional thin, wispy to wavy laminations; medium to light gray, weathers light brownish-gray; sparsely fossiliferous, with fenestrate bryozoans (most common), brachiopods (usually productids) and crinoids, may be quite fossiliferous in spots; common trace fossils, crescent- to S-shaped trails on bedding planes, burrows; exposure here is poor, may conceal several high-angle reverse faults; abundant high-angle to nearly vertical joints; conodont samples (unprocessed) W10 at 1.25 m. and W11 at 11.0 m.	19.85	19.85

Hillsdale Limestone: Total thickness = 26.80 m. (88 ft.)

14.	Limestone, skeletal wackestone; medium-bedded; dark gray; fossiliferous, with abundant echinoderms (crinoids and blastoids), common fenestrate bryozoans, brachiopods and solitary rugose corals; insol-	1.05	26.80

	uble residue contains echinoid spines, holothurian sclerites, gastropods, ostracodes, encrusting foraminifera, conodonts and fish teeth and scales; burrowed; conodont sample W9 at 26.50 m.		
13.	Limestone, skeletal packstone; thick-bedded, with low-angle tabular cross-bedding; dark gray; intraclasts and coated (skeletal and intraclast) grains; fossiliferous, with abundant echinoderms (crinoids and blastoids), lesser brachiopods, bryozoans and solitary rugose corals; abundant calcite veins perpendicular to bedding.	0.75	25.75
12.	Limestone, skeletal (bryozoan) wackestone; thick-bedded; medium-dark gray, weathers light gray; fossiliferous, with abundant fenestrate bryozoans, common echinoderms (crinoids and blastoids), brachiopods and solitary rugose corals.	0.70	25.00
11.	Limestone, oolitic grainstone-packstone; slightly undulose base; medium-dark gray; ooids and coated (skeletal and intraclast) grains; fossiliferous, with echinoderms, brachiopods and solitary rugose corals.	0.35	24.30
10.	Limestone, skeletal wackestone; basal contact is slightly undulose; thin (2-5 cm. thick) skeletal lag at base; thick-bedded; slightly argillaceous; dark gray, weathers light gray; fossiliferous, with echinoderms and brachiopods.	0.50	23.95
9.	Limestone, oolitic packstone-grainstone; massive-bedded, may be tabular cross-bedded; dark gray, weathers medium gray; ooids and coated (skeletal and intraclast) grains; medium- to coarse-grained; abundant, rounded, coarse- to very	1.95	23.45

coarse-grained intraclasts; skeletal grains include crinoids, brachiopods, bryozoans, gastropods and ostracodes; conodont sample W8 at at 23.00 m.		
8. Limestone, skeletal (echinoderm) packstone; massive-bedded, tabular cross-bedded; dark gray, weathers medium gray; few oolitic (coated) grains and small intraclasts; fossiliferous, with abundant echinoderms (crinoids and blastoids), lesser brachiopods, bryozoans and trilobites; bed cut by high-angle reverse fault; conodont sample W7 at 20.45 m.	1.05	21.50
7. Limestone, skeletal (bryozoan) wackestone, like unit 5; fossiliferous, with abundant fenestrate bryozoans, fewer echinoderms, brachiopods and solitary rugose corals; black chert nodules.	0.85	20.45
6. Limestone, skeletal (echinoderm) packstone; dark gray, weathers light gray; fossiliferous, with abundant echinoderms (crinoids), fewer brachiopods and solitary rugose corals.	0.15	19.60

Note: Units 1-5 contain abundant structural features, including: 1) reverse, bedding-plane and wedge faults; 2) high-angle and nearly vertical joints; 3) bedding-plane and nearly vertical stylolites, and 4) abundant calcite veins. These features indicate complex structural modifications related tothe overthrusting of the St. Clair Fault and consequent overturning of the southeast limb of the Hurricane Ridge Syncline.

5. Limestone, skeletal wackestone (bryozoan-echinoderm wackestone and bryozoan wackestone) and lime mudstone, interbedded; massive- to thick-bedded; dark gray, weathers light gray; abundantly fossiliferous, skeletal lag at base, with abundant echinoderms (crinoids and blastoids) and fenestrate bryozoans, common brachiopods (<u>Anthracospir-</u>	11.85	19.45

	ifer, *Dictyoclostus*, *Composita*, *Cliothyridina*, *Orthotetes*, *Chonetes*), fewer gastropods, solitary rugose corals, ostracodes and pelecypods(?), insoluble residue contains conodonts and fish teeth and scales; occasional burrows; common black chert nodules; conodont samples: W3, 7.60 m.; W4, 10.50 m.; W4.5, 11.15 m.; W5, 14.15 m.; W6, 18.15 m.		
4.	Very argillaceous limestone, lime mudstone; thinly laminated; light-medium gray; fossiliferous, with scattered skeletal debris; gradational into unit 5.	0.30	7.60
3.	Calcareous shaley siltstone; very thin-, unevenly (crumbly) bedded; medium gray, weathers light tan.	1.20	7.30
2.	Calcareous mudstone to very argillaceous limestone (lime mudstone), undifferentiated; thin-beded; thinly laminated; tan to light-medium gray; moderately to sparsely fossiliferous, with echinoderms, brachiopods and fenestrate bryozoans; common calcite-filled vugs (1-5 cm. diameter); silty in upper 0.6 m; gradational into unit 3; conodont sample W2 at 5.05 m.	6.10	6.10
1.	Limestone, interbedded skeletal wackestone and packstone; medium-bedded; fossiliferous, with abundant echinooderms (crinoids and blastoids), common brachiopods; Note: this is a wedge of steeply (60-90°, S23°E) beds along the fault contact between the Maccrady Fm. and the Greenbrier Lst.; the wedge is approximately 0.6 to 0.9 m. thick; beds are discordant with beds immediately above and below; highly fractured, with abundant calcite veins; conodont sample W1.	-.--	-.--

Note: The contact between the Maccrady Formation and the overlying Greenbrier Limestone is a high-angle normal fault. The Little Valley Formation and the lowest beds of the Hillsdale Limestone are believed to be faulted out of this exposure, as suggested by conodont evidence. The missing beds may be exposed roughly 150 m. west of this roadside exposure, along the Norfolk and Western railroad tracks at the base of the hill.

Maccrady Formation: not measured, although measured here by Blancher (1974) as 46 m. (151 ft.) thick.

1. Calcareous siltstone and shale; very thin- to thin-bedded; red, tan and white; rare brachiopods.	-.--	-.--

APPENDIX B

Conodont Abundance Data

TABLE 1: ABUNDANCE DATA FOR THE LINDELL SECTION (LH1-L11)

	LITTLE VALLEY FM.						HILLSDALE LIMESTONE											("X" : PRESENT, BUT NOT COUNTED)	
TOTAL	LH1	LH2	LH3	LH4	LH5	LH6	L1	1.5	L2	L3	L4	L5	L7	L8	L9	L10	L11	:SAMPLE NUMBERS	
																			Superfamily HIBBARDELLACEA
																			Family HIBBARDELLIDAE
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		Idioprioniodus sp. aff. I. healdi
8	-	-	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	Sa	Kladognathus levis
45	-	1	-	3	-	-	15	3	4	1	-	-	2	-	1	1	3	Sb	
68	-	1	1	3	13	-	27	4	2	-	-	1	-	3	-	1	-	M	
6	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	1	Sa	
24	-	-	-	-	2	-	13	3	2	-	-	-	-	-	-	-	-	Sb	Kladognathus tenuis
21	-	-	-	-	-	-	5	2	-	-	-	-	-	1	-	-	1	Sc	
9	-	-	-	2	-	-	3	-	-	-	-	-	-	-	-	-	-	Sd	
9	-	-	-	-	-	-	4	-	-	-	-	-	1	1	-	-	-	X	
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
3	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb	Kladognathus sp. A
14	-	-	-	6	-	-	5	-	-	-	-	-	-	-	-	-	-	Sc	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sd	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
																			Superfamily POLYGNATHACEA
																			Family ANCHIGNATHODONTIDAE
16	-	-	-	-	-	-	12	-	-	-	-	1	1	2	-	-	-	Pa	
4	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	Pb	
4	-	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	M	Hindeodus cristula
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	Sb	
4	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	Sc	
64	-	2	-	1	-	-	17	-	-	-	-	-	-	-	-	1	4	Pa	
20	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	Pb	
22	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	1	Sa	
8	-	-	-	-	-	-	13	1	-	-	-	-	-	1	-	-	4	Sb1	Hindeognathus laevipostica
71	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	3	Sb2	
21	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	Sb3	
17	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	Sb4	
X	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	X		Hindeognathus spp.
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Synprioniodina? spicula
																			Family CAVUSGNATHIDAE
155	4	1	1	4	17	-	59	16	1	3	-	2	-	1	-	4	1	α Pa	
30	3	2	1	1	4	-	12	2	-	-	-	-	-	-	-	-	-	β Pa	Cavusgnathus unicornis
15	-	2	-	3	-	-	4	3	-	-	-	-	-	-	-	-	-	γ Pa	
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus X C. unicornis
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Taphrognathus varians
X	X	X	X	X	X	-	X	-	-	-	X	-	X	X	X	-	-	Pa	
41	1	-	1	-	6	-	19	-	-	-	-	-	-	-	-	-	-	Pb	
30	-	-	-	1	7	-	16	-	-	-	-	-	-	-	-	-	1	M	Cavusgnathus spp.
1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	Sa	
4	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	Sb	
32	-	-	-	6	3	-	15	1	-	1	-	-	-	1	-	-	-	Sc	
																			Family IDIOGNATHODONTIDAE
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus bilineatus
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus girtyi girtyi
28	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	7	Pa	Gnathodus homopunctatus
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus texanus
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb	Gnathodus spp.
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc1	
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc2	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc3	
																			Family UNKNOWN
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	Lochriea commutatus
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc	
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Rhachistognathus cf. R. muricatus
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	Pa	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	"Spathognathodus" campbelli
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb1	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb2	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc	
																			Superfamily UNKNOWN
																			Family UNKNOWN
6	-	-	-	-	-	-	5	1	-	-	-	-	-	-	-	-	-	DE	Lonchodina sp. A
10	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	DE	Lonchodina sp. B
931	8	9	4	25	60	0	310	36	10	5	X	4	5	14	1	12	28	Conodont elements per sample	
262.4	4.7	7.1	4.5	9.4	9.0	4.7	16.1	5.0	4.8	4.8	4.8	4.8	4.7	9.6	5.0	7.8	9.0	Sample weight in kilograms	
3.5	1.7	1.3	0.9	2.7	6.7	0	19.3	7.2	2.1	1.0	0	0.8	1.1	1.5	0.2	1.5	3.1	Conodont elements per kilogram	

TABLE 2: ABUNDANCE DATA FOR THE LINDELL SECTION (L12-L32)

HILLSDALE LIMESTONE													"STE. GENEVIEVE" FM.							("X" : PRESENT, BUT NOT COUNTED)	
L12	122	123	L13	L14	L15	L16	L17	L18	L19	L20	L21	L22	L25	L26	L27	L29	L30	L31	L32	:SAMPLE NUMBERS	
																					Superfamily HIBBARDELLACEA
																					Family HIBBARDELLIDAE
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	3		Idioprioniodus sp. aff. I. healdi
-	-	1	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	Sa	Kladognathus levis
-	-	2	6	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	Sb	
-	-	3	1	-	-	-	-	-	-	1	2	-	1	-	1	-	1	-	2	M	Kladognathus tenuis
-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	1	-	-	-	Sa	
-	-	-	-	-	-	1	-	-	-	1	2	-	-	-	-	-	-	-	-	Sb	
-	-	3	2	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	5	Sc	
-	-	-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	-	-	Sd	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	X	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-	-	M	Kladognathus sp. A
-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb	
-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	Sc	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sd	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	
																					Superfamily POLYGNATHACEA
																					Family ANCHIGNATHODONTIDAE
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Hindeodus cristula
-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	Pb	
-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb	
-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	Sc	
3	-	11	6	5	-	-	-	13	1	-	-	-	-	-	-	-	-	-	-	Pa	Hindeognathus laevipostica
-	-	3	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	8	2	3	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	11	4	4	-	-	-	9	1	-	-	-	-	-	-	-	-	-	-	Sb1	
1	-	20	9	9	-	-	-	8	4	-	-	-	-	-	-	-	-	-	-	Sb2	
1	-	11	-	5	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	Sb3	
-	-	4	2	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb4	
-	-	X	X	X	-	X	-	X	X	-	-	-	-	-	-	-	-	-	-		Hindeognathus spp.
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Synprioniodina? spicula
																					Family CAVUSGNATHIDAE
1	-	2	2	2	-	-	-	-	1	4	18	5	-	3	-	2	-	1	-	αPa	Cavusgnathus unicornis
-	-	-	1	1	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	βPa	
-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	γPa	
-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	Pa	Cavusgnathus altus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus X C. unicornis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Taphrognathus varians
-	-	-	X	-	-	-	-	X	X	-	X	-	-	X	-	X	X	-	X	Pa	Cavusgnathus spp.
-	-	4	-	-	-	-	-	-	-	-	8	-	-	2	-	-	-	-	-	Pb	
-	-	1	-	-	-	-	-	-	-	1	1	-	-	-	-	2	-	-	-	M	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	Sb	
-	-	-	2	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	Sc	
																					Family IDIOGNATHODONTIDAE
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	3	2	2	Pa	Gnathodus bilineatus
-	-	-	28	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus girtyi girtyi
-	-	-	-	-	-	-	-	8	10	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus homopunctatus
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	Pa	Gnathodus texanus
-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	Gnathodus spp.
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	M	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc1	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	Sc2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc3	
																					Family UNKNOWN
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	Pa	Lochriea commutatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	Pa	Rhachistognathus cf. R. muricatus
-	-	-	1	-	-	-	-	-	-	-	1	-	-	2	-	-	-	2	-	Pa	"Spathognathodus" campbelli
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	Sb1	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc	
																					Superfamily UNKNOWN
																					Family UNKNOWN
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	OE	Lonchodina sp. A
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	OE	Lonchodina sp. B
6	0	85	71	29	2	5	0	48	20	10	41	5	4	18	2	14	10	8	22	Conodont elements per sample	
4.5	4.5	9.1	9.9	8.7	4.8	8.9	4.1	10.2	8.7	9.2	9.5	8.9	8.4	8.9	4.5	4.7	4.9	5.0	9.2	Sample weight in kilograms	
1.3	0	9.3	7.2	3.3	0.4	0.6	0	4.7	2.3	1.1	4.3	0.6	0.5	2.0	0.4	3.0	2.0	1.6	2.4	Conodont elements per kilogram	

TABLE 3: ABUNDANCE DATA FOR THE BISHOP SECTION

	LITTLE VALLEY FM.				HILLSDALE LIMESTONE									"DENMAR-CASPER" FM.						("X" : PRESENT, BUT NOT COUNTED)	
TOTAL	B1	B2	B3	B4	B5	B6	B7	B8	B85	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	:SAMPLE NUMBERS	
																					Superfamily HIBBARDELLACEA
																					Family HIBBARDELLIDAE
4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	2		Idioprioniodus sp. aff. I. healdi
16	-	-	-	-	-	1	1	-	4	-	1	1	1	-	1	-	4	-	2	Sa	Kladognathus levis
103	-	-	-	-	2	13	3	-	5	1	19	6	18	9	13	-	10	1	3	Sb	
95	-	-	-	-	4	4	3	-	10	1	21	11	19	5	5	-	11	-	1	M	
17	-	-	-	-	-	-	-	-	-	-	-	3	3	2	7	-	1	-	1	Sa	
21	-	-	-	-	1	2	1	-	-	-	5	2	3	-	4	1	1	1	-	Sb	Kladognathus tenuis
44	-	-	-	-	-	3	1	-	-	1	9	13	3	-	2	-	5	4	3	Sc	
15	-	-	-	-	-	1	-	-	2	-	-	4	6	-	1	-	1	-	-	Sd	
14	-	-	-	-	-	-	-	-	-	1	1	-	2	-	3	-	6	-	1	X	
77	-	-	-	-	-	-	-	-	1	-	39	6	23	-	-	-	7	1	-	M	
10	-	-	-	-	-	-	-	-	-	-	5	-	4	-	-	-	-	-	1	Sa	
8	-	-	-	-	-	-	-	-	-	-	5	-	3	-	-	-	-	-	-	Sb	Kladognathus sp. A
76	-	-	-	-	-	-	-	-	3	-	32	3	30	-	-	-	6	-	2	Sc	
11	-	-	-	-	-	-	-	-	-	-	3	1	5	-	-	-	2	-	-	Sd	
38	-	-	-	-	-	-	-	-	-	-	15	1	19	-	-	-	2	-	1	X	
																					Superfamily POLYGNATHACEA
																					Family ANCHIGNATHODONTIDAE
61	-	-	-	-	-	-	-	1	-	-	12	14	5	2	13	-	6	5	3	Pa	
17	-	-	-	-	-	-	-	-	-	-	6	-	5	-	3	-	2	-	1	Pb	
19	-	-	-	-	-	-	-	-	-	-	7	5	2	-	4	-	-	-	1	M	Hindeodus cristula
6	-	-	-	-	-	-	-	-	-	-	1	2	-	-	3	-	-	-	-	Sa	
12	-	-	-	-	-	-	-	-	-	-	4	-	6	-	1	1	-	-	-	Sb	
30	-	-	-	-	-	-	-	1	-	-	11	10	3	-	3	-	1	-	1	Sc	
59	-	-	-	-	5	38	15	-	1	-	-	-	-	-	-	-	-	-	-	Pa	
7	-	-	-	-	-	5	2	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
12	-	-	-	-	1	11	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
61	-	-	-	-	3	53	4	-	1	-	-	-	-	-	-	-	-	-	-	Sb1	Hindeognathus laevipostica
45	-	-	-	-	3	34	7	-	1	-	-	-	-	-	-	-	-	-	-	Sb2	
19	-	-	-	-	2	10	6	-	1	-	-	-	-	-	-	-	-	-	-	Sb3	
9	-	-	-	-	1	7	1	-	-	-	-	-	-	-	-	-	-	-	-	Sb4	
X	-	-	-	-	X	X	X	-	X	-	-	-	-	-	-	-	-	-	-		Hindeognathus spp.
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Synprioniodina? spicula
																					Family CAVUSGNATHIDAE
122	1	-	1	-	16	8	7	4	9	-	22	8	17	9	10	3	5	2	-	α Pa	
46	-	-	-	-	2	3	1	1	1	-	15	3	6	5	5	1	2	-	1	Δ Pa	Cavusgnathus unicornis
25	1	-	1	-	2	1	3	-	-	-	8	1	3	2	1	-	2	-	-	γ Pa	
16	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus
7	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus X C. unicornis
102	74	-	23	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Taphrognathus varians
X	-	-	X	-	X	X	X	X	X	-	X	-	X	X	X	X	X	X	X	Pa	
61	13	-	4	-	3	7	6	-	3	-	10	1	4	1	3	-	4	2	-	Pb	
40	8	-	3	-	2	2	3	-	2	-	12	1	2	1	1	-	1	-	2	M	Cavusgnathus spp.
5	-	-	-	-	-	-	-	-	-	-	4	-	1	-	-	-	-	-	-	Sa	
8	2	-	1	-	-	-	-	-	1	-	3	-	1	-	-	-	-	-	-	Sb	
66	8	-	4	1	11	6	7	1	-	-	17	3	3	-	3	-	1	1	-	Sc	
																					Family IDIOGNATHODONTIDAE
121	-	-	-	-	-	-	-	-	-	1	98	-	-	-	-	-	7	-	15	Pa	Gnathodus bilineatus
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus girtyi girtyi
63	-	-	-	-	-	-	-	-	-	-	2	26	13	-	-	-	20	-	2	Pa	Gnathodus homopunctatus
3	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	Pb	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus texanus
9	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	1	-	2	Pb	
1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	M	
2	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	Sa	
6	-	-	-	-	-	-	-	-	-	-	1	4	1	-	-	-	-	-	-	Sb	Gnathodus spp.
11	-	-	-	-	-	-	-	-	-	-	-	7	1	-	-	-	3	-	-	Sc1	
1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	Sc2	
12	-	-	-	-	-	-	-	-	-	1	5	5	1	-	-	-	-	-	-	Sc3	
																					Family UNKNOWN
108	-	-	-	-	-	-	-	-	-	6	82	-	-	-	-	-	-	-	20	Pa	
19	-	-	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	Pb	
50	-	-	-	-	-	-	-	-	-	2	47	-	-	-	-	-	-	-	1	M	Lochriea commutatus
9	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	Sa	
27	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-	-	-	-	-	Sc	
2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Rhachistognathus cf. R. muricatus
108	-	-	-	-	-	-	-	-	-	2	67	17	-	1	-	-	8	-	13	Pa	
3	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	Pb	
3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	M	
2	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	Sa	"Spathognathodus" campbelli
7	-	-	-	-	-	-	-	-	-	-	2	5	-	-	-	-	-	-	-	Sb1	
6	-	-	-	-	-	-	-	-	-	-	4	2	-	-	-	-	-	-	-	Sb2	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc	
																					Superfamily UNKNOWN
																					Family UNKNOWN
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	OE	Lonchodina sp. A
.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	OE	Lonchodina sp. B
1977	107	0	37	1	63	211	71	8	45	16	687	173	213	37	86	6	119	18	79	Conodont elements per sample	
167.3	9.8	4.8	6.9	8.7	12.3	10.4	9.8	9.8	7.3	10.3	9.3	9.5	9.3	10.0	10.4	4.9	10.3	5.3	8.2	Sample weight in kilograms	
11.8	11	0	5.4	0.1	5.1	20	7.2	0.8	6.2	1.6	74	18	23	3.7	8.3	1.2	12	3.4	9.6	Conodont elements per kilogram	

TABLE 4: ABUNDANCE DATA FOR THE WILLOWTON SECTION (W1-W9)

	HILLSDALE LIMESTONE										("X" : PRESENT, BUT NOT COUNTED)	
TOTAL	W1	W2	W3	W4	W45	W5	W6	W7	W8	W9	:SAMPLE NUMBERS	
												Superfamily HIBBARDELLACEA
												Family HIBBARDELLIDAE
1	-	-	-	1	-	-	-	-	-	-		Idioprioniodus sp. aff. I. healdi
15	-	-	-	-	1	1	1	1	-	2	Sa	Kladognathus levis
115	-	-	4	4	4	6	11	3	8	19	Sb	
104	-	-	2	6	2	7	3	3	8	11	M	
38	-	-	1	1	-	2	1	1	2	5	Sa	
33	-	-	-	2	-	4	1	1	4	6	Sb	Kladognathus tenuis
106	-	-	3	3	4	5	6	4	6	10	Sc	
5	-	-	1	-	2	-	1	-	-	-	Sd	
23	-	-	-	2	1	-	1	4	3	2	X	
48	-	-	4	10	1	4	3	-	-	2	M	
6	-	-	1	1	-	-	-	-	-	1	Sa	
3	-	-	-	-	-	1	1	-	-	1	Sb	Kladognathus sp. A
21	-	-	6	3	2	-	-	-	-	-	Sc	
9	-	-	1	3	1	2	-	-	-	-	Sd	
15	-	-	-	1	2	1	1	-	-	1	X	
												Superfamily POLYGNATHACEA
												Family ANCHIGNATHODONTIDAE
48	1	-	5	1	2	-	1	4	2	18	Pa	
5	-	-	-	1	-	-	-	-	-	3	Pb	
15	-	-	5	-	-	-	1	-	-	1	M	Hindeodus cristula
2	-	-	2	-	-	-	-	-	-	-	Sa	
7	-	-	1	1	-	1	-	-	-	3	Sb	
16	-	-	5	-	-	1	-	-	-	3	Sc	
0	-	-	-	-	-	-	-	-	-	-	Pa	
0	-	-	-	-	-	-	-	-	-	-	Pb	
0	-	-	-	-	-	-	-	-	-	-	Sa	
0	-	-	-	-	-	-	-	-	-	-	Sb1	Hindeognathus laevipostica
0	-	-	-	-	-	-	-	-	-	-	Sb2	
0	-	-	-	-	-	-	-	-	-	-	Sb3	
0	-	-	-	-	-	-	-	-	-	-	Sb4	
3	-	-	-	-	-	-	-	-	-	-		Hindeognathus spp.
6	-	2	-	-	-	-	-	-	-	-	Pa	Synprioniodina? spicula
												Family CAVUSGNATHIDAE
313	1	-	7	6	-	23	15	49	27	20	α Pa	
111	-	-	5	4	1	14	5	9	4	13	β Pa	Cavusgnathus unicornis
59	-	-	2	1	-	4	3	6	4	3	γ Pa	
1	-	-	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus
0	-	-	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus X C. unicornis
0	-	-	-	-	-	-	-	-	-	-	Pa	Taphrognathus varians
X	X	X	X	X	-	X	X	X	X	X	Pa	
37	-	-	2	-	-	5	11	-	1	2	Pb	
25	-	-	2	-	-	2	3	-	1	2	M	Cavusgnathus spp.
4	-	-	-	-	-	1	2	-	-	-	Sa	
7	-	-	1	1	-	-	1	-	-	-	Sb	
42	-	-	2	1	-	8	5	-	-	5	Sc	
												Family IDIOGNATHODONTIDAE
21	-	-	-	-	17	1	-	-	-	3	Pa	Gnathodus bilineatus
0	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus girtyi girtyi
55	-	-	-	17	5	9	22	-	-	2	Pa	Gnathodus homopunctatus
0	-	-	-	-	-	-	-	-	-	-	Pb	
0	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus texanus
1	-	-	-	-	-	-	-	-	-	-	Pb	
0	-	-	-	-	-	-	-	-	-	-	M	
2	-	-	-	-	1	-	-	-	-	-	Sa	
0	-	-	-	-	-	-	-	-	-	-	Sb	Gnathodus spp.
1	-	-	-	-	-	1	-	-	-	-	Sc1	
0	-	-	-	-	-	-	-	-	-	-	Sc2	
2	-	-	-	-	-	2	-	-	-	-	Sc3	
												Family UNKNOWN
43	-	-	-	-	-	-	-	-	-	17	Pa	
8	-	-	-	-	-	-	-	-	-	5	Pb	
16	-	-	-	-	-	-	-	-	-	9	M	Lochriea commutatus
0	-	-	-	-	-	-	-	-	-	-	Sa	
4	-	-	-	-	-	-	-	-	-	3	Sc	
0	-	-	-	-	-	-	-	-	-	-	Pa	Rhachistognathus cf. R. muricatus
23	-	1	-	-	-	5	1	2	-	1	Pa	
0	-	-	-	-	-	-	-	-	-	-	Pb	
0	-	-	-	-	-	-	-	-	-	-	M	
0	-	-	-	-	-	-	-	-	-	-	Sa	"Spathognathodus" campbelli
1	-	-	-	-	-	-	-	-	-	-	Sb1	
1	-	-	-	-	-	-	-	-	-	-	Sb2	
0	-	-	-	-	-	-	-	-	-	-	Sc	
												Superfamily UNKNOWN
												Family UNKNOWN
0	-	-	-	-	-	-	-	-	-	-	DE	Lonchodina sp. A
0	-	-	-	-	-	-	-	-	-	-	DE	Lonchodina sp. B
1421	2	3	62	70	51	103	104	85	70	173	Conodont elements per sample	
2100	11.7	7.3	9.4	11.0	5.9	9.9	10.7	13.3	11.1	13.4	Sample weight in kilograms	
6.8	0.2	0.4	6.6	6.4	8.6	10	9.7	6.4	6.3	13	Conodont elements per kilogram	

TABLE 5: ABUNDANCE DATA FOR THE WILLOWTON SECTION (W13-W28)

"DENMAR-CASPER" FORMATION																		("X" : PRESENT, BUT NOT COUNTED)
W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	235	W24	W25	W26	W27	W28		:SAMPLE NUMBERS
																		Superfamily HIBBARDELLACEA
																		Family HIBBARDELLIDAE
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		Idioprioniodus sp. aff. I. healdi
1	-	-	-	-	1	-	-	1	2	-	-	2	1	-	1	-	Sa	Kladognathus levis
8	5	-	2	-	4	1	1	2	2	1	6	14	-	3	4	3	Sb	
6	3	3	2	-	7	2	2	-	1	-	8	20	1	3	1	3	M	
-	1	1	1	-	5	-	-	-	-	-	4	6	1	-	3	3	Sa	
2	1	1	-	-	-	-	-	-	1	-	1	7	-	1	-	1	Sb	Kladognathus tenuis
3	5	2	-	1	19	2	-	2	6	3	8	10	-	1	-	3	Sc	
-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	Sd	
-	-	-	-	-	3	-	3	-	1	-	-	2	1	-	-	-	X	
-	-	-	-	-	-	-	-	-	-	-	9	11	1	-	1	2	M	
-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb	Kladognathus sp. A
-	-	1	-	-	-	-	-	-	-	-	7	2	-	-	-	-	Sc	
-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	Sd	
-	-	-	-	-	-	-	-	-	-	-	6	3	-	-	-	-	X	
																		Superfamily POLYGNATHACEA
																		Family ANCHIGNATHODONTIDAE
-	-	-	-	-	5	-	-	-	2	1	4	1	-	-	-	1	Pa	
-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	2	1	1	4	-	-	-	-	-	M	Hindeodus cristula
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	Sb	
1	1	-	-	-	-	-	-	-	2	-	3	-	-	-	-	-	Sc	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb1	Hindeognathus laevipostica
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb3	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb4	
-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-		Hindeognathus spp.
-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	Pa	Synprioniodina? spicula
																		Family CAVUSGNATHIDAE
52	11	7	17	-	-	-	2	-	9	2	13	6	2	35	5	4	α Pa	
16	1	3	1	-	-	-	-	1	5	-	5	5	4	8	2	5	β Pa	Cavusgnathus unicornis
12	-	-	6	-	-	-	-	-	-	-	4	6	1	6	-	1	γ Pa	
-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Cavusgnathus altus X C. unicornis
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Taphrognathus varians
X	-	X	X	-	X	-	-	-	X	X	X	X	X	X	X	X	Pa	
5	1	1	-	-	-	-	-	-	2	-	1	1	-	3	2	-	Pb	
9	-	-	-	-	-	-	-	-	1	-	-	5	-	-	-	-	M	Cavusgnathus spp.
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	Sb	
5	1	-	2	-	-	-	-	-	2	-	8	3	-	-	-	-	Sc	
																		Family IDIOGNATHODONTIDAE
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus bilineatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus girtyi girtyi
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus homopunctatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Gnathodus texanus
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sb	Gnathodus spp.
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc1	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc3	
																		Family UNKNOWN
-	-	4	-	-	-	-	-	-	-	-	2	17	-	2	-	1	Pa	
-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-	M	Lochriea commutatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	
-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	Sc	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pa	Rhachistognathus cf. R. muricatus
3	-	-	3	-	1	-	-	-	-	-	3	1	-	-	-	2	Pa	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pb	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sa	"Spathognathodus" campbelli
-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	Sb1	
-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	Sb2	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sc	
																		Superfamily UNKNOWN
																		Family UNKNOWN
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	DE	Lonchodina sp. A
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	DE	Lonchodina sp. B
127	32	24	35	1	45	5	8	8	40	8	107	134	12	69	19	29		Conodont elements per sample
8.6	5.2	10.2	4.8	4.4	9.8	4.5	4.5	4.4	8.7	4.8	7.6	10.0	5.0	4.7	4.8	4.5		Sample weight in kilograms
15	6.1	2.4	7.3	0.2	4.6	1.1	1.8	1.8	4.6	1.7	14	13	2.4	15	4.0	6.4		Conodont elements per kilogram

VITA

I, Michael James Huggins, was born in Glens Falls, New York, on July 15, 1955. I was raised in the town of Argyle, New York, and graduated from Argyle Central School in June, 1973. In September of that year I enrolled at Adirondack Community College and graduated cum laude in June, 1975. In August, 1975, I transferred to State University College at Potsdam, New York, and, in December, 1977, graduated cum laude with a BA in Liberal Arts (Major: Geology). In September, 1978, I enrolled in the graduate school of Virginia Polytechnic Institute and State University, in a program leading to the MS in Geology. While at VPI, I was a graduate teaching assistant and was elected to the national honor society, Phi Kappa Phi. After the completion of my MS I will be employed as an exploration geologist, with Shell Offshore, Inc. in New Orleans, Louisiana.

Michael J. Huggins