SILURIAN CONODONTS FROM THE WILLS MOUNTAIN ANTICLINE, VIRGINIA, WEST VIRGINIA, AND MARYLAND

by

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INTRODUCTION

Purpose.-- This study was undertaken for the following purposes:

a) Establishment of a middle and upper Silurian zonal scheme based on stratigraphic changes in conodont faunas in the central Appalachians;

b) Establishment of intra- and extra-basinal correlations of middle and upper Silurian strata based on conodonts;

c) Detection of natural associations of discrete conodont elements which would allow establishment of multi-element species.

In pursuit of these aims, sequential samples of carbonate rocks were collected from six sections comprising an aggregate thickness of approximately 2,500 feet. The units sampled include the Mifflintown, Wills Creek, and Tonoloway formations of late Wenlock, Ludlow, and Pridoli ages. The classic section of the Wills Creek and Tonoloway formations at Pinto, Maryland, were included in this study, and the McKenzie Member of the Mifflintown Formation was sampled near Keyser, West Virginia, approximately 13 miles southwest of its type section at McKenzie Station near Pinto, Maryland.

Area of study.--All sections in this study are located along the Wills Mountain anticline or along a subsidiary and adjacent structure in Highland County, Virginia, Pendleton, Grant, and Mineral Counties, West Virginia, and Allegany County, Maryland. The Wills Mountain anticline lies on the western edge of the Valley and Ridge Province and is bounded on the northwest by the Cumberland-Alleghany Plateau. The general locations of the sampling localities are given in Figure 1. The exact locations are given in the Appendix under the respective measured sections.

Previous work.--The major unifying work for studies related to strata of Silurian age in the central Appalachians is the volume entitled Silurian published by the Maryland Geologic Survey (1923). In this volume, Swartz described the physical stratigraphy and Ulrich and Bassler discussed the biostratigraphy of the Silurian System for this region.

A second major stratigraphic work which has proved very useful is the Silurian of West Virginia compiled by Woodward (1941) and published by the West Virginia Geologic Survey. In this volume, Woodward located, described,

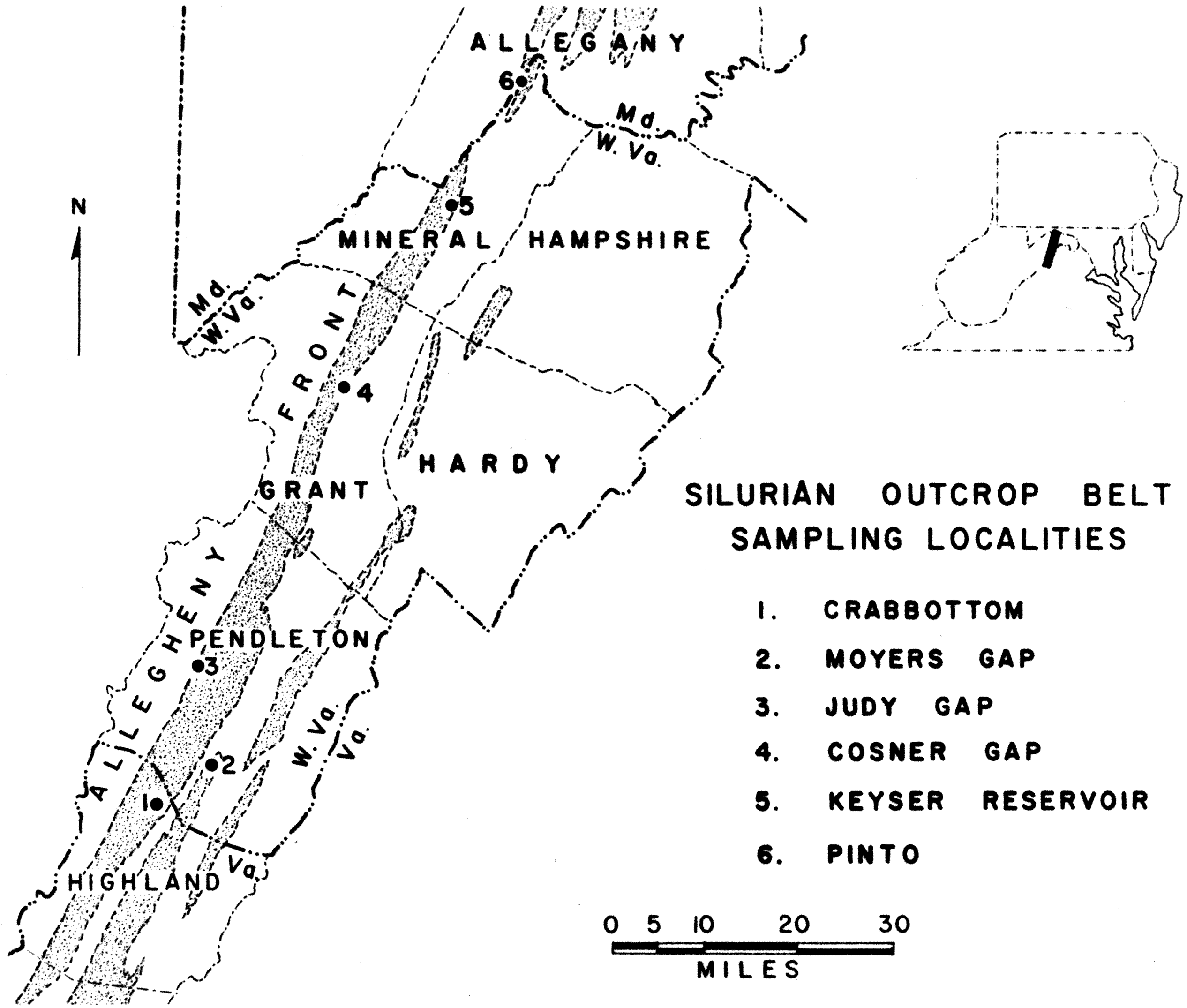

Figure 1—Sketch map of area studied showing sampling localities.

and gave faunal lists for all stratigraphic sections included in this study.

Butts (1941) also detailed much physical and biostratigraphic information on Silurian strata in his work on the Appalachian Valley of Virginia.

Swartz (1934) detailed the biostratigraphy of the McKenzie Member of the Mifflintown Formation near Mount Union in Pennsylvania.

Studies which deal with the biostratigraphy of the Keyser Formation of Silurian-Devonian age were made by Swartz (1929) and Bowen (1967).

Hunter (1960), in an unpublished doctoral dissertation, presented a study on iron sedimentation in the Clinton Group of the central Appalachians. This study included the lower part of the Mifflintown Formation.

Miller (1961) revised the nomenclature of the middle and lowest upper Silurian rock units of Pennsylvania. Miller dropped the term Clinton Group for the Rose Hill, Keefer, and "Rochester" formations and defined the Mifflintown Formation which included the Keefer, "Rochester", and McKenzie formations of previous authors.

Folk (1962) published a study of the carbonate petrography of the Mifflintown Formation in the vicinity of Martinsburg, West Virginia to the east of the Wills

Mountain anticline. In this study, Folk also discussed a depositional model for sediments of the upper Rose Hill and Mifflintown formations of the central Appalachian basin.

Head (1969) in an unpublished doctoral dissertation detailed a model for the deposition of Cayugan and Helderberg sediments in the central Appalachians.

STRATIGRAPHY

Introduction

The stratigraphic succession along the Wills Mountain anticline includes formations which range from Ordovician through Devonian in age. This study is limited to conodont biostratigraphy of the middle and upper Silurian Mifflintown, Wills Creek, and Tonoloway formations. The Rose Hill and Keyser formations are included in the discussion of the stratigraphic units because they have an extensive megafauna of some importance for biostratigraphic correlation in the central Appalachian region. The only other formation of Silurian age in the area is the Tuscarora Sandstone which is basal Silurian and does not contain a marine macrofauna or any lithology which would be suitable for conodont studies. See Figure 2 for comparison of stratigraphic nomenclature used by previous authors.

Silurian rocks are exposed in two broad belts on the opposing flanks of the Wills Mountain anticline from Virginia on into Pennsylvania. Good exposures of the

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<tr><td>Tuscarora Ss.</td><td>Tuscarora Ss.</td><td colspan="2">Tuscarora Ss.</td><td colspan="2">Tuscarora Ss.</td></tr>
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Figure 2—Stratigraphic nomenclature for Silurian strata of the central Appalachians.

various units are generally limited to gaps which have been eroded across the structure and subsequently enhanced by the construction of roads and railroads or quarrying. Generalized columnar sections for each collecting locality are shown in Figures 3A and 3B. Detailed columnar sections are given in Figures 10 and 11. A complete faunal list and zonal scheme for these sections is given on Table VIII.

Rose Hill Formation

Name and type locality.-- The name Rose Hill Formation was proposed by Swartz (1923) and comprises all the beds between the top of the Tuscarora Sandstone and the bottom of the Mifflintown Formation along Wills Mountain. The type section is south of Wills Creek in the cut of the Western Maryland Railway, just east of "The Narrows" through Wills Mountain, Allegany County, Maryland.

Description.-- Along the Wills Mountain anticline, the Rose Hill Formation consists of shale interbedded with lesser amounts of sandstone and a few beds of limestone. The shale is dominantly olive to medium gray, thin bedded, and fissile, with some interbeds of olive-gray siltstone. The shales in some of the upper beds in some

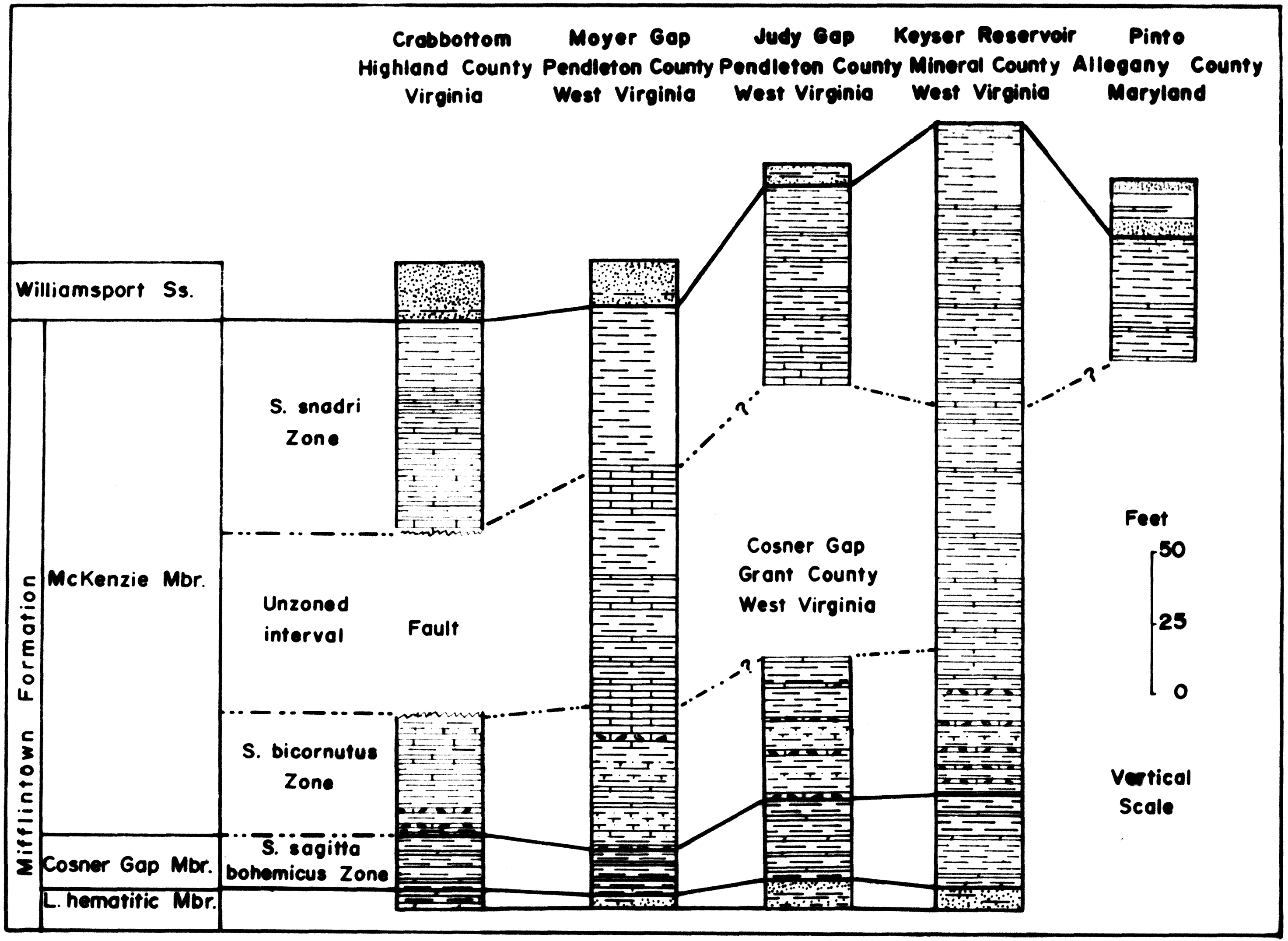


Figure 3A—Generalized columnar sections of the Mifflintown Formation.

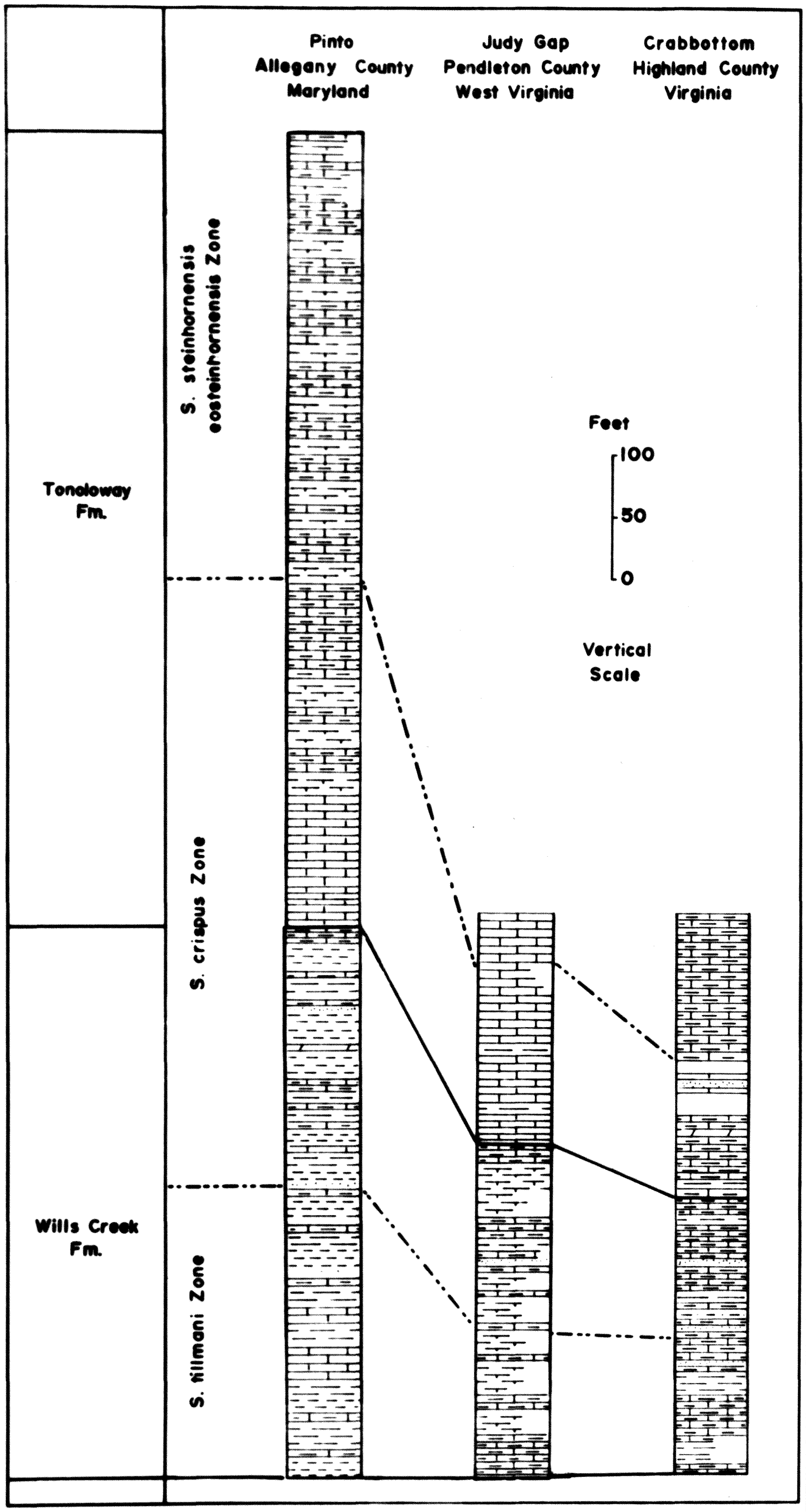


Figure 3B—Generalized columnar sections of the Wills Creek and Tonoloway formations.

sections are reddish-purple. Hematite-cemented sandstone, the Cresaptown Iron Sandstone of Swartz (1923), is found about 175 feet above the base of the formation along the Wills Mountain anticline in Allegany County, Maryland. At Pinto, Maryland, the Cresaptown Iron Sandstone is more than 30 feetthick. At Pinto, Maryland, and at Keyser Reservoir, Mineral County, West Virginia, the upper 50 feet of the formation contains a few light- to dark-gray, thin to medium beds of dolomitic limestone. These beds are extremely fossiliferous and weather brownish orange. Swartz (1923) gives the thickness of the Rose Hill as 550 feet along the Wills Mountain anticline in the vicinity of Cumberland, Maryland.

Fauna.-- Fossils are abundant in the Rose Hill Formation. It contains a prolific ostracode fauna in association with brachiopods, trilobites, pelecypods, and gastropods. Swartz (1932) described the general fauna as the Coelospira hemispherica fauna and also listed seven ostracode zones established by Ulrich and Bassler. These zones in ascending order are: the Zygobolbina anticostiensis Zone, the Zygolbina decora Zone, the Zygobolbina emaciata Zone, the Mastigobolbina lata Zone, the Zygosella postica Zone, the Bonnemaia rudis Zone, and the Mastigobolbina typus Zone.

Of these zones, only the Mastigobolbina typus Zone was sought in the field. At Crabbottom, Highland County, Virginia, and at Moyer Gap, Pendleton County, West Virginia, Mastigobolbina typus was recovered from fossiliferous shales within 5 feet of the base of the overlying Mifflintown Formation. No identifiable conodonts were recovered from the Rose Hill Formation. A few fragments were found, however, in residues from thin dolomitic beds in the upper Rose Hill at Cosner Gap in Grant County, West Virginia.

Mifflintown Formation

Name and type locality.--The Mifflintown Formation (Lesley, J.P. in Dewees, 1878, p. xxv-xxvi) was redefined by Miller in Miller and Conlin (1961) to include in ascending order the Keefer, "Rochester", and McKenzie formations of previous authors. The older names were retained by Miller as members of the Mifflintown Formation.

The type section of the Mifflintown Formation is a composite section consisting of two exposures in the vicinity of Mifflintown, Pennsylvania. The composite section consists of exposures of the "Rochester" and Keefer members along the main line of the Pennsylvania

Railroad, 0.25 mile northwest, and the McKenzie Member along the east side of U.S. Route 22, 0.3 mile north of the borough boundary of Mifflintown, Pennsylvania.

Lower hematitic member

Name and locality.--In the type section of the Mifflintown Formation the Keefer Member consists of approximately 34 feet of light-gray, medium- to thick-bedded sandstone and quartzite of which the upper 3 feet contains bands of oölitic hematite.

In the type area at Keefer Mountain near Hancock, Maryland, the Keefer Sandstone is reported by Swartz (1923) to be a pure quartzitic sandstone. Swartz also reported that this sandstone becomes limy westward and that in Allegany County, Maryland it is overlain by a bed of the Roberts Iron Ore which is in part oölitic hematite.

Along the Wills Mountain anticline, from Pinto, Maryland, to Crabbottom, Virginia, the lower Mifflintown Formation contains a sequence of beds 5 to 10 feet thick in the position of the Keefer. The general lithology includes fossiliferous and oölitic hematite, but little or no quartzitic sandstone. Because this interval lacks the normal lithologic character of the true Keefer Sandstone, the author has used the informal name lower hematitic member for the basal member of the Mifflintown Formation.

Description.--The lower hematitic member consists of 7 feet of dark-gray, fine-grained sandstone overlain by a 0.5-foot hematitic ore bed at Pinto, Maryland. The unit grades southward to light-gray, coarsely crystalline dolomite, dark-gray siltstone, interbedded medium-gray, arenaceous, shale, and hematite. At Crabbottom, Virginia, the member is 5.5 feet thick and the upper part contains bands of disseminated hematite and thin beds of coarsely arenaceous, oölitic hematite. Pods of medium-gray, medium-crystalline, arenaceous limestone with disseminated oölitic hematite are found in the lower hematitic member at Cosner Gap. The quartz fraction of the residue from the limestone at Cosner Gap was doubly terminated crystals. The member is 7.0 feet thick at Keyser Reservoir, 10.2 feet thick at Cosner Gap, and 4.7 feet thick at Moyer Gap.

Fauna.--Poorly preserved brachiopods and fragments of Ligonodina sp. were found at Cosner Gap. Crinoid stems were found in dolomitic beds at Crabbottom. Fossils from the lower hematitic member were not useful for correlation; however, at all sections visited, the ostracode _Drepanellina clarki_ was found in shales and limestones of the overlying Cosner Gap member. At Moyer Gap and at Crabbottom, the ostracode _Mastigobolbina typus_ was recovered from shales immediately underlying the lower hematitic member.

Cosner Gap Member

Name and type locality.--The name Cosner Gap Member is here proposed for the lower fossiliferous shale and interbedded limestone of the Mifflintown Formation. These beds were formerly called "Rochester". The exposure along State Route 42, at the eastern end of Cosner Gap, approximately 1 mile northwest of Maysville in Grant County, West Virginia, is proposed as the type section.

Description.--The Cosner Gap Member consists largely of shale with some interbedded dolomite and limestone. The shale which is medium to dark gray, calcareous, and fossiliferous, weathers readily to soft chips. The dolomite which is light gray, saccharoidal to coarse grained, and thin bedded, weathers orangish red. In thin-section, these dolomite beds show abundant ghosts of fossils. The limestone is medium to dark gray, fine to medium crystalline, very thin to thin bedded, and very fossiliferous. The lower contact with the lower hematitic member is sharp in the area studied. The upper contact with the McKenzie Member is gradational and difficult to define because of the varied lithologies in the lower McKenzie along the Wills Mountain anticline. The writer has placed the upper contact of the Cosner Gap Member at the top of the shales underlying the first occurrence of intraformational limestone conglomerate, dark-gray, thin-bedded, silty limestone, or medium-gray, thin-bedded, argillaceous limestone of the McKenzie Member. At the type section, the Cosner Gap Member is 28.2 feet thick and at Keyser Reservoir 31.9 feet. Its thickness at Moyer Gap and Crabbottom is 15.0 feet and 19.0 feet respectively. The type section is described in the Appendix under the heading Cosner Gap Section.

Fauna.--Both the shale and the limestone of the Cosner Gap Member are profusely fossiliferous. The fauna includes brachiopods, ostracodes, trilobites, pelecypods, and cephalopods. The important ostracode species *Drepanellina clarki* was identified at the type section and appears to be limited to the interval assigned to the Cosner Gap Member.

Swartz (1923) described three faunal zones from the Cosner Gap Member. In ascending order, these are the *Uncinulus stricklandi* Zone, the *Schuchertella tenuis* Zone, and the Whitfieldella marylandica Zone. The brachiopod, Whitfieldella marylandica is found in very finely crystalline, argillaceous limestone which the writer has included in the basal part of the McKenzie along the Wills Mountain anticline.

The Cosner Gap Member contains a distinctive conodont fauna which includes the forms Spathognathodus sagitta bohemicus and Ozarkodina edithae mariae n. ssp. in its upper beds and Spathognathodus walliseri n. sp. in its lower beds.

Remarks.--The name Rochester was used by Conrad and Hall (1839) for a sequence of fossiliferous shale and interbedded fossiliferous limestone exposed in western New York in the vicinity of Rochester along the Genesee River. The use of the term in Maryland and in surrounding states was established by Swartz (1923) on the basis of faunal and lithological similarities. The Rochester of western New York has not been traced physically into Pennsylvania, Maryland, Virginia, and West Virginia, and the lithologic sequence in the two areas is different. In western New York the Rochester Formation is underlain by the Irondequoit Limestone and overlain by the Lockport Dolomite. In Maryland and the surrounding states, the Cosner Gap Member is underlain by the lower hematitic member or the Keefer Member and overlain by the McKenzie

Member of the Mifflintown Formation, units which are lithologically different from those above and below the Rochester of New York.

The use of the name Rochester in Maryland as extended by Swartz (1923) was influenced by Ulrich and Bassler's regional, historical, and faunal interpretations. In view of this and the desirability of defining rock units on the basis of physical properties, the writer has applied the name Cosner Gap Member to those beds along the Wills Mountain which were previously called Rochester.

McKenzie Member

Name and type locality.--The McKenzie Member of the Mifflintown Formation was originally named the McKenzie Formation by Ulrich (1911). The name is taken from McKenzie Station on the Baltimore and Ohio Railroad formerly located at the eastern end of the cut made by the Potomac River across the western flank of the Wills Mountain anticline at Pinto, Maryland. This cut contains the type locality and is located nine miles southwest of Cumberland, Allegany County, Maryland. The type section is intricately folded and faulted and cannot be accurately measured or sampled. A complete and undisturbed section of the McKenzie Member can be seen on the eastern flank of the Wills Mountain anticline along State Route 14 opposite the Keyser City Reservoir approximately 4 miles south of Keyser, Mineral County, West Virginia.

Description.--In the area studied the McKenzie Member consists largely of shale and interbedded argillaceous limestone. The shales are medium gray, and calcareous, and weather greenish gray. These shales weather rapidly so that most potential outcrops are covered with soil and loose shale chips. In the area studied the limestone of the lower third of the unit includes silty limestone, intraformational conglomerate, very finely crystalline, argillaceous limestone, and oölitic limestone beds. Silty laminae with some cross-bedding stand out on weathered surfaces of the silty limestone. As seen in thin section, the silt fraction consists of large proportions of quartz and ostracode valves with an admixture of oölites. The intraformational conglomerates consist of tabular fragments of very finely crystalline, argillaceous limestone in a matrix of medium- to coarsely crystalline limestone. The matrix of these conglomerates can contain abundant ostracode valves. The intraformational conglomerates thicken and thin rapidly and 0.5-0.1-foot beds can be seen to pinch out laterally within a few feet. The very finely crystalline, argillaceous limestones which are medium to dark gray, weather bluish gray and can contain abundant small, globose brachiopods. Thin to thick beds of oölitic limestone occur in the lowest part of the McKenzie Member. In the field these beds could be taken for pelletiferous limestone or even ostracode coquinas. In thin section the oölitic nature of these beds is obvious and the oölites are also seen to be darkly stained, possibly, by organic residue.

The middle beds of the McKenzie Member consist of shales and interbedded limestones. The limestones which are medium to dark gray, medium to coarsely crystalline, and thin to massively bedded, weather reddish brown. Acid residues of these limestones are commonly more than 90 percent dolomite rhombs which can be separated magnetically from the fossil fraction.

The upper part of the McKenzie Member consists largely of shales with thin interbeds of fossiliferous limestone and siltstone. The shales become progresssively more arenaceous upward toward the overlying Williamsport Sandstone. At Moyer Gap, sample MG-14 (Appendix, Moyer Gap Section) of a thick bed of limestone contains abundant hematitic lithic fragments. This bed is in the stratigraphic position of the Rabble Run Sandstone Member (Swartz, 1923) to the northeast. The shales directly under the Williamsport are occasionally siliceous and appear to be penetrated by worm borings.

Swartz (1923) reported the thickness of the McKenzie at the Pinto section as 241.5 feet. At Keyser Reservoir and Moyer Gap the thickness of the McKenzie measured 233.0 feet and 190.6 feet, respectively. At Crabbottom, the middle part of the McKenzie has been removed by a high-angle fault (Appendix, Crabbottom Section). Approximately 35 feet of the McKenzie is exposed below the fault and is contiguous with the underlying Cosner Gap Member. From the fault upward to the overlying Williamsport Sandstone approximately 70 feet of McKenzie beds is exposed.

Fauna.--The McKenzie Member in the region studied contains a diverse ostracode fauna, as well as a few brachiopods, gastropods, and cephalopods. Ostracode remains can constitute a significant fraction of the limestone beds but were unobserved in the shales. Swartz (1923) set up three non-ostracode faunal zones in the McKenzie in ascending order as follows: the *Reticularia bicostata* Zone, the *Hormatoma-Orthoceras* Zone, and the *Camerotoechia andrewsi* Zone. These zones are useful for recognizing the stratigraphic position of a doubtful or incomplete exposure of the McKenzie Member but have not been useful in correlation outside of the area of the Central Appalachians. The *Hormatoma-Orthoceras* Zone is easily recognized at the outcrop by the profusion of the high spired gastropods on the surface of thin limestone plates. This zone is completely faulted out of the section at Crabbottom in Highland County, Virginia.

A fourth zone, the *Whitfieldella marylandica* Zone, originally included in the upper part of the Cosner Gap Member by Swartz, but subsequently included as the basal part of the McKenzie by Woodward (1941) and Dennison (1963), is herein included in the McKenzie Member. Woodward and Dennison used the *Whitfieldella* coquinas as a basis for recognizing the base of the McKenzie along the Wills Mountain anticline. The author has included these beds in the McKenzie on the basis of their lithology.

The McKenzie has yielded two distinct conodont faunas. The lower and upper McKenzie faunas are characterized by the distinctive forms *Spathognathodus bicornutus* and *Spathognathodus snajdri*, respectively. The two faunas are separated by an unzoned interval which is characterized by the long ranging form *Spathognathodus primus primus*.

Williamsport Sandstone

Name and type locality.--Reger (1924) used the name Williamsport Sandstone for an interval of sandy beds between the McKenzie Member of the Mifflintown Formation and the Wills Creek Formation. The type section is located along a short branch of Patterson Creek 0.6 mile east of Williamsport, Grant County, West Virginia. Reger considered the Williamsport Sandstone to be a member of the Bloomsburg Shale, which is an eastern red-bed facies of the McKenzie and Wills Creek formations. Swartz (1923) referred to beds of this horizon at Pinto, Maryland, on the west flank of the Wills Mountain anticline as the Bloomsburg Member of the Wills Creek Formation. Swartz and Swartz (1940) proposed the name Crabbottom Sandstone for an exposure at this horizon near Crabbottom, Highland County, Virgnia. Woodward (1941) disassociated the Williamsport from the Bloomsburg Shale and extended it as the basal unit of the Cayugan Group along the Wills Mountain anticline. The author has used the name Williamsport as defined by Woodward.

Description.--Along the Wills Mountain anticline, the Williamsport consists of an upper and a lower sandstone unit separated by shale or limestone. In its type locality the lithology includes shale, siltstone, fine-grained sandstone, and arenaceous siltstone, all of which are dominantly olive gray. At Pinto, Allegany

County, Maryland, the Williamsport is 20.6 feet thick. The lower 8 feet consists of greenish-gray, medium-bedded, fine grained sandstone. This is separated from the upper sandstone and arenaceous shale by the Cedar Cliff limestone lentil which is 8 feet thick. At Keyser Reservoir, the Williamsport is 8.5 feet thick. The lower part consists of 4 feet of greenish-gray, medium-bedded, fine-grained sandstone. The upper 4 feet consists of lumpy, argillaceous, greenish-gray sandstone. These two units are separated by 3 feet of red shale and sandstone. The Williamsport is 7.5 feet thick at Judy Gap, Pendleton County, West Virginia. The lower part consists of a 2-foot bed of greenish-gray, fine-grained sandstone. The upper bed is a massive, 2.7-foot thick bed of grayish-green siltstone which is spearated from the lower bed by greenish shale. At Pinto, Keyser Reservoir, and Judy Gap the sandstones and siltstones weather rusty brown. At Moyer Gap, Pendleton County, West Virginia, approximately 16 feet of light-gray, thin- to thick-bedded, fine-grained sandstone is exposed above the McKenzie. At Crabbottom, Highland County Virginia, the Williamsport is 21 feet thick and consists of light greenish-gray, thin- to thick-bedded, fine-grained sandstone with some shale beds and partings in the lower part. At Cosner Gap, Grant County, West Virginia, the Williamsport consists of greenish-gray, thin-bedded siltstones and shales and appears to be very similar to the Williamsport at its type section. Except at Cosner Gap, the upper and lower Williamsport contacts are sharp.

Fauna.--At Pinto, Swartz (1923) reported leperditiid ostracodes and worm borings in this interval. The upper beds of the underlying McKenzie Member of the Mifflintown Formation contain *Spathognathodus snajdri* and *Ozarkodina serrata* n. sp. The lowest beds of the overlying Wills Creek Formation contain *Spathognathodus tillmani* n. sp. as well as *Spathognathodus primus multidentatus* n. ssp. and *Ozarkodina typica intermedia* n. ssp.

Wills Creek Formation

Name and type locality.--The Wills Creek Formation was named by Uhler (1905) for exposures on Wills Creek at Cumberland, Maryland, where the strata were formerly well exposed. Swartz (1923) listed the section along the Baltimore and Ohio Railroad at Pinto, Maryland, along the Wills Mountain anticline as a reference section. Despite the general tendency of this unit to disintegrate rapidly, the section at Pinto has endured without serious loss of character since Swartz described it in 1923.

Description.--The dominant lithology of the Wills Creek Formation is calcareous shale and interbedded platy, argillaceous limestone. Impersistent sandy horizons occur in the upper and lower third of the unit. Thick, mud-cracked units also occur in most sections, but these units do not maintain a constant stratigraphic level along the Wills Mountain anticline. At Pinto, massive beds of mud-rock are common; however, this lithology was not observed at Judy Gap, Pendleton County, West Virginia, or at Crab-bottom, Highland County, Virginia. At Judy Gap and Crab-bottom, the lower 10 feet of the Wills Creek Formation consists largely of thin- to thick-bedded, fossiliferous limestone and interbedded shale.

An estimation of the amount of shale in this unit depends on the freshness of the exposure. At Greenland Gap, Grant County, West Virginia, the upper part of the Wills Creek is exposed in an active quarry. The rock appears to be a thick- to massive-bedded, argillaceous limestone. This same lithology is visible at Crabbottom where the road was being widened when visited by the writer. At Crabbottom the fresh, massive beds can be traced laterally into weathered zones where they are seen to break down into the typical Wills Creek shale. Fresh exposures of the Wills Creek are dominantly dark gray to black but weathered exposures are characteristically olive green.

The base of the Wills Creek Formation along the Wills Mountain anticline is a sharp contact with the Williamsport Sandstone. The upper contact of the Wills Creek and the Tonoloway is not sharp. At weathered exposures visited, the upper contact was placed at the horizon where the shaly weathering beds of the Wills Creek give way to the more massive and resistant limestone beds of the Tonoloway.

The measured thickness of the Wills Creek Formation is 446 feet at Pinto, 271 feet at Judy Gap, and 224 feet at Crabbottom.

Fauna.--The fauna of the Wills Creek Formation, as reported by Swartz (1923), includes ostracodes, brachiopods, trilobites, and eurypterids. Swartz also listed four faunal zones for the Wills Creek. These are in ascending order the Lower ostracode Zone, the *Spirifer vanuxemi* Zone, and the Upper ostracode Zone. None of these zones were identified by the author. The dominant faunal element in the Wills Creek is leperditiid ostracodes. The valves of these ostracodes can be found on bedding surfaces at almost any horizon in the formation.

Conodonts are rare in the Wills Creek Formation as a whole, however sufficient specimens were recovered to describe a distinctive lower and upper fauna. The lower fauna includes among other form species *Spathognathodus tillmani* n. sp. and *Spathognathodus primus multidentatus* n. ssp. The upper fauna which persists through the lower half of the Tonoloway Formation includes *Spathognathodus crispus* and *Spathognathodus primus highlandensis* n. ssp.

Tonoloway Formation

Name and type locality.--The Tonoloway Limestone was named for exposures along the east flank of Tonoloway Ridge, along Cacapon River near Rock Ford, Morgan County, Maryland. Although first mentioned by Ulrich (1911), the formation was described by Stose and Swartz (1912). Swartz (1923) listed the section at Pinto, Allegany County, Maryland, along the Baltimore and Ohio Railroad, as a reference section.

Description.--This formation consists largely of interbedded argillaceous limestone and calcareous shale. The limestone is generally dark gray with frequent light-gray laminae and is thin bedded. In addition, the lower half of the Tonoloway, in the area studied, contains beds with mud-cracks, thick sandstone, massive dolomitic limestones with conchoidal fracture, and thick, arenaceous and oölitic limestone beds. The upper part of the Tonoloway is largely covered at the sections studied. At Crabbottom, however, where more than 90 feet of the upper Tonoloway is exposed, the section consists largely of dark-gray, thin-bedded, fossiliferous limestone.

The base of the Tonoloway was placed at the horizon where the Wills Creek shales give way to slightly more resistant, laminated limestone which is the dominant Tonoloway lithology. The contact of the Tonoloway with the overlying Keyser Formation is sharp. The dark-gray, platy, argillaceous limestone of the upper Tonoloway changes abruptly to the greenish shale and interbedded crystalline limestone or cobbly weathering massive limestone of the Keyser. The measured thickness of the Tonoloway is 625 feet at Pinto, Maryland. At Judy Gap, Pendleton County, West Virginia, 183 feet of Tonoloway limestone is exposed, above which is an 163-foot covered interval up to in-place Keyser beds for a maximum possible thickness of 343 feet. At Crabbottom, Highland County, Virginia, the contact of the Tonoloway with the Keyser Formation is faulted out; the thickness of the Tonoloway present is

225 feet.

Fauna.--The fauna of the Tonoloway is too little known to be useful for correlations outside of the central Appalachians. Berry and Boucot (1970) state, however, that a silicified fauna collected from the Tonoloway by T. Perry closely resembles the fauna of the Pridoli age part of the Keyser Formation. A silicified brachiopod collection was recovered from sample P-T22 (Appendix, Pinto Section) at Pinto, Maryland, but it has not been evaluated. Swartz (1923) recognized three faunal zones in the Tonoloway Formation. In ascending order, these are an unnammed ostracode zone, the Hindella congregata Zone, and the Spirifer corallinensis Zone. These zones were not systematically observed by the writer while in the field. Fossils listed by Swartz as belonging to the Spirifer corallinensis Zone, however, were collected easily in the highest beds of the Tonoloway along the eastern wall of the quarry exposing the Keyser Formation at its type section. This quarry is three-fourths mile east of Keyser, West Virginia, along the tracks of the Baltimore and Ohio Railroad.

Conodonts are rare in the lower Tonoloway, however, samples from Crabbottom, Highland County, Virginia, indicate that the fauna in the lower half of the Tonoloway

Formation is similar to that of the upper Wills Creek Formation. This fauna includes both Spathognathodus primus highlandensis n. ssp. and Spathognathodus crispus. This latter form persists into the lower part of the upper Tonoloway Formation at Crabbottom. The upper part of the Tonoloway at every section sampled, yielded Spathognathodus steinhornensis eosteinhornensis and related forms including Ozarkodina typica denckmanni, Hindeodella priscilla, Plectospathodus alternatus. At Pinto, a distinctive new platform species was recovered with Spathognathodus steinhornensis eosteinhornensis and is listed as N. gen. et n. sp.

Keyser Formation

Name and type locality.--The Keyser Formation was first mentioned by Ulrich (1911) and later described by Swartz (in Schuchert et al., 1913) as the basal unit of the Helderberg Group. The unit is named for Keyser in Mineral County, West Virginia, and the type section is in an abandoned quarry adjacent to the Baltimore and Ohio Railroad tracks just north of State Route 46, approximately one quarter mile east of Keyser.

Description.--The Keyser Formation consists largely of medium- to dark-gray, medium- to thick-bedded limestone with subordinant amounts of shale. The lower half of the unit in which the limestones are typically thick bedded, nodular, and argillaceous is characterized by a shelly fauna, and bedded or nodular black chert. The limestones of the upper half of the Keyser are dominantly medium to coarsely crystalline, medium to thick bedded, and crinoidal. South of Keyser along the Wills Mountain anticline in Pendleton County, West Virginia, and in Highland County, Virginia, a shale unit, is recognizable in the middle of the Keyser. This shale was named the Big Mountain Shale by Swartz (1929) for the exposure on Big Mountain at Smoke Hole, in Pendleton County, West Virginia. In places the Keyser contains thick stromatoporoid bioherms.

Fauna.--Fossils are both diverse and abundant in the Keyser. The fauna includes stromatoporoids, corals, brachiopods, crinoids, cystoids, tentaculitids, trilobites, cephalopods, and ostracodes. Bowen (1967) lists two faunal zones based on brachiopods for the Keyser, the *Eccentricosta jerseyensis* Zone and the *Meristella praenuntia* Zone. The presence of the halysitid coral *Cystihalysites* in the *Eccentricosta jerseyensis* Zone has been interpreted as indicating a Silurian age for this fauna and the presence of the brachiopod *Nanothyris* sp. in the *Meristella prae-*

nuntia Zone is interpreted as indicating a Devonian age for this zone. The top of the Eccentricostica jerseyensis Zone coincides with the top of the Big Mountain Shale Member locally. It is this horizon that Boucot (in Berry and Boucot, 1970) equates with the top of the Pridoli of uppermost Silurian age.

Conodonts collected by the writer from the Keyser Formation are assignable to Walliser's (1964) eostein-hornensis zone. The form genus Icriodus was recovered from the Keyser in only one sample representing the uppermost 8 feet of the Keyser at Smoke Hole, Pendleton County, West Virginia.

THE SILURIAN CONODONT SUCCESSION

Europe

Walliser (1964) published the results of his study of a complete Silurian section near Cellon in the Carnic Alps of Austria. With the succession established in the Cellon section and with supplementary data from Algeria, Czechoslovakia, England, Germany, and Spain, Walliser set up a sequence of 11 zones spanning the entire Silurian or Llandovery through Pridoli ages. Walliser also attempted to extend the usefulness of the Cellon conodont succession by relating it to the known graptolitic standard section of Bohemia. A summary of Walliser's zonal scheme is given in Figure 4. European, Asian, African, and Australian work has tended largely to corroborate the work of Walliser.

North America

Isolated Silurian formations have been studied by various workers but no complete succession has yet been described for North America. The North American conodont faunas which have been reported from Silurian strata are listed on Figure 4. The ranges of the faunas are also indicated, and compared with Walliser's zonal scheme.

The study of conodonts from the Bainbridge Formation at Lithium, Missouri by Branson and Mehl (1933) was the first significant paper published on Silurian conodonts. In this paper Branson and Mehl established the form genera Ozarkodina, Polygnathoides, Plectospathodus, and Spathognathodus. The Bainbridge was resampled at Lithium and the fauna redescribed by Rexroad and Craig (1971). A review was also given of Branson and Mehl's type material. Branson and Mehl reported Polygnathoides siluricus which was established by Walliser as the zonal indicator of his siluricus Zone of middle Ludlow age. Rexroad and Craig also reported the occurrence of Spathognathodus snajdri from the Bainbridge Formation. This species was reported by Walliser from the upper part of the siluricus Zone and marks the snajdri Horizon.

Branson and Branson (1947) studied conodonts from the Brassfield Formation as well as from the Plum Creek Member of the Crab Orchard Formation in Kentucky. Both these formations are lower Silurian or Llandovery in age and the fauna indicates that these units fall in the Icriodina irregularis Assemblage Zone of Rexroad (1968).

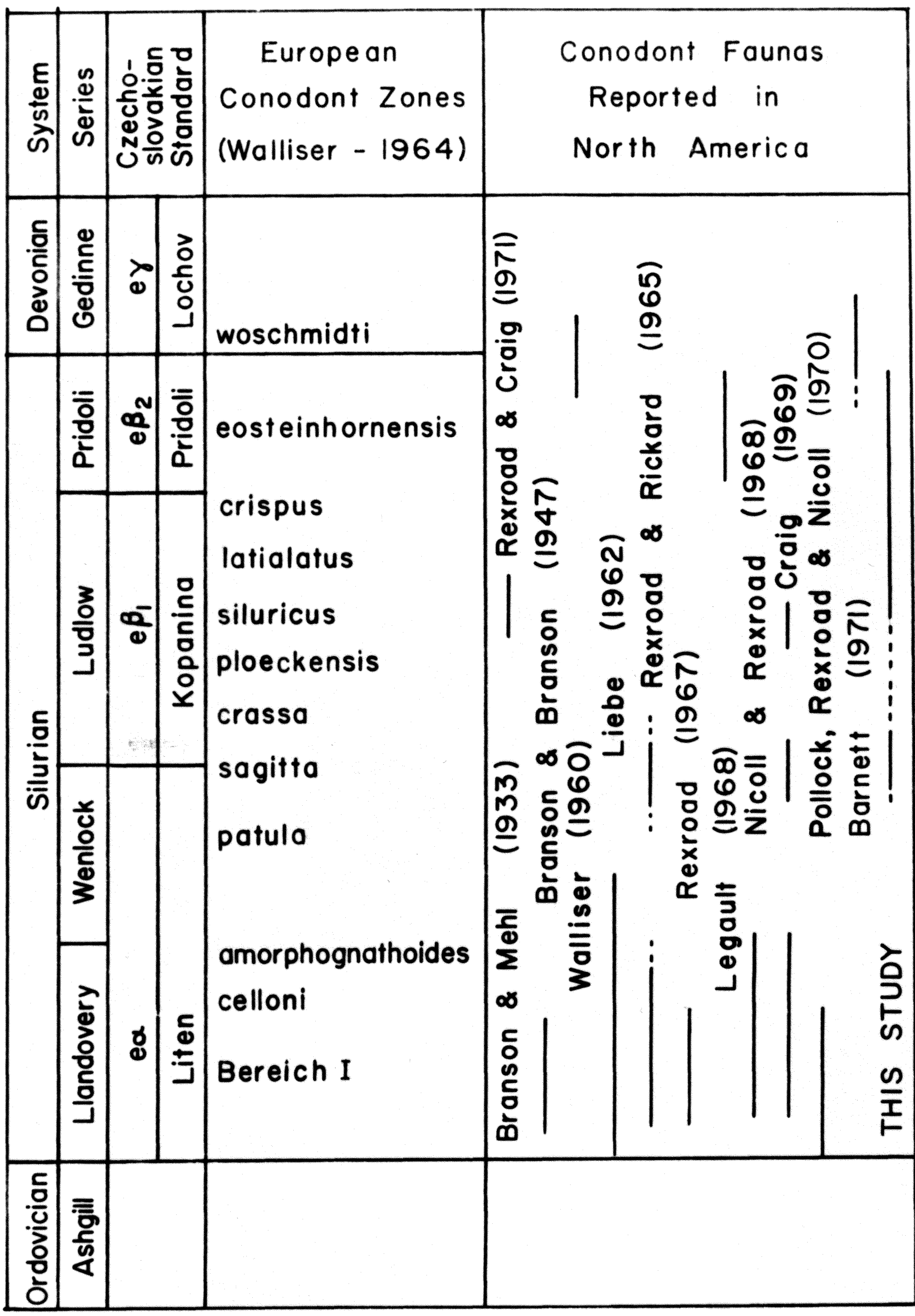


Figure 4—Previous studies of North American conodont faunas of Silurian age; summary of Walliser's conodont zones.

The *Icriodina irregularis* Assemblage Zone is correlated by Rexroad with the upper part of Walliser's Bereich I or lowest Silurian zone.

Walliser and others, including Boucot (1960) reported on the fauna of the Sutherland River Formation from Devon Island in the Canadian Artic Archipelago. At that time, the fauna, including conodonts, was tentatively dated as late Silurian in age. Berry and Boucot (1970), however, favor an early Gedinne age for the Sutherland River Formation. This conclusion is based on the occurrence of *Monograptus ultimus* in the underlying Devon Island Formation.

Leibe (1962) in an unpublished doctoral thesis, described conodonts from the Alexandrian and Niagaran Series of the Illinois Basin. Conodonts in this study range from Walliser's Bereich I to the *amorphognathoides* Zone of earliest Llandovery to middle Wenlock age.

Rexroad and Rickard (1965) in a survey study of conodont occurrences in the Silurian strata of the Niagara Gorge, established the occurrence of zonal conodonts from Bereich I through the *sagitta* Zone of Walliser, or earliest Llandovery through earliest Ludlow ages, in the New York section.

The Stonehouse Formation of Arisaig, Nova Scotia, as reported by Legault (1968), has yielded a fauna that correlates with the eosteinhornensis Zone of the Carnic Alps. The eosteinhornensis Zone is of post-Ludlow or Pridoli age.

A study by Rexroad (1967) of the conodont fauna of the Brassfield Formation in the Cincinnati Arch area established a correlation of the unit with the upper part of Walliser's lowest Silurian zone, Bereich I. This age was based on the occurrence of Icriodina irregularis.

Nicoll and Rexroad (1968) described conodonts which span Walliser's Bereich I, celloni and amorphognathoides zones from the Salamonie Dolomite and the Lee Creek Member of the Brassfield Formation in southeastern Indiana and adjacent Kentucky. Some overlap of zonal species necessitated a slight revision of Walliser's zones, and the Icriodina irregularis, Neospathognathodus celloni, and Pterospathodus amorphognathoides-Spathognathodus ranuliformis assemblage zones were described. The lower limit of Nicoll and Rexroad's Icriodina irregularis Assemblage Zone is marked by the earliest occurrence of Icriodina irregularis. The upper limit of this zone is marked by the earliest occurrence of the genus Neospathognathodus or Ozarkodina adiutricis and correlates with

Walliser's Bereich I. The Neospathognathodus celloni Assemblage Zone spans the local range of the genus Neospathognathodus and includes Walliser's celloni Zone as well as the lowest part of his amorphognathoides Zone. The Pterospathodus amorphognathoides-Spathognathodus ranuliformis Assemblage Zone begins above the latest occurrence of the genus Neospathognathodus. The upper limit of this zone is taken as the base of Walliser's patula Zone. No species which are definitely restricted to the patula Zone were reported by Nicoll and Rexroad.

Craig (1969) published a faunal list in a summary of his work on Silurian conodonts in the Batesville District of Arkansas. The Cason Shale and the overlying St. Clair and Lafferty limestones yielded conodonts which indicate beds correlative with Bereich I, the celloni Zone, amorphognathoides Zone, sagitta Zone, and siluricus Zone of Walliser's European standard.

Pollock, Rexroad, and Nicoll (1970) describe a lower Silurian conodont fauna from northern Michigan and Ontario, which they correlate with Walliser's Bereich I. In this paper, the authors identified the upper Bereich I, Icriodina irregularis Assemblage Zone, and established a name, the Panderodus simplex Assemblage Zone, for the pre-Icriodina fauna of Walliser's Bereich I.

Barnett (1971) in a biometric study of *Spathognathodus remscheidensis* established the presence of *eosteinhornensis* Zone fossils of Pridoli age well down into the upper Cayugan rocks of the New York Silurian section.

Walliser and Rexroad's conodont zones are compared on Figure 5.

<table>
<tr><th>European Conodont Zones
(Walliser—1964)</th><th>North American Conodont Zones
(Rexroad—1968)
(Nicoll & Rexroad—1970)
(This Study)</th></tr>
<tr><td>eosteinhornensis</td><td>Spathognathodus steinhornensis eosteinhornensis</td></tr>
<tr><td>crispus</td><td>Spathognathodus crispus</td></tr>
<tr><td>latialatus</td><td>Spathognathodus tillmani</td></tr>
<tr><td>siluricus — snajdri Horizon</td><td>Spathognathodus snajdri</td></tr>
<tr><td>ploeckensis</td><td>Unnamed interval</td></tr>
<tr><td>crassa</td><td>Spathognathodus bicornutus</td></tr>
<tr><td>sagitta</td><td>Spathognathodus sagitta bohemicus</td></tr>
<tr><td>patula</td><td>Unreported</td></tr>
<tr><td>amorphognathoides</td><td>Pterospathodus amorphognathoides-Spathognathodus ranuliformis (1968)</td></tr>
<tr><td>celloni</td><td>Neospathodus celloni (1968)</td></tr>
<tr><td rowspan="2">Bereich I</td><td>Icriodina irregularis (1968)</td></tr>
<tr><td>Panderodus simplex (1970)</td></tr>
</table>

Figure 5—Comparison of European and North American conodont zones of Silurian age.

THE CONODONT SUCCESSION IN THE CENTRAL APPALACHIANS

Local Concurrent Range Zones

General statement.--The carbonates of the Mifflintown, Wills Creek, and Tonoloway formations along the Wills Mountain anticline in Maryland, West Virginia, and Virginia have yielded an important succession of conodont faunas. The succession of faunas in the Central Appalachians compares very closely with the succession established in Europe by Walliser (1964). The main difference between the conodont successions described by Walliser and by the writer is the lack of platform species in the Appalachian fauna. By comparison with Walliser's faunas, the strata in this study are upper Wenlock through middle Pridoli age (Figure 4). Walliser is the only worker who has described the faunal succession for this time span, so all comparisons of faunas for purposes of faunal zonation will be limited largely to Walliser's European standard.

The zonation established by Walliser for European strata of comparable age to those studied by the writer is shown in Figure 6. Of these zones the writer has identified the faunas of the *sagitta*, *crispus*, and *eostein-*

System	Series: Europe	Series: New York	Wills Mountain Anticline: Formations	Wills Mountain Anticline: Conodont Zones	European Conodont Zones (Walliser-1964)
Devonian	Gedinne	Helderberg	New Creek Ls.	Icriodus woschmidti	woschmidti
Silurian	Pridoli	Helderberg	Keyser Ls.	Spathognathodus steinhornensis eosteinhornensis	eosteinhornensis
Silurian	Pridoli	Cayuga	Tonoloway Fm.	Spathognathodus steinhornensis eosteinhornensis	eosteinhornensis
Silurian	Ludlow	Cayuga	Tonoloway Fm.	Spathognathodus crispus	crispus
Silurian	Ludlow	Cayuga	Wills Creek Fm.	Spathognathodus tillmani	latialatus
Silurian	Ludlow	Cayuga	Williamsport Ss.	Spathognathodus snajdri	siluricus \ snajdri horizon
Silurian	Ludlow	Cayuga	Mifflintown Fm. – McKenzie Mbr.	Spathognathodus snajdri	siluricus \ snajdri horizon
Silurian	Ludlow	Cayuga	Mifflintown Fm. – McKenzie Mbr.	Unnamed interval	ploeckensis
Silurian	Ludlow	Cayuga	Mifflintown Fm. – McKenzie Mbr.	Spathognathodus bicornutus	crassa
Silurian	Wenlock	Niagara	Mifflintown Fm. – Cosner Gap Mbr.	Spathognathodus sagitta bohemicus	sagitta
Silurian	Wenlock	Niagara	Mifflintown Fm. – Lower Hematitic Mbr.		patula
Silurian	Wenlock	Niagara	Rose Hill Fm.		patula

Figure 6—Comparison of conodont zones established for strata of Silurian age along the Wills Mountain anticline with those established in Europe by Walliser (1964).

hornensis zones of the European section on the basis of the local occurence of Walliser's zonal indices. The crassa Zone, based on the rare form Ozarkodina crassa, has not been identified in the Central Appalachians although the very distinctive form Spathognathodus bicornutus n. sp. occurs in the comparable interval. The ploeckensis Zone of Europe, based on the occurrence of Ancoradella ploeckensis has not been identified. An unzoned interval occupies the approximate stratigraphic position of this zone, however, in the middle part of the McKenzie Member of the Mifflintown Formation. The siluricus Zone, based on the presence of Polygnathoides siluricus which was originally described from the Bainbridge Formation in Missouri, was identified indirectly by the local occurrence of Spathognathodus snajdri. This form was reported by Walliser from the snajdri Horizon of the upper siluricus Zone in Bohemia and by Rexroad and Craig (1971) from the Bainbridge Formation in Missouri. The latialatus Zone, based on the occurrence of Icriodus latialatus, was not positively identified. The newly described Spathognathodus tillmani Zone is tentatively correlated with Walliser's latialatus Zone, however, on the basis of the occurrence of S. primus multidentatus n. ssp. in the Appalachians. This latter form was illustrated by Walliser

(1964, Pl. 22, fig. 14) from the latialatus Zone. Correlations based on the S. primus Lineage are made cautiously, however, because of the earlier occurrence of this form in the Central Appalachians. Walliser reported the earliest occurrence of S. primus in the Cellon section as the siluricus Zone. In the central Appalachians, S. primus is present as low as the S. sagitta bohemicus Zone and it could range even lower.

The zones established by the writer (Table VIII) are considered to be concurrent range zones and have been named for distinctive species of the form genus Spathognathodus. The base of these concurrent range zones in all cases is taken as the first occurrence of the distinctive name giver. Overlap of the ranges of the zonal species is observed in several instances and this allows for even more precise stratigraphic correlation than the lone occurrence of a zonal indicator. Overlap of all zonal indicators was not observed. Lack of overlap is generally associated with intervals which show a considerable decrease in the total number of specimens and species recovered.

Definitions of Concurrent Range Zones

Spathognathodus sagitta bohemicus Zone.--This zone is recognized by the occurrence of Spathognathodus sagitta bohemicus, Spathognathodus walliseri n. sp., Ozarkodina aequalis, Ozarkodina edithae mariae n. ssp., and Neoprioniodus multiformis, all of which occur no higher than this zone. Spathognathodus walliseri n. sp. is relatively rare and ranges somewhat lower stratigraphically than Spathognathodus sagitta bohemicus through their ranges overlap. The base of this zone can not be defined since the faunas of the underlying lower hematitic member of the Mifflintown Formation and of the Rose Hill Formation are not known at present. The top of this zone is marked by the first occurrence of Spathognathodus bicornutus n. sp. and the local extinction of the named forms.

Stratigraphic horizon.--Cosner Gap Member of the Mifflintown Formation.

Spathognathodus bicornutus Zone.--This zone is recognized by the first occurrence of Spathognathodus bicornutus n. sp. in association with Ozarkodina ziegleri crassatoides n. ssp., O. tenuiramea, Ligonodina brevis n. sp., Lonchodina? greilingi, Synprioniodina lowryi n. sp., and Trichonodella inconstans. S. bicornutus n. sp. is restricted to the zone in the lower McKenzie. O. tenuiramea ranges on through the rest of the McKenzie Member. The other named forms all disappear locally with S. bicornutus n. sp., but reappear again in the Spathoganthodus tillmani Zone in the Wills Creek Formation. The upper limit of this zone is determined locally by the last appearance of Spathognathodus bicornutus n. sp. The disappearance of this zonal fauna is marked also by a decrease in abundance and variety of all conodonts recovered and a local abundance of Hormatoma sp., a high spired gastropod.

Stratigraphic horizon.--Lower third of McKenzie Member of Mifflintown Formation.

Unzoned interval.--Only long ranging forms are found in this interval in all sections studied, and these forms are generally limited in number. Examination of the Range Chart (Table VIII) suggests that there is not another fauna in this interval and that the S. snajdri Zone follows the S. bicornutus Zone directly with the boundary between the two occurring within the unzoned interval.

Stratigraphic horizon.--Middle third of McKenzie Member of Mifflintown Formation.

Spathognathodus snajdri Zone.--This zone is recognized by the occurrence of Spathognathodus snajdri, Ozarkodina serrata n. sp., Ligonodina n. sp., Plectospathodus n. sp., Synprioniodina n. sp., and Trichonodella n. sp. All the forms named appear first in this zone and are restricted to it. The species which characterize this zone disappear in the uppermost beds of the McKenzie Member of the Mifflintown Formation with the influx of sand heralding the deposition of the Williamsport Sandstone.

Stratigraphic horizon.--Upper third of the McKenzie Member of the Mifflintown Formation.

Spathognathodus tillmani Zone.--This zone is recognized by the occurrence of *Spathognathodus tillmani* in association with *S. primus multidentatus* n. ssp., *Ozarkodina sinuosa* n. sp., and *O. typica intermedia* n.ssp. The forms named make their first appearance in this zone and all extend into younger beds. This zone also marks the local reappearance of *Ligonodina brevis* n. sp., *Lonchodina? greilingi*, *Ozarkodina ziegleri crassatoides* n. ssp., *Synprioniodina lowryi* n. sp., and *Trichonodella inconstans*.

Stratigraphic horizon.--Lower Wills Creek Formation.

Spathognathodus crispus Zone.--This zone is recognized by the occurrence of *Spathognathodus crispus*, *Spathognathodus primus highlandensis* n. ssp., and *Ozarkodina ortuformis*. *Spathognathodus crispus* ranges through to the next higher zone in the upper Tonoloway and is found in the lowest samples containing *Spathognathodus steinhornensis eosteinhornensis*.

Stratigraphic horizon.--Upper Wills Creek Formation-lower Tonoloway Formation.

Spathognathodus steinhornensis eosteinhornensis Zone.--This zone is recognized by the first occurrence of *Spathognathodus steinhornensis eosteinhornensis*, *Ozarko-*

dina typica denckmanni, *Hindeodella priscilla*, and *Plecto-spathodus alternatus*. This fauna ranges into the overlying Keyser Limestone, and preliminary studies of the Keyser Limestone and the overlying New Creek Limestone indicate that the Gedinne form *Icriodus woschmidti* appears first in the uppermost beds of the Keyser Limestone or at the base of the New Creek Limestone. Several, if not all, of the zonal species listed extend into Devonian age beds.

Stratigraphic horizon.--Upper Tonoloway Formation-Keyser Limestone.

AGE OF THE CONODONT FAUNAS

Spathognathodus sagitta bohemicus which occurs in the Cosner Gap Member of the Mifflintown Formation is reported by Walliser (1964, p. 83) from his sagitta Zone in the vicinity of Prague, Czechoslovakia, where it is found in the lower part of the Monograptus nilssoni Zone of latest Wenlock-lower Ludlow age. Spathognathodus walliseri n. sp., also found in the Cosner Gap Member, is reported by Walliser (1964, p. 88, Pl. 22, fig. 8) from the sagitta Zone in the vicinity of Giessen, Germany. Walliser's sagitta Zone species Ozarkodina edithae is represented by Ozarkodina edithae mariae n. ssp. in the Cosner Gap Member. The total fauna of the Cosner Gap Member includes 20 species of conodonts, and 6 of these species are amongst the 12 species reported by Walliser from the sagitta Zone in Europe. The presence of Walliser's zonal species in the Cosner Gap Member, as well as its stratigraphic position in reference to the rest of the Wills Mountain fauna suggests its correlation with the European sagitta Zone of latest Wenlock-early Ludlow age.

Spathognathodus bicornutus n. sp., from the lower third of the McKenzie Member of the Mifflintown Formation, is reported by Walliser (1964, p. 91, 92; Pl. 32, figs. 2 and 27) from the sagitta Zone near Giessen. The position of this species over Spathognathodus sagitta bohemicus along the Wills Mountain anticline would indicate an early Ludlow age for the lower part of the McKenzie Member of the Mifflintown Formation.

The crassa and ploeckensis zones of Walliser were not identified by the writer, but they would fall in the lowest third and middle third of the McKenzie Member of the Mifflintown Formation by comparison with Walliser's zonal scheme.

Spathognathodus snajdri occurs in the upper third of the McKenzie Member of the Mifflintown Formation. Both Walliser (1964, p. 84) and Rexroad and Craig (1971, p. 700) reported this form in association with Polygnathoides siluricus, the zonal species of the siluricus Zone. In the European section this form was reported by Walliser from the uppermost beds of the siluricus Zone at Mušlovka, Czechoslovakia, below beds containing Monograptus ultimus and over beds containing Monograptus fritschi linearis (Walliser, 1964, p. 97-98). This indicates a middle to upper Ludlow age for the siluricus Zone and a similiar age for the upper third of the McKenzie Member of the Mifflintown Formation. Walliser (1964, p. 80-82) reported the first occurrence of Spathognathodus primus primus in the Cellon section from the siluricus Zone. Along the Wills Mountain anticline, this form occurs in the lowest beds sampled, i.e., with Spathognathodus sagitta bohemicus. The important form Kockelella variabilis, reported by Walliser (1964, p. 40) from the crassa through the siluricus zones, was not recovered along the Wills Mountain anticline.

Spathognathodus primus multidentatus n. ssp., which occurs in the lower Wills Creek Formation, is reported by Walliser (1964, Pl. 22, fig. 14) from the upper Ludlow latialatus Zone. Walliser's index fossil Icriodus latialatus was not recovered along the Wills Mountain anticline. The position of the form S. primus multidentatus n. ssp. over S. snajdri of the upper McKenzie Member of the Mifflintown Formation and below S. crispus of the upper Wills Creek-lower Tonoloway formations, however, does argue for the tentative correlation of the lower Wills Creek fauna with the latialatus Zone of upper Ludlow age.

Spathognathodus crispus, the index fossil of Walliser's crispus Zone, is found in the upper Wills Creek, the lower Tonoloway, and the lowest beds of the upper Tonoloway formations. Both on faunal evidence and stratigraphic position, this interval can be correlated with Walliser's crispus Zone which is interpreted as uppermost

Ludlow by Berry and Boucot (1970). Ozarkodina ortuformis, as identified by the writer, is associated with S. crispus along the Wills Mountain anticline. S. primus highlandensis n. ssp., from the same interval as S. crispus along the Wills Mountain anticline, is similar to forms of Spathognathodus primus (sensu latu) reported by Walliser (1964, Pl. 22, figs. 23 and 25) from the eosteinhornensis Zone in the Cellon section.

Spathognathodus steinhornensis eosteinhornensis and Ozarkodina typica denckmanni, both from the upper Tonoloway Formation, are reported from Walliser's eosteinhornensis Zone considered to be of Přídolí age by Berry and Boucot (1970, p. 37). Walliser (1964, p. 98) also reported the occurrence of S. steinhornensis eosteinhornensis from samples at Hvížďalk, Czechoslovakia, in association with Mongraptus bouceki and Monograptus transgradiens ($e\beta_2$). At this same section, the Gedinne form Icriodus woschmidti was found with Monograptus uniformis. At the Cellon section in Austria, Icriodus woschmidti was also found in the beds overlying the eosteinhornensis Zone. This is consistent with the interpretation of the eosteinhornensis Zone as being uppermost Silurian by Walliser or Pridoli in age according to Berry and Boucot (1970, p. 37). On the basis of preliminary studies of sequential samples through sections of the Keyser and New

Creek limestones along the Wills Mountain anticline, *Icriodus woschmidti* is known to occur in the upper few feet of the Keyser and the overlying New Creek limestones.

In interpreting the similarities noted for the conodont successions along the Wills Mountain anticline to that of Walliser's Cellon section in Europe, the reader should keep the following point in mind. The thickness of Walliser's Cellon section is a little more than 190 feet thick. This includes beds of upper Ashgill as well as Gedinne ages. In Highland County, Virginia, the combined thickness of the Mifflintown, Wills Creek, and Tonoloway formations is more than 570 feet and in the vicinity of Pinto in Allegany County, Maryland, this same interval is represented by approximately 1340 feet of strata. The considerable difference in the rate of sedimentation in the two areas as well as probable differences in depositional environment may account for the lack of important platform genera *Kockelella*, *Ancoradella*, and *Polygnathoides*, in the formations on Wills Mountain anticline.

REGIONAL CORRELATION OF SILURIAN UNITS OF THE CENTRAL APPALCHIANS

Mifflintown Formation

Lower hematitic member.--Only a few non-diagnostic conodonts were recovered from this unit at the Cosner Gap section in Mineral County, West Virginia. The unit lies directly on the Rose Hill Formation and the zonal ostracode *Mastigobolbina typus* was collected at the Crabbottom section in Highland County, Virginia, and at the Moyer Gap section in Pendleton County, West Virginia, in the upper few inches of the Rose Hill Formation. The upper part of the Rose Hill is the zone of *Mastigobolbina typus* and is also reported to contain the brachiopod *Eocoelia sulcata* (Berry and Boucot, 1970, p. 215-16) which is late Llandovery in age. The beds above the lower hematitic member also contain the ostracode *Paraechmina spinosa* and are interpreted as the lateral equivalent of the Keefer Sandstone and as a partial correlative of the New York Rochester Shale (Ulrich and Bassler, 1923, p. 353).

Cosner Gap Member.--The Cosner Gap Member contains (Tables III, IV, and VIII) the distinctive conodonts *Spathognathodus walliseri* n. sp., *S.*

sagitta bohemicus, and Ozarkodina edithae mariae n. ssp., forms which are found in the sagitta Zone of Walliser. Walliser's sagitta Zone is late Wenlock to earliest Ludlow in age (Walliser, 1964, p. 93-99). The Cosner Gap Member also contains the ostracodes Paraechmina spinosa and Drepanellina clarki. Paraechmina spinsoa and Drepanellina clarki have also been identified in New York State; however they have not been found together. In east-central New York where Drepanellina clarki has been found in the uppermost beds of the Herkimer Sandstone (Berdan and Zenger, 1965, p. C96-100) it is stratigraphically higher than Paraechmina spinosa. In the Niagara Gorge section of western New York, Paraechmina spinosa is found in all but the uppermost beds of the Rochester Formation, but Drepanellina clarki has not been found in this area. Rexroad and Rickard (1965, p. 1217-19) reported Spathognathodus sagitta ssp. indet. and Ozarkodina edithae ssp. indet. from the Niagara Gorge area. These forms were found in the top beds of the Rochester Shale, through the Gasport, DeCew, and the lower few feet of the Goat Island members of the Lockport Dolomite. On this basis the Cosner Gap Member is correlated with the Herkimer Sandstone in the vicinity of Clinton in east-central New York and with the Rochester Shale and the Gasport through the lowest Goat Island members of the Lockport Dolomite at Niagara Gorge in western New York.

Spathognathodus sagitta rhenanus was reported by Craig (1969, p. 1626) over the basal few feet of the St. Clair Limestone in the Batesville District of Arkansas. This report indicates a possible correlation of the Cosner Gap Member with at least part of the St. Clair Limestone.

McKenzie Member.--The McKenzie Member contains two distinctive faunas. These are found in the lower and upper parts and are separated by an interval which contains only long ranging forms. The lower fauna, found in the lower third of the unit contains the distinctive form Spathognathodus bicornutus n. sp. which is restricted to this horizon. The forms Ligonodina brevis n. sp., Ozarkodina ziegleri crassatoides n. ssp., Lonchodina? greilingi, Synprioniodina lowryi n. sp., and Trichonodella inconstans all make their first appearance in the lower McKenzie but all of these forms reappear at higher levels in the section studied. The middle beds of the McKenzie Member have not yielded any restricted forms that are useful in correlation.

A fauna similar to the one described for the lower McKenzie Member has not been reported elsewhere in North America so that no direct faunal correlations are possible at present. The occurrence of this fauna over beds containing *Spathognathodus sagitta* and under beds containing *Spathognathodus snajdri* indicates that these beds are correlative with the middle part of the New York Lockport Group.

The upper McKenzie fauna includes *Spathognathodus snajdri* which is restricted to the upper part of Walliser's *siluricus* Zone, the distinctive form *Ozarkodina serrata* n. sp. and the rare but distinctive forms *Plectospathodus?* n. sp., *Ligonodina* n. sp., *Synprioniodina* n. sp. and *Trichonodella* n. sp. All of these forms are restricted to the upper McKenzie.

Spathognathodus snajdri of Walliser's *siluricus* Zone has been reported by Rexroad and Craig (1971, p. 700) from the Bainbridge Formation along with *Polygnathoides siluricus*, by Rickard (Berry and Boucot, 1970, p. 179) from the Oak Orchard Member of the Lockport Group of New York, and by Rexroad (Berry and Boucot, 1970, p. 172) from the Kokomo Limestone Member of the Salina Formation of Indiana. Craig (1969) has reported a single specimen of *Polyganthoides siluricus* from the Lafferty Formation in Arkansas. The presence of species presently known only from the *siluricus* Zone in these units can tenatively be taken as a basis for their correlation in part or entirely with the upper McKenzie Member of the Mifflintown Formation. Lowenstam (Berry and Boucot, 1970, p. 173) reports what he believes to be pisocrinoids of pre-Ludlow age in the Lafferty Formation, and this presents a problem which will have to be resolved by further study of this unit since Polygnathoides siluricus is widely regarded as middle to upper Ludlow in age.

Wills Creek Formation

The Wills Creek contains two distinctive faunas, one which is restricted to the lower part of the unit, and the other which ranges through the upper Wills Creek and the lower part of the Tonoloway Formation. The lower fauna contains the distinctive forms Spathognathodus tillmani n. sp. and S. primus multidentatus n. ssp. as well as many long ranging forms which are listed on Tables V-VIII. The upper part of the unit and the lower part of the Tonoloway Formation contain the distinctive forms Spathognathodus crispus and S. primus highlandensis n. ssp.

These two faunas have not been reported in any previous studies of North American strata of Silurian age so that no correlation can be presently made with particular units on the basis of these forms. The presence of Walliser's zonal species S. crispus of the uppermost Ludlow age is interpreted to indicate that the Wills Creek is late Ludlow and not of late Ludlow to early Pridoli age as tentatively suggested by Berry and Boucot (1970, p. 257).

Tonoloway Formation

The lower Tonoloway contains forms similar to those in the upper Wills Creek and they indicate a late Ludlow age. The upper Tonoloway fauna contains forms indicative of Walliser's eosteinhornensis Zone. This fauna includes the forms Spathognathodus steinhornensis eosteinhornensis, Ozarkodina typica typica, Hindeodella priscilla, Plectospathodus alternatus, all of which appear initially in the upper half of the Tonoloway. These forms, which are interpreted as being of Pridoli age, continue on through the overlying Keyser Limestone, which is also interpreted as Pridoli in age, at least in part.

Legault (1968) described the fauna of the Stonehouse Formation of Arisaig, Nova Scotia which contains Spathognathodus steinhornensis eosteinhornensis, Ozarkodina typica denckmanni as well as other forms similar to those of the upper Tonoloway and the Keyser Formations. The occurrence of similar forms in the Tonoloway and the Stonehouse formations is interpreted to mean that the upper Tonoloway is correlative to part of the Stonehouse.

Regional correlations are summarized in Figure 7.

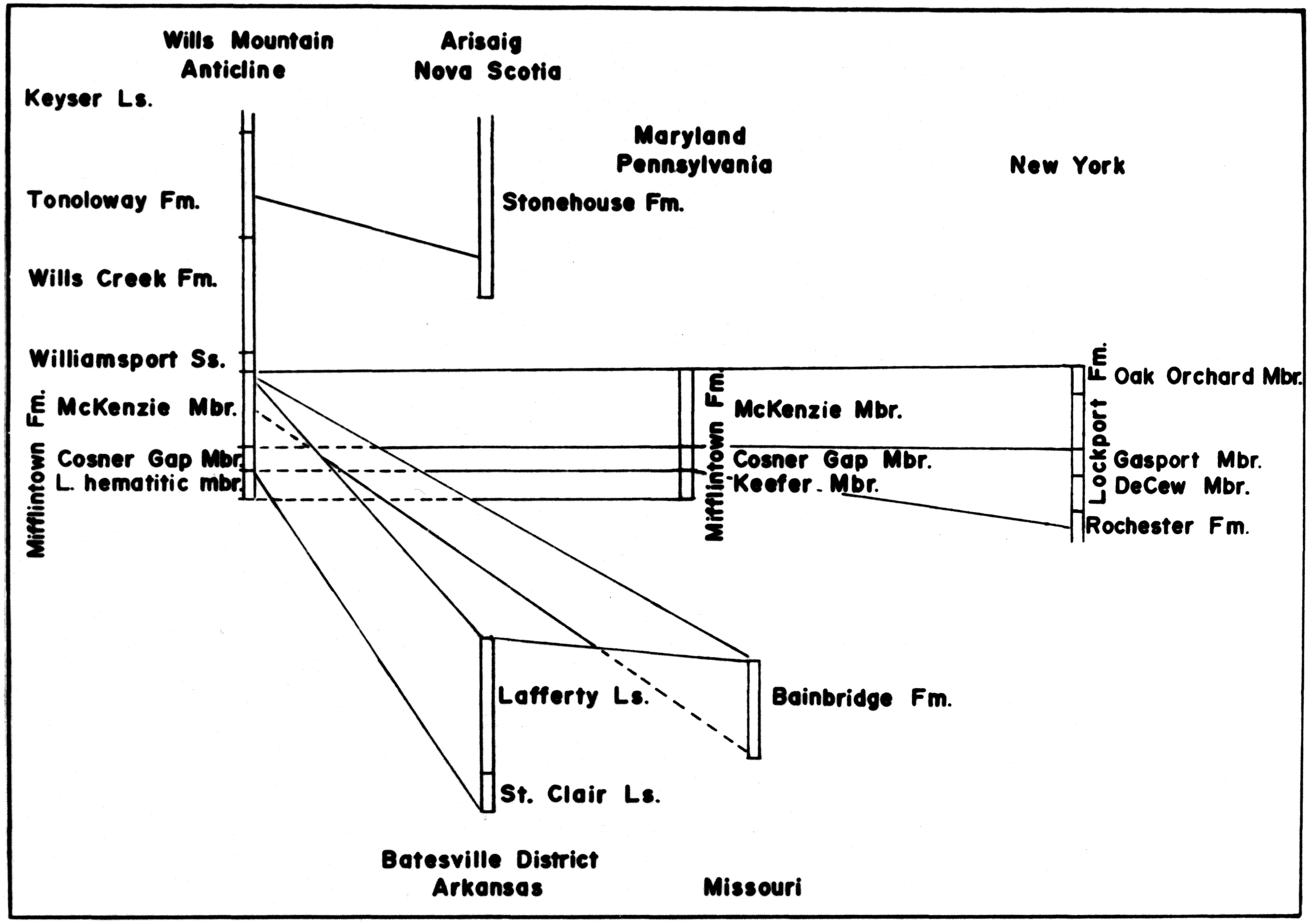


Figure 7—Regional correlation of North American rock units based on reported conodont faunas.

BIOLOGICAL INTERPRETATIONS

Form Lineage

The concept of the evolving organism is the basis of refinement of the geologic calendar. When working with a significantly long succession of strata, the paleontologist hopes to recognize a succession of changes in the fossil record. This succession is then broken into taxa which hopefully can be recognized over larger geographic areas and will allow geologists to make time-stratigraphic correlations between strata of different regions.

Several kinds of biostratigraphic variation can be observed in the fossil record. The most obvious involves drastic changes in the classes of organisms due to fluctuations in the environment of the depositional basin, and is linked very often to intrabasinal shifts in depositional patterns which favor organisms with different feeding habits. Variation in relative abundance of different species and abundance of individuals of particular species is also observed stratigraphically. This type of change is of limited use in correlation, and must be used carefully in conjunction with other evidence.

Relative abundance is not necessarily related to evolution of a fauna but may reflect local environmental conditions which allow temporal numerical dominance by selected groups of organisms in an existing community. The most useful changes that can be observed, however, involve continuous morphologic evolution within a limited taxonomic group through long periods of time.

In studying the succession of conodonts in the Mifflintown, Wills Creek, and Tonoloway formations, it has been possible to recognize two distinct lineages of form species which are assigned to the form genus Spathognathodus (Fig. 8). The placing of the spathognathodid elements in the respective form lineages is based on similarities of overall morphology, persistence in distinctive denticle patterns, shape of the basal excavation, and association of particular elements with various other elements in multi-element species.

The directness of the relationship of the various spathognathodid elements implied in the lineages is based on the degree of morphological similarity as well as a comparison of all of the elements associated with these spathognathodids in the respective multi-element species and on stratigraphic position.

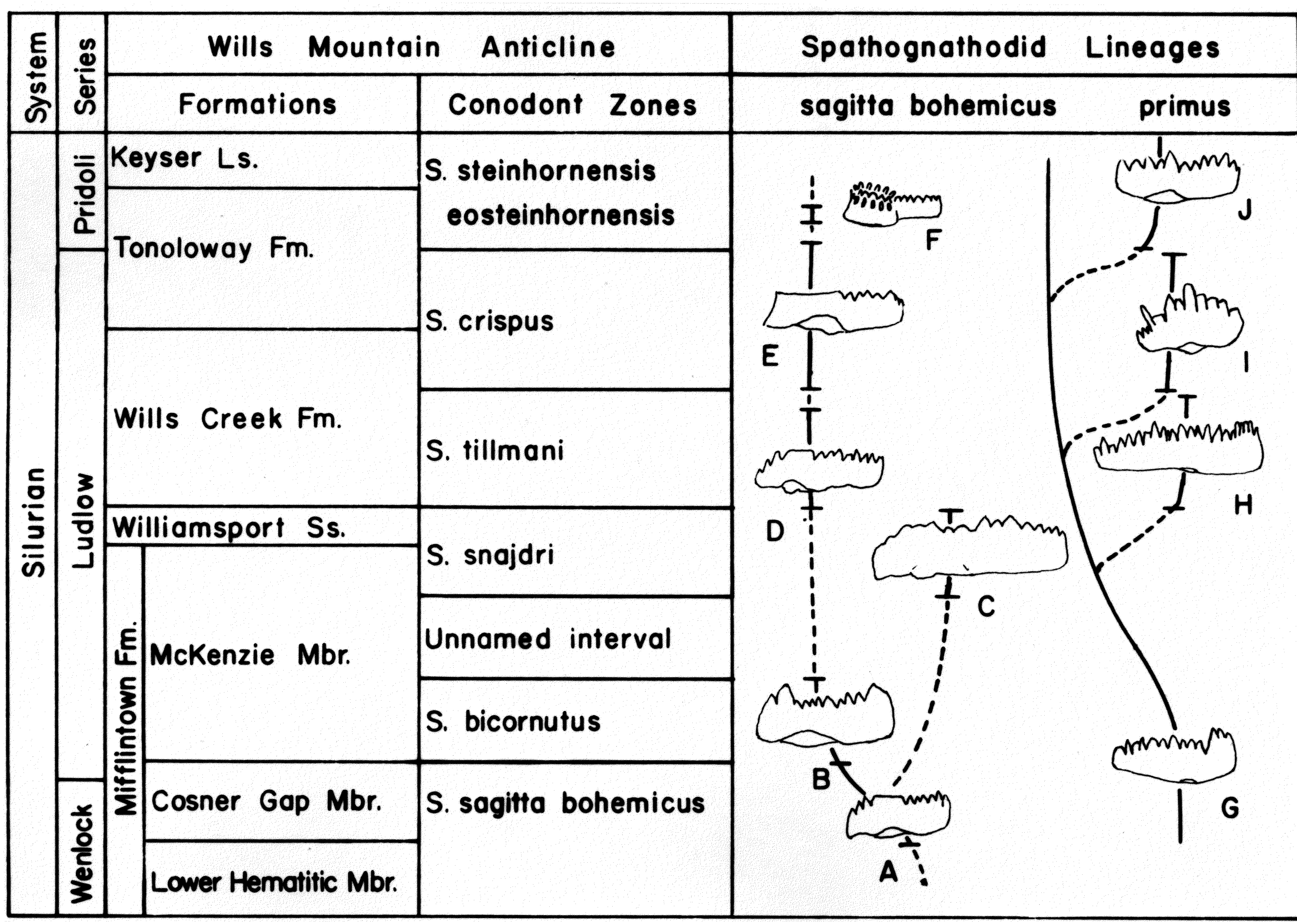
Spathognathodus primus Lineage.--The elements of this lineage include S. primus primus, S. primus multidentatus n. ssp., S. primus highlandensis n. ssp., and S. steinhornensis eosteinhornensis as illustrated in Figure 8.

All elements show a similarity in the shape, position, and size of the basal excavation which is medial to submedial with asymmetrical lateral lobes. A second morphological similarity of the members of this lineage is the tendency of the anteriormost denticles to stand higher than the rest of the blade denticles. In terms of multi-element species, all of the elements of this lineage are associated with various subspecies of Ozarkodina typica (Table I and II: Groups IV, VI, VII, IX, and XI).

Spathognathodus primus primus, the first form in this lineage is found in the Mifflintown Formation, and stratigraphically is at the base of this lineage. This form is associated with Ozarkodina typica typica. This association with O. typica typica is also reported by Jeppsson (1969, p. 15) and plays an important role in placing the elements in this lineage. (Table I, Group IV and VI).

Spathognathodus primus multidentatus n. ssp.,

Figure 8—Spathognathodus sagitta bohemicus and S. primus Lineage: A = S. sagitta bohemicus; B= S. bicornutus, n. sp.; C= S. snajdri; D= S. tillmani, n. sp.; E= S. crispus; F= N. gen. et n. sp.; G= S. primus primus; H= S. primus multidentatus, n. ssp.; I= S. primus highlandensis, n. ssp.; J= S. steinhornensis eosteinhornesis.


System
Series
Wills Mountain Anticline
Formations
Conodont Zones
Spathognathodid Lineages
sagitta bohemicus
primus
Silurian
Pridoli
Ludlow
Wenlock
Keyser Ls.
Tonoloway Fm.
Wills Creek Fm.
Williamsport Ss.
Mifflintown Fm.
McKenzie Mbr.
Cosner Gap Mbr.
Lower Hematitic Mbr.
S. steinhornensis eosteinhornensis
S. crispus
S. tillmani
S. snajdri
Unnamed interval
S. bicornutus
S. sagitta bohemicus
A
B
C
D
E
F
G
H
I
J

which occurs stratigraphically in the lower Wills Creek Formation, is placed in this lineage because of its overall resemblance to S. primus primus and its stratigraphic association with Ozarkodina typica intermedia n. ssp. (Table II, Group VII).

Spathognathodus primus highlandensis n. ssp. from the lower Wills Creek Formation shows little gross resemblance to mature specimens of S. primus primus. However, it shows similar position of the basal excavation, and the denticle pattern of S. primus highlandensis n. ssp. is similar to that of many small specimens of S. primus primus (Pl. 3, fig. 4) recovered from the Mifflintown Formation. S. primus highlandensis n. ssp. is associated with Ozarkodina typica intermedia n. ssp. (Table II, Group IX). Walliser (1964, Pl. 22, figs. 21-25) places specimens similar to S. primus highlandensis n. ssp. under the form species Spathognathodus primus (sensu lato). Walliser's specimens were recovered from his eosteinhornensis Zone.

Spathognathodus steinhornensis eosteinhornensis from the upper Tonoloway Formation and the Keyser Limestone has a slightly off-center basal excavation similar in position to that of S. primus primus, but differs in having the asymmetrical lateral lips developed into flaring lobes. S. steinhornensis eosteinhornensis is associated in a multi-element species with Ozarkodina typica denckmanni both by the writer (Table II, Group XI) and by Walliser (1964, p. 14). Rexroad and Craig (1971, p. 700) also report their general agreement with the idea of the evolution of S. steinhornensis eosteinhornensis from S. primus primus.

Spathognathodus sagitta bohemicus Lineage.--The elements in this lineage include S. sagitta bohemicus, S. bicornutus n. sp., S. snajdri, S. tillmani n. sp., and S. crispus. The form designated as N. gen. et n. sp. is tentatively placed in this lineage. The lineage is illustrated on Figure 8.

All the elements in this lineage have a basal excavation of similar form and position which, however, is observed to move posteriorly gradually on successive, stratigraphically younger species. All of the spathognathodid elements except S. bicornutus n. sp. also show a similar tendency toward fusion of the blade denticles over part or all of the basal excavation, becoming more pronounced on successive, stratigraphically younger species. The multi-element association of the species in this lineage is more varied than in the S. primus primus Lineage, but strong similarities are seen in nearly all of the elements associated with these spathognathodids. The multi-element associations are discussed under the section on proposed multi-element species and are listed on Tables I and II, Groups I, II, III, VII, and X.

Spathognathodus sagitta bohemicus which occurs in the Cosner Gap Member of the Mifflintown Formation is stratigraphically the oldest form in this lineage. It has a subquadrate basal excavation which is developed posteriorly of the middle of the blade and has several blade denticles over the basal excavation fused into a knife-like edge. The only form that could definitely be associated with this element is Ozarkodina edithae mariae n. ssp. (Table I, Group I). This ozarkodinid shows a marked tendency toward development of a completely excavated aboral surface and fusion of some of the anterior denticles into the cusp.

Spathoganthodus bicornutus n. sp. which occurs in the lower third of the McKenzie Member of the Mifflintown Formation is related in this lineage because of the similarity of its basal excavation to that of S. sagitta bohemicus. Small forms of S. bicornutus n. sp., prior to the development of the cusp-like distal denticles, show an overall gross similarity to S. sagitta bohemicus except for the lack of fusion of blade denticles over the basal excavation. S. bicornutus n. sp. is associated with Ozarkodina ziegleri crassatoides n. ssp. and other elements also found in association with the stratigraphically younger forms S. tillmani n. sp. and S. crispus. (Table I, Group II).

Spathognathodus snajdri from the upper third of the McKenzie Member of the Mifflintown Formation is placed in this lineage on the basis of the position and development of the basal excavation. This spathognathodid also shows partial fusion of the blade denticles over the basal excavation. It is associated with Ozarkodina serrata n. sp. which also has the aboral surface completely excavated and marked fusion of all blade denticles over the basal excavation. It is associated with Ozarkodina serrata n. sp. which also has the aboral surface completely excavated and marked fusion of all blade denticles (Table I, Group III).

Spathognathodus tillmani n. sp. from the lower Wills Creek Formation is placed in this lineage on the basis of its gross similarity to S. sagitta bohemicus from which it is distinguished by its slightly longer blade and its posteriorly shifted basal excavation. S. tillmani n. sp. is associated with forms not significantly different from those associated with *S. bicornutus* n. sp. (Table I, Group II, and Table II, Group VIII).

Spathognathodus crispus from the upper Wills Creek and lower Tonoloway formations is placed in this lineage on the basis of the development of its basal excavation and the fusion of the blade denticles over the basal excavation. It is associated with *Ozarkodina ortuformis* and other elements similar to those found with S. tillmani n. sp. and *S. bicornutus* n. sp. (Table II, Group X).

The form listed as N. gen et n. sp. from the upper Tonoloway Formation is tentatively placed in this lineage because of the gross similarity of the blade outline to that of *S. crispus* and the position of the basal excavation. The form N. gen. et n. sp. has a platform or parapet built up over the lateral lobes of the basal excavation. There is, however, no evidence of gradational forms between N. gen. et n. sp. and the other elements includes in the *Spathognathodus sagitta* lineage.

Multi-element Conodont species

Criteria for Recognition of Multi-element Conodont Species.--Klapper and Philip (1971) recounted the criteria used by various workers for the logical reconstruction of conodont apparatuses from collections of discrete form elements as follows:

"(1) Constant numerical ratios of constituent elements in collections numbered in hundred thousands;

"(2) Similarity of stratigraphic ranges of the elements;

"(3) Similarity or identity of size, denticulation, character of basal cavity, distribution of white matter, and other morphological features of the elements."

A fourth criterion can be added from Bergström and Sweet (1966) as follows: a survey of the literature and of reference collections to ascertain whether most faunas from other localities that contain one of the form elements of a multi-element group also contain the others.

Criteria Used in the Present Study.--In working with the Wills Mountain fauna, several associations of conodont elements were inferred. These associations were interpreted as representing multi-element species and are discussed presently under the heading, "Proposed Multi-element Conodont Species". The local ranges of these multi-element species, along with the number of individual elements recovered are listed in Tables I and II.

The proposed multi-element species were recognized primarily on the basis of consistent joint occurrences of the grouped elements through long stratigraphic sections.

Consistent joint occurrences of the grouped elements are taken to mean that the ranges and numbers of specimens of the elements are consistent with the idea that the form elements in biological apparatuses occurred in low, whole number multiples of one another. In the case of some form species, associations were indicated by the abrupt joint appearance and disappearance of a group of form elements resembling previously described conodont apparatuses. Associations of elements through intervals which gave low yields of conodonts were determined by consideration of the lineage of the spathognathodid elements in the fauna and by comparison of the associated fauna with established multi-element groups belonging to the same lineage. Relatively minor use was made of subjective criteria of similarity of growth and development.

Numbers of specimens per sample are noted as well as numbers of species per sample on Tables III-VII. This was done to check forconsistent joint occurrences of the elements considered as possible members of a group. This concern with numbers is due to the conclusion, based on published studies of conodont assemblages on bedding surfaces in black shales, that the various form elements in a multi-element conodont species occurred in low multiple, whole number ratios of one another.

In picking specimens for this study, considerable variation both in abundance of the various forms and size of the elements was noted from sample to sample. Considerable variation was also noted between actual abundances of forms and expected abundances based on probable ratios of form elements in known multi-element groups. The difference in size, form, and relative abundance of elements in various samples from the Wills Mountain belt is considered to be a function of hydrodynamic sorting. This interpretation is based on the observed presence of primary depositional features, cross-bedding, ripple marks, oölites, and shell hash, indicative of various degrees of sorting of the original sediments, as well as relative abundance data discussed below.

Three types of samples related to sorting were observed in this study. Type I samples contain relatively large numbers of various form species, both bars and blades, <u>of all sizes</u>. Sample CB-McK6C is of this type and is interpreted as being relatively unsorted. This sample yielded 520 specimens of all sizes distributed among 19 form species. 58 spathognathodid were counted in this sample. All six form elements associated in Group IV have been identified in sample CB-McK6C. Their abundances are as follows: <u>Spathognathodus primus primus</u>-44, <u>Ozarko-</u>

dina typica typica-35, Ligonodina "silurica"-116, Neo-prioniodus excavatus-46, Plectospathodus extensus-40, Trichonodella excavata-39. The expected ratios for elements in this type of apparatus probably are 2(4):2:4:2:2:1(2). The numbers in parentheses following the first and last numbers indicate uncertainty in the literature about those specific elements. The ratio based on the actual counts of elements in this sample is 1.13:0.89:2.97:1.17:1.02:1.0. The total count for these same elements for all samples from the Mifflintown Formation at Crabbottom (Table III) is: 446, 243, 866, 373, 312, and 361 for a ratio of 1.24:0.67:2.40:1.03:0.86:1.0.

Type II samples contain relatively large numbers of small conodonts with a wide range of forms which are sorted strongly by size but only moderately by form. Sample JG-16B which contained 248 small conodonts (Table VI) distributed among 15 form species is of this type. 72 spathognathodids were counted in this sample. The limited size of the specimens as well as the wide range of forms in this type of sample is interpreted as due to smaller differences in hydrodynamic lift between immature bar and blade forms. Rocks yielding Type II samples were limestones which contained a considerable fraction of fine-grained quartz (sand) or fine-grained calcareous sandstones with ripple-marked bedding surfaces. The six form elements associated in Group X (Table II) are found associated in Sample JG-16B. The abundances of these elements are as follows: Spathognathodus crispus-72, Ozarkodina ortuformis-23, Ligonodina brevis-60, Synprioniodina lowryi-11, Lonchodina? greilingi-28, Trichonodella inconstans-20. This gives an actual ratio of 3.6:1.15:3.0:0.55:1.4:1.0. This ratio still compares rather favorable with the presumed ratio of 2(4):2:4:2:2:1(2).

Type III samples contain relatively large numbers of moderate to large conodonts, which are strongly sorted by size and form. Sample KR-McK5, which yielded 787 conodonts (Table IV) distributed among only 9 form species is an example of this type sorting. A total of 558 elements in this sample were spathognathodids; bar-like forms were represented by only 229 specimens. Rocks yielding this type sample often contain a coarse fraction consisting of quartz grains, lithic fragments, oölites, and shell hash, and commonly show cross-bedding on weathered surfaces. Form and size sorting of this kind was interpreted as due to the larger effective hydrodynamic lift of the large spathognathodids in contrast to that of the large bar-like forms and smaller sized elements. The elements of Group II (Table I) occur in this sample in the following abundances: Spathognathodus bicornutus-536, Ozarkodina ziegleri crassatoides-101, Ligonodina brevis-34, Lonchodina? greilingi-24, Synprioniodina lowryi-55, Trichonodella inconstans-12. This gives a ratio that is completely meaningless. Even in such a sample, however, the co-occurring elements are taxonomically consistent with multi-element groupings obtained from less obviously sorted samples.

Proposed Multi-element Conodont Species

In the section that follows, there are a number of recurrent form species that are associated with different form species of Spathognathodus and Ozarkodina in successively higher strata. For example, Groups II, VIII, and X differ only in their spathognathodid and ozarkodinid elements. The spathognathodid elements associated with Groups II, VIII, and X are members of the Spathognathodus sagitta bohemicus lineage. Groups IV, VII, and IX have the same form genera and some identical form species of ligonodinid, neoprioniodid, plectospathodid, and trichonodellid elements associated with different forms of Spathognathodus and Ozarkodina in successively higher strata. The spathognathodid elements associated with groups IV, VII, and IX are members of the *Spathognathodus primus* lineage.

Group I:

Spathognathodus sagitta bohemicus

Ozarkodina edithae mariae n. ssp.

Evidence of association.--The elements in this group are considered to belong to a single multi-element species because of their consistent joint occurrence in the beds of the Cosner Gap Member of the Miflintown Formation, as well as their restriction to these beds. The association is similar to "Conodonten Apparat F" described by Walliser (1964, p. 14, 18) which includes the forms:

Spathognathodus sagitta

Ozarkodina edithae

Remarks.--By comparison with the other groups listed here and with the constituent elements of the multi-element genus *Hindeodella* Jeppsson (1969, p. 13-20) which include spathognathodid and ozarkodinid form elements, there are probably as many as four more elements which belong to this group still to be recognized. Other elements recovered from the Cosner Gap Member do not occur exclusively with these forms, that is, they range through older or younger beds, or do not occur in numbers that would warrant their inclusion in this group (Tables I, III, IV).

Occurrence.--Cosner Gap Member of Mifflintown Formation.

Group II:

Spathognathodus bicornutus n. sp.

Ozarkodina ziegleri crassatoides n. ssp.

Ligonodina brevis n. sp.

Lonchodina? greilingi

Synprioniodina lowryi n. sp.

Trichonodella inconstans

Evidence of association.--These elements are thought to belong to the same multi-element species for the following reasons. All of the elements associated in this group were recovered together in the lower part of the McKenzie Member of the Mifflintown Formation. They appear for the first time at this horizon. Also all of these elements disappear simultaneously locally in the McKenzie. The local range of the form element Spathognathodus bicornutus n. sp. is limited to the lower part of the McKenzie Member of the Mifflintown Formation. The other elements in the apparatus are then absent locally until the lower beds of the Wills Creek Formation where they all recur locally in association with other spathognathodid elements of the

Spathoganthodus sagitta lineage (Table II, Groups VIII and X).

Occurrence.--Lower third of McKenzie Member of Mifflintown Formation.

Group III:

Spathognathodus snajdri

Ozarkodina serrata n. sp.

Ligonodina n. sp.

Plectospathodus? n. sp.

Synprioniodina n. sp.

Trichonodella n. sp.

Evidence of association.--The elements in this group are all limited to the upper part of the McKenzie Member but are generally quite rare. These elements were first associated because they represent in the number and kind of form species present a group similar to multi-element apparatuses containing the form genera Spathognathodus and Ozarkodina which were described by Walliser (1964, p. 13-19) and by Jeppsson (1969, p. 13-21). In addition, the denticles of the individual form elements, except the spathognathodid, are strongly compressed laterally and have sharp edges in the plain of the blade.

Occurrence.--Upper third of McKenzie Member of Mifflintown Formation.

Group IV:

Spathognathodus primus primus

Ozarkodina typica typica

Ligonodina "silurica"

Plectospathodus extensus

Neoprioniodus extensus

Trichonodella excavata

Evidence of association.--The elements of this group from the Cosner Gap and McKenzie members of the Mifflintown Formation have been associated on the basis of consistent joint occurrences in approximately 100 samples from six different sections along the Wills Mountain anticline. The spathognathodid and ozarkodinid elements have a common characteristic in that they show a loss of mirror image symmetry due to one-sided flattening (see discussions under the respective genera and species under the heading "Systematic Paleontology"). The denticles of the four bar-like elements, i.e. ligonodonid, neoprioniodid, plectospathodid, and trichonodellid elements, are all discrete, evenly spaced, and similar in cross-section, outline, and curvature.

Remarks.--The form *Ozarkodina typica typica* is similar in range to the other elements in this group; on the basis of whole number ratios, however, its inclusion in preference to Ozarkodina tenuiramea is questionable. The form Ozarkodina tenuiramea, on the basis of range and whole number ratios, could be considered as part of this multi-element group. Ozarkodina tenuiramea has not been included in this group because it is not blade-like nor laterally flattened as is Spathognathodus primus primus. Both Walliser and Jeppsson considered an ozarkodinid similar to O. typica typica to be associated with such blade-like spathognathodid elements.

Walliser's "Conodonten Apparat H" as well as Jeppsson's multi-element species Hindeodella confluens and H. excavata include form elements similar to elements in Group IV. "Conodonten Apparat H" and Hindeodella excavata Jeppsson are identical and include the following forms:

Spathognathodus inclinatus
Ozarkodina media
Hindeodella equidentata
Plectospathodus extensus
Neoprioniodus excavatus
Trichonodella excavata

The taxonomically complex forms Spathognathodus inclinatus and Ozarkodina media of Walliser's "Conodonten Apparat H" and Jeppsson's multi-element species Hindeodella excavata were not positively identified in the writer's collection. Hindeodella equidentata, while present in the Wills Mountain material, occurs only in small numbers and cannot be associated with any multi-element group. Its functional analog is considered to be Ligonodina "silurica". The plectospathodid, neoprioniodid, and trichonodellid elements of "Conodonten Apparat H" are undoubtedly associated in individual samples in the Wills Mountain material and are placed in Group IV. The placing of Spathognathodus primus and Ozarkodina typica in Group IV is supported by their occurrence together in many samples of Wills Mountain material.

Hindeodella confluens Jeppsson includes the following forms:

Spathognathodus primus
Ozarkodina typica
Hindeodella confluens
Plectospathodus flexuosus
Synprioniodina bicurvata
Trichonodella symmetrica

The four elements grouped by Jeppsson in Hindeodella confluens, in addition to S. primus and O. typica, are found in the Appalachian material, but not in relative abundances that would justify their grouping with Spathognathodus *primus primus* and *Ozarkodina typica typica*. *Hindeodella confluens* Jeppsson 1969 is discussed further under Group VI.

Occurrence.--Cosner Gap and McKenzie members of Mifflintown Formation.

Group V:

Ozarkodina aequalis

Ozarkodina tenuiramea

Ozarkodina sinuosa n. sp.

Lonchodina walliseri

Evidence of association.--Group V actually represents three stratigraphic sub-groups in which the intergradational forms *Ozarkodina aequalis*, *O. tenuiramea*, and *O. sinuosa* n. sp. are successively found associated with *Lonchodina walliseri*. Because of the intergradational nature of these ozarkodinids, the writer has defined their ranges by assigning gradational forms to the range of the dominant species. *O. aequalis* dominates this series in the Cosner Gap Member, *O. tenuiramea* dominates in the McKenzie Member of the Mifflintown Formation, and *O. sinuosa* n. sp. dominates in the Wills Creek Formation. The range of the group is the same as the local range of the form *Lonchodina walliseri* which is associated in individual samples throughout with the successive members of this stratigraphically changing series of ozarkodinids.

Remarks.--The writer is uncertain whether this group might represent a natural grouping which is completely different in form and number of elements from the other groupings presented in this paper, and also, whether the taxonomically complex group Spathognathodus inclinatus and Ozarkodina media might represent a similar group rather than be associated as suggested by Walliser (1964) and by Jeppsson (1969).

Occurrence.--Mifflintown-Wills Creek formations.

Group VI:

Spathognathodus primus ssp. indet.
Ozarkodina typica ssp. indet.
Hindeodella confluens
Plectospathodus flexousus
Synprioniodina bicurvata
Trichonodella symmetrica

Evidence of association.--This group is similar to Jeppsson's multi-element species Hindeodella confluens. The hindeodella, plectospathodid, synprioniodinid, and trichonodellid elements in Group VI have been grouped on the basis of stratigraphic range (Tables I and II) and their similarly compressed blade and denticles. The relative abundances of these elements, 128, 110, 221, and 88 respectively, are consistent with their original occurrence in a single apparatus with the relationship between their numbers expressible in low, whole number multiples. No spathognathodid and ozarkodinid elements could definitely be assigned to this group using similar criteria. The species Spathognathodus primus and Ozarkodina typica are present in the same beds but subspecies of these which could definitely be identified by morpology, ratios, and range were not recognized by the writer. The species, Spathognathodus primus and Ozarkodina typica are listed as interdeterminant members of this group in accordance with Jeppsson's reconstruction. The hindeodellid (ligonodinid), plectospathodid, synprioniodinid, and trichonodellid elements of Groups IV and VI show varying degrees of intergradation with one another. The intergradation of these elements is interpreted as meaning that Group IV and Group VI are closely related biologically and that the spathognathodid and ozarkodinid elements are like-wise probably intergradational and unrecognized in the Appalachian material.

Occurrence.--Mifflintown-Wills Creek formations.

Group VII:

Spathognathodus primus multidentatus n. ssp.

Ozarkodina typica intermedia n. ssp.

Ligonodina "silurica"

Plectospathodus extensus

Neoprioniodus excavatus

Trichonodella excavata

Evidence of association.--Group VII is a direct biological descendant of Group IV and is distinguished from Group IV on the basis of the form of the included spathognathodid and ozarkodinid elements. The ligonodinid, plectospathodid, neoprioniodid, and trichonodellid elements all belong to the same form species as their counterparts in Group IV.

Occurrence.--Lower Wills Creek Formation.

Group VIII:

Spathognathodus tillmani n. sp.

Ozarkodina ziegleri crassatoides n. ssp.

Ligonodina brevis n. sp.

Lonchodina? greilingi

Synprioniodina lowryi n. sp.

Trichonodella inconstans

Evidence of association.--The elements in this group are rather sparse in the lower Wills Creek Formation and their association is based largely on a comparison with Group II and Group X which include the same form species of ligonodinid, lonchodinid, synprioniodid, and trichonodellid form elements as well as the distinctive spathognathodid element _S. tillmani_ of the writer's _Spathognathodus sagitta bohemicus_ lineage. The spathognathodid element of this group is the only element which has been distinguished as a stratigraphically recognizable form species.

Occurrence.--Lower Wills Creek Formation.

Group IX:

Spathognathodus primus highlandensis n. ssp.
Ozarkodina typica intermedia n. ssp.
Ligonodina "silurica"
Plectospathodus extensus
Neoprioniodus excavatus
Trichonodella excavata

Evidence of association.--The elements in Group IX are associated on the basis of similar range and by comparison with the related Groups IV and VII which also contain spathognathodid elements from the _Spathognathodus_ *primus* lineage.

Occurrence.--Upper Wills Creek Formation.

Group X:

Spathognathodus crispus

Ozarkodina ortuformis

Ligonodina brevis n. sp.

Lonchodina? greilingi

Synprioniodina lowryi n. sp.

Trichonodella inconstans

Evidence of association.--The elements in Group X are associated on the basis of similar stratigraphic occurrence and by comparison with Groups II and VIII which also contain spathognathodid elements from the *Spathognathodus sagitta bohemicus* lineage.

Occurrence.--Upper Wills Creek-lower Tonoloway formations.

Group XI:

Spathognathodus steinhornensis eosteinhornensis

Ozarkodina typica denckmanni

Hindeodella priscilla

Plectospathodus alternatus

Synprioniodina bicurvata

Trichonodella symmetrica

Evidence of association.--The elements in Group XI are associated on the basis of similar stratigraphic occurrence, and by comparison with Walliser's "Conodonten Apparat J" which includes the following elements:

Spathognathodus steinhornensis ssp.

Ozarkodina typica ssp.

Hindeodella priscilla

Plectospathodus flexuosus

Neoprioniodus bicurvatus = Synprioniodina bicurvata

Trichonodella symmetrica

The only significant difference between Walliser's proposed multi-element species and Group XI involves the plectospathodid element. The writer has associated Plectospathodus alternatus in Group XI, while Walliser included P. flexuosus in his multi-element species. Study of Walliser's detailed listing of the occurrences of forms by samples (1964, Tab. II, Teil II) shows that P. alternatus is similar in range and consistent in numbers with this group rather than P. flexuosus as listed by Walliser.

Occurrence.--Upper Tonoloway Formation-Keyser Limestone.

Symmetry Observations on the Form Genera *Ozarkodina* and *Spathognathodus*

Introduction.--H.R. Lane (1968) described four symmetry classes for conodont elements. Briefly, these classes are as follows:

Class I.--Unpaired or possibly paired bilaterally symmetrical elements; e.g., *Hibbardella* Bassler, *Trichonodella* (Branson and Mehl).

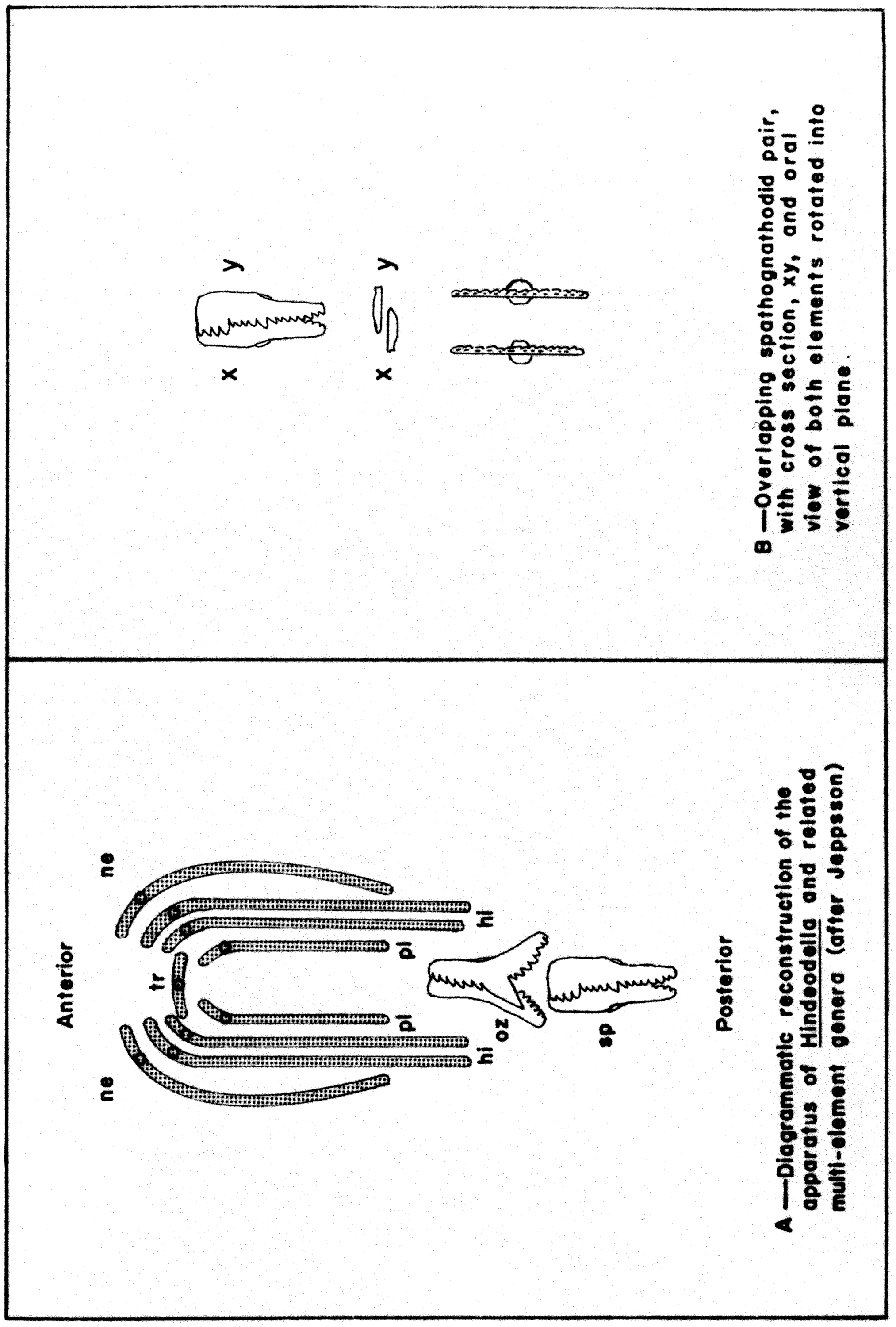
Class II.--Mirror image paired asymmetrical elements; e.g., *Ligonodina* Bassler. Most conodont elements belong in this class.

Class III.--Asymmetrically paired asymmetrical elements; e.g., all "double denticle row" species of the genus *Spathognathodus* (Branson and Mehl), as well as some "single denticle row" species of *Spathognathodus* (Branson and Mehl) and some species of *Ozarkodina* Branson and Mehl.

Class IV.--Unpaired asymmetrical elements; all species of *Cavusgnathus* Harris and Hollingsworth.

Observations.--Nearly all specimens of the forms *Spathognathodus primus primus*, *S. primus multidentatus* n. ssp., *Ozarkodina typica typica*, and *O. serrata* n. sp. in the writer's collection were observed to be flattened on one side. Further observation of these forms revealed that the lateral flattening of the element occurs without regard to lateral bowing of some specimens, and that all specimens of a form species were left-handed with regard to lateral flattening (Fig. 9).

Interpretation.--The asymmetric or left-handed flattening of these form species can be interpreted as a secondarily acquired or developed character that was imposed on their original mirror image symmetry. This interpretation is compatible with the hypothetical positioning of the ozarkodinid and spathognathodid elements in the original conodont apparatus (Fig. 9) as recently summarized by Jeppsson (1971). From the study of assemblages of conodont elements preserved on bedding planes of shales, it appears that the ozarkodinid and spathognathodid elements laid in successive pairs posteriorly of the other elements in the apparatus. The ozarkodinid and spathognathodid elements are also pictured as being rotated 90 degrees about their long axes so that their oral edges overlap. The existence of left-hand flattened single elements as well as oppositely bowed pairs is compatible with the rotated, overlapping position of these blade-like forms. Jeppsson considers the rotated position to be secondary. These elements were derived probably from elements that were oriented vertically in bilaterally symmetrical pairs. In the course



A —Diagrammatic reconstruction of the apparatus of <u>Hindeodella</u> and related multi-element genera (after Jeppsson)

B —Overlapping spathognathodid pair, with cross section, xy, and oral view of both elements rotated into vertical plane.

Figure 9— Position of spathognathodid elements in a multi-element reconstruction, and symmetry modification of elements in the rotated position.

of evolution of the conodont animal, these elements were rotated into a horizontal plane with the denticulated oral edges overlapping along the longitudinal axis of the apparatus. Once this rotated position was attained the flattening of the surfaces in contact could take place. When the element pair is observed with oral edges upward, both elements of the pair will be flattened on the left side. The left hand element, however, is convex to the left and the right hand element is convex to the right. Bilateral or mirror image symmetry (class II symmetry) has been lost by the pair. Secondary asymmetry (class III symmetry) has been acquired by the element pair in response to the new functional positioning of the elements in the apparatus.

The elements pairs in question could have been oppositely curved or straight in the ancestors before rotation. If the pair had been oppositely curved in the ancestors before rotation, the elements would now overlap perfectly, both being curved mutually in the same direction in the new position withoutany loss of this bilateral symmetry character. If the original element pair was not curved before rotation, but in response to the new orientation evolved a mutual curvature in the upward or downward direction, the element pair would now appear oppositely curved when viewed in the upright position.

Review of the Nomenclature of Multi-element Conodont Species

The naming of multi-element species of conodonts has been attempted by several people including Scott, Rhodes, Berström and Sweet, Jeppsson, Lindström, and Klapper and Philip. From the beginning two approaches have been taken by those who accepted the necessity of rejecting the pragmatic "form taxonomy" in favor of multi-element or "natural species taxonomy". The one approach has been to coin new names for the conodont assemblages or multi-element species while reducing the form names of the component elements to adjectival forms which can be used in description of new species. Scott (1942) and Rhodes (1952) took this view following extensive research on conodont assemblages in black shales. The other approach has been to apply the Law of Priority to the form names of the component elements in an assemblage to derive a name for the assemblage. Names of elements which did not have priority would be placed in synonymy with the name having priority. This second approach has been taken with notable success by Berström and Sweet (1966) and Webers

(1966) who used logical methods to group discrete conodont elements from acid residues into multi-element species. Jeppsson (1969) and Klapper and Philip (1971) used similar logical methods to derive multi-element genera. These latter papers stress the homologizing of the myriad of form elements and have opened the way for the recognition of suprageneric groupings that in some way approach a truely biological grouping.

While the taxonomic climate favors the transition to multi-element taxonomy at present, the mechanics of the transition are still very formative. The nomenclatorial problems revolve around the appropriateness of form names for the newly described multi-element species. Jeppsson (1969) described two genera of upper Silurian multi-element conodont species. Both of these, Hindeodella and Ligonodina, have been placed in synonymy by Lindström (1971) and Klapper and Philip (1971). Lindström and Klapper and Philip agree on the existing form name Ozarkodina to replace Hindeodella proposed by Jeppsson. Klapper and Philip have proposed the new genus Delotaxis to replace Ligonodina Bassler as revised by Jeppsson.

The problem with generic names, however, is not really difficult since these names fit a form or class of apparatus rather than a specific apparatus. The problem of priority is greatest with the specific names that have been applied to individual elements, and is summed up by Klapper and Philip (1971, p. 440) in their discussion of the position ofthe specific name denckmanni in the multi-element taxonomy. Although this name was employed by Ziegler in 1956 for a species of the form genus Ozarkodina and although it clearly has priority over the other elements with which they have associated this form, the name is judged a nomen dubium. Forms reported as O. denckmanni are considered natural assicates with three different platform genera, Spathognathodus, Eognathodus, and Polygnathodus in three different multi-element genera, and they judge it unlikely that it will ever be possible to decide with which of these multi-element genera the form type of Ozarkodina denckmanni is associated. To some extent it is possible to make the same judgement about nearly every species name which has been applied to form elements.

Nomenclatorial Review of Groups IV and II

Group IV includes the form elements, Spathognathodus primus primus, Ozarkodina typica typica, Ligonodina "silurica", Neoprioniodus excavatus, Trichonodella excavata, all of which were named by Branson and Mehl in their 1933 paper on the Bainbridge Formation, as well as Plectospathodus _extensus_ Rhodes 1952 from the Amystry Limestone in Great Britain.

Following Rhodes' statement (1962, p. W79) that the "generic identity between discrete conodonts and natural assemblages can only be recognized if the type species of the discrete genus is present in an assemblage of the genus" only two form names compete for the generic name for Group IV. Both the type species of _Ozarkodina_ and _Spathognathodus_ are present in the proposed grouping. Both of these genera were described by Branson and Mehl (1933), however _Ozarkodina_ has priority over _Spathognathodus_ which was proposed by Branson and Mehl (1942) for _Spathodus_ 1933. The names that are available for the specific name include _primus_, _typica_, _silurica_, _excavata_, _excavatus_, all used by Branson and Mehl (1933) and _extensus_ used by Rhodes (1952). The name _primus_ has page priority and is also acceptable from the standpoint that this important _name_ would be preserved in the new taxonomy of multi-element species. Thus the valid name for Group IV would be _Ozarkodina prima_. All of the proposed multi-element groups except Group V would similarly be placed in the multi-element genus _Ozarkodina_. Group V represents a different type of apparatus and its composition and multi-element affinities are not certain.

Group II includes the form elements, Spathognathodus bicornutus n. sp., Ozarkodina ziegleri crassatoides n. sp., Ligonodina brevis n. sp., Lonchodina? greilingi, Synprioniodina lowryi n. sp., and Trichonodella inconstans n. sp. This group belongs to Ozarkodina, the same multi-element genus as Group IV. The species names greilingi, inconstans, and ziegleri were introduced by Walliser in the same paper in 1957. These names should have priority, and by page priority the name greilingi should have precedence over ziegleri and inconstans as the species name for Group II. A problem arises in that the form elements O. ziegleri crassatoides, L. brevis, L.? greilingi, S. lowryi, and T. inconstans are also recognized as constituent elements of Group VIII and all except O. ziegleri crassatoides are recognized as constituent elements of Group X. The problem here can be resolved in either of two ways. The name greilingi can be applied as a species name to the group and the unique specific name in the group, bicornutus, can be applied as a subspecies making Ozarkodina greilingi bicornutus the multi-element name of Group II. In preference to this, the specific name of the form element which is unique to this group can be used as the specific name of the group making Ozarkodina bicornutus the name of Group II.

The author has refrained from using biological names for the groups proposed in this paper in the belief that the composition of the proposed multi-element groups is still open to study and that present application of names would only necessitate future revisions.

SYSTEMATIC PALEONTOLOGY

Introduction

Only form species are described in the following section. The interpretation of form, however, has been modified by the realization that discrete form species of conodonts are parts of a multi-element apparatus. The writer has assumed wide morphologic variation in the interpretation of the form species found in a given sample, and has also accepted wide variation for some form species through time. Such variation is recorded in the remarks following the description of these forms.

Where a form lineage has been definitely spelled out by previous workers through the use of form subspecies, the writer has followed the original worker's interpretation unless there was compelling evidence to the contrary. Thus the writer has followed Walliser's interpretations of the forms *Ozarkodina typica* and *Spathognathodus primus* and has named new subspecies of these forms. However, the writer has also given species rank to two of Walliser's subspecies of the form *Ozarkodina ziegleri*. This later change was made when it was realized that the two subspecies did not fit into a multi-element group similar to that including _Ozarkodina ziegleri ziegleri_ (Walliser, 1964, p. 14).

In the case of the _Spathognathodus sagitta bohemicus_ lineage described by the writer, species designations have been given to the various forms included. This was done to distinguish them clearly from the geographic form subspecies described by Walliser for _Spathognathodus sagitta_.

Repository.--All figured specimens in the writer's collection have been assigned individual museum numbers. These are listed under the heading, _Repository_, following the taxonomy of each individual form species.

The bulk of the specimens in the collection have been catalogued in the following manner:

Each productive bulk sample has been assigned a museum number. These numbers are listed on Tables III to VII.

Each species described has been assigned an index letter. These species indices are as follows:

Species index	Form species
A	_Hindeodella confluens_
B	_Hindeodella equidentata_
C	_Hindeodella priscilla_
D	_Ligonodina brevis_ n. sp.

E	Ligonodina "silurica"
F	Ligonodina n. sp.
G	Lonchodina detorta
H	Lonchodina walliseri
I	Lonchodina? greilingi
J	Neoprioniodus excavatus
K	Neoprioniodus multiformis
L	Ozarkodina aequalis
M	Ozarkodina edithae mariae n. ssp.
N	Ozarkodina ortuformis
O	Ozarkodina serrata n. sp.
P	Ozarkodina sinuosa n. sp.
Q	Ozarkodina tenuiramea
R	Ozarkodina typica denckmanni
S	Ozarkodina typica intermedia n. ssp.
T	Ozarkodina typica typica
U	Ozarkodina ziegleri crassatoides
V	Panderodus simplex
W	Plectospathodus alternatus
X	Plectospathodus extensus
Y	Plectospathodus flexuosus
Z	Plectospathodus? n. sp.
AA	Spathognathodus bicornutus n. sp.

BB	*Spathognathodus crispus*
CC	*Spathognathodus primus highlandensis* n. ssp.
DD	*Spathognathodus primus multidentatus* n. ssp.
EE	*Spathognathodus primus primus*
FF	*Spathognathodus sagitta bohemicus*
GG	*Spathognathodus snajdri*
HH	*Spathognathodus steinhornensis eosteinhornensis*
II	*Spathognathodus tillmani* n. sp.
JJ	*Spathognathodus walliseri* n. sp.
KK	*Spathognathodus* sp.
LL	*Synprioniodina bicurvata*
MM	*Synprioniodina lowryi* n. sp.
NN	*Synprioniodina* n. sp.
OO	*Synprioniodina* sp.
PP	*Trichonodella excavata*
QQ	*Trichonodella inconstans*
RR	*Trichonodella symmetrica*
SS	*Trichonodella* n. sp.
TT	*Trichonodella* sp.
UU	Gen. et sp. indet A
VV	Gen. et sp. indet B
WW	Gen. et sp. indet C

XX Nov. gen. et n. sp.

Specimens in the bulk collection are catalogued by the bulk sample museum number and the index letter assigned to the particular species. For example, all unfigured specimens of Spathognathodus primus primus from sample CB-McK6C (Table III) are deposited on the slide bearing the designation VPIL-1314EE.

All specimens are deposited in the paleontological collection of the Department of Geological Sciencesof the Virginia Polytechnic Institute and State University.

GENUS HINDEODELLA Bassler, 1925

Hindeodella Bassler, 1925, p. 219; Ulrich and Bassler, 1926, p. 38-39; Huddle, 1968, p. 15.

Type species.--*Hindeodella subtilis* Bassler, 1925.

Remarks.--Specimens of the form genus *Hindeodella* from the upper Devonian are typified by denticles of alternating size on the posterior blade. This characteristic, however, is lacking in some Silurian forms, for example, *Hindeodella equidentata*. Silurian conodonts assigned to the form genus *Hindeodella* are not always clearly distinguishable from specimens assigned to the form genus *Ligonodina*. Furthermore the transition of plectospathodid elements such as *Plectospathodus alternatus* into *Hindeodella* like forms has been observed in upper Silurian f..unas. This feature of late Silurian plectospathodid elements has been referred to by Jeppsson (1971) as hindeodellization.

HINDEODELLA CONFLUENS Branson & Mehl

Pl. 5, figs. 5,9-11,21,23,25,26; Pl. 15, fig. 7

Hindeodella confluens Branson & Mehl, 1933, p. 45-6, Pl. 3, figs. 21-23; Rexroad & Craig, 1971, p. 690, Pl. 79, figs. 21-23.

Lectotype.--*Hindeodella confluens* Branson & Mehl , 1933, Pl. 3, fig. 23; as designated by Rexroad & Craig (1971).

Diagnosis.--A species of *Hindeodella* with strongly compressed blade and denticles, with antero-lateral blade one-third to one-half as long as posterior blade. Oral margin of posterior blade twisted outward distally.

Oral view.--Entire unit strongly compressed. Posterior blade straight, twisted along axis with oral margin deflected outward distally. Antero-lateral blade straight and bent abruptly inward, or continuously curved inward as much as 45 degrees. Flexure of blade occurs at anterior edge of cusp or as far back as mid-point of cusp in which case the anterior edge of the cusp is sharply flexed inward along its whole length.

Aboral view.--Basal excavation a deep, elongate groove under cusp, constricted anteriorly and posteriorly to narrow, shallow groove continuing toward both ends of blade.

Inner lateral view.--Posterior blade deep, straight or gently arched. Antero-lateral blade straight or slightly curved, bent donward as much as 45 degrees from horizonatal.

Cusp weakly biconvex in cross-section, with sharp anterior and posterior edges; cusp as broad in plane of blade as blade is deep, slightly inclined to posterior. Anterior edge of cusp twisted or folded inward in position of flexure of the antero-lateral blade.

Posterior blade denticles, 7 to 12 in number, weakly biconvex in cross-section, with sharp anterior and posterior edges, partially fused. Blade denticles increasingly inclined posteriorly to as much as 45 degrees at end of blade. Base of denticles lengthened in posterior direction with increasing posterior inclination.

Denticles of antero-lateral blade, 3 to 9 in number, erect, unequal in size, broadest in medial part of blade, partially fused, with sharp edges in plane of blade, height as great as two-thirds height of cusp.

Occurrence.--Cosner Gap Member of Mifflintown-middle Tonoloway formations.

Material studied.--Approximately 150 specimens.

Repository.--Figured specimens, VPIL 900-908.

HINDEODELLA EQUIDENTATA Rhodes

Pl. 10, figs. 16, 22; Pl. 15, fig. 2; Pl. 16, fig. 27

Hindeodella equidentata Rhodes, 1953, p. 303, Pl. 23, figs. 248, 252-254; Walliser, 1957, p. 34, Pl. 2, fig. 23; Ziegler, 1960, p. 182-183, Pl. 15, fig. 10; Spasov & Veselinović, (1962) 1963, p. 244; Pl. 2, figs. 10, 11; Serpagli & Greco, 1964, p. 200-201, Pl. 37, fig. 7; Walliser, 1964, p. 36, Pl. 8, fig. 3; Pl. 32, fig. 11; Philip, 1965, p. 102, Pl. 8, fig. 11; Philip, 1966, p. 445, Pl. 3, fig. 1; Mashkova, 1970, p. 212-213; Pl. 5, fig. 7.

Hindeodella cf. *H. equidentata* Rhodes. Walliser, 1960, p. 182-183, Pl. 15, fig. 10.

Holotype.--*Hindeodella equidentata* Rhodes, 1953, Pl. 23, figs. 248, 253, 254.

Remarks.--Material from the Appalachians is comparable in every respect to the material described by Rhodes (1953) from the Aymestry Limestone in Great Britain. Complete specimens bear 12 to 14 denticles on the posterior blade. The material studied suggests a close relationship to *Ligonodina* "*silurica*". The writer has specimens of *L.* "*silurica*" which show denticle development intergradational with *H. equidentata*.

Occurrence.--Cosner Gap Member of Mifflintown-Wills Creek formations.

Material studied.--Approximately 120 specimens.

Repository.--Figured specimens, VPIL 909-912.

HINDEODELLA PRISCILLA Stauffer

Pl. 14, figs. 8, 13, 16.

Hindeodella priscilla Stauffer, 1938, p. 429, Pl. 50, fig. 6; Walliser, 1964, p. 36, Pl. 9, fig. 12; Pl. 32, figs. 12, 13; Philip, 1965, p. 102, Pl. 8, figs. 13, 14, 24, 25; Philip, 1966, p. 445, Pl. 3, figs. 2, 6-9, 11, 18.

Hindeodella n. sp. Walliser, 1960, p. 30, Pl. 8, fig. 6; Ziegler, 1960, p. 183, Pl. 15, figs. 3, 4.

Holotype.--*Hindeodella priscilla* Stauffer, 1938, Pl. 50, fig. 6.

Remarks.--No complete specimens were recovered, but numerous fragments show good agreement with *Hindeodella priscilla*. Fragments of mature specimens indicate that the element undergoes considerable ontogenetic change; the blade becomes bar-like and the denticles become discrete with increasing size.

Occurrence.--Upper Tonoloway Formation.

Material studied.--Approximately 50 specimens.

Repository.--Figured specimens, VPIL 913-915.

GENUS LIGONODINA Bassler, 1925

Ligonodina Bassler, 1925, p. 218; Ulrich & Bassler, 1926, p. 12-13; Huddle, 1968, p. 15.

Type species.--Ligonodina pectinata Bassler, 1925.

Remarks.--Like Hindeodella, this form genus ranges from middle Ordovician to middle Triassic and is a common element in many apparatuses with highly evolved auxilliary elements. Like Hindeodella, variation of this form genus is poorly understood because of the fragmentalnature of most specimens obtained from acid residues. The form genus is characterized by a large cusp, a denticulated posterior bar, and a denticulated downward extension from the main cusp or an anticusp as redefined by Huddle (1968).

An anticusp is defined as a "downward projection of main cusp" (Hass in Moore, 1962, p. W6).

In the strict terms of this definition, it is questionable whether many Silurian forms assigned to the form genus Ligonodina are properly assigned. It seems that the strict use of anticusp in identifying the form genus Ligonodina has been tacitly overlooked. Ethington and Furnish (1962, p. 1268) distinguished forms as Ligonodina or Hindeodella on the basis of the development of the antero-lateral process. If the antero-lateral process branches laterally and aborally from the cusp, the form is assigned to Ligonodina; and, if the antero-lateral process is produced by bending and twisting of the anterior bar, the form is assigned to Hindeodella.

Some authors, however, have assigned the form name Ligonodina to specimens which have the antero-lateral process turned inward and downward sharply, regardless of whether it branches laterally and aborally from the cusp or anterior to the cusp. An example of this is Ligonodina salopia Rhodes (1958, Pl. 23, figs. 245, 257, 260). These figures specimens clearly show the bending of the antero-lateral process well in advance of the cusp, and they have been placed by various authors, including Ethington and Furnish (1962, p. 1272), in synonymy with Ligonodina "silurica."

The writer has followed Rhodes (1953), Walliser (1964), and Rexroad and Craig (1971) in assigning such specimens to the form genus Ligonodina. Reexamination of the form genera Ligonodina and Hindeodella is warranted in view of the observations made by Jeppsson (1971) on the spatial arrangement of elements in the conodont apparatus.

It is generally accepted that at least two pairs of ligonodinid elements are part of the conodont apparatus on the basis of assemblages found in shales and of the ratios of elements found in acid residues. These elements (hi elements in Figure 9) occur in right- and left-handed symmetry pairs and are visualized by Jeppsson as being arranged in nested lateral pairs, bounding a single medial trichonodellid and a pair of plectospathodid elements. On the basis of measurements of specimens of Ligonodina elegans, Jeppsson reports that the outer and inner element of the right- and left-handed groups are distinguishable. The distinction is based on the slight posteriorward shift of the denticles on the outer element so that the denticles of the posterior bars of the nested pair of elements of the apparatus are positioned opposite one another. This is taken to mean that Jeppsson is reporting that ligonodinid elements of the same apparatus can occur in two morphologically distinct varieties. Alignment of the denticles of the posterior bars of a nested pair of elements could also be produced if the flexure of the anterior bar of the outer pair moved anteriorly. Variations similar to this seem to occur in Ligonodina "silurica" of the writer's collection.

Jeppsson's observation does alert us to the possbility that the position and mode of development of the flexure of the antero-lateral process may not be adequate criteria for distinguishing the two form genera *Hindeodella* and *Ligonodina*, but simply the means of distinguishing the inner and outer members of the right and left handed pairs of the form elements in a single apparatus. Jeppsson also states that the hindeodelliform and ligonodiniform elements fill homologous functions in the conodont apparatus.

LIGONODINA BREVIS n. sp.

Pl. 10, figs. 1, 4, 6-9, 12, 15; Pl. 15, figs. 6, 10, 11.

Holotype.--Pl. 10, fig. 12.

Diagnosis.--A species of *Ligonodina* with both posterior bar and antero-lateral process short and of nearly equal length.

Oral view.--Posterior bar straight, short, only slightly longer than cusp. Antero-lateral process bowed inward from anterior of cusp at angle of 45 to 90 degrees with line of development of bar. Bar widest at cusp, gradually tapering distally.

Aboral view.--Basal excavation deepest under cusp, continuing to ends of posterior bar and antero-lateral process as tapering V-shaped trough.

Inner lateral view.--Posterior bar gently arched. Antero-lateral process with nearly straight or continuously curved aboral margin, curved downward 45 to 90 degrees from horizontal. Lateral faces of bar and antero-lateral process flattened to convex.

Cusp subcircular to subqradrate near base, compressed distally with sharp edges on outer posterior and inner anterior margins, gently curved posteriorly between 10 and 30 degrees.

Denticles of posterior bar, 5 to 6 in number, circular to ovate in cross section, separated from one another about width of smallest denticle, increasing in size posteriorly. Bar denticles increasingly inclined posteriorly toward end of bar with base elongated in direction of inclination.

Antero-lateral process denticles, 5 to 7 in number, circular to ovate in cross-section, separated from one another as much as width of 2 denticles, smallest adjacent to cusp and distally, all denticles gently curved posteriorly.

Remarks.--Small specimens from the Wills Creek and lowest Tonoloway formations have widely separated denticles and generally 1 or 2 fewer denticles on the posterior bar and the antero-lateral process than specimens from the McKenzie Member of the Mifflintown Formation.

The cusp in these forms is inclined posteriorly 30 degrees or more. These forms may represent a distinct phyletic subspecies or juvenile specimens of Ligonodina brevis n. sp.

Occurrence.--McKenzie Member of Mifflintown-lowest Wills Creek formations.

Material studied.--Approximately 200 specimens.

Repository.--Holotype, VPIL 922, paratypes, VPIL 916-921, 923-926.

LIGONODINA "SILURICA" Branson & Mehl

Pl. 10, figs. 2, 3, 5, 10, 13, 19, 21, 23;

Pl. 15, figs. 15, 17, 19-22.

Ligonodina silurica Branson& Mehl, 1933, p. 48, Pl. 3, figs. 18-20; Walliser, 1957, p. 38, Pl. 2, fig. 10; Reichstein, 1962, p. 538, Pl. 1, fig. 2; Spasov & Veselinović, (1962) 1963, p. 244, Pl. 1, fig. 5; Philip, 1969, p. 291, Pl. 18, figs. 4, 7, 8; Mashkova, 1970, p. 214, Pl. IV, fig. 16, Pl. 6, figs. 2, 6, Pl. 8, figs. 2, 4, 8; Text-fig. 1, fig. 5.

Ligonodina kentuckyensis Branson & Branson, 1947, p. 555, Pl. 82, figs. 28, 35; Rexroad, 1967, p. 35-36, Pl. 2, fig. 5; Pollock, Rexroad, & Nicoll, 1970, p. 755, Pl. 114, figs. 9, 10.

Ligonodina ingens Walliser, 1957, p. 37, Pl. 2, fig. 20.

Ligonodina n. sp. A, Rexroad and Craig, 1971, p. 691, Pl. 79, figs. 18-20.

Lectotype.--*Ligonodina silurica* Branson & Mehl, 1933, Pl. 3, fig. 18, as designed by Walliser, 1957.

Diagnosis.--A species of *Ligonodina* Bassler with long, gently arched posterior bar, long recurved cusp, and inwardly and downwardly curved, denticulate antero-lateral process. Denticles of posterior bar increases in size and posterior inclination toward the end of the bar.

Oral view.--Posterior bar long, straight or gently bowed outward, occasionally twisted along its axis with oral surface turned outward. Bar tapers gradually toward posterior end. Antero-lateral process turned inward sharply at anterior edge of cusp or slightly in front of cusp making an angle of 45 to 90 degrees with the longitudinal axis of the posterior bar.

Aboral view.--Basal excavation deepest under cusp, as wide as bar, and continuous under posterior bar and antero-lateral process as broad shallow V-shaped trough.

Postero-lateral view.--Posterior bar straight to gently arched, with flat or gently convex lateral faces.

Antero-lateral process curved downward 45 to 90 degrees, slightly twisted distally.

Cusp, stout, inclined or curved posteriorly 20 to 45 degrees, subquadrate to ovate in cross section at base becoming sub-circular distally, compressed laterally, with anterior edge frequently twisted distally in direction of antero-lateral process. Posterior edge of cusp occasionally flattened at base or with shallow depression extending vertically about one-fifth length of cusp.

Posterior bar denticles, 8 to 12 in number, circular to ovate. One to two needle-like denticles immediately posterior to cusp, then denticles gradually increase in size and become increasingly inclined posteriorly to a maximum of 45 degrees toward end of blade. Denticles uniformly to irregularly separated about width of 1 or 2 of the smallest denticles. Base of distal 4 or 5 denticles increasingly lengthened in the direction of inclination of the denticles.

Denticles of antero-lateral process, 4 to 7 in number, ovate to circular in cross-section, discrete, slightly curved posteriorly.

Comparisons.--This species agrees with the forms which have previously been assigned to the form genus *Ligonodina silurica*. In the redescription of the fauna of the Bainbridge Formation, Rexroad & Craig (1971) point out that two distinct forms are present in the topotype material. One form is consistent with the fragmented lectotype and one form is consistent with Ligonodina silurica of previous authors. This latter form has been listed as Ligonodina n. sp. A. by Rexroad and Craig. The writer is in complete agreement with the redefinition of L. silurica but has simply listed his material tentatively as L. "silurica" rather than establish a new form species. This action is discussed below under "Remarks". Ligonodina "silurica" in the writer's collection also shows a tendency to grade into Hindeodella equidentata which has a straight posterior blade and posterior blade denticles of nearly equal size, in contrast to the arched posterior bar of L. "silurica" with denticles which increase in size from anterior to posterior.

Remarks.--The writer is dissatisfied with the generic assignment of the material here described as L. "silurica" and to emphasize these doubts has listed the form tentatively as L. "silurica" rather than assign it to a new species of Ligonodina. The writer's doubts concerning this form center around the variability of the point of flexure of the antero-lateral process in relation to the cusp. Ethington and Furnish (1962) place forms in Ligonodina if the antero-lateral process branches laterally and aborally from the cusp. They place forms which have the flexure of the antero-lateral process anterior to the cusp, in the form genus Hindeodella. According to these criteria some of the writer's forms would be assigned to the form genus Hindeodella and others to the form genus Ligonodina. Large numbers of forms which the writer has assigned to L. "silurica" vary in just this detail so that they could be divided between these two form genera. No compelling reason was obvious to the writer which should dictate dividing the two groups. Biological considerations based on multi-element species seem to indicate the two forms occurred in the same multi-element apparatus indicating that the form genera might eventually have to be revised. This problem is also discussed in the remarks under the generic section on Ligonodina.

Occurrence.--Cosner Gap Member of Mifflintown-Wills Creek formations.

Material studied.--Approximately 1300 specimens.

Repository.--VPIL 927-940.

LIGONODINA n. sp.

Pl. 9, figs. 7, 8, 10; Pl. 10, fig. 18.

Description.--A species of *Ligonodina* Bassler with high, gently arched, laterally bowed posterior blade. Antero-lateral process half as long as posterior blade, bent downward approximately 90 degrees, nearly in plane of posterior blade or with cusp and antero-lateral process broadly curved inward as much as 45 degrees. Posterior blade and antero-lateral process strongly compressed laterally. Posterior blade denticles, as many as 14 in number, biconvex in cross section, compressed laterally, partially fused, with sharp edges in plane of blade. Denticles of antero-lateral blade inclined toward cusp, otherwise as posterior blade denticles. Cusp biconvex in cross-section, with sharp edges in plane of blade, inclined slightly inward and toward posterior.

Occurrence.--Upper McKenzie Member of Mifflintown Formation.

Material studied.--5 specimens.

Repository.--Figured specimens, VPIL 941-944.

GENUS LONCHODINA Bassler, 1925

Lonchodina Bassler, 1925, p. 219; Ulrich & Bassler, 1926, p. 30-31; Huddle, 1968, p. 21.

Type species.--Lonchodina typicalis Bassler, 1925.

Remarks.--This form genus is typified by a marked offset of the denticle rows of the anterior and posterior bar and a wide attachment area. The form genus can be confused with Plectospathodus on the basis of overall appearances and the descriptions of the two form genera are not mutually exclusive. The importance of distinguishing the two form genera becomes obvious when biological considerations are observed. Jeppsson (1969) placed Lonchodina in the multi-element genus Ligonodina. According to Jeppsson this latter genus does not include any element which is homologous with the form genus Spathognathodus. The form genus Plectospathodus, however, is associated by Jeppsson with Spathognathodus in the multi-element genus Hindeodella.

LONCHODINA DETORTA Walliser

Pl. 15, fig. 14

Lonchodina n. sp. (a) Walliser, 1957, p. 39, Pl. 3, figs. 29, 30.

Lonchodina detorta Walliser, 1964, p. 42, Pl. 9, fig. 20; Pl. 30, figs. 34-37; Legault, 1968, p. 11, 12, Pl. 2, figs. 1-4.

Holotype.--Lonchodina detorta Walliser, 1964, Pl. 30, fig. 34.

Stratigraphic horizon.--Upper Tonoloway Formation.

Material studied.--1 specimen.

Repository.--Figured specimen, VPIL 945.

LONCHODINA WALLISERI Ziegler

Pl. 5, figs. 1, 2, 6; Pl. 6, figs. 1-3, 5, 6, 17, 27; Pl. 15, figs. 18, 24, 25; Pl. 16, fig. 29.

Lonchodina n. sp. Walliser, 1957, p. 40, Pl. 3, figs. 27, 28.

Lonchodina walliseri Ziegler, 1960, p. 188, Pl. 14, figs. 6, 7; Spasov & Veselinović, (1962) 1963, p. 245, Pl. 2, figs. 13, 15; Walliser, 1964, p. 44, Pl. 8, fig. 17; Pl. 30, figs. 26-30; Rexroad, 1967, p. 37, Pl. 3, fig. 6; Nicoll & Rexroad, 1968, p. 40, Pl. 4, figs. 8, 9; Mashkova, 1970, p. 217, Pl. 4, fig. 13; Pl. 8, fig. 1.

Holotype.--Lonchodina walliseri Ziegler, 1960, Pl. 14, fig. 7.

Diagnosis.--A species of Lonchodina with gently arched, laterally bowed, occasionally twisted blades. Submedial cusp rotated on blade so that posterior edge is turned inward. Anterior and posterior denticle rows offset, continuous with edge of cusp. Anterior blade compressed laterally, blade widens under cusp, tapers gradually to posterior end. Basal excavation expanded inwardly under cusp, continuing posteriorly as shallow gradually tapering trough. Inner margin of basal excavation strongly arched upward under cusp, continuing in gentle arch to posterior end of blade.

Oral view.--Anterior and posterior blade straight or gently bowed, concave inward. Anterior blade laterally compressed. Blade widened inwardly under cusp, tapered gradually to posterior end. Submedial cusp rotated on blade with posterior edge inward. Denticle rows of posterior and anterior blade offset with reference to one another, but continuous with anterior and posterior edges of cusp. Posterior blade of large specimens twisted axially so that oral margin is turned outward.

Aboral view.--Basal excavation deepest and expanded inward under cusp, continuing posteriorly as shallow V-shaped trough. Excavation constricted anteriorly, continuing to anterior end of blade as shallow groove.

Inner lateral view.--Blade nearly straight or gently arched, inner margin of basal excavation strongly curved upward under cusp, continuing in gentle arch to posterior end of blade.

Cusp biconvex, with or without sharp edges in plane of blade, slightly inclined inward and posteriorward.

Posterior blade denticles 5 to 8 in number, largest over medial part of blade, often slightly spearated, erect, or rarely curved inward.

Anterior blade denticles 4 to 7 in number, discrete or partially fused at base, erect or rarely curved inward.

Remarks.--Some small and medium-sized specimens of *L. walliseri* resemble *Ozarkodina tenuiramea* and can not always be definitely distinguished from it.

Occurrence.--Cosner Gap Member of Mifflintown-Wills Creek formations.

Material studied.--Approximately 475 specimens.

Repository.--Figured specimens, VPIL 959-972.

LONCHODINA? GREILINGI Walliser

Pl. 7, figs. 5, 13, 17, 21, 24; Pl. 9, figs. 12, 13; Pl. 12, fig. 2; Pl. 15, figs. 23, 26, Pl. 16, figs. 9, 15, 16, 21.

Lonchodina greilingi Walliser, 1957, p. 38-9, Pl. 3, figs. 20-26; 1960, p. 31, Pl. 8, figs. 17, 18; Ethington & Furnish, 1962, p. 1274, Pl. 173, fig. 10 Spasov & Veselinović, (1962) 1963, p. 245, Pl. 1, fig. 11; Walliser, 1964, p. 44, Pl. 8, fig. 7; Pl. 30, figs. 7-9; Barnett, Kohut, Rust & Sweet, 1966, Pl. 58, fig. 8; Legault, 1968, p. 12-13, Pl. 2, figs. 10-12; Philip, 1969, p. 292, Pl. 17, figs. 17, 18, 21; Text-fig. 1, fig. e.

Lonchodina greilingi grelingi Walliser. Mashkova, 1970, p. 215, Pl. 14, fig. 15; Pl. 9, fig. 3; Text-fig. 1, fig. 20.

Lonchodina? greilingi Walliser. Rexroad & Craig, 1971, p. 692, Pl. 79, figs. 33-38.

Holotype.--Lonchodina greilingi Walliser, 1957, Pl. 3, fig. 21.

Diagnosis.--A species of Lonchodina? with variably arched, laterally bowed blade. Blade denticles unequal in size, irregularly spaced. Apical cusp erect to strongly curved inward. Basal excavation expanded inward under cusp with inner margin of excavation deflected in direction of longer blade.

Oral view.--Posterior and anterior blades extended straight or bowed inward with interior angle between blades as small as 120 degrees. Cusp nearly erect or curved inward as much as 45 degrees.

Aboral view.--Basal excavation deepest under cusp, expanded inward with inner rounded margin deflected posteriorly. Basal excavation continuing to ends of blades. Blade widest at base with flattened faces or with strongly rounded cross-section.

Inner lateral view.--Posterior blade one-half to twice as long as anterior blade. Aboral margin of posterior blade gently curved, aboral margin of anterior blade usually straight. Angle between posterior and anterior blade varies from 90 to 120 degrees. Basal excavation expressed on inner face of blade beneath cusp as rounded conical ridge rising nearly to height of blade.

Cusp subtriangular, with inner edge rounded to nearly circular in cross-section at base, becoming circular or biconvex distally. Inner face of cusp commonly deflected in direction of longer blade. Cusp with sharp edges in plane of blade or with ridges originating at oral surfaces of blades, extending along length of cusp.

Posterior blade denticles 5 to 8 in number, circular to ovate in cross-section, occasionally with sharp edges, unequal in size. Denticles irregularly spaced, nearly erect, generally smaller adjacent to cusp and at end of blade. Denticles over middle of blade gently to strongly curved inward.

Remarks.--The writer has questioned the generic assignment of this species because of its symmetry transition with Trichonodella inconstans. Walliser (1957, p. 51) also noted the similarity in development of L.? greilingi to Trichonodella inconstans and assigned the two forms to the same biological apparatus. The difference between the two forms is a matter of symmetry. L.? greilingi is asymmetrical while T. inconstans is bilaterally symmetrical. This same development similarity and symmetry pattern is noted also for the bilogically related pairs, Plectospathodus extensus-Trichonodella excavata and Plectospathodus flexuosus-Trichonodella symmetrica. Since Walliser's types have not been studied by the writer, the questioned generic assignment raised by Rexroad and Craig (1971) is continued.

Occurrence.--McKenzie Member of Mifflintown-Wills Creek Formations.

Material studied.--Approximately 110 specimens.

Repository.--Figured specimens, VPIL 946-958A.

GENUS NEOPRIONIODUS Rhodes and Müller, 1956

Neoprioniodus Rhodes & Müller, 1956, p. 698-699.

Type species.--*Prioniodus conjunctus* Gunnell, 1931, as designated by Rhodes and Müller, 1957, p. 695.

Remarks.--This form genus is distinguished by its undenticulated anticusp from the very similar genus *Synprioniodina*. In terms of multi-element species, the distinction between these form genera has little significance. Species of both form genera occur within the complex of multi-element species associated with *Spathognathodus primus* (sensu latu). In the writer's collection, the form *Neoprioniodus excavatus* is associated with *Spathognathodus primus primus*. Jeppsson (1969) reports that the form *Synprioiodina bicurvata* is associated with *Spathognathodus primus*. Indeed, a form ascribed to *Synprioniodina bicurvata* (sensu latu) is associated with *Spathognathodus steinhornensis eosteinhornensis* of the *Spathognath-*

odus primus lineage.

In terms of form taxonomy, the dichotomy between Neoprioniodus and Synprioniodina is also quite questionable since the two forms are intergradational. Specimens of N. excavatus with a denticulated, anticisp as well as specimens of S. bicurvata with a non-denticulated anticusp are quite common.

In describing N. excavatus, the cusp and anticusp are considered to be anterior with reference to the denticulated bar. This is consistent with the orientation established by Jeppsson (1971). It must be understood, however, that in specimens with curvature like N. excavatus the denticulated blade originates on the outer side of the cusp and then curves posteriorly.

NEOPRIONIODUS EXCAVATUS (Branson & Mehl)

Pl. 9, figs. 16, 21, 22, 25, 27; Pl. 15, fig. 8.

Prioniodus excavatus Branson & Mehl, 1933, p. 45, Pl. 3, figs. 7, 8.

Prioniodina bicurvata (Branson & Mehl). Walliser, 1957. p. 46, Pl. 2, figs. 18, 19; Ethington & Furnish, 1962, p. 1283, Pl. 173, fig. 17; Spasov & Veselinović, (1962) 1963, p. 247-8, Pl. 2, fig. 14.

Prioniodus bicurvatus Branson & Mehl. Serpagli & Greco, 1964, p. 207, Pl. 37, fig. 11.

Neoprioniodus excavatus (Branson & Mehl). Walliser, 1964, p. 49, Pl. 8, fig. 4; Pl. 29, fig. 26; Text-fig. 5c; Mashkova, 1970, p. 218, Pl. 4, fig. 8; Pl. 7, fig. 7; Rexroad & Craig, 1971, p. 692-3; Pl. 80, figs: 6-9.

Neoprioniodus cf. N. excavatus (Branson & Mehl). Pollock, Rexroad, & Nicoll, 1970, p. 756, Pl. 114, figs. 18?, 19, (non fig. 20, ?=N. latidentatus).

Neotype.--Prioniodus excavatus Branson & Mehl, 1933. Designated by Rexroad & Craig, 1971, Pl. 80, fig. 7.

Diagnosis.--A species of Neoprioniodus Rhodes & Müller with cusp strongly curved inward so that the end of the cusp is oriented at approximately 90 degrees to the end of the arched, inwardly curved posterior blade. Short compressed anterior process directed outward as much as 30 degrees in reference to plane of development of cusp and posterior blade.

Oral view.--Posterior blade curved inward as much as 45 degrees from plane of development of cusp. Cusp curved inward as much as 45 degrees. Short compressed anterior process extends from outer anterior margin of cusp, bent outward as much as 30 degrees from plane of development of cusp. Blade widest at base of cusp, tapers gradually to posterior end. Faces of posterior blade plane to gently convex.

Aboral view.--Basal excavation deepest and broadest under cusp, continuing to end of, and completely excavating, posterior blade. Basal excavation broadly rounded under inner anterior edge of cusp, strongly constricted to outer anterior margin and continuing under anterior process as fine groove.

Inner lateral view.--Posterior blade curved downward 60 to 80 degrees along its length. Inner aboral margin curved upward sharply from anterior corner of cusp, gently curved to end of posterior blade exposing the basal excavation along its entire length. Anterior process produced outward with anterior aboral corner broadly rounded.

Cusp subterminal, sub-triangular, unequally biconvex, or subquadrate in cross-section at base, becoming biconvex or lacrymalform distally, with posterior edge twisted inward. Cusp strongly curved inward as much as 45 degrees, often with sharp edges in plane of blade.

Denticles of posterior blade, 6 to 22 in number, subequal in size, discrete, nearly circular in cross-section, slightly curved inward, occasionally with sharp edges in plane of blade.

Anterior process with no denticles or bearing as many as three fused or discrete denticles.

Remarks.--Specimens from the Cosner Gap Member of the Mifflintown Formation have the greatest number of posterior blade denticles. Specimens from the McKenzie Member of the Mifflintown and Wills Creek formations generally have 10 to 12 posterior blade denticles.

Occurrence.--Cosner Gap Member of Mifflintown-Wills Creek formations.

Material studied.--Approximately 625 specimens.

Repository.--Figured specimens, VPIL 973-978.

NEOPRIONIODUS MULTIFORMIS Walliser

Pl. 9, figs. 2-5

Neoprioniodus multiformis Walliser, 1964, p. 50-51. Pl. 8, fig. 10; Pl. 29, figs. 14, 16-25; Text-fig. 5a; Rexroad & Craig, 1971, p. 693, Pl. 80, figs. 1-5.

Holotype.--*Neoprioniodus multiformis* Walliser, 1964, Pl. 29, fig. 16.

Remarks.--The few specimens in the writer's collection agree fairly closely with Walliser's figured specimens (Pl. 29, figs. 17-25). The holotype (Pl. 29, fig.

16) designated by Walliser does not appear consistent with the other figures that he shows of this species; it appears to agree more closely with N. excavatus than with the rest of the figured specimens.

Occurrence.--Cosner Gap Member of Mifflintown Formation.

Material studied.--4 specimens.

Repository.--Figured specimens, VPIL 979-982.

GENUS OZARKODINA Branson & Mehl, 1933

Ozarkodina Branson & Mehl, 1933, p. 51.

Type species. -Ozarkodina typica Branson & Mehl, 1933.

Remarks.--The type species of Ozarkodina, as originally defined by Branson and Mehl is characterized by an arcuate, denticulate blade with a large medial to submedial cusp. Many bar-like forms, e.g., O. media and O. ziegleri, have since been included in this form genus. Differences in development between bar- and blade-like ozarkodinids along with increasing certainty of the association of this element in multi-element species will eventually necessitate a complete revision of this form genus. Developmental differences are superficially evident betwen bar- and blade-like forms. In addition, however, blade forms in the writer's collection show a distinct lack of bilateral symmetry. All specimens of O. typica, for example, when placed with the posterior end of the blade toward the observer are seen to be flattened on the left hand side of the blade.

An explanation of this phenomena is probably related to the spatial arrangement of these blade-like forms in the multi-element apparatus. Jeppsson (1971), on the basis of the study of clusters of conodonts argues that in some apparatuses the ozarkodinid and spathognathodid elements lie posterior to all other elements in the apparatus and were rotated about the longitudinal axis of the apparatus with the denticle rows of the paired elements partially overlapped. When two specimens of O. typica are placed side by side and then rotated about their long axis toward each other so that their denticle rows overlap, the flattened surfaces abut each other.

The blade-like forms of Ozarkodina consistently occur with spathognathodid elements. Some bar-like ozarkodinids in the writer's collection could not be associated with any spathognathodid elements on the basis of common stratigraphic range and similar abundances. Moreover, Jeppsson (1969) has established a multi-element genus Ligonodina in which the equivalent of a spathognathodid element is apparently lacking. In the spatial reconstruction of this genus, the ozarkodinid elements are placed erect and well within the posterior extremity of the ligonodinid elements. These differences should prove useful in development of lineages of form species and multi-element species as well as allow for the useful distinction of kinds of ozarkodinids in multi-element genera.

In the following form descriptions, all specimens are conventionally oriented with the cusp erect. The terms inner and outer are dropped with reference to side views in favor of right and left in describing asymmetric forms. The right and left sides of the elements are determined by viewing them with their cusp erect and the posterior ends toward the observer.

OZARKODINA AEQUALIS Walliser

Pl. 6, figs. 22, 25; Pl. 7, figs. 28, 29.

Ozarkodina ziegleri aequalis Walliser, 1964, p. 62, Pl. 7, fig. 24; Pl. 24, figs. 19-21, text-fig. 3f.

Holotype.--Ozarkodina ziegleri aequalis Walliser, 1964, Pl. 24, fig. 21.

Diagnosis.--A species of *Ozarkodina* with gently arched blade, with posterior blade slightly lower than anterior blade, and with medial basal excavation. Denticles of anterior blade and posterior bladeequally closely set and somewhat laterally compressed.

Oral view.--Blade straight or occasionally gently bowed. Some specimens with oral margin of posterior blade slightly twisted outward.

Aboral view.--Basal excavation developed as deep conical pit under apical cusp, slightly off-set to inner side of blade, strongly constricted anteriorly and posteriorly, and continuing to both ends of blade as shallow groove.

Lateral view.--Aboral margin continuously arched in a gentle curve, or with posterior aboral margin delfected downward as much as 45 degrees, from line of development of anterior margin. Basal excavation on some specimens expressed on inner side of blade as conical ridge rising nearly to base of denticles. Lateral faces of blade convex in vertical section. Blade strongly constricted parallel to aboral margin often with development of lip along aboral margin. Posterior blade generally lower in height than anterior blade.

Cusp apical, stout, circular to strongly biconvex in cross-section, inclined or gently curved posteriorly.

Blade denticles 10 to more than 20 in number, anterior blade denticles as numerous as, or 2 to 3 more or less in number than posterior blade denticles. All denticles closely set, ovate to biconvex in cross-section, with rounded or sharp anterior and posterior edges. Height of denticles increases toward cusp.

Comparisons.--Many specimens of *O. aequalis* show considerable similarity to and even grade into *O. tenuiramea*. *O. aequalis* has a medially restricted basal excavation and similarly developed denticles on both the anterior and posterior blade. It is distinguished from *O. tenuiramea* which has the posterior half of the blade excavated as well as relatively widely spaced denticles on the posterior blade. *O. aequalis* shows considerable similarity to *O. ziegleri ziegleri* and *O. ziegleri crassatoides* n. ssp. *O. aequalis* has a straight or gently bowed blade and is thus distinguished from the various subspecies of *O. ziegleri* which generally have the anterior blade bent inward.

Remarks.--Walliser found this form restricted to his *patula* Zone of middle Wenlock age, underlying the *sagitta* Zone. The Appalchian material contains specimens assignable to this form species well up into the local *Spathognathodus snajdri* Zone of middle to upper Ludlow age. This species grades into the form species, *Ozarkodina tenuiramea* and many specimens in the writer's collection are difficult to assign to either species. Ozarkodina aequalis is the dominate form, however, in the Spathognathodus sagitta bohemicus Zone.

The writer has interpreted the forms, O. aequalis, O. tenuiramea, and O. sinuosa n. sp. as part of an evolutionary complex associated with Lonchodina walliseri in a single biological apparatus. Because of the intergradational nature of the forms O. aequalis and O. tenuiramea the counts of these two species has been handled arbitrarily. Specimens from the S. sagitta bohemicus Zone have been counted as O. aequalis, while all specimens from the S. bicornutus through the S. snajdri zones have been counted as O. tenuiramea.

Walliser originally described O. aequalis as a subspecies of O. ziegleri. O. ziegleri ziegleri Walliser as well as the specimens assigned to this species by the writer, generally have the anterior blade bent inward. This feature of O. ziegleri is not developed in the form O. aequalis. Specimens assigned to O. ziegleri by the writer are consistently associated with spathognathodid elements of the sagitta lineage. O. aequalis, in the Appalachian material, is consistently associated with Lonchodina walliseri. Because of the differences in development and association, the writer has raised Walliser's subspecies O. ziegleri aequalis to species rank.

Occurrence.--Cosner Gap Member of Mifflintown Formation.

Material studied.--Approximately 120 specimens.

Repository.--Figured specimens, VPIL 983-986.

OZARKODINA EDITHAE MARIAE n. ssp.

Pl. 4, figs. 1-5, 8, 9, 12, 16

Holotype.--Pl. 4, fig. 8.

Derivation of name.--After my wife, Mary, who helped support this research.

Diagnosis.--A subspecies of Ozarkodina edithae Walliser with arched aboral margin. Basal excavation generally restricted to area under cusp but may extend along entire aboral surface.

Oral view.--Blade straight or gently blowed laterally. Cusp and denticles curved laterally on some bowed specimens. Basal excavation often expanded asymmetrically.

Aboral view.--Basal excavation formed under medial cusp, commonly small, asymmetrically expanded laterally, constricted anteriorly and posteriorly to form shallow groove continuing toward both ends of blade. A few specimens with excavation continuing posteriorly, or to both ends of blade, as tapering, shallow trough.

Lateral view.--Aboral margin curved gently. A few specimens with anterior aboral margin curved downward sharply. Anterior oral margin increasing in height toward medial cusp with tips of denticles rising in nearly straight line to tip of cusp. Posterior blade lower than anterior blade with oral margin increasing in height toward cusp to one-half or two-thirds height of cusp. Thickening of unit occurs from oral margin to a distinct line just below and parallel to base of denticles. Blade asymmetrically flattened on left side independently of lateral curvature of blade (Cf. definition under Genus Ozarkodina and discussion under O. typica typica).

Cusp 2 to 4 times as wide in plane of blade as blade denticles, slightly inclined to posterior, with sharp anterior and posterior edges. Anterior edge of cusp sharply curved to posterior; posterior edge of cusp straight. Anterior blade denticles occasionally fused into edge of cusp causing width of cusp to vary greatly. Cusp thickened medially along its length on one side making cusp subtriangular in cross-section.

Denticles, 10 to 20 in number, fine, closely set along nearly whole length but not coalesced, nearly equal in number on anterior and posterior blades. Occasional stout specimens bear discrete denticles. A few specimens with 2 or 3 fewer denticles on anterior blade than posterior blade; decrease in number of anterior blade denticles apparently related to fusion of denticles into cusp. Anterior denticles increasingly inclined posteriorly approaching cusp.

Comparisons.--Some specimens of O. edithae mariae n. ssp. show strong similarities to O. edithae edithae, O. typica typica, O. typica intermedia n. ssp., and O. typica denckmanni. O. edithae mariae n. ssp. has arched aboral margin and nearly equally long anterior and posterior blades and is distinguished from O. edithae edithae which has a straight aboral margin with anterior blade longer than posterior blade. O. edithae mariae n. ssp. has fine denticles, no noticeable constriction of blade parallel to aboral margin and is thus distinguished from O. typica typica which has coarse denticles, with noticeable concave constriction on both sides of blade paralleling aboral margin. O. edithae mariae n. ssp. has 10 or fewer denticles on each half of the blade and is thus distinguished from O. typica intermedia n. ssp. which has a longer blade, from 10 to 15 denticles on each half of the blade, and a constriction paralleling aboral margin of blade. O. edithae mariae n. ssp. is distinguished from O. typica denckmanni by the longer lower blade and noticeable constriction of blade paralleling aboral margin in O. typica denckmanni.

Occurrence.--Upper Cosner Gap Member of Mifflintown Formation.

Material studied.--Approximately 70 specimens.

Repository.--Holotype, VPIL 992; paratypes, VPIL 987-991, 993-995.

OZARKODINA ORTUFORMIS Walliser

Pl. 12, figs. 5, 9, 21, 25, 28

Ozarkodina ortuformis Walliser, 1964, p. 59, Pl. 9, fig. 18; Pl. 24, figs. 7-13; Text-fig. 3, figs. 1, m.

Holotype.--Ozarkodina ortuformis Walliser, 1964, Pl. 24, fig. 10.

Diagnosis.--A species of Ozarkodina with large stout cusp, rather few, discrete, long, blade denticles, with anterior blade bent inward and downward anterior to cusp, and relatively large basal excavation under the cusp.

Oral view.--Anterior blade bent inward as much as 30 degrees from axis of posterior blade, posterior blade twisted slightly along its axis with oral surface outward. Cusp slightly curved inward.

Aboral view.--Basal excavation deepest and widest under cusp with slight lateral expansion of margins. Inner lateral expansion of basal excavation displaced posteriorly in relation to smaller outer expansion. Basal excavation constricted anteriorly, continuing toward end of blade as narrow groove; basal excavation constricted posteriorly to narrow groove or shallow tapering trough continuing toward end of blade.

Lateral view.--Anterior blade bent downward as much as 60 degrees from axis of posterior blade and slightly higher than posterior blade. Cusp high, curved posteriorly, with sharp anterior and posterior edges. Denticles, 5 to 9 in number, unequal in size, with sharp anterior and posterior edges, separated from one another as much as the width of single denticle. Anterior blade generally with one less denticle than posterior blade. Middle denticle or denticles of anterior blade largest. Denticles of posterior blade increasingly inclined posteriorly to as much as 45 degrees.

Comparisons.--O. ortuformis has the denticles of the anterior and posterior blade evenly spaced and the anterior blade bent inward and downward. It is distinguished from O. ortus in which the anterior denticles are more closely spaced than the posterior denticles and which has a relatively straighter blade. O. ortuformis has strong similarities to the various subspecies of O. ziegleri, with single specimens sometimes being indistinguishable. However. O. ortuformis has a cusp which is high in relation to blade length and widely separated denticles and is thus distinguished from O. ziegleri ssp. which have relatively longer blades and more closely spaced denticles.

Remarks.--Walliser described this species from the eosteinhornensis Zone in the Cellon section. The Appalachian occurrence extends therange of this species downward to the base of Walliser's (1964) crispus Zone.

Occurrence.--Upper Wills Creek-lowest Tonoloway formations.

Material studied.--Approximately 35 specimens.

Repository.--Figured specimens, VPIL 996-1000.

OZARKODINA SERRATA n. sp.

Pl. 4, figs. 11, 15, 19-25

Holotype.--Pl. 4, fig. 22a-b.

Derivation of name.--Serratus, Lat., toothed like a saw; after the serrate appearance of the oral margin.

Diagnosis.--A species of Ozarkodina with stout strongly arched blade, with numerous, very short, fused blade denticles, and with base completely excavated.

Oral view.--Blade straight or gently bowed laterally, oral margin and edges of cusp offset to flattened side of blade. Posterior blade occasionally twisted slightly along its axis.

Aboral view.--Basal excavation deepest under cusp and expanded laterally to produce small flaring lips. Basal excavation continues distally toward both ends of blade as shallow, gradually tapering trough.

Lateral view.--Aboral margin curved with anterior blade bent downward as much as 80 degrees from line of development of posterior blade. Oral margin of anterior blade rises in a nearly straight line to tip of cusp. Oral margin of posterior blade straight from posterior end, rising sharply 2 or 3 denticles before cusp. Posterior blade lower and generally greatly reduced in development in contrast to anterior blade. Blade, cusp, and denticles flat on inner side, thickened on outer side from oral edge to concave constriction, subparallel to aboral margin and marking depth of basal excavation. This constriction generally developed onboth sides of blade.

Cusp, medial, slightly inclined posteriorly, subtriangular in cross-section. Cusp with sharp anterior and posterior edges.

Denticles, small, 28 to 32 in number, generally equally numerous on anterior and posterior blades, subequal to unequal in size, very short, with or without tips fused to finely serrate edge.

Comparisons.--*Ozarkodina serrata* n. sp. is morphologically distinct from all other species studied. The development of the basal excavation and of the anterior oral margin indicate a possible evolutionary relationship to *O. edithae mariae* n. ssp. and *O. ziegleri crassatoides* n. ssp.

Occurrence.--Upper McKenzie Member of Mifflintown Formation.

Material studied.--Approximately 60 specimens.

Repository.--Holotype, VPIL 1007; paratypes, VPIL 1001-1006, 1008-1009.

OZARKODINA SINUOSA n. sp.

Pl. 16, figs. 13, 14, 18, 22, 24, 25, 28, 30.

Holotype.--Pl. 16, fig. 30.

Derivation of name.--Sinuosus, Lat.; full of curves.

Diagnosis.--A species of Ozarkodina with blade strongly twisted axially, with anterior oral surface twisted outward and posterior oral surface twisted inward. Blade slightly sigmoidal in oral view, with anterior end of blade curved inward and posterior end of blade curved outward. Basal excavation generally limited to area under cusp and posterior aboral surface but in some specimens extends under anterior blade. Posterior blade denticles often widely spaced and separated from each other as much as width of single denticle. Anterior blade denticles closely set or spaced as posterior blade denticles.

Oral view.--Blade slightly sigmoidal with anterior end of blade curved inward and posterior end of blade curved outward. Entire blade twisted strongly along axis with anterior oral surface turned outward and posterior oral surface inward.

Aboral view.--Basal excavation widest and deepest under medial cusp. Excavation continuing to posterior end of blade as gradually tapering shallow V-shaped trough, constricted anteriorly to shallow tapering groove.

Lateral view.--Aboral margin gently arched from anterior end to cusp, or slightly posterior of cusp, and then strongly curved downward. Faces of blade flat or gently convex in vertical section, with line of constriction paralleling aboral margin to produce slight lateral lip. Height of blade relatively low in comparison to O. tenuiramea, with posterior blade lower than anterior blade.

Cusp, medial, stout, circular in cross-section, to reduced and indistinguishable from other blade denticles.

Denticles of posterior blade, 7 to 9 in number, erect, nearly circular in cross-section, separated as much as width of single denticle. Anterior blade denticles 5 to 7 in number, oval to circular in cross-section, closely set and slightly inclined toward cusp, or separated as much as width of single denticle and erect.

Comparisons.--O. sinuosa n. sp. grades into forms which are assignable to O. tenuiramea and some specimens can be assigned only arbitrarily to either species. O. sinuosa n. sp. appears sigmoidal in oral view and has a strongly twisted blade, especially the posterior part which is sharply curved downward. It is distinguished from O. tenuiramea which is nearly straight in oral view and which has a relatively higher blade with relatively moderate twisting of the posterior blade.

Remarks.--This form is interpreted as part of a gradational series which also includes O. aequalis and O. tenuiramea. O. sinuosa becomes the dominant form of this series in the Wills Creek Formation. Each of the forms in this series is associated with Lonchodina walliseri in the Appalachian material. This series is interpreted as one of the elements associated with L. walliseri in a single biological apparatus.

Occurrence.--Wills Creek Formation.

Material studied.--Approximately 70 specimens.

Repository.--Holotype, VPIL 1017, paratypes, VPIL 1010-1016.

OZARKODINA TENUIRAMEA Walliser

Pl. 6, figs. 4, 7-16, 18-21, 23, 24, 26, 28, 29;
Pl. 7, figs. 1, 6, 8, 11, 15, 19,23

Ozarkodina ziegleri tenuiramea Walliser, 1964, Pl. 7, fig. 15; Pl. 24, figs. 22-28; Text-fig. 3g, h; Philip, 1969, p. 294, Pl. 18, figs. 5, 10, 16, 20, 26-28.

Holotype.--Ozarkodina ziegleri tenuiramea Walliser, 1964, Pl. 24, fig. 26.

Diagnosis.--A species of Ozarkodina with gently arched blade, posterior blade with basal excavation along its entire length. Posterior blade lower than anterior blade and with widely spaced denticles in contrast with closely set denticles of anterior blade. Posterior blade axially twisted with oral surface inward.

Oral view.--Blade straight, gently bowed, or occasionally sigmoidal with posterior end of blade curved outward and anterior end of blade curved inward. Blade commonly tiwsted axially with oral surface of posterior blade turned inward, or with posterior oral surface turned inward and anterior oral surface turned outward. Cusp and denticles occasionally gently curved inward. Inner aboral margin of basal excavation commonly expanded inward to produce lateral lip.

Aboral view.--Basal excavation deepest under medial cusp, expanded laterally on inner side and continuing to posterior end of blade as gradually tapering shallow trough. Excavation constricted anteriorly and continuing to anterior end of blade as narrow groove.

Lateral view.--Anterior aboral margin straight or very gently curved. Aboral margin slightly arched under medial cusp, variably curved downward to posterior end of blade. Blade relatively low in height compared to O. aequalis, with posterior blade slightly lower than anterior blade. Lateral faces of blade convex in vertical section with line of constriction paralleling aboral margin, often producing slight lateral lip. Cusp stout, medial, nearly circular in cross-section, inclined toward posterior.

Anterior blade denticles, 5 to 8 in number, closely set, nearly circular to biconvex in cross-section, increasingly inclined toward posterior from anterior end of blade to cusp. Posterior blade denticles, 5 to 8 in number, closely set or each separated as much as width of single denticle, generally circular in cross-section, erect or slightly inclined toward posterior.

Comparison.--*O. tenuiramea* shows considerable similarity to *O. aequalis* and *O. sinuosa* n. sp. *O. tenuiramea* has the posterior aboral surface completely excavated and has widely separated posterior blade denticles. In contrast *O. aequalis* has a relatively higher blade with the basal excavation restricted to a medial position, and equally large anterior and posterior blade denticles. *O. tenuiramea* is distinguished from *O. sinuosa* n. sp. which is sigmoidal in oral view and has the blade strongly twisted axially, especially the posterior part of the blade which is also strongly curved downward. *O. tenuiramea* also shows considerable similarity to *O. ziegleri ziegleri* and *O.*

ziegleri crassatoides. *O. tenuiramea* has a straight or sigmoidally curved blade as seen in oral view in contrast to the subspecies of *O. ziegleri*, which have the anterior blade bent inward.

Remarks.--*O. tenuiramea* was originally named by Walliser (1964) as a subspecies of *O. ziegleri*. *O. tenuiramea*, in the Appalachian material is associated with *Lonchodina walliseri*, while forms assigned to *O. ziegleri* are associated with elements of the *sagitta* lineage. Because of the differences cited, the writer has raised Walliser's subspecies *O. ziegleri tenuiramea* to species rank.

Occurrence.--McKenzie Memberof Mifflintown Formation.

Material studied.--Approximately 800 specimens.

Repository.--Figured specimens, VPIL 1018-1044.

OZARKODINA TYPICA Branson & Mehl

OZARKODINA TYPICA DENCKMANNI Ziegler

Pl. 12, figs. 14, 16, 24, 27.

Ozarkodina denckmanni Ziegler, 1956, p. 103, Pl. 6, figs. 30, 31; Pl. 7, figs. 1, 2; Ziegler, 1960, p. 190, Pl. 15, figs. 13-15; Walliser, 1960, p. 31, Pl. 8, figs. 13, 14; Spasov & Veselinović, (1962) 1963, p. 246, Pl. 1, fig. 10; Philip, 1966, p. 106, Pl. 9, figs. 2, 4, 6-8; Barnett, Kohut, Rust & Sweet, 1966, Pl. 58, fig. 7; Moskalenko, (1966) 1967, p. 201, Pl. 1, fig. 11.

Ozarkodina typica denckmanni Ziegler. Walliser, 1964, p. 61, Pl. 9, fig. 14; Pl. 26, figs. 3-11; Legault, 1968, p. 15-16, Pl. 1, figs. 5, 6.

Holotype.--Ozarkodina denckmanni Ziegler. 1956, Pl. 7, figs. 1, 2.

Diagnosis.--A subspecies of Ozarkodina typica with long low blade, fine partially fused to discrete denticles, and with basal excavation under medial cusp expanded laterally to produce a conical pit. Posterior typically lower than anterior blade.

Occurrence.--Upper Tonoloway Formation.

Material studied.--Approximately 130 specimens.

Repository.--Figured specimens, VPIL 1045-1048.

OZARKODINA TYPICA INTERMEDIA n. ssp.

Pl. 12, figs. 1, 3, 6, 15, 17, 19, 20, 23.

Holotype.--Pl. 12, fig. 20a,b.

Derivation of name.--Intermedius Lat., intermediate, after its transitional development between O. typica typica and O. typica denckmanni.

Diagnosis.--A subspecies of *Ozarkodina typica* with 20 to 35 closely set blade denticles on a relatively long blade which is constricted along both sides parallel to aboral margin. Basal excavation under medial cusp and expanded laterally to produce a conical pit.

Comparisons.--In contrast to *Ozarkodina typica intermedia* n. ssp., *O. typica typica* has approximately 10 to 20 coarse, unequal blade denticles with basal excavation only slightly produced laterally. *O. typica denckmanni* has denticles which are slightly more discrete and a longer lower blade than *O. typica intermedia* n. ssp. *O. edithae mariae* n. ssp. generally has fewer than 16 denticles on a relatively short blade which is not compressed parallel to aboral margin.

Occurrence.--Lower Wills Creek-?upper Wills Creek Formation.

Material studied.--Approximately 70 specimens.

Repository.--Holotype, VPIL 1055; paratypes, VPIL 1049-1054, 1056.

OZARKODINA TYPICA TYPICA Branson & Mehl

Pl. 4, figs. 6, 7, 10, 13, 14, 17, 18; Pl. 7, figs. 30-32.

Ozarkodina typica Branson & Mehl, 1933, p. 51-52, Pl. 3, figs. 43-45; Rhodes, 1953, p. 320-321, Pl. 23, figs. 251, 261, 262; Rexroad, 1967, p. 39-40, Pl. 2, figs. 7, 8; Pollock, Rexroad & Nicoll, 1970, p. 757, Pl. 113, figs. 16-18; Rexroad & Craig, 1971, p. 694, Pl. 80, figs. 32-34.

Ozarkodina typica typica Branson & Mehl. Walliser, 1964, p. 61, Pl. 9, fig. 21; Pl. 25, figs. 20, 21; Pl. 26, figs. 1, 2.

Lectotype.--Ozarkodina typica Branson & Mehl, 1933, Pl. 3, figs. 44; designated by Walliser (1964).

Diagnosis.--A subspecies of Ozarkodina typica with arched blade, and stout cusp over small medial basal excavation. Anterior and posterior blades increase in height slightly toward cusp. Anterior blade slightly higher than posterior blade. Denticles, 10 to 20 in number, coarse, equally numerous on anterior and posterior blades.

Oral view.--Blade straight or slightly bowed. Occasional specimens have posterior blade glently twisted about long axis of blade. Outer margins of basal excavation not visible.

Aboral view.--Basal excavation approximately medial, with slight lateral protrusion of margins under cusp. Anterior and posterior to cusp, basal excavation constricted to shallow groove continuing toward both ends of blade.

Lateral view.--Blade arched with anterior end of blade bent downward 30 to 80 degrees from line of development of posterior blade. Aboral margin arched continuously or with anterior and posterior aboral margins straight and meeting at an angle beneath basal excavation. Anterior blade generally higher than posterior blade. Height of both blades increases slightly toward medial cusp. Oral margin of both anterior and posterior blades straight, with anterior margin rising one-half to two-thirds of height of cusp. Blade increases gradually in thickness from oral margin to line continuous with upper surface of laterally expressed basal excavation, then constricts to form concave groove paralleling aboral margin, developed on both sides of blade. Blade, denticles, and cusp considerably flattened on one side.

Cusp apical, 2 to 3 times as wide in plane of blade, as blade denticles, with sharp anterior and posterior edges, slightly inclined to posterior. Anterior edge of cusp sharply inclined to posterior along line continuous with tips of anterior blade denticles. Cusp subtriangular in cross-section.

Blade denticles, 10 to 20 in number, coarse, subequal to unequal in size, fused to midpoint, generally with broad tips. Denticles equally numerous on anterior and posterior blades or with posterior blade bearing as many as four more denticles than anterior blade. Posterior blade denticles nearly erect or slightly inclined posteriorly. Anterior blade denticles erect at anterior end but increasingly inclined posteriorly toward cusp. Blade and denticles flattened only on left side of blade in oral view with posterior end of blade toward observer. Such flattening is lacking on some specimens.

Comparisons.--See Comparisons under *O. edithae* n. ssp., *O. typica*, n. ssp., and *O. typica denckmanni*.

Discussion.--Specimens of *O. typica* are observed with right- and left-handed bowing of blade; and it is possible to interpret 2 oppositely bowed blades as a bi-laterally symmetrical pair. This mirror image symmetry is only apparent, since the elements are left-handed with respect to lateral flattening. However, if two oppositely bowed ozarkodinid elements are placed side by side and then turned inward so that their oral margins overlap, the flattened sides can be arranged so that they are in contact and both elements of the pair will then curve either upward or downward. This interpretation is consistent with the hypothetical orientation of ozarkodinid and spathognathodid elements in the conodont animal as discussed by Jeppsson (1971). Some species now referred to Ozarkodina do not show the asymmetric development of Ozarkodina typica typica. A new form genus may eventually be needed when more ozarkodinid species are studied with respect to the orientation of the element in a biological apparatus as proposed by Jeppsson.

Occurrence.--Cosner Gap Member of Mifflintown-Wills Creek, ?lower Tonoloway formations.

Material studied.--More than 300 specimens.

Repository.--Figured specimens, VPIL 1057-1066.

OZARKODINA ZIEGLERI CRASSATOIDES n. ssp.

Pl. 5, figs. 3, 4, 7, 8, 12-20, 24.

Holotype.--Pl. 5, fig. 18.

Derivation of name.--Similar to crassa; after the gross similarity of the form to O. crassa Walliser.

Diagnosis.--A subspecies of Ozarkodina ziegleri Walliser with stout medial cusp having subtriangular cross-section, and with tips of anterior blade denticles rising along a line continuous with anterior edge of cusp.

Oral view.--Anterior blade bent inward as much as 30 degrees from line of development of cusp and posterior blade. Cusp commonly curved inward.

Aboral view.--Basal excavation deep, diagonally expanded under apical cusp, continuous under posterior blade as shallow tapering trough and under anterior blade as narrow groove.

Lateral view.--Aboral margin arched with anterior blade bent downward 10 to 45 degrees from line of development of posterior blade. Anterior blade higher than posterior blade. Oral margin of anterior blade rises continuously from end of blade in straight line continuous with anterior edge of cusp. Posterior blade about one-third as high as cusp. Basal excavation expressed laterally as rounded conical ridge rising one half height of posterior blade. Cusp stout, equal to one half blade length in height, with sharp or rounded anterior and posterior edges, inclined posteriorly. Posterior margin of cusp straight or slightly curved posteriorly, anterior margin broken sharply and inclined posteriorly in line with tips of anterior blade denticles. Cusp with substriangular cross-section.

Denticles, 10 to 18 in number, subequal to unequal in size, equally divided between anterior and posterior blade or with anterior blade bearing as many as 4 more denticles than posterior blade. Anterior denticles commonly closely set but not coalesced, erect anteriorly, increasingly inclined posteriorly toward cusp. Posterior denticles closely set or discrete and separated as much as width of single denticle, erect adjacent to cusp, increasingly inclined posteriorly toward end of blade up to as much as 45 degrees.

Comparisons.--O. ziegleri crassatoides n. ssp. shows a resemblance to O. ziegleri ziegleri, O. crassa, O. edithae, and O. typica. O. ziegleri crassatoides n. ssp. has closely set anterior blade denticles, the tips of which rise continuously in a straight line to tip of cusp and is thus distinguished from O. ziegleri ziegleri which has discrete, separated denticles on anterior blade with highest denticles not adjacent to cusp, and from O. crassa which has coarse, discrete anterior denticles and a straight blade in oral view. O. ziegleri crassatoides n. ssp. has coarse, closely set denticles and is distinguished from O. edithae which has fine partially fused denticles both anterior and posterior to cusp and a straight blade in oral view. O. ziegleri crassatoides n. ssp. has a moderately large, asymmetrically flared medial basal excavation which is often continuous to posterior end of blade and is thus distinguished from O. typica which has a small basal excavation restricted to region under cusp and a straight or gently bowed blade in oral view.

Occurrence.--Lower third of McKenzie Member of Mifflintown-?lower Wills Creek formations.

Material studied.--Approximately 225 specimens.

Repository.--Holotype, VPIL 1077; paratypes, VPIL 1067-1076, 1078-1080.

GENUS PANDERODUS Ethington, 1959

Panderodus Ethington, 1959, p. 284.

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

PANDERODUS SIMPLEX (Branson & Mehl)

Pl. 5, fig. 22; Pl. 10, figs. 14, 17, 20.

Paltodus simplex Branson & Mehl, 1933, p. 42, Pl. 3, fig. 4.

Paltodus acostatus Branson & Branson, 1947, (part), p. 554, Pl. 82, figs. 1-5 (only); Rhodes 1953, p. 296, Pl. 21, figs. 111, 112; Pl. 22, figs. 163, 164; Pl. 23, figs. 212, 213.

Paltodus cf. P. acostatus Branson & Branson. Walliser, 1960. p. 31, Pl. 7, fig. 10.

Panderodus acostatus (Branson & Branson). Serpagli & Greco, 1964, p. 204, Pl. 36, figs. 4a,b.

Panderodus simplex (Branson & Mehl). Rexroad, 1967, p. 45, Pl. 4, figs. 7, 8; Nicoll & Rexroad, 1968, p. 54, Pl. 7, fig. 28; Pollock, Rexroad, & Nicoll, 1970, p. 758, Pl. 114, figs. 23-25; Rexroad & Craig, 1971, p. 697, Pl. 81, figs. 35-40.

Holotype.--*Panderodus simplex* (Branson & Mehl), 1933, Pl. 81, fig. 35 a,b; re-illustrated by Rexroad & Craig, 1971, Pl. 81, fig. 35a, b.

Occurrence.--Cosner Gap Member of Mifflintown , Tonoloway formations.

Material studied.--Approximately 90 specimens.

Repository.--Figured specimens, VPIL 1081-1084.

GENUS PLECTOSPATHODUS Branson & Mehl, 1933

Plectospathodus Branson & Mehl, 1933, p. 47.

Type species.--*Plectospathodus flexuosus* Branson & Mehl, 1933.

PLECTOSPATHODUS ALTERNATUS Walliser

Pl. 14, figs. 18, 20.

Plectospathodus cf. P. extensus Ziegler, 1960, p. 191, Pl. 15, figs. 6, 7.

Sp. indet. a Walliser, 1960, p. 35, Pl. 7, fig. 14.

Plectospathodus alternatus Walliser, 1964, p. 64, Pl. 9, fig. 17; Pl. 30, figs. 23-25; Philip, 1966, p. 448, Pl. 3, figs. 10, 17, 21, 25; Barnett, Kohut, Rust & Sweet, 1966, Pl. 58, fig. 15.

Holotype.--Plectospathodus alternatus Walliser, 1964, Pl. 30, fig. 25.

Occurrence.--Upper Tonoloway Formation.

Material studied.--Approximately 40 specimens.

Repository.--Figured specimens, VPIL 1085-1086.

PLECTOSPATHODUS EXTENSUS Rhodes

Pl. 7, figs. 4, 7, 9, 10, 14, 16, 20, 27; Pl. 12, fig. 18; Pl. 15, figs. 1, 3-5, 13; Pl. 16, figs. 4, 5.

Plectospathodus extensus Rhodes, 1953, p. 523, Pl. 23, figs. 236-240; Walliser, 1957, p. 43, Pl. 3, figs. 1, 2; Walliser, 1960, p. 32, Pl. 8, fig. 20; Ethington & Furnish, 1962, p. 1281, Pl. 173, fig. 6; Spasov & Veselinović, (1962) 1963, p. 247, Pl. 2, fig. 4; Walliser, 1964, p. 64, Pl. 8, fig. 1; Pl. 30, figs. 13, 14; Serpaglio & Greco, 1964, p. 207, Pl. 37, fig 10; Barnett, Kohut, Rust, & Sweet, 1966, p. 435, Pl. 58, fig. 13, Mashkova, 1970, p. 221, Pl. 4, fig. 2; Pl. 11, fig. 6-8; Pl. 12, figs. 1-4; Text-fig. 1, fig. 6; Rexroad & Craig, 1971, p. 698, Pl. 82, figs. 26,27.

Holotype.--Plectospathodus extensus Rhodes, 1953, specimen under Cat. no. CIIA4d, deposited with the Geology Department of the University of Birmingham; designated by Rhodes but not figured in text.

Diagnosis.--A species of Plectospathodus with very variably arched and inwardly bowed blade. Blade denticles discrete, with one or two denticles of anterior blade nearly as large as apical cusp. Cusp nearly erect to strongly inclined inward, with base of cusp strongly expressed on inner side of blade. Basal excavation extended inward under cusp, inner margin of basal excavation strongly emarginated vertically on inner face of cusp.

Oral view.--Anterior and posterior blades nearly straight or strongly bowed with aboral edges twisted inward. Shorter anterior blade typically curved inward more than posterior blade. Anterior blade occasionally curved around with distal end subparallel to distal end of inwardly curved posterior blade, with aboral margins twisted inward so that ends of posterior and anterior blades are nearly perpendicular to each other. Cusp nearly erect or inclined inward as much as 60 degrees.

Aboral view.--Basal excavation deepest under cusp, strongly produced inward under base of cusp. Basal excavation broadly rounded on inner margin or extended under inner side of cusp as elongate trough. Basal excavation slightly constricted anteriorly and posteriorly, continuous toward ends of both blades as shallow tapering trough.

Inner lateral view.--Blades gently to strongly arched, with posterior blade curved downward more strongly than anterior blade. Anterior blade approximately one-half length of posterior blade. Inner margin of basal excavation emarginated vertically as rounded notch or as elongate compressed trough rising on inner face of cusp nearly to height of blades.

Cusp subtriangular, ovate, or subcircular in cross-section near base, frequently with sharp edges in plane of blade. Distally cusp becomes biconvex or lacrymalform with posterior edge of cusp twisted inward. Cusp nearly erect on gently arched and bowed specimens or strongly inclined inward as much as 60 degrees on strongly arched and bowed specimens.

Denticles of posterior blade 7 to 12 in number, subequal in size ovate to subcircular in cross-section. Denticles discrete, divergent in plane of blade, slightly curved inward.

Denticles of anterior blade 4 to 7 in number, unequal in size ovate to subcircular in cross-section. Denticles erect adjacent to cusp; denticles inclined away from cusp as much as 45 degrees near end of blade. Third and fourth or fourth and fifth denticles often nearly as large as cusp.

Remarks.--Specimens of *P. extensus* from the Cosner Gap Member are generally less strongly arched and bowed than specimens from the McKenzie Member of Mifflintown and Wills Creek formations. Cosner Gap specimens, on the average, have longer anterior and posterior blades with 1 or 2 more denticles per blade than McKenzie and Wills Creek specimens.

The few specimens from the upper Tonoloway Formation which are referable to this species have nearly straight anterior and posterior blades with the anterior blade bent inward at the cusp. These latter specimens do not have the base of the cusp strongly produced to the inner side of the blade, but they do have the inner margin of the basal excavation slightly emarginated vertically under the cusp. The specimens from the upper Tonoloway Formation are not as stout or as well preserved as material from the Rochester, McKenzie, and Wills Creek formations, but probably represent a phyletic subspecies of *P. extensus*.

Occurrence.--Cosner Gap Member of Mifflintown-Tonoloway formations.

Material studied.--Approximately 700 specimens.

Repository.--Figured specimens, VPIL 1087-1102.

PLECTOSPATHODUS FLEXUOSUS Branson & Mehl

Pl. 7, figs. 12, 18, 22, 25, 26; Pl. 16, fig. 7.

Plectospathodus flexuosus Branson & Mehl, 1933, p. 47, Pl. 3, fig. 31, 32; Walliser, 1964, p. 65, Pl. 9, fig. 10; Pl. 30, figs. 15, 16; Pollock, Rexroad & Nicoll, 1970, p. 758, Pl. 113, figs. 19, 20; Mashkova, 1970, p. 222-223, Pl. 2, fig. 10; Pl. 4, fig. 4; Pl. 11, figs. 9-13; Rexroad & Craig, 1971, p. 698-699, Pl. 82, figs. 3-7.

Plectospathodus elegans Rhodes, 1953, p. 323, Pl. 23, figs. 255, 263, 264.

Lectotype.--*Plectospathodus flexuosus* Branson & Mehl, 1933, Pl. 3, fig. 31; as designated by Walliser (1964).

Diagnosis.--A species of *Plectospathodus* with strongly compressed blade, cusp, and denticles. Posterior blade generally longer than anterior blade. Angle between posterior blade and anterior blade 90 to 135 degrees in vertical plane. Cusp variably inclined inward. Anterior blade bowed inward with second and/or third denticle nearly as large as cusp.

Oral view.--Posterior blade long straight or gently curved. Anterior blade, one-half as long as posterior blade, bent or curved inward 20 to 45 degrees with reference to posterior blade. Cusp nearly erect or inclined inward as much as 45 degrees. Blade, cusp, and denticles strongly compressed laterally.

Aboral view.--Basal excavation a small pit under apical cusp, slightly expanded inward. Basal excavation strongly constricted anteriorly and posteriorly and continuous under both blades as shallow, barely visible groove.

Inner lateral view.--Posterior blade long, gently curved downward. Anterior blade, one-half length of posterior blade, straight or gently curved downward, Measured in vertical plane angle between posterior and anterior blade varies from 90 to 135 degrees. Posterior blade and anterior blade diverge 45 to 55 degrees, and 45 to 80 degrees respectively from line of development of cusp. Lateral faces of blade flat or gently convex. Inner margin of basal excavation slightly emarginated vertically under cusp.

Cusp apical, nearly erect or inclined inward as much as 45 degrees, with outer face weakly concave to convex, inner face convex.

Denticles of posterior blade, 6 to 10 in number, of unequal size, fused nearly to tips or discrete with sharp lateral edges. Denticles erect along most of blade, with several at end of blade slightly inclined posteriorly.

Denticles biconvex to plano-convex in cross-section with flattened face outward.

Denticles of anterior blade, 3 to 6 in number, typically with second and/or third denticle as large as cusp, otherwise developed as denticles of posterior blade.

Occurrence.--Cosner Gap Member of Mifflintown-Wills Creek formations.

Material studied.--Approximately 120 specimens.

Repository.--Figured specimens, VPIL 1103-1108.

PLECTOSPATHODUS? n. sp.

Pl. 9, figs. 6, 9, 11, 14, 15.

Description.--Posterior? blade bent strongly downward about third or fourth denticle from cusp. Anterior? blade curved downward, then curved inward strongly about third or fourth denticle from cusp. Cusp and all blade denticles closely set, partially fused, with sharp edges in plane of blade. Basal excavation deepest, slightly expanded inward under apical cusp, continued under both blades as shallow V-shaped trough.

Remarks.--Poorly preserved material permits only uncertain generic assignment of this new species.

Occurrence.--Upper third of McKenzie Member of Mifflintown Formation.

Material studied.--8 specimens, all fragmentary.

Repository.--Figured specimens, VPIL 1109-1113.

GENUS SPATHOGNATHODUS Branson & Mehl, 1941

Spathognathodus Branson & Mehl, 1941, p. 98 [pro Spathodus Branson & Mehl, 1933].

Type species.--Spathodus primus Branson & Mehl, 1933.

Remarks.--This genus is the most abundant form in the sections being studied. It is also the most highly variable form studied and one which shows perhaps the greatest evolution. This may indicate that its functional role in the conodont animal was active and changing in Silurian times.

Several species of this genus were observed to lack bilateral symmetry. These species are all one-handed in that they all are flattened consistently on the same side.

The occurrence of asymmetric forms such as Spathognathodus primus concurs with Jeppsson's (1971) spatial arrangement of these elements in the conodont animal. Jeppsson pictures the spathognathodid elements as the most posterior elements in the conodont apparatus, paired, and with their longitudinal axis paralleling the long axis of the apparatus. In addition, the elements of the pair are rotated about their longitudinal axis approximately 90 degrees toward each other so that the oral margins overlap or mesh with each other. In the rotated, overlapping position, the flattened sides of the blade pair would be against each other.

Klapper (1969) reported that the lower Devonian forms, S. remscheidensis, S. optimus, and S. exiguus philipi have the anterior third of the blade offset to the right. This offset could also be related to secondary developmental features of the spathognathodid pair which has been rotated into a horizontal plane and with overlapping oral margins. In such a position, the offset of the anterior third of the blade would be away from the plane in which the blades overlap, the lower blade being offset downward and the upper blade being offset upward.

In describing specimens of Spathognathodus which are not bilaterally symmetrically, the writer has used the terms right and left rather than inner and outer to describe lateral views. In determining right and left sides, the blade is placed upright with the posterior end of the element toward the observer.

SPATHOGNATHODUS BICORNUTUS n. sp.

Pl. 1, figs. 5-7, 11, 13-16, 18; Pl. 2, figs. 1, 4, 16.

Gen. indet., sp. Walliser, 1964, p. 92, Pl. 32, fig. 2.

Gen. indet., n. sp. d Walliser, 1964, p. 91, Pl. 32, fig. 27.

Holotype.--Pl. 1, fig. 11a, b.

Derivation of name.--Bicornutus, Lat.; having two horns; refers to prominent anterior and posterior cusps.

Diagnosis.--A species of *Spathognathodus* with large asymmetric, subquadrate basal excavation and with prominent anterior and posterior terminal or subterminal cusps.

Oral view.--Blade straight or gently bowed laterally. Blade tapers anteriorly and posteriorly to sharp edge. Lateral lobes of basal excavation variously positioned under posterior half of blade, subquadrate to rounded in outline. Lateral lobes of several small specimens begin anterior to midpoint of blade and may extend along axis of blade as much as one-half length of blade. Lateral lobes extend along axis of blade approximately one-fifth length of blade in large specimens. Inner lobe rectangular to rounded, outer lobe rounded, often with outer posterior corner strongly directed posteriorly. Outer lobe as much as twice width of inner lobe perpendicular to blade.

Aboral view.--Basal excavation broadest and deepest under posterior half of blade, continues to anterior end of blade as shallow groove and to posterior end as tapering V-shaped trough.

Lateral view.--Blade outline changes from rectangular to trapezoidal with increasing size of specimen. Blade increases in thickness from oral margin to longitudinal line continuous with upper surface of lateral lobes of basal excavation, then constricts sharply to aboral margin. Anterior and posterior edges of blade straight and nearly vertical on small specimens. With development of anterior and posterior cusps, aboral corners become increasingly elongated to longitudinal spur-like processes and anterior and posterior margins of blade become convex, concave, or resupinate. Aboral margin straight in small specimens, with increased elongation of aboral corners, anterior and posterior ends of blade progressively arch downward. Apices of terminal cusps same height as rest of blade in small specimens, as much as twice height of blade in some large specimens. In all growth stages blade length varies greatly relative to blade height; there are many very short adult specimens.

Denticles, including cusps, strongly compressed laterally with sharp anterior and posterior edges. Denticles between cusps, subequal, fused except for discrete tips, vary in number from 5 to 8. Medial denticles fewest in number on large specimens. Medial denticles decrease in number due to fusion of denticles into edges of anterior and posterior cusps. Some small or intermediate specimens have single small denticles at ends of blade on free edges of cusps; these become fused into cusps on large specimens.

Remarks.--Variation in this form is extreme. There are few identical specimens within single samples.

Comparisons.--Walliser (1964, Pl. 32, figs. 2, 27) figured two specimens which the writer has interpreted as being conspecific with S. bicornutus n. sp. Walliser treated the smaller of these specimens (Pl. 32, fig. 2) as an aberrant form of S. sagitta rhenanus but did not give a species designation for the larger one (P. 32, fig. 27). The collection under study, however, contains specimens which show a complete gradation between forms similar to Walliser's specimens.

Small specimens of S. bicornutus n. sp. show considerable resemblance to S. sagitta bohemicus. However, these specimens of S. bicornutus n. sp. lack the fused denticles over the basal excavation which are typical of *S. sagitta bohemicus*.

Occurrence.--Lowest third of McKenzie Member of Mifflintown Formation.

Material studied.--More than 800 specimens.

Repository.--Holotype, VPIL 1117; paratypes, VPIL 1114-1116, 1118-1126.

SPATHOGNATHODUS CRISPUS

Pl. 14, figs. 1-4, 9, 14, 19, 21, 24, 27.

Spathognathodus crispus. Walliser, 1964, p. 74, 75. Pl. 9, fig. 3, Pl. 21, figs. 7-13.

Holotype.--*Spathognathodus crispus* Walliser, 1964, Pl. 21, figs. 12.

Diagnosis.--A species of *Spathognathodus* with large asymmetric, subquadrate basal excavation extending under posterior half of blade or slightly beyond end of blade. Denticles over posterior half of blade completely fused to knife-like ridge.

Oral view.--Blade straight with large asymmetric, subquadrate lobes of basal excavation extending under posterior half of blade and slightly beyond end of blade.

Transverse width of outer lateral lobe of basal excavation as much as twice that of inner lateral lobe. A few specimens from middle of Wills Creek Formation with basal excavation asymmetrically bilobate, developed diagonally to blade, and extending beyond end of blade.

Aboral view.--Basal excavation widest under third quarter of blade, tapering gradually to posterior end of blade, or rounded and extending beyond end of blade. Anteriorly, basal excavation constricted sharply and continuing toward anterior end of blade as narrow groove.

Lateral view.--Blade rectangular with straight aboral, oral, and anterior margins. Posterior margin straight, erect or inclined slightly to anterior, or concave with posterior oral corner extending beyond posterior aboral corner. A few specimens show gradual decrease in height of blade over posterior third of basal excavation to end of blade.

Denticles over anterior half of blade, 6 to 8 in number, subequal, fused except for tips. Denticles over posterior half of blade completely fused to knife-like ridge, or with 1 to 2 discrete denticles at posterior end of blade. A few specimens with 9 to 17 denticles with no fusion over posterior half of blade and with height of blade decreasing gradually to end of blade over posterior part of basal excavation.

Comparisons.--*S. crispus* has a markedly asymmetric basal excavation which extends beyond the posterior end of the blade and has the denticles of the posterior half of the blade completely fused. In contrast *S. sagitta bohemicus* has a subrounded basal excavation under the third quarter of blade, with only 2 to 4 completely fused denticles over the basal excavation, also the height of the blade decreases over the posterior quarter of blade. Further, *S. tillmani* has a subquadrate basal excavation extending from the midpoint not quite to the posterior end of the blade, with the denticles over the basal excavation fused to a knife-like ridge, and the height of the blade posterior to the basal excavation decreasing gradually to the end of the blade.

Occurrence.--Upper Wills Creek-lowest upper Tonoloway formations.

Material studied.--Approximately 140 specimens.

Repository.--Figured specimens, VPIL 1127-1136.

SPATHOGNATHODUS PRIMUS HIGHLANDENSIS n. ssp.

Pl. 14, figs. 7, 10-12, 15, 17, 22, 23, 25, 26, 28, 29.

Spathognathodus primus (Branson & Mehl), Walliser, 1964, Pl. 22, figs. 21-25; Text-fig. 8m, n.

Holotype.--Pl. 14, fig. 23.

Diagnosis.--A subspecies of *Spathognathodus primus* with discrete high denticles. Height of denticles and blade decreases both anteriorly and posteriorly of nearly medial cusp-like denticle.

Oral view.--Blade straight or slightly bowed laterally. Occasional specimens have posterior half of blade slightly twisted along longitudinal axis. Lateral lobes of basal excavation small.

Aboral view.--Basal excavation small, flaring laterally, under midpoint to slightly anterior of midpoint of blade. Basal excavation constricted anteriorly and posteriorly to shallow, tapering trough, continuing toward both ends of blade.

Lateral view.--Aboral margin straight or gently arched. Anterior and posterior margins straight or rounded, with aboral corners generally obtuse. Oral margin increases in height from anterior end of blade to cusp-like denticle over or slightly posterior to midpoint of blade and then decreases in height to posterior end. Posterior oral margin relatively lower than anterior half. In large specimens, posterior half of unit bar-like in contrast to blade-like anterior half.

Denticles, 8 to 14 in number, subequal to unequal, discrete to base, occasionally separated as much as width of one denticle over posterior end of blade. Cusp-like denticle over, or slightly posterior to, basal excavation. Cusp and denticles posterior to cusp inclined posteriorly as much as 20 degrees.

Bilateral symmetry in development of basal excavation apparently lacking. Viewed with the blade flat and posterior end of blade to left, margin of lateral lobe of basal excavation is drawn upward above aboral margin, making basal excavation visible. Viewed from opposite side, aboral margin and lateral lobe of basal excavation form a continuous straight line.

Comparisons.--*Spathognathodus primus highlandensis* n. ssp. is probably conspecific with specimens of *S. primus* illustrated by Walliser (1964, Pl. 22, figs. 21-25) from the *eosteinhornensis* Zone. The posterior half of *S. primus highlandensis* n. ssp. is bar-like and considerably lower than the anterior half. It is thus distinguished from *Spathognathodus interpositus* Mashkova, in which the height of the blade is more uniform and the basal cavity is less conspicuously asymmetric.

Occurrence.--Upper Wills Creek-lower Tonoloway formations.

Material studied.--Approximately 60 specimens.

Repository.--Holotype, VPIL 1144; paratypes, VPIL 1137-1143, 1145-1148.

SPATHOGNATHODUS PRIMUS MULTIDENTATUS n. ssp.

Pl. 13, figs. 12-17; Pl. 16, fig. 26.

Spathognathodus primus (Branson & Mehl). Walliser, 1964, Pl. 22, fig. 14, Text-fig. 8d.

Holotype.--Pl. 13, fig. 14.

Derivation of name.--Multidentatus, Lat., having many denticles, referring to the large number of blade denticles.

Diagnosis.--A subspecies of Spathognathodus primus with approximately 20 to 30 irregular blade denticles. Denticles acicular to coarse and cusp-like, closely crowded, partially fused to discrete.

Comparisons.--S. primus multidentatus n. ssp. appears to be conspecific with the specimen pictured as S. primus by Walliser (1964, Pl. 22, fig. 14) from the latialatus Zone in the Carnic Alps. Spathognathodus primus multi-

dentatus n. ssp. has a large number of partially fused to discrete, irregular blade denticles and is distinguished from *Spathognathodus primus primus* (Branson & Mehl) which has approximately 12 to 15 denticles, generally fused except for discrete tips.

Occurrence.--Lower Wills Creek Formation.

Material studied. Approximately 120 specimens.

Repository.--Holotype, VPIL 1151; paratypes, VPIL 1149-1150, 1152-1155.

SPATHOGNATHODUS PRIMUS (Branson & Mehl)

SPATHOGNATHODUS PRIMUS PRIMUS (Branson & Mehl)

Pl. 2, figs. 2, 5, 8, 9; Pl. 3, figs. 1-12; Pl. 11, fig. 11; Pl. 13, figs. 5, 10; Pl. 16, fig. 23.

Spathodus primus Branson & Mehl, 1933, p. 46, Pl. 2, figs. 25-30.

Spathognathodus primus (Branson & Mehl). Rhodes, 1953, p. 325, Pl. 23, figs. 243, 256, 258, 259; Walliser, 1964, p. 80-82, Pl. 8, fig. 14; Pl. 22, figs. 9-25; Pl. 23, figs. 1-4; Text-fig. 8; Philip, 1969, p. 295, Pl. 17, figs. 22, 24; Rexroad & Craig, 1971, p. 700, Pl. 82, figs. 11-15.

Lectotype.--Spathodus primus Branson & Mehl, 1933, Pl. 3, fig. 25; designated by Walliser, 1957, p. 48.

Diagnosis.--A subspecies of Spathognathodus primus with small, nearly medial basal excavation and small asymmetric lateral lobes. Anteriorly, 1 to 4 denticles raised prominently above rest of denticles. 1 or 2 prominent denticles commonly over or slightly posterior to basal excavation. Height of blade decreases from midpoint to posterior end of blade. Blade and denticles flattened on left side of blade.

Oral view.--Blade straight. Small asymmetric lateral lobe of basal excavation developed medially or slightly anterior of midpoint of blade.

Aboral view.--Basal excavation small, consisting of a laterally produced pit located medially or slightly anterior to midpoint of blade. Basal excavation sharply constricted anteriorly and posteriorly, continued toward both ends of blade as shallow groove.

Lateral view.--Posterior aboral margin commonly offset above anterior aboral margin. A few specimens with straight aboral margin or with anterior aboral margin curved upward across basal excavation as much as 25 degrees from line of posterior aboral margin. Posterior aboral margin commonly gently arched. Anterior aboral margin straight or gently rounded. From anterior end, oral margin increases in height for as much as one-fifth length of blade, then is sharply offset downward as much as one-half height of anterior end of blade, and gently curves downward until oral margin joins aboral margin at posterior end of blade. Contrast in height of anterior and posterior denticles subdued on large specimens. Blade thickens slightly from oral margin downward to line continuous with upper surface of lateral lobes and parallel to aboral margin, then constricts sharply to aboral margin. Left side of blade and denticles flattened. Right side of blade and denticles gently convex. Elements lack mirror image symmetry.

Denticles, 10 to 19 in number, fused except for discrete tips, subequal to unequal in height, 1 or 2 denticles over or immediately posterior to basal excavation often prominent and cusp-like. Denticles erect or with those posterior to basal excavation increasingly inclined to posterior to as much as 30 degrees at end of blade.

Comparisons.--A few specimens of *S. primus* have blade of relatively uniform height and resemble *S. steinhornensis eosteinhornensis*. These forms of *S. primus* have small lateral lobes in contrast to large flaring lateral lobes of *S. steinhornensis eosteinhornensis*.

Discussion.--The absence of mirror image or bilaterally symmetrical pairs has been observed by the writer. If specimens are set upright with the posterior end of the blade oriented toward the observer, the flattened side is consistently to the left (symmetry class III a, Lane, 1968).

Jeppsson (1971) in discussing the various elements and their positions in the biological species has oriented spathognathodid elements with the blades in a horizontal plane with the denticle rows possibly overlapping. This is consistent with the asymmetric lateral flattening of the blade of *S. primus primus*. Any two specimens of *S. primus primus* placed parallel to one another, with the posterior end of the blades toward the observer, when turned on their sides with the denticle rows toward one another can be made to overlap on their flattened sides. The writer interprets this asymmetry as secondarily imposed on the original bilateral symmetry of the element pairs, possibly reflecting their change in functional position in the conodont apparatus.

Occurrence.--Cosner Gap Member of Mifflintown-Tonoloway formations.

Material studied.--More than 1100 specimens.

Repository.--Figured specimens, VPIL 1156-1175.

SPATHOGNATHODUS SAGITTA BOHEMICUS Walliser

Pl. 1, figs. 2-4, 8, 12, 17, 20.

Spathognathodus sagitta bohemicus Walliser, 1964, p. 83, Pl. 7, fig. 4; Pl. 18, figs. 23, 24.

Holotype.--*Spathognathodus sagitta bohemicus* Walliser, 1964, Pl. 18, fig. 24.

Diagnosis.--A subspecies of *Spathognathodus sagitta* with subcircular, asymmetric basal excavation.

Oral view.--Blade straight or rarely bowed laterally. Basal excavation small to large. Lateral lobes of basal excavation begin medially and continue posteriorly a distance up to one-third length of blade. Inner lobe rounded to subquadrate, outer lobe subcircular. Transverse width of outer lobe as much as twice that of inner lobe. Blade thickens gradually from oral edge to longitudinal line continuous with upper surface of lateral lobes, then constricts sharply to aboral margin.

Aboral view.--Basal excavation continues as narrow groove beyond lateral lobes to both anterior and posterior ends of blade.

Lateral view.--Aboral margin straight or rarely arched, anterior and posterior aboral corners nearly rectangular.

Oral profile of uniform height, decreasing in height posteriorly, or decreasing toward both ends of blade.

Denticles 8 to 16 in number, fused except for discrete tips, 2 to 4 denticles over basal excavation commonly fused to form knife-like ridge. Denticles subequal in size or, posterior denticles twice as wide in plane of blade as anterior denticles.

Comparisons.--The subcircular basal excavation of *S. sagitta bohemicus* distinguishes it from *S. sagitta sagitta* which has a symmetrical lanceolate basal excavation and from *S. sagitta rhenanus* which has an asymmetrical lanceolate basal excavation.

Discussion.--A few specimens show the development of a cusp at one or both ends of the blade. These are interpreted as intermediate between *S. sagitta bohemicus* and *S. bicornutus* n. sp. Generally these specimens have several denticles over the basal excavation fused to form a knife-like ridge in the manner of *S. sagitta bohemicus* and are included in the total count of this subspecies.

Occurrence.--Cosner Gap Member of Mifflintown Formation.

Material studied.--Approximately 450 specimens.

Repository.--Figured specimens, VPIL 1176-1182.

SPATHOGNATHODUS SNAJDRI Walliser

Pl. 2, figs. 3, 7, 10-15, 17.

Spathognathodus snajdri Walliser, 1964, p. 83, Pl. 21, figs. 14, 15, Pl. 22, figs. 1-4; Rexroad & Craig, 1971, p. 700, Pl. 82, figs. 16, 17.

Holotype.--Spathognathodus snajdri Walliser, 1964, Pl. 20, fig. 1.

Diagnosis.--A species of Spathognathodus with large asymmetric basal excavation under posterior half of blade. Basal excavation flares laterally under third quarter of blade to produce large asymmetric lateral lobes, then constricts sharply and tapers to posterior end of blade.

Oral view.--Blade straight with asymmetric lateral lobes of basal excavation extending along third quarter of blade. Inner lobe subquadrate, offset anteriorly in relation to outer rounded lobe. Curvature of upper surface of inner lobe broken by two low ridges which diverge anteriorly and posteriorly toward outer edge of lobe, producing angular outer corners. Perpendicular to blade, outer lobe as much as twice width of inner lobe. Curvature of outer lobe broken by single ridge directed to posterior corner, making posterior corner of lobe angular in appearance.

Aboral view.--Posterior half of blade completely excavated. Excavation with widest development under third quarter of blade, constricted posteriorly, continued to posterior end of blade as wide, gradually tapering, V-shaped trough. Anteriorly, basal excavation constricted to narrow groove, continuing to anterior end of blade. Aboral surface of lateral lobes of basal excavation marked by angular breaks in curvature paralleling low ridges on upper surface.

Lateral view.--Blade long relative to height. Aboral margin straight under posterior half of blade, arched under anterior half of blade. Anterior aboral corner on some specimens curved downward. Anterior margin straight on small specimens; on large specimens, blade lengthens anteriorly and oral edge curves down to join aboral margin. Oral profile increases in height from anterior end of blade along first quarter of blade, lowers slightly and continues parallel to aboral margin to middle of basal excavation, then curves downward over posterior quarter of blade to meet aboral margin.

Denticles, 11 to more than 18 in number, subequal in size, fused nearly to tips. Tips of denticles more prominent over anterior and posterior quarters of blade. Blade denticles of some specimens fused to form sharp, slightly crenulated ridge over middle part of basal excavation.

Occurrence.--Upper third of McKenzie Member of Mifflintown Formation.

Material studied.--Approximately 90 specimens.

Repository.--Figured specimens, VPIL 1183-1191.

SPATHOGNATHODUS STEINHORNENSIS EOSTEINHORNENSIS Walliser

Pl. 11, figs. 1-10, 12-16; Pl. 14, figs. 5, 6.

Spathognathodus steinhornensis eosteinhornensis Walliser, 1964, p. 85, 86, Pl. 9, fig. 15; Pl. 20, figs. 7-16, 19-25; Text-fig. 9; Legault, 1968, p. 17, 18, Pl. 1, figs. 1-3.

Holotype.--Spathognathodus steinhornensis eosteinhornensis Walliser, 1964, Pl. 20, fig. 21.

Diagnosis.--A subspecies of Spathognathodus steinhornensis with variably expanded, asymmetric basal excavation extending under middle to third quarter of blade and with nearly regular oral margin.

Oral view.--Blade straight or gently bowed laterally. Lateral lobes of large asymmetric basal excavation extended under middle or third quarter of blade. Outline of lateral lobes strongly bilobate, subcircular, subquadrate, to heart-shaped with apex directed posteriorly. Perpendicular to blade, outer lateral lobe as much as twice width of inner lateral lobe.

Aboral view.--Asymmetric, laterally expanded basal excavation, medial or under third quarter of blade, generally narrows to point posteriorly and continues to end of blade as narrow tapering V-shaped trough. Anteriorly basal excavation constricted sharply, continuing toward anterior end of blade as shallow groove.

Lateral view.--Aboral margin straight or with anterior margin straight and posterior margin bent up out of line as much as 40 degrees across basal excavation. A few specimens show slight arching of anterior or posterior aboral margin. Anterior and posterior margin straight and erect. Oral margin nearly regular in outline, subparallel to aboral margin. A few specimens with height of blade decreasing at oral corners.

Denticles, 9 to 13 in number, subequal to unequal in size, fused except for discrete tips. Denticles of large specimens of nearly uniform height with denticle over basal excavation and second denticle from anterior end of blade commonly wider in plane of blade. Denticles of small specimens irregular in size and development, with denticle over basal excavation cusp-like. Median denticle occasionally thickened on outer side to form convex ridge extending down to lobe of basal excavation.

Comparisons.--*S. steinhornensis eosteinhornensis* shows considerable resemblance to *S. steinhornensis remscheidensis*. The difference between these two subspecies is one of degree of variation of the outline of the lateral lobes and of the oral margin. *S. steinhornensis eosteinhornensis* has a very variable lateral lobe outline but nearly regular oral margin and is distinguished from *S. steinhornensis remscheidensis* which according to Walliser has a more consistently heart-shaped lateral lobe outline, with the denticle over the basal excavation and the second denticle from the anterior end of the blade prominent and cusp-like.

Small specimens of *S. steinhornensis eosteinhornensis* have a *remscheidensis*-like oral margin. Larger specimens from the same samples show a gradual reduction in size of the cusp-like denticles to produce an *eosteinhornensis*-like oral margin.

Occurrence.--Upper Tonoloway Formation-Keyser Limestone.

Material studied.--About 425 specimens.

Repository.--Figured specimens, VPIL 1192-1208.

SPATHOGNATHODUS TILLMANI n. sp.

Pl. 13, figs. 1-4, 6-9, 11.

Holotype.--Pl. 13, fig. 6.

Derivation of name.--After C. G. Tillman, Professor of Geology at Virginia Polytechnic Institute and State University.

Diagnosis.--A species of Spathognathodus with large asymmetric, subquadrate basal excavation extending posteriorly from mid-point of blade approximately one-third length of blade. Denticles over basal excavation fused to knife-like ridge.

Oral view.--Blade straight, strongly compressed laterally. Large asymmetric, subquadrate lateral lobes of basal excavation extend posteriorly from midpoint of blade for distance approximately one-third length of blade. Perpendicular to blade, outer lobe as much as twice width of inner lobe. Outer lateral lobe of basal excavation slightly offset to posterior in relation to inner lateral lobe.

Aboral view.--Basal excavation strongly constricted anteriorly and posteriorly to lateral lobes, continuous as shallow narrow groove to both ends of blade.

Lateral view.--Blade rectangular in outline, with straight aboral margin. Anterior margin straight, erect or slightly inclined to posterior. Oral margin relatively straight from anterior end of blade to posterior end of basal excavation, then decreasing in height sharply at anterior end of blade. A few specimens with anterior end of oral margin reduced in height also. Posterior blade only one-half as high as blade over midpoint. Blade increases slightly in thickness from oral margin to line continuous with upper surface of lateral lobes of basal excavation, then constricts to aboral margin. Both sides of blade compressed and flattened.

Denticles, 13 to 18 in number, subequal, fused except for discrete tips. Denticles over basal excavation completely fused to knife-like ridge.

Comparisons.--*Spathognathodus tillmani* n. sp. shows considerable resemblance to *S. sagitta bohemicus* and to *S. snajdri*. *S. tillmani* n. sp. is distinguished by its subquadrate basal excavation and the strong lateral compression of the blade. *S. sagitta bohemicus* has a subrounded basal excavation and is not compressed strongly laterally. *S. snajdri* has a relatively longer blade and the posterior half of the blade is excavated.

Occurrence.--Lower Wills Creek Formation.

Material studied.--37 specimens.

Repository.--Holotype, VPIL 1213; paratypes, VPIL 1209-1212, 1214-1217.

SPATHOGNATHODUS WALLISERI n. sp.

Pl. 1; figs. 1, 9, 10, 19, 21.

Spathognathodus n. sp. Walliser, 1964, p. 88, Pl. 22, fig. 8.

Holotype.--Pl. 1, fig. 21.

Derivation of name.--After Dr. Otto H. Walliser.

Diagnosis.--A species of Spathognathodus with large asymmetric posterior basal excavation, and with a lateral blade developed at approximately 90 degrees to main blade on outer, larger lobe of basal excavation.

Oral view.--Blade straight to near posterior end where blade over posterior third of basal excavation is bent inward about 30 degrees. Lateral denticulated blade extends at right angle to blade over posterior third of outer, larger lobe of basal excavation. Lobes of basal excavation begin slightly posterior to midpoint of blade. Basal excavation subquadrate, anterior corners rounded, posterior corners rectangular. Greatest dimension of basal excavation at right angle to blade, with outer lobe as much as twice as wide as inner lobe.

Aboral view.--Basal excavation broadest and deepest under posterior half of blade, continuing as trough to anterior end of blade, but terminating posteriorly at point under junction of blade and auxiliary lateral blade.

Lateral view.--Blade rectangular in outline, aboral and anterior margins straight, posterior margin concave, oral profile lower anteriorly and posteriorly.

Denticles 7 to 13 in number from anterior end of blade to junction with lateral blade. Denticles erect or with 3 to 4 denticles at anterior and posterior end of blade inclined as much as 30 degrees toward anterior and toward posterior respectively. Inwardly flexed portion of blade and outer lateral blade increase in length by addition of discrete denticles on lobes of basal excavation, with observed number of denticles increasing up to 6 and 8 respectively. These discrete denticles increase in size and fuse to form the blade-like processes.

Comparisons.--The specimens studied appear to be conspecific with *Spathognathodus* n. sp. Walliser (1964, Pl. 22, fig. 8) from the *sagitta* Zone near Giessen.

Discussion.--Nicoll and Rexroad (1968) noted that specimens identified by them as Spathognathodus ranuliformis Walliser sometimes had a denticle on the outer lobe of the basal excavation and questioned whether S. n. sp. Walliser (1964, Pl. 22, fig. 8) might be a gerontic form of that species. None of the specimens of S. ranuliformis illustrated by Walliser or Rexroad show a row of denticles over the basal excavation in the position of the lateral blade. This lateral blade, or a row of discrete denticles is present on all but the smallest of the specimens from the Cosner Gap Member of the Mifflintown Formation. However, the secondary addition of denticles on the basal excavation to form the lateral process of the Appalachian form indicates that the two species are probably part of a direct evolutionary lineage.

Occurrence.--Lower Cosner Gap Member of Mifflintown Formation.

Material studied.--14 specimens.

Repository.--Holotype, VPIL 1222; paratypes, VPIL 1218-1221.

SPATHOGNATHODUS sp.

Pl. 7, figs. 2, 3.

Description.--A species of Spathognathodus with slightly expanded basal excavation situated posterior to mid-point of blade and continued toward posterior about one-quarter of length of blade. Blade straight in oral view, slightly arched over mid-point of basal excavation in lateral view. Denticles, closely set, discrete to near base, with 2 or 3 denticles over basal excavation twice as wide in plane of blade as remaining denticles.

Occurrence.--Lower Cosner Gap Member of Mifflintown Formation.

Material studied.--2 specimens.

Repository.--Figured specimens, VPIL 1223-1224.

GENUS SYNPRIONIODINA Bassler, 1925

Synprioniodina Bassler, 1925, p. 219; Ulrich & Bassler, 1926, p. 42; Huddle, 1968, p. 45.

Type species.--Synprioniodina alternata Bassler, 1925.

SYNPRIONIODINA BICURVATA (Branson & Mehl)

Pl. 9, figs. 1, 17-19, 24; Pl. 12, figs. 4, 12, 13.

Prioniodus bicurvatus Branson & Mehl, 1933, p. 44, Pl. 3, figs. 9-12.

Prioniodina bicurvata pronoides Walliser, 1960, p. 33, Pl. 8, figs. 8-10.

Neoprioniodus bicurvatus (Branson & Mehl). Walliser, 1964, p. 46, Pl. 9, fig. 13; Pl. 29, figs. 27-33; Text-fig. 5d; Barnett, Kohut, Rust, & Sweet, 1966, Pl. 58, fig. 22; Philip, 1966, p. 292, Pl. 17, fig. 15; Mashkova, 1970, p. 217-8, Pl. 3, fig. 8; Pl. 4, fig. 5; Pl. 7, fig. 6, 8-10; Text-fig. 1, fig. 17.

Synprioniodina bicurvata pronoides (Walliser). Moskalenko, (1966) 1967, p. 202, Pl. 1, figs. 16-18.

Synprioniodina bicurvata (Branson & Mehl). Pollock, Rexroad, & Nicoll, 1970, p. 762, Pl. 114, figs. 16, 17; Rexroad & Craig, 1971, p. 700-701, Pl. 80, figs. 18, 19.

Lectotype.--Prioniodus bicurvatus Branson & Mehl, 1933, Pl. 3, fig. 12; as designated by Walliser (1957).

Diagnosis.--A species of Synprioniodina with long inwardly curved terminal cusp with subtriangular cross-section. Posterior blade arched, bowed, and bearing numerous closely set, laterally compressed, partially fused denticles, oriented subparallel to cusp.

Oral view.--Cusp curved inward as much as 45 degrees. Posterior blade gently bowed.

Aboral view.--Basal excavation deepest under cusp and expanded inward with rounded inner margin. Basal excavation constricted posteriorly and anteriorly, continued under posterior blade as shallow, tapering V-shaped trough and under anticusp as shallow groove.

Lateral view.--Posterior blade gently arched, nearly twice as long as cusp. Anticusp increasing in length with size of specimen from short non-denticulate ridge on anterior edge of cusp to denticulate process more than half as long as cusp on large specimens. Angle between posterior blade and anticusp approximately 80 degrees. Posterior blade diverges about 50 degrees from line of development of cusp. Anticusp diverges about 30 degrees from line of development of cusp. Basal excavation expressed on inner side of cusp as conical ridge extending to height of blade. Outer face of blade flattened, inner face gently convex to rounded.

Cusp long, subtriangular in cross-section with sharp edges in plane of blade, outer face plane to gently convex with inner face angular to broadly rounded.

Denticles of posterior blade, 10 to 20 in number, subequal in size, subparallel to cusp, crowded, discrete or partially fused.

Denticles of anticusp, increasing in number with size of specimen from none visible to as many as 8, partially or almost completely fused. A few specimens have denticles fused entirely into anterior edge of cusp making cusp appear asymmetric in cross-section and in relation to position of basal cavity.

Remarks.--This species is fairly consistent in overall form; two changes do occur, however, which could prove useful stratigraphically. Specimens from the Cosner Gap Member typically have finer, more numerous, closely set denticles; while specimens from the Tonoloway Formation have fewer denticle which are discrete or slightly separated.

Occurrence.--Cosner Gap Member of Mifflintown-Tonoloway formations.

Material studied.--Approximately 275 specimens.

Repository.--Figured specimens, VPIL 1225-1232.

SYNPRIONIODINA LOWRYI n. sp.

Pl. 9, figs. 20, 23, 26, 28-32; Pl. 12, figs. 10, 11; Pl. 16, fig. 11.

Holotype.--Pl. 9, fig. 30.

Derivation of name.--After Dr. W. D. Lowry, Professor of Geology at Virginia Polytechnic Institute and State University.

Diagnosis.--A species of Synprioniodina with long rounded, gently curved posterior blade. Cusp stout, rounded, gently curved inward. Anticusp blade-like, laterally compressed, denticulated, strongly produced downward from outer anterior edge of cusp.

Oral view.--Posterior blade slightly curved inward. Anticusp strongly compressed laterally, produced from outer anterior edge of cusp. Cusp curved inward 20 to 45 degrees.

Aboral view.--Basal excavation deepest under cusp, and expanded inward to form a conical pit. Basal excavation constricted slightly posteriorly and continuous under posterior blade as gradually tapering shallow V-shaped trough. Basal excavation constricted strongly anteriorly and continuous under anticusp as tapering V-shaped groove.

Inner lateral view.--Posterior blade strongly bent downward adjacent to cusp, then continued straight or in a gentle arch. Anticusp produced strongly downward, straight, makes angle of 60 to 80 degrees with posterior blade. In vertical plane, posterior blade diverges 40 to 50 degrees from axis of cusp, and anticusp diverges 20 to 30 degrees from axis of cusp. Basal excavation expressed on inner side of blade beneath cusp as rounded conical ridge rising approximately the height of the blade.

Cusp circular in cross-section or occasionally with sharp edges in plane of blade.

Denticles of posterior blade, 5 to 10 or more in number, unequal in size, discrete, irregularly spaced. Denticles nearly circular in cross-section adjacent to cusp, becoming laterally compressed distally. Denticles adjacent to cusp inclined in direction of cusp and nearly parallel to cusp. Distally the denticles become erect.

Denticles of anticusp, 2 to 5 in number, otherwise developed exactly as denticles of posterior blade.

Comparisons.--*Synprioniodina lowryi* n. sp. shows some similarities to *S. bicurvata*. *S. lowryi* n. sp. has strongly rounded blade, cusp, and denticles and is thus distinguished from *S. bicurvata* which is strongly compressed laterally.

Remarks.--Specimens from the McKenzie Member of the Mifflintown have approximately 10 denticles on the posterior blade and 3 to 5 denticles on the anticusp. Specimens of *S. lowryi* n. sp. from the Wills Creek Formation have as few as 5 blade denticles and 2 to 3 denticles on the anticusp. The Wills Creek specimens are small in comparison to the McKenzie specimens, and the differences noted may be due to different growth stages or represent stratigraphic change.

Occurrence.--McKenzie Member of Mifflintown-Wills Creek formations.

Material studied.--Approximately 100 specimens.

Repository.--Holotype, VPIL 1238; paratypes, VPIL 1233-1237, 1239-1243.

SYNPRIONIODINA n. sp.

Pl. 9, fig. 33.

Description.--A species of Synprioniodina with deep, curved, laterally compressed, posterior blade which in lateral view makes an angle of approximately 70 degrees with anticusp. Denticles of posterior blade and anticusp, partially fused, compressed in plane of blade, inclined toward cusp. Cusp short, curved inwardly, unequally biconvex in cross-section, with sharp edges in plane of blade. Basal excavation deepest under cusp, expanded posteriorly to form conical pit, constricted anteriorly and posteriorly, continued under posterior blade and anticusp as shallow V-shaped trough.

Occurrence.--Upper McKenzie Memberof Mifflintown Formation.

Material studied.--5 specimens.

Repository.--Figured specimens, VPIL 1244.

SYNPRIONIODINA sp.

Pl. 10, fig. 11.

Description.--A species of Synprioniodina with inwardly curved, ovate, apical cusp. Posterior blade, arched, rounded on inner face. Anticusp strongly compressed, offset to outer anterior margin of cusp. Denticles of posterior blade closely set, subparallel to cusp adjacent to cusp, becoming erect toward posterior end of blade. Denticles of anterior process, 2 in number, subcircular, subparallel to cusp, slightly curved inward.

Occurrence.--Upper Cosner Gap Member of Mifflintown Formation.

Material studied.--1 specimen.

Repository.--Figured specimen, VPIL 1245.

GENUS TRICHONODELLA (Branson & Mehl), 1948

Trichonodella (Branson & Mehl), 1948, p. 527 [pro Trichognathus Branson and Mehl, 1933]

Type species.--Trichognathus prima Branson & Mehl, 1933.

TRICHONODELLA EXCAVATA (Branson & Mehl)

Pl. 8, figs. 1, 4, 5, 7, 9, 10, 14, 17, 23-25, 27, 28, 30, 31; Pl. 15, figs. 9, 12, 16.

Trichognathus excavata Branson & Mehl, 1933, p. 51, Pl. 3

figs. 35, 36.

Trichonodella aborflexa Rhodes, 1953, p. 312-313, Pl. 23, figs. 231, 241, 242.

Trichnodella excavata (Branson & Mehl). Walliser, 1957, p. 48, Pl. 3, figs. 3, 4, 6-8; Text-fig. 2; Ethington & Furnish, 1962, p.1287, Pl. 173, fig. 8; Serpagli & Greco, 1964, p. 209, Pl. 37, fig. 12; Walliser, 1964, p. 89, Pl. 8, fig. 2; Pl. 31, figs. 26, 27; Barnett, Kohut, Rust, & Sweet, 1966, Pl. 58, fig. 14; Nicoll & Rexroad, 1968, p. 63, Pl. 4, fig. 2; Mashkova, 1970, p. 226, Pl. 4, fig. 2; Pl. 14, figs. 15-16, 18, 21; Rexroad & Craig, 1971, p. 701, Pl. 79, figs. 43-46.

Lectotype.--Trichognathus excavata Branson & Mehl, 1933, Pl. 3, fig. 36; designated by Walliser (1957).

Diagnosis.--A species of Trichonodella with large apical cusp, strongly curved to posterior, with basal excavation elongated posteriorly under base of cusp and extended vertically on posterior face of cusp. Base of cusp strongly developed posteriorly to plane of lateral blades.

Oral view.--Lateral blades extended slightly anteriorly from antero-lateral margins of cusp and then extended laterally or curved slightly to posterior as much as 30 degrees from transverse vertical plane.

Aboral view.--Base of cusp strongly developed to posterior of lateral blades. Basal excavation developed transverse to cusp and continuous under lateral blades as narrow, gradually tapering groove, and posteriorly under cusp as broad V-shaped trough as wide as base of cusp.

Posterior view.--Aboral margin of lateral blades nearly straight to continuously curved with angle between lateral blades varying from 80 to 140 degrees. Basal excavation produced vertically along posterior face of cusp as elongate tapering trough or as elongate parallel-sided trough with rounded apical margin.

Cusp continuously curved or straight and inclined posteriorly as much as 45 degrees. Cusp ovate in cross-section distally with longest axis of oval directed laterally. At junction of cusp with lateral blades, cusp cross-section subtriangular to subrectangular. These two cross-sectional shapes are gradational into one another in specimens from the same sample. Many specimens have incised grooves on lateral faces of cusp parallel to antero-lateral edges; grooves originate on upper surface of lateral blades and extend nearly to tip of cusp.

Blade denticles, 5 to 12 in number per blade, unequal in size, rounded to subovate, occasionally with sharp lateral edges. Blade denticles decrease in size adjacent to cusp and at ends of blades. Denticles curved slightly to posterior and separated by space equal to single denticle or closely set at base. A few specimens have denticles adjacent to cusp fused into antero-lateral edges of cusp.

Comparisons.--Specimens of *Trichonodella excavata* with triangular cusp show considerable similarity to *T. symmetrica*. *T. excavata* has the cusp strongly developed posteriorly of the lateral blades and strongly inclined posteriorly, and is distinguished from *T. symmetrica* which has the base of the cusp largely in the plane of the lateral blades.

Remarks.--Variation is wide in all samples, however, most specimens from the Cosner Gap Member of Mifflintown Formation have cusp with concave anterior face near base, sharp lateral edges, subtriangular cross-section, and lateral blades with straight aboral margins. Specimens from the McKenzie Member of Mifflintown and Wills Creek formations have a cusp with a convex anterior face, a subtriangular to subrectangular cross-section near base, and grooves on the antero-lateral edges; the lateral blades have curved aboral margins.

Close affinity with *Roundya* is shown by the development of a denticle on the apex of the posterior margin of the basal excavation of a few specimens.

Occurrence.--Cosner Gap Member of Mifflintown-Wills Creek formations.

Material studied.--Approximately 625 specimens.

Repository.--Figured specimens, VPIL 1246-1263.

TRICHONODELLA INCONSTANS Walliser

Pl. 8, figs. 6, 11-13, 16, 20, 21; Pl. 16, figs. 19, 20.

Trichonodella inconstans Walliser, 1957, p. 50, Pl. 3, figs. 10-17; Text-fig. 3; 1960, p. 35, Pl. 7, figs. 11, 12; Ethington & Furnish, 1962, p. 1287, Pl. 173, fig. 7; Walliser, 1964, p. 90, Pl. 8, fig.8, Pl. 30, figs. 10-12; Nicoll & Rexroad, 1968, p. 64, Pl. 4, fig. 1; Legault, 1968, p. 18, 19, Pl. 1, figs. 7-9; Philip, 1969, p. 295, Pl. 18, figs. 9, 12, 14, 15; Pollock, Rexroad, & Nicoll, 1970, p. 762-3, Pl. 113, figs. 26, 27; Rexroad & Craig, 1971, p. 701, Pl. 79, figs. 39-42.

Holotype.--Trichonodella inconstans Walliser, 1957, Pl. 3, fig. 16.

Diagnosis.--A species of Trichonodella with long, stout, posteriorly curved apical cusp, with lateral blades variably arched and curved posteriorly, with discrete denticles, and with deep subapical basal excavation extended to ends of lateral blades as a shallow trough.

Oral view.--Cusp gently to strongly curved toward posterior, lateral blades compressed to rounded, extended straight laterally or curved posteriorly as much as 30 degrees from transverse vertical plane.

Aboral view.--Basal excavation deepest under cusp, expanded posteriorly with rounded or angular margin, continued to ends of lateral blades as shallow V-shaped trough.

Posterior view.--Lateral blades arched with interior angle varying from 80 to 140 degrees. Posterior margin of basal excavation straight or with slight vertical emargination.

Cusp nearly straight or curved posteriorly as much as 30 degrees, subcircular to subtriangular incross-section, with sharp or rounded lateral edges.

Denticles, 5 to 9 in number per blade, ovate to rounded with sharp or rounded lateral edges, unequal in size, generally discrete, and regularly to irregularly spaced. Denticles generally smallest adjacent to cusp and at end of lateral blades, a few specimens with small needle-like denticles inserted between larger denticles along the length of the blade. A few specimens with one or two pairs of coalesced blade denticles.

Comparisons.--Some specimens of *Trichonodella inconstans* are grossly similar to *T. excavata* and *T. symmetrica*. However, *T. inconstans* has the cusp developed largely in the plane of the blades, with the basal excavation extended to the ends of the lateral blades as a shallow V-shaped trough. In contrast, *T. excavata* has the cusp strongly developed posteriorly of the plane of the lateral blades and the basal excavation extended under the lateral blades as a narrow groove. *T. inconstans* has discrete, ovate to rounded, irregularly separated denticles and is distinguished in this way from *T. symmetrica* which has closely set or partially fused, strongly compressed blade denticles.

Remarks.--Specimens from the lower McKenzie Member of the Mifflintown Formation associated with *Spathognathodus bicornutus* n. sp. show no vertical emargination of the posterior margin of the basal excavation. Stratigraphically higher specimens generally have the posterior margin slightly emarginated vertically.

Occurrence.--McKenzie Memberof Mifflintown-lower Tonoloway formations.

Material studied.--Approximately 85 specimens.

Repository.--Figured specimens, VPIL 1264-1272.

TRICHONODELLA SYMMETRICA (Branson & Mehl)

Pl. 8, figs. 2, 3, 15, 19, 26, 29; Pl. 16, figs. 8, 12, 17.

Trichognathus symmetrica Branson & Mehl, 1933, p. 50, Pl. 3, figs. 33, 34.

Trichonodella symmetrica (Branson & Mehl). Rhodes, 1953, p. 315-316, Pl. 23, figs. 232, 246; Walliser, 1964, p. 90, Pl. 9, fig. 11; Pl. 31, figs. 28-30; Philip, 1969, p. 295, Pl. 18, fig. 24; Pollock, Rexroad & Nicoll, 1970, p. 763, Pl. 113, figs. 22-24; Rexroad & Craig, 1971, p. 701-702, Pl. 79, figs. 47-51.

Neotype.--Trichonodella symmetrica (Branson & Mehl), 1933; designated by Rexroad & Craig (1971, Pl. 79, fig. 47.)

Diagnosis.--A species of Trichonodella with strongly compressed lateral blades and denticles, and nearly erect cusp which is subtriangular in cross-section along its entire length.

Oral view.--Lateral blades straight to slightly curved posteriorly. Cusp slightly inclined posteriorly or occasionally strongly bent posteriorly at point above lateral blades.

Aboral view.--Basal excavation triangular, deep under cusp, continuous under lateral blades as shallow grooves or barely noticeable striae.

Posterior view.--Aboral margin of lateral blades straight or gently curved with angle between blades varying between 90-150 degrees.

Cusp subtriangular in cross-section along its entire length, with sharp lateral edges, and with sharp or rounded posterior edge. Anterior face of cusp concave to convex, lateral faces plane to convex. Posterior basal margin slightly emarginated vertically.

Denticles of lateral blades, 7 to 9 in number per blade, compressed in plane of blade, closely set or partially fused at base with sharp lateral edges. Denticles subequal to unequal in size, smallest adjacent to cusp and at ends of blade.

Comparisons.--*Trichondella symmetrica* shows considerable similarity to some specimens of *T. excavata*. *T. symmetrica* has a cusp which is subtriangular in cross-section along its entire length and nearly erect or bent posteriorly above point of attachment of the lateral blades. It is distinguished from *T. excavata* in which the cusp has an ovate cross-section distally, and is offset posteriorly from lateral blades so that the base is almost wholly behind the plane of the lateral blades, with the basal excavation elongated posteriorly under the base of the cusp.

Occurrence.--Cosner Gap Member of Mifflintown-lower Tonoloway formations.

Material studied.--Approximately 100 specimens.

Repository.--Figured specimens, VPIL 1273-1281.

TRICHONODELLA n. sp.

Pl. 8, figs. 18, 22.

Description.--A species of Trichonodella with deep lateral blades; interior angle between blades in posterior view approximately, 60 degrees. Blade denticles biconvex in cross-section, with sharp edges in plane of blade. Cusp short, unequally biconvex in cross-section, with sharp lateral edges, curved posteriorly. Basal excavation deepest under cusp, slightly expanded posteriorly, constricted laterally, continued under lateral blades as shallow V-shaped trough.

Occurrence.--Upper McKenzie Member of Mifflintown Formation.

Material studied.--3 specimens.

Repository.--Figured specimens, VPIL 1282-1283.

TRICHONODELLA sp.

Pl. 8, fig. 8.

Description.--A species of Trichonodella with stout triangular cusp, with straight lateral blades meeting at angle of approximately 120 degrees, and with 3 erect denticles on each blade. Antero-basal margin of cusp rounded and projected below base of lateral blades.

Occurrence.--Upper Cosner Gap Member of Mifflintown Formation.

Material studied.--1 specimen.

Repository.--Figured specimen, VPIL 1284.

Gen. et. sp. indet. A.

Pl. 12, fig. 26.

Description.--A simple cone, recurved, bilaterlly, symmetrical in cross-section with single costa on each side originating approximately at mid-point of basal lateral margin. Basal excavation rises approximately one-fourth of height of cusp.

Occurrence.--Lower Tonoloway Formation.

Material studied.--1 specimen.

Repository.--Figured specimen, VPIL 1289.

Gen. et sp. indet. B.

Pl. 12, figs. 7,8,22.

Description.--A laterally compressed, asymmetric, cone-like form, with base elongated in antero-posterior plane. Cusp, long, strongly curved toward posterior, twisted distally, with costate ridge on inner antero-lateral margin. With several small vertically directed denticles on lower part of antero-lateral costate ridge. With several needle-like, erect denticles arranged in vertical row on posterior margin toward base of cusp.

Remarks.--The specimens bear some resemblance to the form genus *Cordylodus*.

Occurrence.--Lower Tonoloway Formation.

Material studied.--3 specimens.

Repository.--Figured specimens, VPIL 1290-1292.

Gen. et sp. indet. C.

Pl. 16, fig. 10.

Description.--A laterally compressed form with base elongated in antero-posterior plane. Cusp long, strongly curved toward posterior, with 5 denticles in a vertical row on lower posterior margin.

Occurrence.--Lower Tonoloway Formation.

Material studied.--1 specimen.

Repository.--Figured specimen, VPIL 1293.

N. Gen. et n. sp.

Pl. 16, figs. 1-3, 6.

Description.--A form with anterior blade and posterior platform. Anterior blade spathognathodid-like in development; posterior half, elongate, ovoid platform, completely excavated. Basal excavation deepest medially, rises approximately one-third height of platform. Platform rises from margin of basal excavation to height of blade or slightly higher. Denticle row of anterior blade continued across platform as row of small denticles or carina. A series of ridges extends outward from both sides of carina. Vertical faces of platform concave.

Occurrence.--Upper Tonoloway Formation.

Material studied.--4 specimens.

Repository.--Figured specimens, VPIL 1285-1288.

Explanation of Plate 1

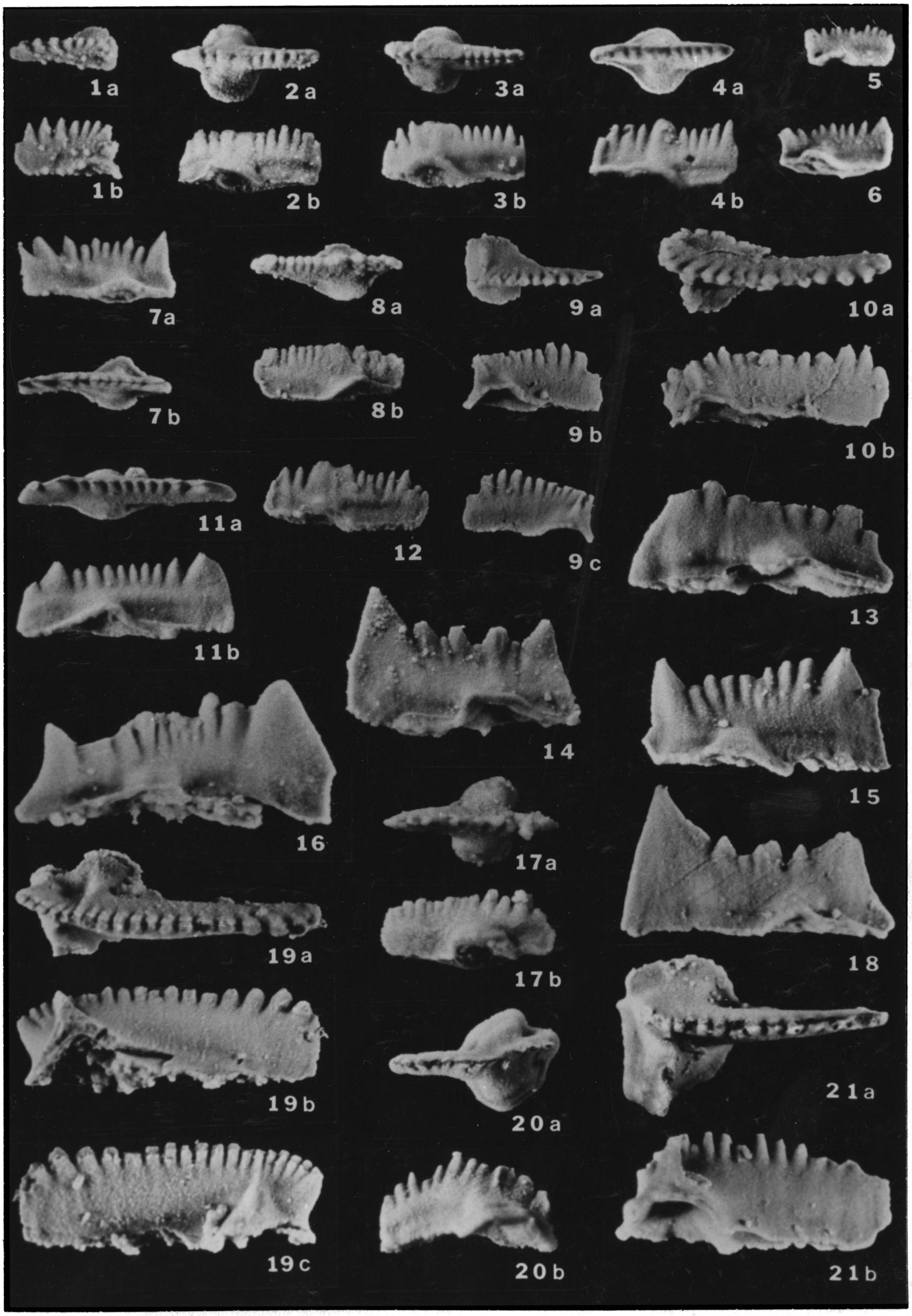
All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,9,10,19,21--Spathognathodus walliseri n. sp. 1a-b, Upper and left lateral views of paratype VPIL 1218 (CG-CG1); 9a-c, upper, right, and left lateral views of paratype VPIL 1219 (CB-CG2); 10a-b, upper and right lateral views of paratype VPIL 1220 (MG-CG3); 19a-c, upper, right, and left lateral views of paratype VPIL 1221 (CG-CG5); 21a-b, upper and right lateral views of holotype VPIL 1222 (CG-CG6).

2-4,8,12,17,20--Spathognathodus sagitta bohemicus Walliser. 2a-4b, Upper and right lateral views of VPIL 1176 (MG-CG5), VPIL 1177 (MG-CG5), and VPIL 1178 (MG-CG5); 8a-b, upper and left lateral views of VPIL 1179 (CG-CG7); 12, right lateral view of VPIL 1180 (CG-CG7); 17a-b, upper and left lateral views of VPIL 1181 (MG-CG5); 20a-b, upper and left lateral views of VPIL 1182 (MG-CG5).

5-7,11,13-16,18.--Spathognathodus bicornutus n. sp. 5,6, Right lateral views of paratypes VPIL 1114

(KR-McK5) and VPIL 1115 (KR-McK5); 7a-b, upper and left lateral views of paratype VPIL 1116 (CB-McK4); 11a-b, upper and left lateral views of holotype VPIL 1117 (CB-McK3); 13-16, left, left, right, and right lateral views of paratypes VPIL 1118 (CG-McK1), VPIL 1119 (CG-McK1), VPIL 1120 (KR-McK5), and VPIL 1121 (CB-McK3); 18, left lateral view of paratype VPIL 1122 (CB-McK2).


1a
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17a
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21a
19c
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21b

Plate 1

Explanation of Plate 2

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,4,6,16--Spathognathodus bicornutus n. sp. 1a-b, Upper and right lateral views of paratype VPIL 1123 (KR-McK5); 4, left lateral view of paratype VPIL 1124 (KR-McK5); 6a-b 16a-b, upper and left lateral views of paratype VPIL 1125 (KR-McK5), and VPIL 1126 (CB-McK1).

2,5,8,9--Spathognathodus primus primus (Branson & Mehl). 2,5, Left and right lateral views of VPIL 1156 (KR-McK12) and VPIL 1157 (CB-McK9C); 8a-b, left and right lateral views of VPIL 1158 (KR-CG2B); 9, left lateral view of VPIL 1159 (KR-McK6).

3,7,10-15,17--Spathognathodus snajdri Walliser. 3, Left lateral view of VPIL 1183 (CB-McK7C); 7, 10, right and left lateral views of VPIL 1184 (CB-McK7C) and VPIL 1185 (KR-McK12); 11a-b, upper and right lateral views of VPIL 1186 (CB-McK7); 12,13, left and right lateral views of VPIL 1187 (CB-McK7C) and VPIL 1188 (KR-McK12); 14a-15b, upper and left lateral views of VPIL

1189 (CB-McK8A), and VPIL 1190 (CB-McK5C); 17a-b, upper and right lateral views of VPIL 1191 (CB-McK7A).

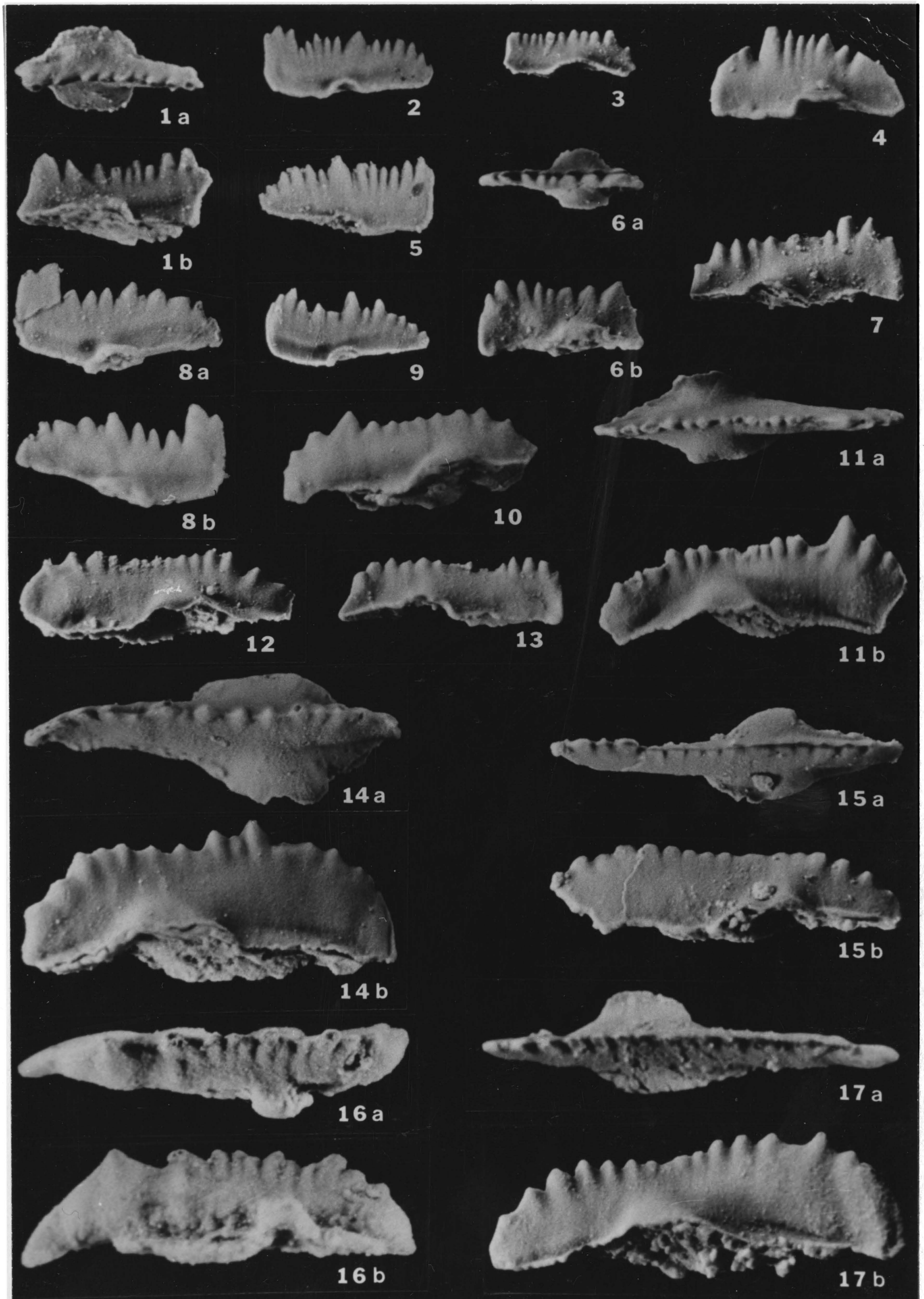
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Plate 2

Explanation of Plate 3

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1-12--Spathognathodus primus primus (Branson & Mehl). 1a-c, Aberrant specimen, left lateral, upper, and right lateral views of VPIL 1160 (P-McK1); 2-5, right, right, left, and left lateral views of VPIL 1161 (MG-7), VPIL 1162 (CB-McK9D), VPIL 1163 (KR-McK6), and VPIL 1164 (KR-McK6); 6a-b, upper and right lateral views of VPIL 1165 (CB-McK6A); 7, right lateral view of VPIL 1166 (CB-McK14); 8a-b, upper and left lateral views of VPIL 1167 (CB-McK9D); 9,10, right lateral views of VPIL 1168 (CB-McK6D) and VPIL 1169 (CB-McK6D); 11a-c, upper, left, and right lateral views of VPIL 1170 (CB-McK7C); 12a-b, upper and right lateral views of VPIL 1171 (CB-McK9C).

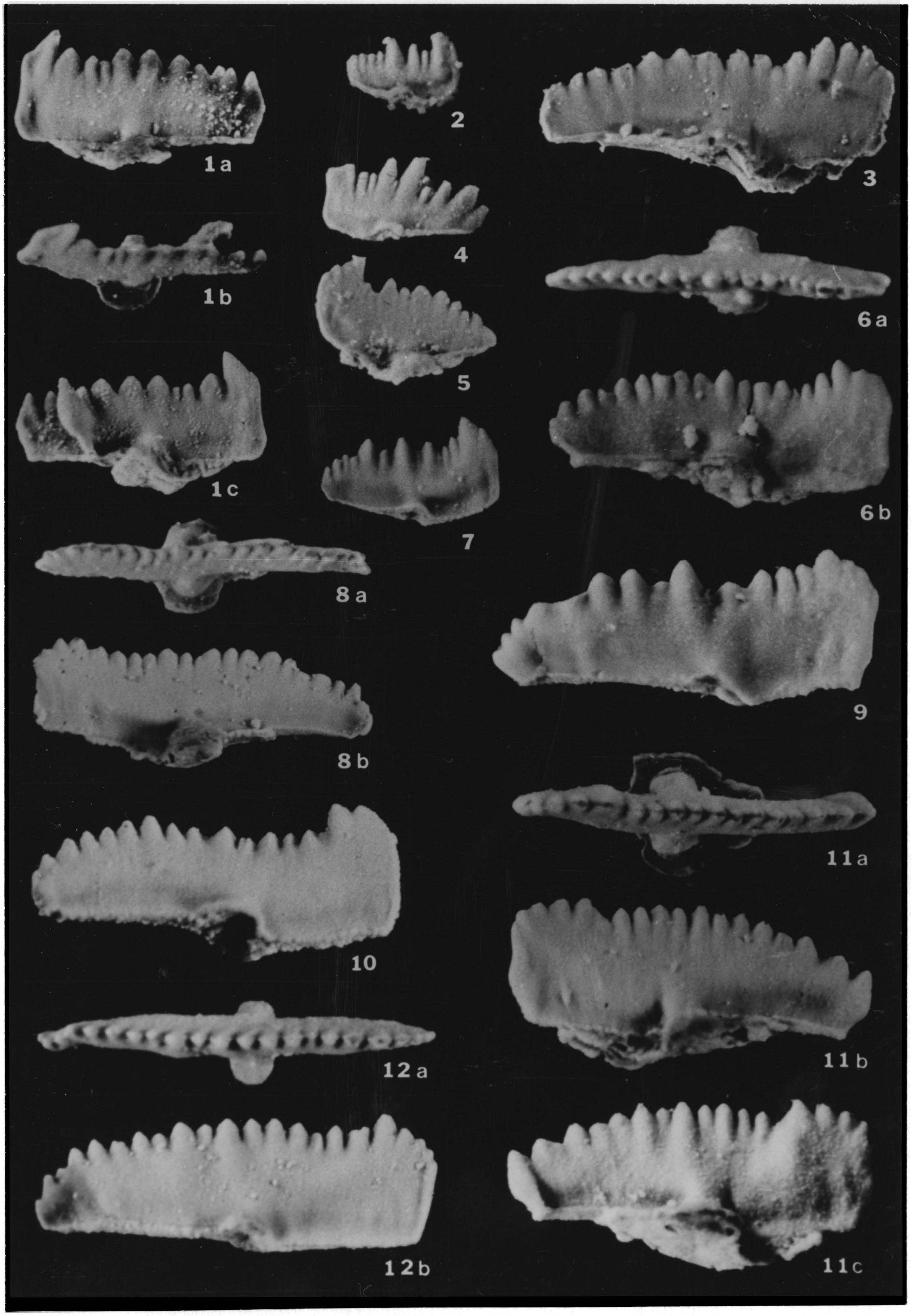

Plate 3

Explanation of Plate 4

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1-5,8,9,12,16--Ozarkodina edithae mariae n. ssp. 1-4, Right lateral views of paratypes VPIL 987 (CB-CG2), VPIL 988 (CB-CG3), VPIL 989 (CB-CG3), and VPIL 990 (MG-CG5); 5a-b, right and left lateral views of paratype VPIL 991 (MG-CG5); 8,9, right lateral views of holotype VPIL 992 (CB-CG3) and paratype VPIL 993 (CG7); 12,16, left lateral views of paratypes VPIL 994 (CG-CG7) and VPIL 995 (CB-CG3).

6,7,10,13,14,17,18--Ozarkodina typica typica Branson & Mehl. 6,7,10,13,14,17, right, left, right, left, right, and right lateral views of VPIL 1057 (MG-7), VPIL 1058 (MG-1), VPIL 1059 (CB-McK14), VPIL 1060 (MG-7), VPIL 1061 (CB-McK6), and VPIL 1062 (P-McK1); 18a-b, left and right lateral views of VPIL 1063 (CB-McK6A).

11,15,19-25--Ozarkodina serrata n. sp. 11,15,19-21, left, left, left, left, and right lateral views of paratypes VPIL 1001 (CB-McK6D), VPIL 1002 (CB-McK7C), VPIL 1003 (CB-McK7C), VPIL 1004

(CB-McK7C), and VPIL 1005 (CB-McK8A); 22a-b, left and right lateral views of holotype VPIL 1006 (CB-McK6C); 23, right lateral view of paratype VPIL 1007 (CB-McK7C); 24a-b, left and right lateral views of paratype VPIL 1008 (CB-McK7); 25, right lateral view of paratype VPIL 1009 (CB-McK8A).

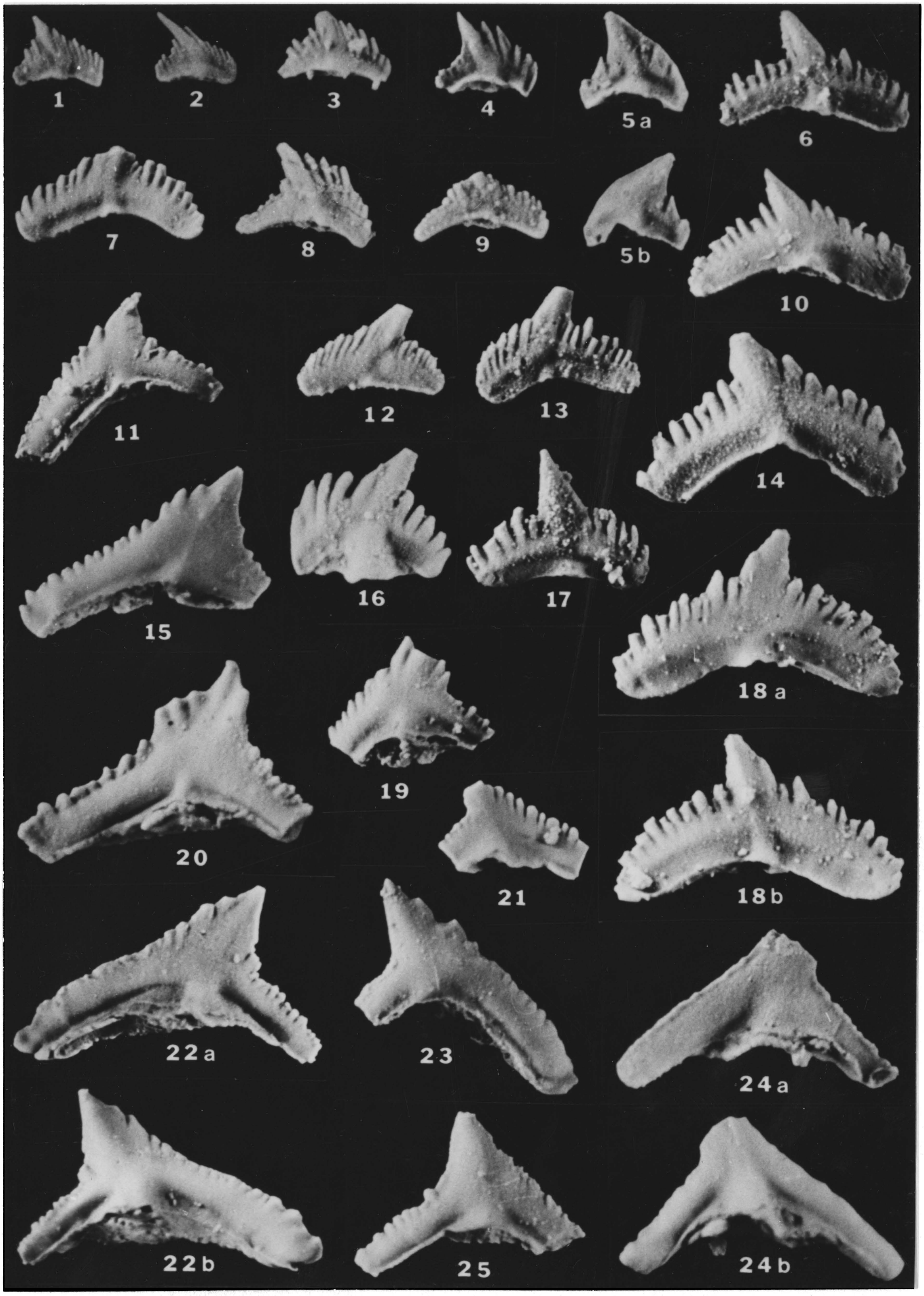
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Plate 4

Explanation of Plate 5

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,2,6--*Lonchodina walliseri* Ziegler. 1,2. Inner lateral views of VPIL 959 (CB-McK6C) and VPIL 960 (CB-McK7C); 6a-b, outer and inner lateral views of VPIL 961 (CB-McK8).

3,4,7,8,12-20,24--*Ozarkodina ziegleri crassatoides* n. ssp. 3,4,7,8,12,13, Right lateral views of paratypes VPIL 1067 (CB-McK4), VPIL 1068 (CB-McK4), VPIL 1069 (MG-5), VPIL 1070 (CB-McK4), VPIL 1071 (CB-McK3), and VPIL 1072 (CG-McK1); 14-17, left, left, right, and right lateral views of paratypes VPIL 1073 (KR-McK5), VPIL 1074 (MG-6), VPIL 1075 (CB-McK3), and VPIL 1076 (CG-McK1); 18, left lateral view of holotype VPIL 1077 (CB-McK3); 19a-b, left and right lateral views of paratype VPIL 1078 (KR-McK5); 20,24, right and left lateral views of paratypes VPIL 1079 (CB-McK4) and VPIL 1080 (KR-McK5).

5,9-11,21,23,25,26--*Hindeodella confluens* Branson & Mehl. 5,9-11, Inner lateral views of VPIL 900 (MG-CG5), VPIL 901 (KR-McK6), VPIL 902 (MG-8), and VPIL 903 (MG-CG5); 21,23,25,26, inner lateral views of VPIL 904 (JG-3), VPIL 905 (CG-CG6), VPIL 906 (CB-McK6C), and VPIL 907 (CB-McK9E).

22--*Panderodus* *simplex* (Branson & Mehl). 22a-b Lateral views of VPIL 1081 (CG-CG1).

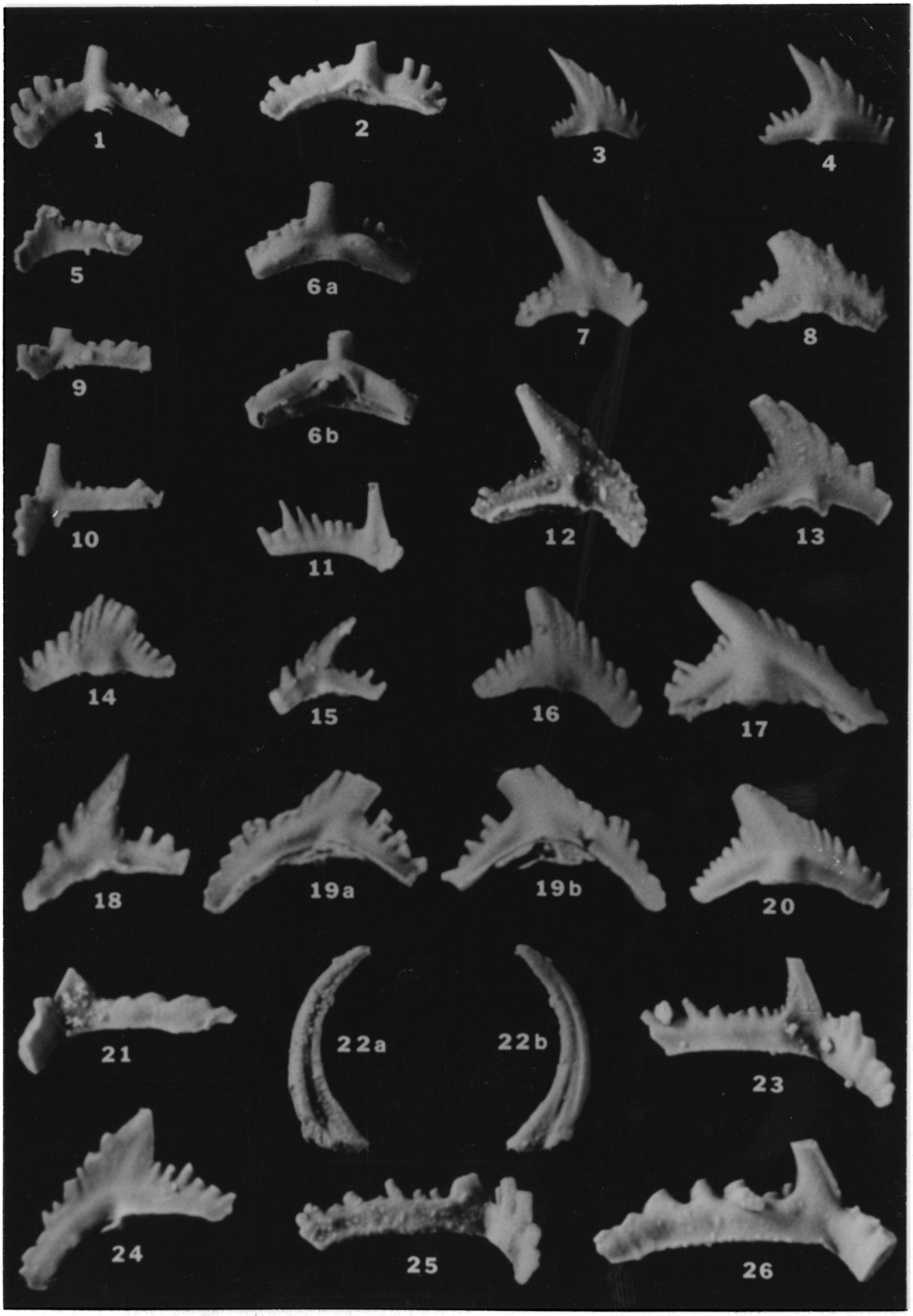
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Plate 5

Explanation of Plate 6

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1-3,5,6,17,27--Lonchodina walliseri Ziegler. 1-3, 5,6, Inner lateral views of VPIL 962 (CB-McK9E), VPIL 963 (CB-McK9), VPIL 964 (CB-McK7C), VPIL 965 (CB-McK7C), and VPIL 966 (CB-McK9D); 17, 27, inner lateral views of VPIL 967 (CB-McK9C) and VPIL 968 (KR-McK14).

4,7-16,18-21,23,24,26,28,29--Ozarkodina tenuiramea Walliser. 4,7,8, Right, left, and right lateral views of VPIL 1018 (CB-McK10), VPIL 1019 (CB-McK9), and VPIL 1020 (MG-7); 9-12, left, left, right, and right lateral views of VPIL 1021 (CB-McK7C); VPIL 1022 (CB-McK8), VPIL 1023 (CB-McK10), and VPIL 1024 (CB-McK6); 13-16, left, left, right, and right lateral views of VPIL 1025 (JG-6), VPIL 1026 (KR-McK9), VPIL 1027 (JG-2), and VPIL 1028 (MG-7); 18-20, left, right, and right lateral views of VPIL 1029 (CB-McK8A), VPIL 1030 (KR-McK6), and VPIL 1031 (CB-McK6B); 21,23, left and right lateral views of VPIL 1032 (MG-12) and VPIL 1033 (JG-2); 24,26,28,29, left, right, left, and right lateral views of VPIL 1034 (MG-7), VPIL 1035 (KR-McK7), VPIL 1036 (KR-McK8), and VPIL 1037 (KR-McK12).

22,25--Ozarkodina aequalis Walliser. 22,25, Left and right lateral views of VPIL 983 (CG-CG1) and VPIL 984 (CB-CG2).

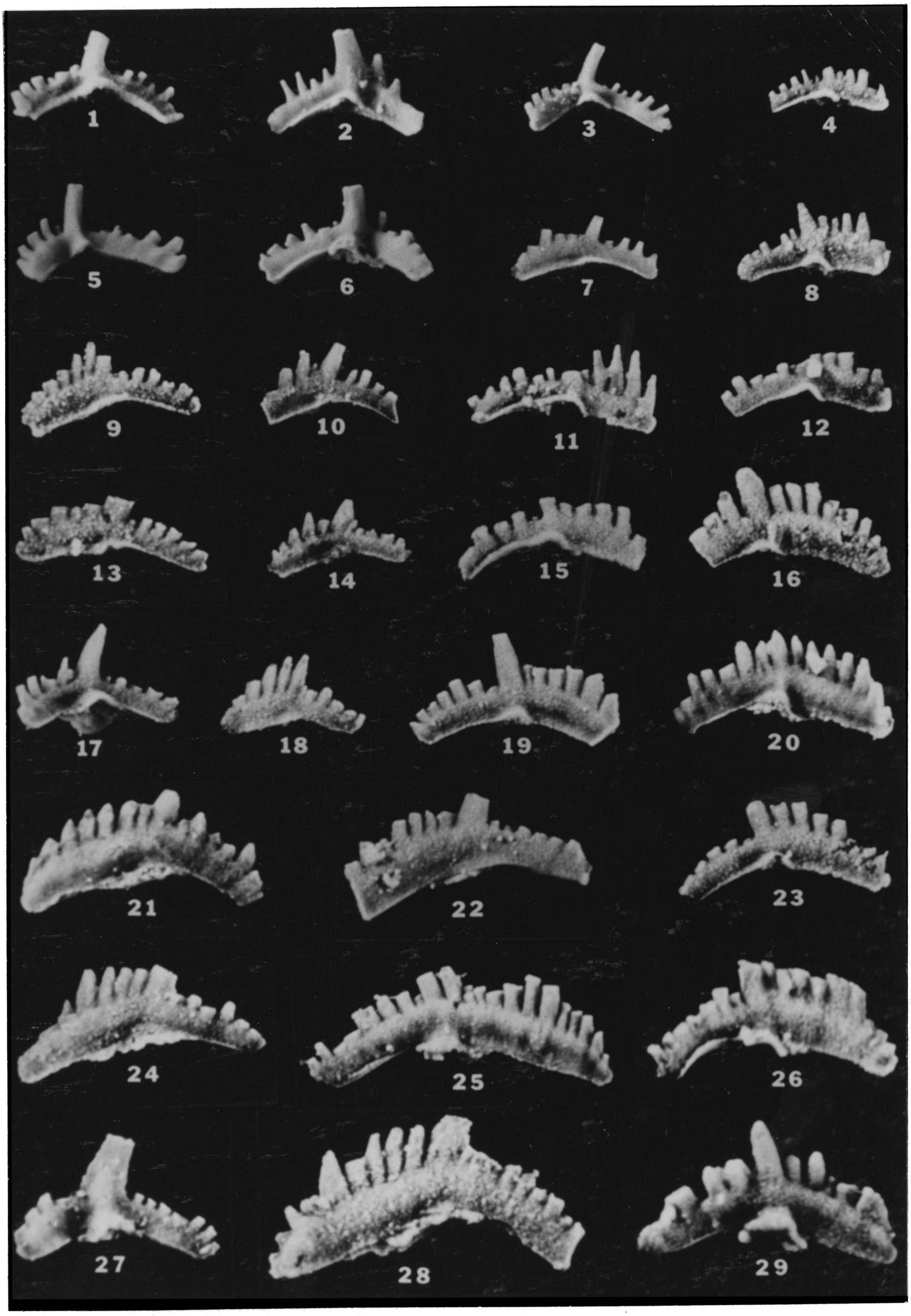

Plate 6

Explanation of Plate 7

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,6,8,11,15,19,23--Ozarkodina tenuiramea Walliser. 1,6,8,11, Left, left, right, and right lateral views of VPIL 1038 (KR-McK10), VPIL 1039 (CB-McK6C), VPIL 1040 (CB-McK9D), and VPIL 1041 (CB-McK6C); 15,19,23, left, right, and left lateral views of VPIL 1042 (CB-McK9D), VPIL 1043 (CB-McK6C), and VPIL 1044 (MG-8).

2,3--Spathognathodus sp. 2,3, Left and right lateral views of VPIL 1223 (CG-CG1) and VPIL 1224 (CG-CG1).

4,7,9,10,14,16,20,27--Plectospathodus extensus Rhodes. 4,7, Inner lateral views of VPIL 1087 (MG-7) and VPIL 1088 (CG-CG2); 9a-b, inner and outer lateral views of VPIL 1089 (CB-McK9E); 10,14,16,20,27, inner lateral views of VPIL 1090 (MG-7), VPIL 1091 (KR-McK6), VPIL 1092 (CB-McK6C), VPIL 1093 (MG-7), and VPIL 1094 (CG-CG2).

5,13,17,21,24--Lonchodina? greilingi Walliser. Inner lateral views of VPIL 946 (CB-McK4), VPIL 947 (CG-McK1), VPIL 948 (CG-McK1), VPIL 949 (CB-McK3), and VPIL 950 (CG-McK1).

12,18,22,25,26--Plectospathodus flexuosus Branson & Mehl. Inner lateral views of VPIL 1103 (CB-McK6D), VPIL 1104 (CG-CG6), VPIL 1105 (CB-McK6), VPIL 1106 (KR-McK18), and VPIL 1107 (CG-CG6).

28,29--Ozarkodina aequalis Walliser. Left and right lateral views of VPIL 985 (CB-CG6) and VPIL 986 (CG-CG1).

30-32--Ozarkodina typica typica Branson & Mehl. Left, right, and right lateral views of VPIL 1064 (CB-McK6D), VPIL 1065 (CB-CG2), and VPIL 1066(CB-McK9E).

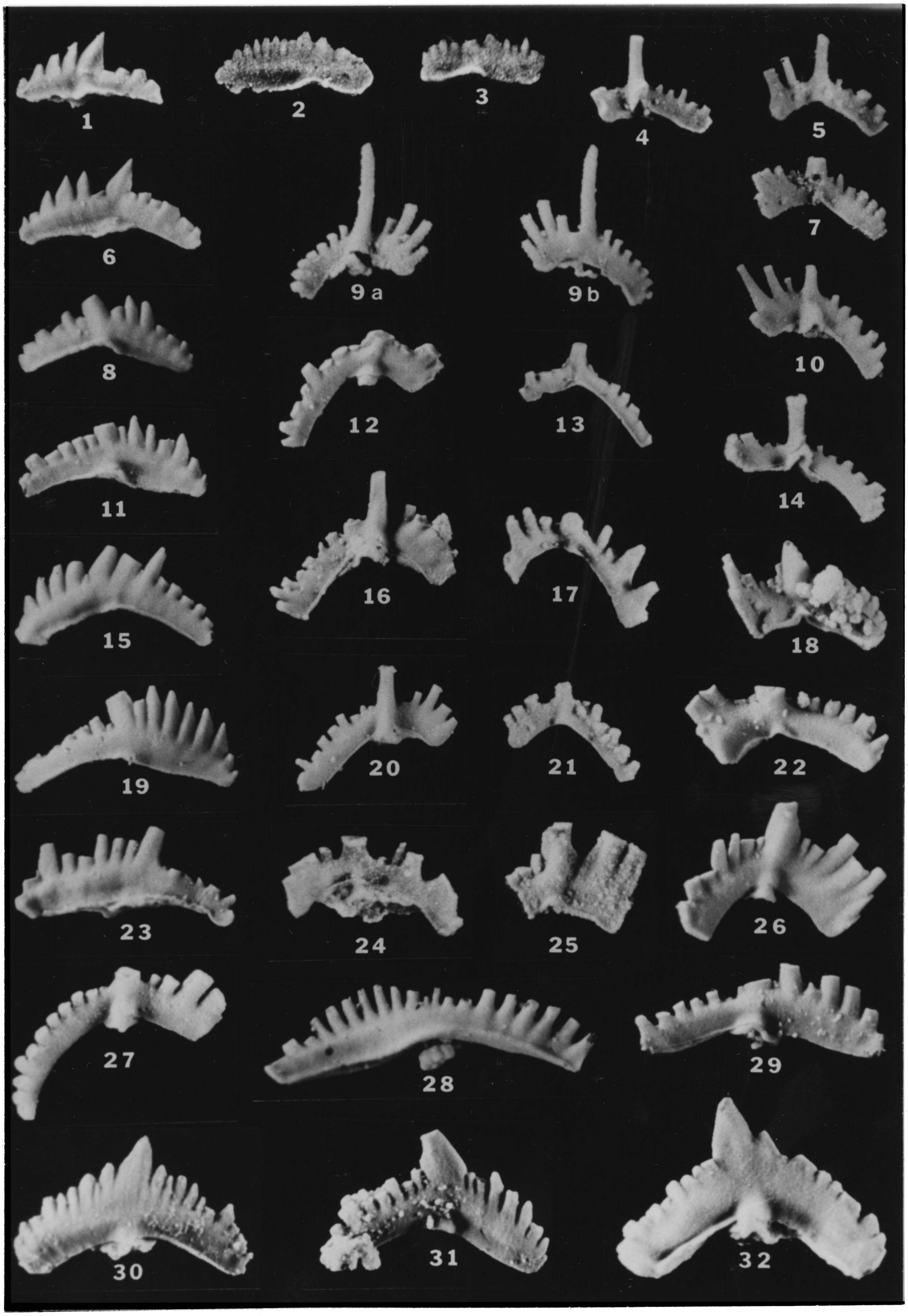
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Plate 7

Explanation of Plate 8

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,4,5,7,9,10,14,17,23-25,27,28,30,31--Trichonodella excavata (Branson & Mehl). Posterior views of VPIL 1246 (KR-McK6), VPIL 1247 (CB-McK9E), VPIL 1248 (CG-CG2), VPIL 1249 (CB-McK9D), VPIL 1250 (CB-McK9C), VPIL 1251 (CB-McK5), VPIL 1252 (MG-7), VPIL 1253 (KR-McK9), VPIL 1254 (CB-McK8A), VPIL 1255 (CG-CG8), VPIL 1256 (CG-CG2), VPIL 1257 (KR-McK16), VPIL 1258 (JG-4), VPIL 1259 (MG-8), and VPIL 1260 (CB-McK6).

2,3,15,19,26,29--Trichonodella symmetrica (Branson & Mehl). Posterior views of VPIL 1273 (CG-CG6), VPIL 1274 (CG-CG6), VPIL 1275 (CB-McK11), VPIL 1276 (CB-McK6D), VPIL 1277 (CB-McK9B), and VPIL 1278 (CB-McK9C).

6,11-13,16,20,21--Trichonodella inconstans Walliser. Posterior views of VPIL 1264 (CB-McK4), VPIL 1265 (MG-5), VPIL 1266 (CB-McK3), VPIL 1267 (CG-McK1), VPIL 1268 (MG-5), VPIL 1269 (KR-McK5), and VPIL 1270 (CB-McK3).

8--Trichonodella sp. Posterior view of VPIL 1284 (MG-CG5).

18,22, *Trichonodella* n. sp. Posterior views of VPIL 1282 (CB-McK6) and VPIL 1283 (CB-McK6).

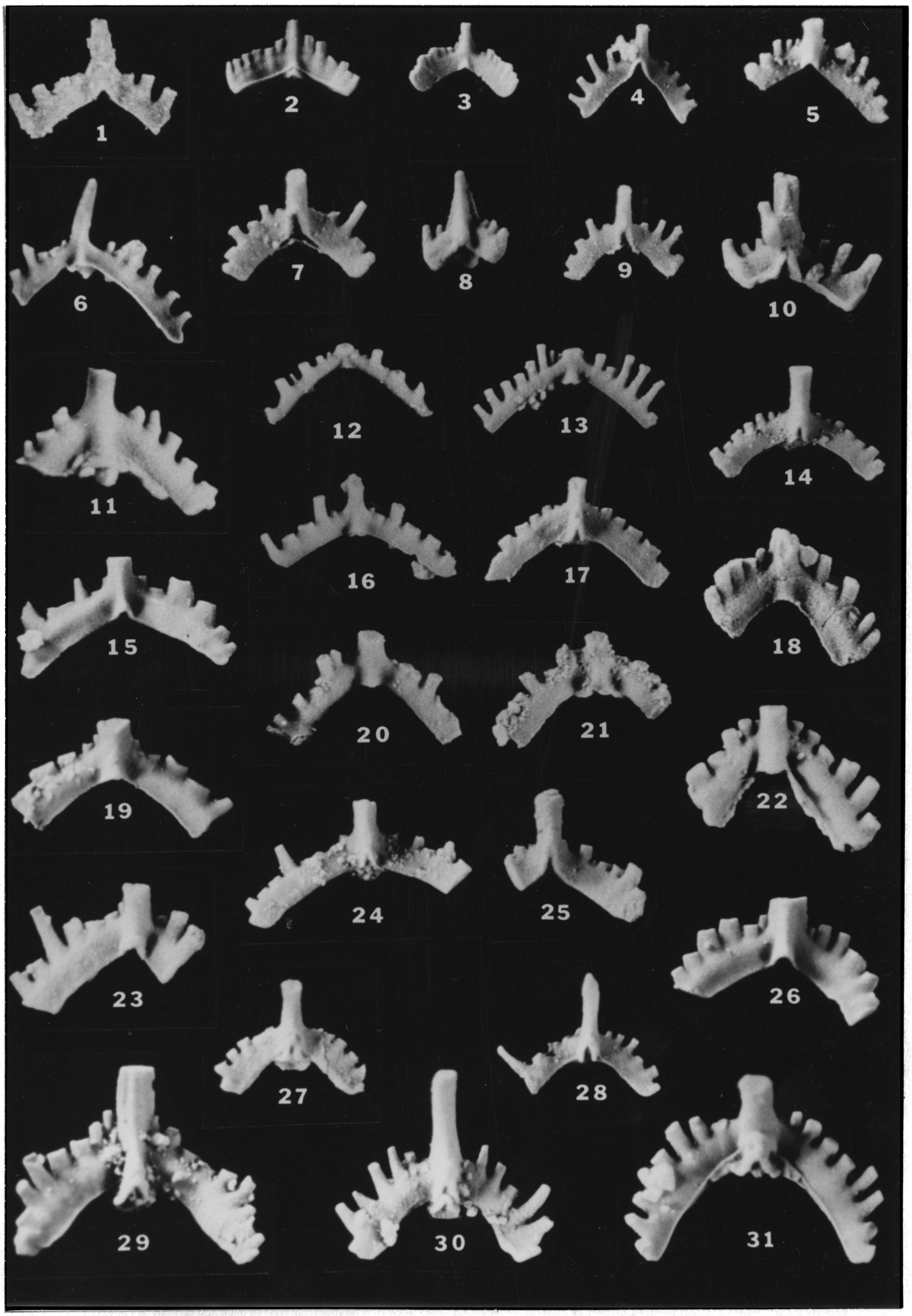
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Plate 8

Explanation of Plate 9

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,17-19,24--Synprioniodina bicurvata (Branson & Mehl). Posterior views of VPIL 1225 (MG-7), VPIL 1226 (CG-McK1), VPIL 1227 (CG-CG7), VPIL 1228 (CB-CG2), and VPIL 1229 (CG-CG6).

2-5--Neoprioniodus multiformis Walliser. Posterior views of VPIL 979 (MG-CG5), VPIL 980 (MG-1), VPIL 981 (MG-2), and VPIL 982 (MG-CG5).

6,9,11,14,15--Plectospathodus? n. sp. 6,9, outer and inner lateral views of VPIL 1110 (CB-McK7A); 11, 15, inner and outer lateral views of VPIL 1111 (CB-McK8A); 14, inner lateral view of VPIL 1112 (CB-McK8A).

7,8,10--Ligonodina n. sp. Inner lateral views of VPIL 941 (KR-McK14), VPIL 942 (CB-McK8A), and VPIL 943 (CB-McK8A).

12,13--Lonchodina? greilingi Walliser. Inner lateral views of VPIL 951 (CB-McK4) and VPIL 952 (CB-McK4).

16,21,22,25,27--Neoprioniodus excavatus (Branson& Mehl). 16,21, Inner lateral views of VPIL 973 (CB-McK7C) and VPIL 974 (CG-CG2); 22a-b, inner and outer lateral views of VPIL 975 (CB-McK9D); 25,27, inner lateral views of VPIL 976 (KR-McK6) and VPIL 977 (CB-McK6C).

20,23,26,28-32--Synprioniodina lowryi n. sp. 20,23, 26,28,29, Inner lateral views of paratypes VPIL 1233 (CB-McK4), VPIL 1234 (MG-5), VPIL 1235 (CG-McK1), VPIL 1236 (CG-McK1), and VPIL 1237 (CG-McK1); 30, inner lateral view of holotype VPIL 1238 (MG-5); 31,32, inner lateral views of paratypes VPIL 1239 (KR-McK5) and VPIL 1240 (KR-McK5).

33--Synprioniodina n. sp. Inner lateral view of VPIL 1244 (CB-McK6A).

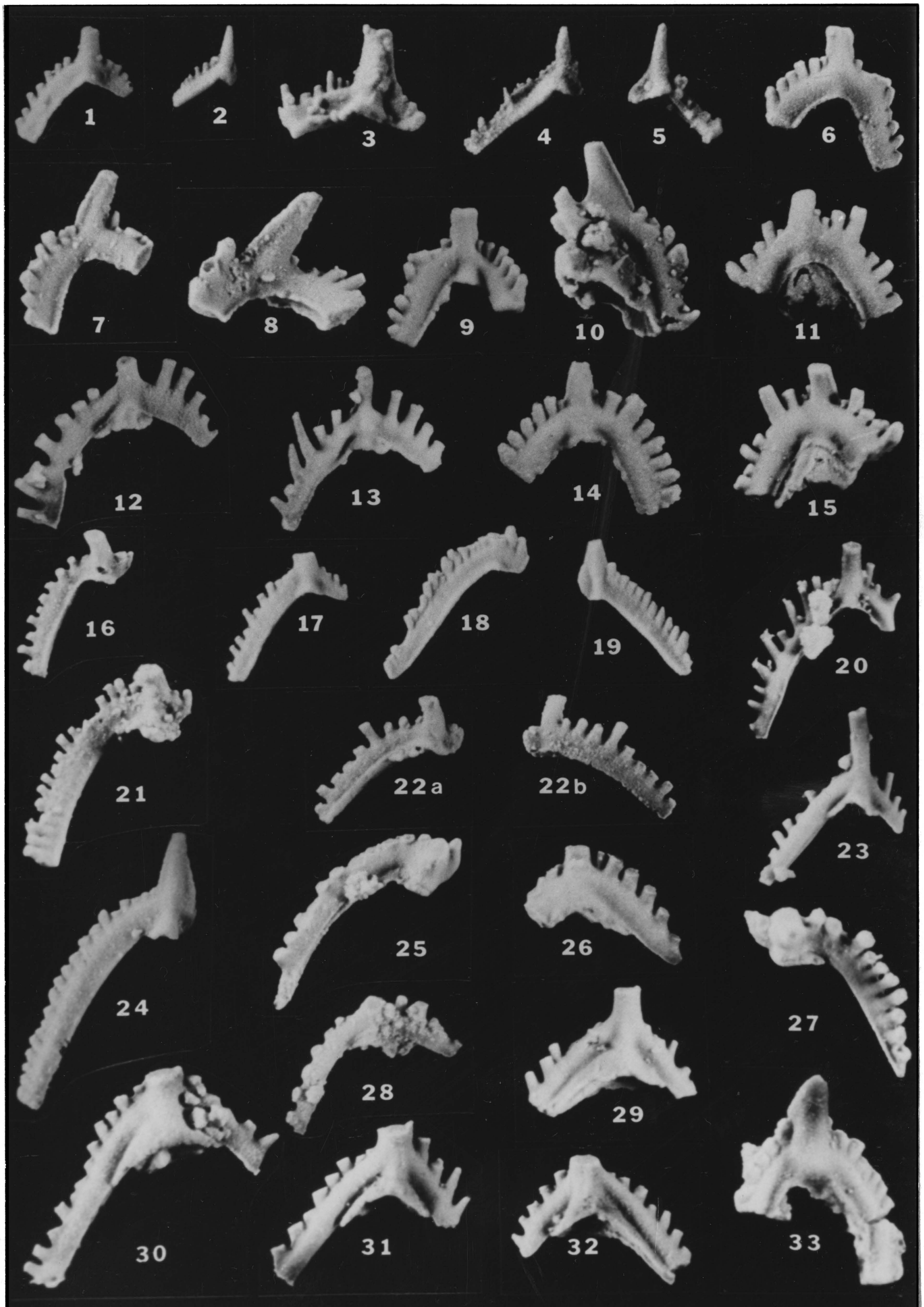
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Plate 9

Explanation of Plate 10

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,4,6-9,12,15--Ligonodina brevis n. sp. 1,4,6-9, Inner lateral views of paratypes VPIL 916 (MG-5), VPIL 917 (MG-5), VPIL 918 (KR-McK5), VPIL 919 (CB-McK3), VPIL 920 (KR-McK5), and VPIL 921 (CB-McK4); 12, inner lateral view of holotype VPIL 922 (CB-McK4); 15, inner lateral view of paratype VPIL 923 (KR-McK5).

2,3,5,10,13,19,21,23--Ligonodina "silurica" Branson & Mehl. Inner lateral views of VPIL 927 (CB-McK9E), VPIL 928 (CB-McK6D), VPIL 929 (KR-McK6), VPIL 930 (CB-McK8A), VPIL 931 (CB-McK5), VPIL 932 (CB-McK7A), VPIL 933 (CB-McK6A), and VPIL 934 (CB-McK5C).

11--Synprioniodina sp. Inner lateral view of VPIL 1245 (CB-CG3).

14,17,20--Panderodus simplex (Branson & Mehl). 14a-b, 17a-b, 20a-b, Lateral views of VPIL 1082 (CG-CG6), VPIL 1083 (CG-CG2), and VPIL 1084 (MG-1).

16,22--Hindeodella equidentata Rhodes. Inner lateral views of VPIL 909 (CG-CG6) and VPIL 910 (CB-CG2).

18--Ligonodina n. sp. Inner lateral view of VPIL 944 (CB-McK6D).

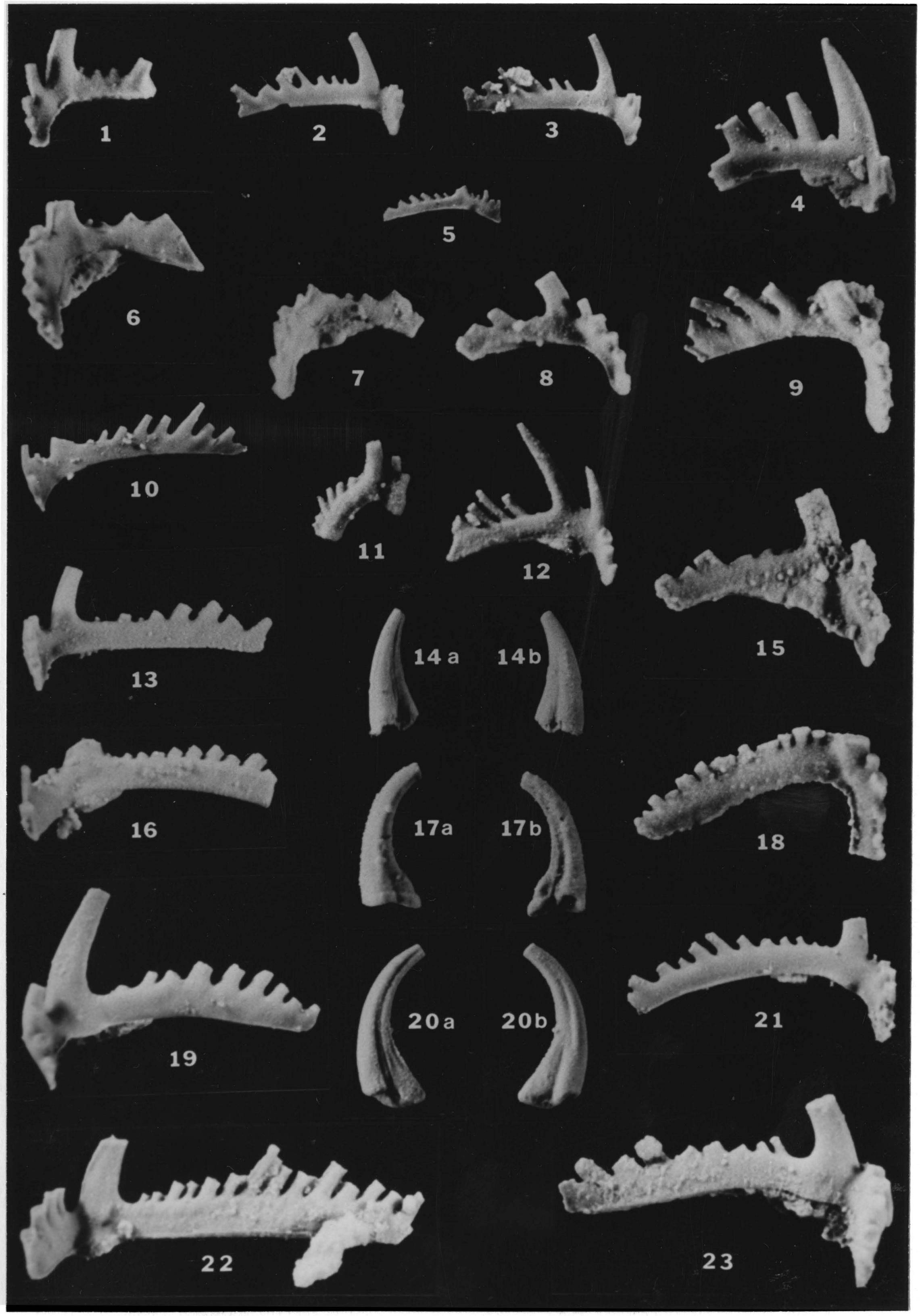

Plate 10

Explanation of Plate 11

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1-10,12-16--Spathognathodus steinhornensis eosteinhornensis Walliser. 1, Left lateral view of VPIL 1192 (CB-UT2); 2a-10b, upper and right lateral views of VPIL 1193 (CB-UT8), VPIL 1194 (CB-T4*), VPIL 1195 (CB-UT8), VPIL 1196 (CB-UT1), VPIL 1197 (CB-UT2), VPIL 1198 (CB-UT8), VPIL 1199 (CB-UT8), VPIL 1200 (CB-UT2), and VPIL 1201 (CB-UT2); 12, left lateral view of VPIL 1202 (CB-T4*); 13a-c, upper, right, and left lateral views of VPIL 1203 (CB-UT1); 14a-b, upper and left lateral views of VPIL 1204 (P-T19); 15a-c, upper, right, and left lateral views of VPIL 1205 (CB-T4*); 16a-b, upper and left lateral views of VPIL 1206 (CB-UT7).

11--Spathognathodus primus primus (Branson & Mehl). 11a-b, Right and left lateral views of VPIL 1172 (CB-UT2).

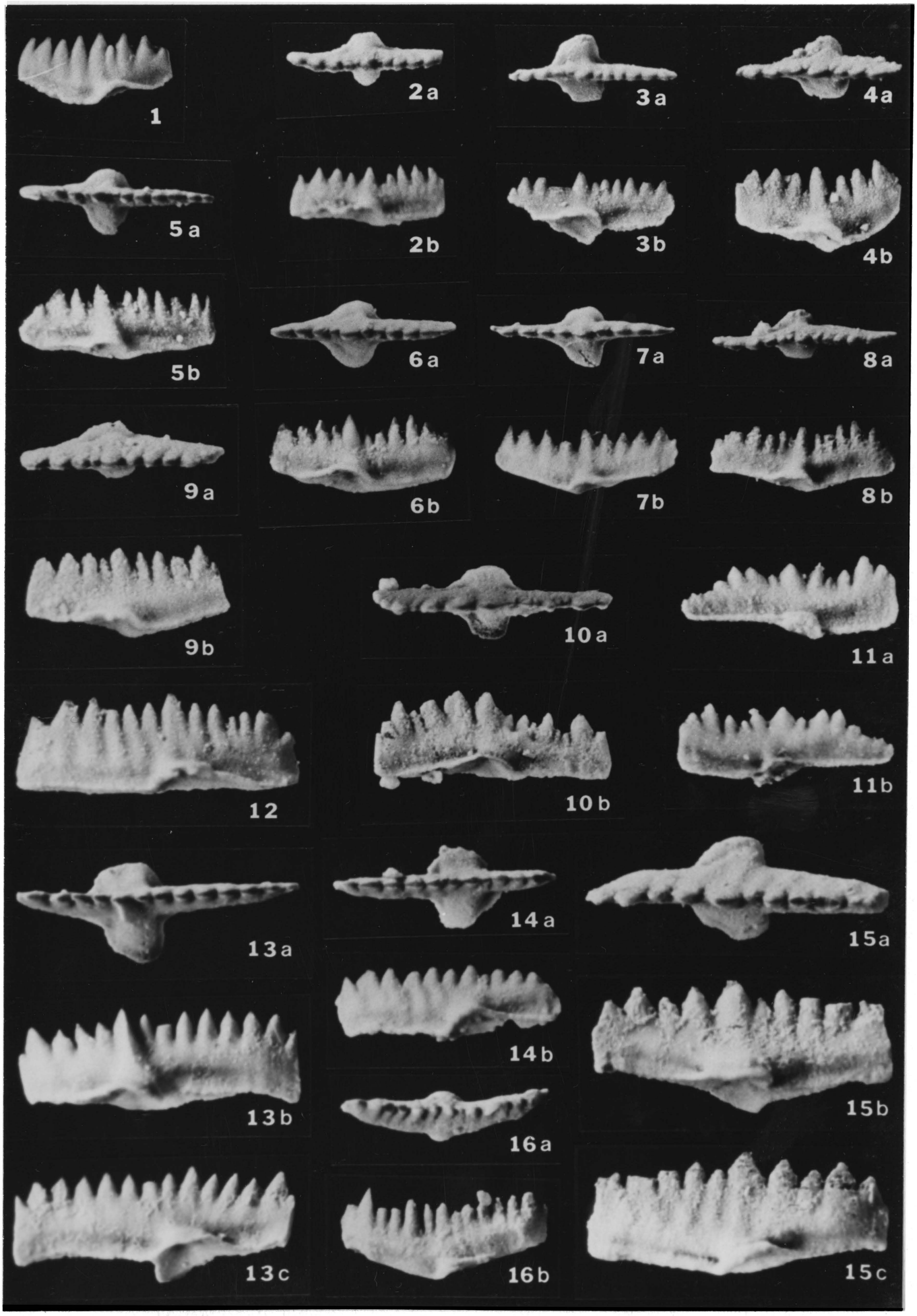
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Plate 11

Explanation of Plate 12

All figures x 35. VPI Museums numbers are followed by sample numbers in parentheses.

Figs. 1,3,6,15,17,19,20,23--Ozarkodina typica intermedia n. ssp. 1,3, Right lateral views of paratypes VPIL 1049 (CB-T4B) and VPIL 1050 (JG-16); 6a-b, 15a-b, left, right, right, and left lateral views of paratypes VPIL 1051 (JG-8) and VPIL 1052 (CB-WC1D); 17,19, left lateral views of paratypes VPIL 1053 (CB-WC1D); and VPIL 1054 (JG-19); 20a-b, left and right lateral views of holotype VPIL 1055 (CB-WC1DUB); 23, right lateral view of paratype VPIL 1056 (CB-WC1DUB).

2--Lonchodina? greilingi Walliser. Inner lateral view of VPIL 953 (JG-14).

4,12,13--Synprioniodina bicurvata (Branson & Mehl). Inner lateral views of VPIL 1230 (CB-T4*), VPIL 1231 (CB-WC1DUB), and VPIL 1232 (CB-UT3).

5,9,21,25,28--Ozarkodina ortuformis Walliser. Inner lateral views of VPIL 996 (CB-WC7B), VPIL 997 (JG-14A), VPIL 998 (CB-WC15), VPIL 999 (P-WC22B), and VPIL 1000 (CB-T1B).

7,8,22--Gen. et sp. indet. B, Lateral views of VPIL 1290 (CB-T1A), VPIL 1291 (CB-T1A), and VPIL 1292

(CB-T3).

10,11--_Synprioniodina_ _lowryi_ n. sp. Inner lateral views of paratypes VPIL 1241 (P-WC22B) and VPIL 1242 (JG-19).

14,16,24,27--_Ozarkodina_ _typica_ _denckmanni_ Ziegler. 14a-b, Left and right lateral views of VPIL 1045 (CB-UT2); 16,24,27, left, left, and right lateral views of VPIL 1046 (P-T19), VPIL 1047 (JG-32), and VPIL 1048 (CB-UT8).

18--_Plectospathodus_ _extensus_ Rhodes. Inner lateral view of VPIL 1095 (CB-WC1DUB).

26--Gen. et sp. indet. A. Lateral views of VPIL 1289 (CB-T1C).

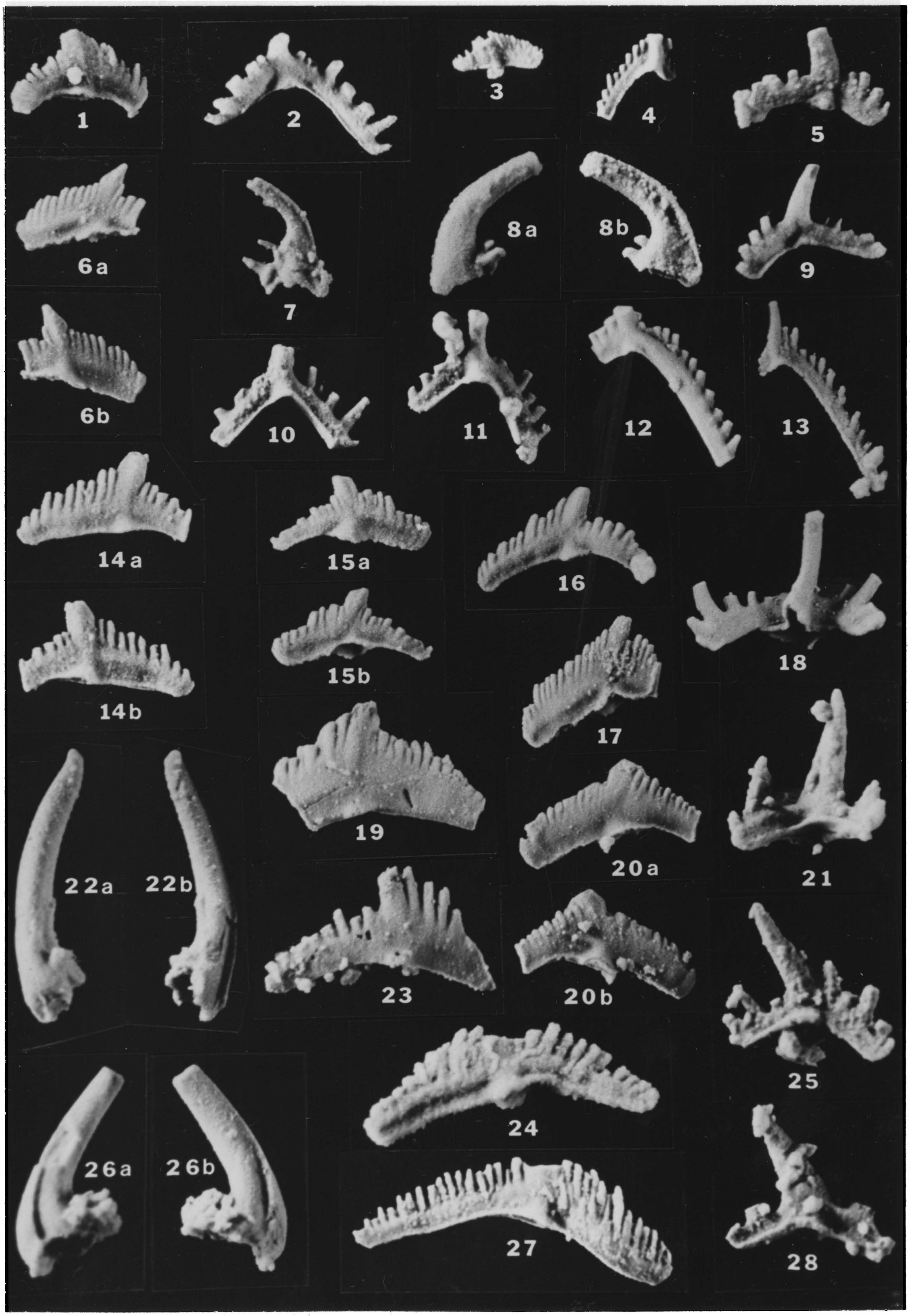
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Plate 12

Explanation of Plate 13

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1-4,6-9,11--Spathognathodus tillmani n. sp. 1a-2b, Upper and right lateral views of paratypes VPIL 1209 (CB-WC1D) and VPIL 1210 (CB-WC1D); 3a-c, upper, right, and left lateral views of paratype VPIL 1211 (JG-8); 4a-b, upper and right Lateral views of paratype VPIL 1212 (CB-WC1DUB); 6a-b, upper and right lateral views of holotype VPIL 1213 (CB-WC1DUB); 7,8, left and right lateral views of paratypes VPIL 1214 (CB-WC1DUB) and VPIL 1215 (JG-14); 9a-b, 11a-b, upper and right lateral views of paratypes VPIL 1216 (JG-8) and VPIL 1217 (CB-WC1).

5,10--Spathognathodus primus primus (Branson & Mehl). Right and left lateral views of VPIL 1173 (CB-WC10) and VPIL 1174 (JG-19).

12-17--Spathognathodus primus multidentatus n. ssp. 12a-b, Upper and right lateral views of paratype VPIL 1149 (CB-WC1D); 13, right lateral view of paratype VPIL 1150 (CB-WC1DUB); 14a-c, upper, right, and left lateral views of holotype VPIL

1151 (CB-WC1DUB); 15, right lateral view of paratype VPIL 1152 (CB-WC1D); 16a-c, upper, right, and left lateral views of paratype VPIL 1153 (CB-WC1DUB); 17a-b, upper and right lateral views of paratype VPIL 1154 (CB-WC1D).

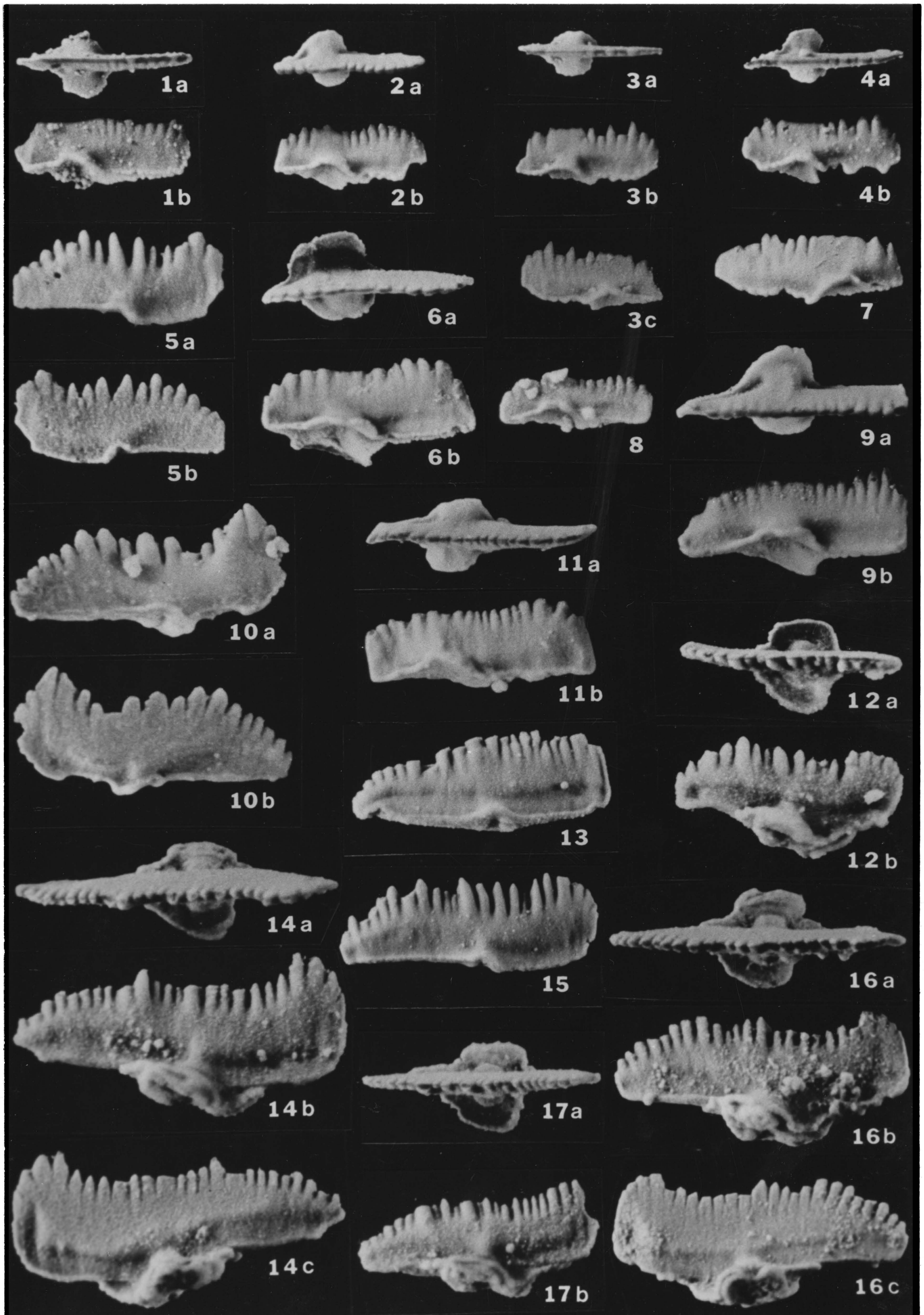
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Plate 13

Explanation of Plate 14

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1-4,9,14,19,21,24,27--Spathognathodus crispus Walliser. 1a-c, Upper, lower, and right lateral views of VPIL 1127 (JG-16); 2a-c, upper, right, and left lateral views of VPIL 1128 (JG-16); 3a-4b, upper and right lateral views of VPIL 1129 (CB-UT3) and VPIL 1130 (CB-T4B); 9, left lateral view of VPIL 1131 (CB-UT3); 14a-b, upper and right lateral views of VPIL 1132 (CB-T1A); 19, right lateral view of VPIL 1133 (CB-UT3); 21a-b, upper and left lateral views of VPIL 1134 (CB-T1A); 24,27, right and left lateral views of VPIL 1135 (CB-T4B) and VPIL 1136 (CB-T4B).

5,6--Spathognathodus steinhornensis eosteinhornensis Walliser. 5a-6b, Upper and left lateral views of VPIL 1207 (CB-UT8) and VPIL 1208 (CB-UT1).

7,10-12,15,17,22,23,25,26,28,29--Spathognathodus primus highlandensis n. ssp. 7, Left lateral view of paratype VPIL 1137 (JG-11B); 10, right lateral view of paratype VPIL 1138 (P-WC22); 11a-12b, right and left lateral views of paratypes VPIL 1139

(P-WC22B) and VPIL 1140 (JG-14); 15a-b, 17a-b, right and left lateral views of paratypes VPIL 1141 (P-WC22) and VPIL 1142 (JG-14); 22, left lateral view of paratype VPIL 1143 (CB-WC11B); 23a-b, right and left lateral views of holotype VPIL 1144 (P-WC22); 25a-26b, right and left lateral views of paratypes VPIL 1145 (CB-T1B) and VPIL 1146 (CB-WC15); 28,29, right and left lateral views of paratypes VPIL 1147 (CB-WC15) and VPIL 1148 (CB-WC15).

8,13,16--*Hindeodella priscilla* Stauffer. Inner lateral views of VPIL 913 (JG-32), VPIL 914 (CB-UT1), and VPIL 915 (JG-32).

18,20--*Plectospathodus alternatus* Walliser. Inner lateral views of VPIL 1085 (CB-UT4) and VPIL 1086 (P-T19A).

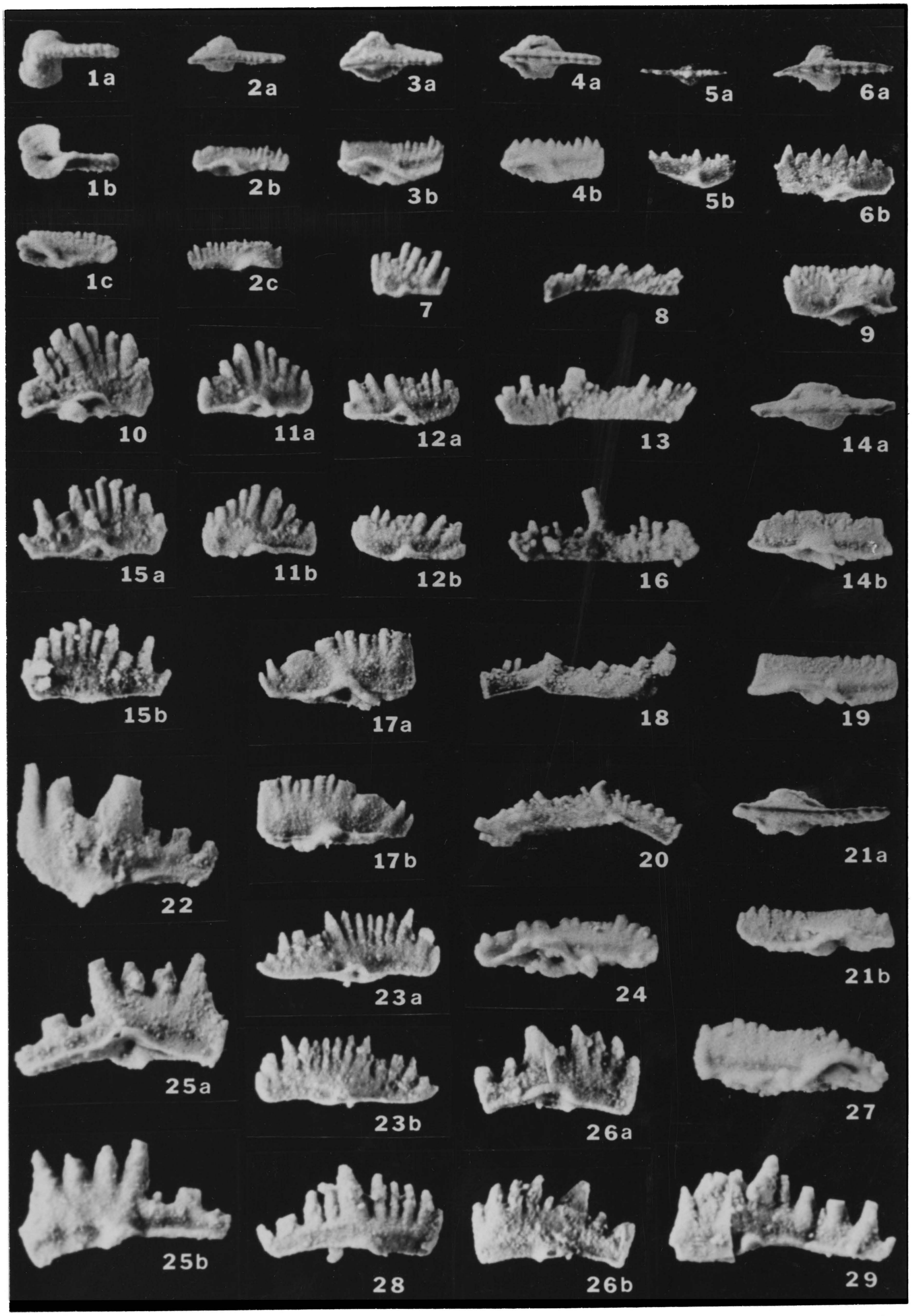
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Plate 14

Explanation of Plate 15

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1,3-5,13--Plectospathodus extensus Rhodes. 1a-b, Upper and inner lateral views of VPIL 1096 (P-T21A); 3-5,13, inner lateral views of VPIL 1097 (CB-T2B), VPIL 1098 (JG-16), VPIL 1099 (CB-WC1D), and VPIL 1100 (P-T19).

2--Hindeodella equidentata Rhodes. Inner lateral view of VPIL 911 (CB-WC1DUB).

6,10,11--Ligonodina brevis n. sp. Inner lateral views of VPIL 924 (P-WC22), VPIL 925 (JG-16A), and VPIL 926 (CB-WC11BL).

7--Hindeodella confluens Branson & Mehl. Inner lateral view of VPIL 908 (CB-WC1DUB).

8--Neoprioniodus excavatus (Branson & Mehl). Inner lateral view of VPIL 977 (CB-WC1D).

9,12,16--Trichonodella excavata (Branson & Mehl). Posterior views of VPIL 1261 (CB-WC1DUB), VPIL 1262 (CB-WC1DUB), and VPIL 1263 (JG-14).

14--Lonchodina detorta Walliser. Posterior view of VPIL 945 (P-T19).

15,17,19-22--Ligonodina "silurica" Branson & Mehl.

Inner lateral views of VPIL 935 (CB-WC1D), VPIL 936 (CB-WC1DUB), VPIL 937 (JG-19), VPIL 938 (CB-WC1DUB), VPIL 939 (CB-WC1DUB), and VPIL 940 (CB-WC1DUB).

18,24,25--Lonchodina walliseri Ziegler. Inner lateral views of VPIL 969 (CB-WC1D), VPIL 970 (CB-WC1DUB), and VPIL 971 (CB-WC1DUB).

23,26--Lonchodina? greilingi Walliser. Inner lateral views of VPIL 954 (CB-WC1DUB) and VPIL 955 (CB-WC1DUB).

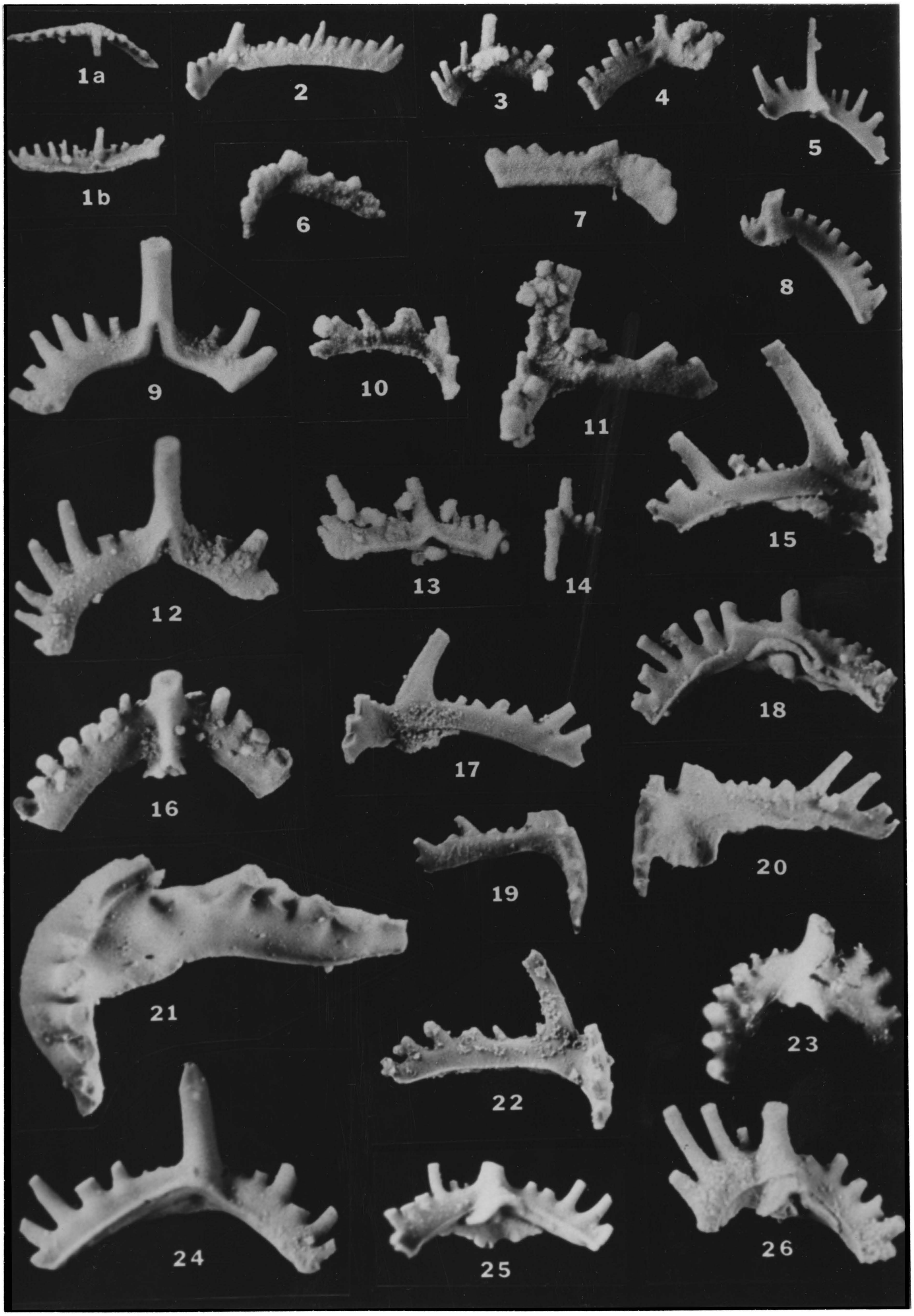

Plate 15

Explanation of Plate 16

All figures x 35. VPI Museum numbers are followed by sample numbers in parentheses.

Figs. 1-3,6--N. gen. et n. sp. 1a-c, Right lateral, lower, and upper views of VPIL 1285 (P-T21B); 2,3, upper views of VPIL 1286 (P-T21B) and VPIL 1287 (P-T21B); 6a-b, upper and lower views of VPIL 1288 (P-T21B).

4,5--Plectospathodus extensus Rhodes. Inner lateral views of VPIL 1101 (JG-16B) and VPIL 1102 (JG-16B).

7--Plectospathodus flexuosus Branson & Mehl. Inner lateral view of VPIL 1108 (CB-WC1D).

8,12,17--Trichonodella symmetrica (Branson & Mehl). Posterior views of VPIL 1279 (CB-WC1D), VPIL 1280 (CB-WC1D), and VPIL 1281 (CB-WC1D).

9,15,16,21--Lonchodina? greilingi Walliser. Inner lateral views of VPIL 956 (CB-WC7B), VPIL 957 (CB-WC15), VPIL 958 (CB-T1BL), and VPIL 958A (CB-WC11BL).

10--Gen. et sp. indet. C. Lateral view of VPIL 1293 (CB-T2B).

11--Synprioniodina lowryi n. sp. Inner lateral view of paratype VPIL 1243 (P-WC22B).

13,14,18,22,24,25,28,30--Ozarkodina sinuosa n. sp.

13,14,18, Right, left, and left lateral views of paratypes VPIL 1010 (CB-WC10B), VPIL 1011(JG-16A), and VPIL 1012 (CB-WC1); 22,24,25,28, right lateral views of paratypes VPIL 1013 (CB-WC1D), VPIL 1014 (CB-WC1D), VPIL 1015 (CB-WC1DUB), and VPIL 1016 (CB-WC1DUB); 30, left lateral view of holotype VPIL 1017 (CB-WC1DUB).

19,20--Trichonodella inconstans Walliser. Posterior views of VPIL 1271 (CB-WC1A) and VPIL 1272 (JG-8).

23--Spathognathodus primus primus (Branson & Mehl). Right lateral view of VPIL 1175 (P-T19).

26--Spathognathodus primus multidentatus n. ssp. Right lateral view of paratype VPIL 1155 (CB-WC1DUB).

27--Hindeodella equidentata Rhodes. Inner lateral view of VPIL 912 (CB-WC10).

29--Lonchodina walliseri Ziegler. Inner lateral view of VPIL 972 (P-WC22).

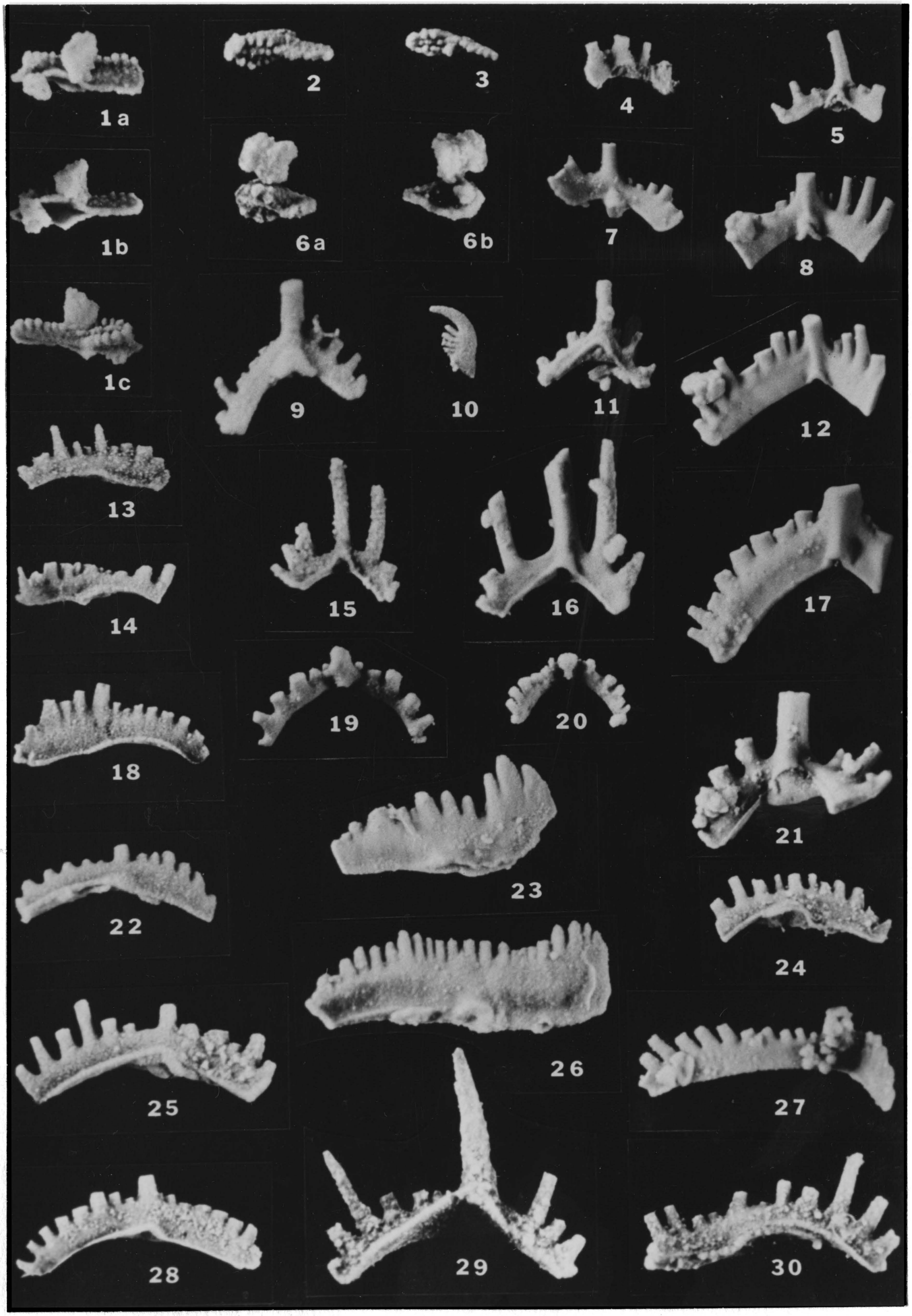
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Plate 16

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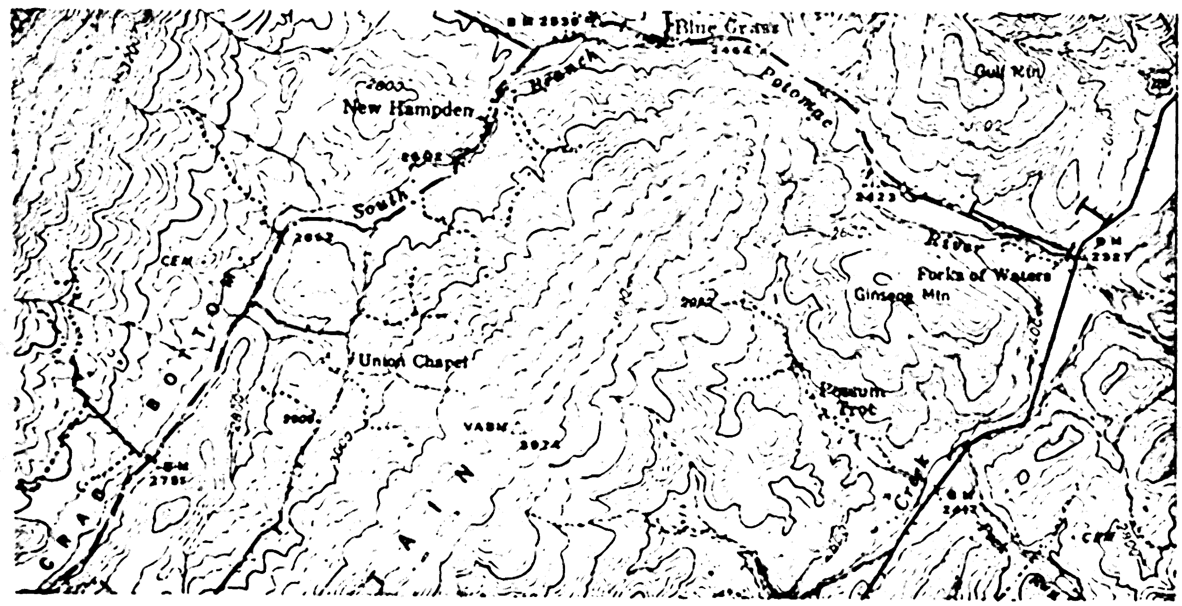
Appendix

STRATIGRAPHIC SECTIONS

Crabbottom Section

Location.--In northeast ninth of USGS 15-minute Monterey, Virginia-West Virginia Quadrangle. This section is exposed along State Road 642 in Highland County, Virginia. The section begins 0.7 mile west of the intersection of State Road 642 with U.S. Route 220, continues east to intersection with U.S. Route 220, and then up the slope on the west side of U.S. Route 220 just north of the intersection.



	Thickness of Unit Feet	Total Thickness Feet
Ridgeley Sandstone (?) (Not measured)		
Isolated blocks of calcareous sandstone, light-gray, coarse-grained, thick-bedded; weathers ribby; in fault contact with Tonoloway Formation		
Tonoloway Formation (225 feet +)		
52. Limestone, dark-gray, very finely crystalline, argillaceous, thin-bedded; beds crumpled and slickensided; thickness estimated; no sample	15.0	449.1
51. Limestone, dark-gray, very finely to finely crystalline, argillaceous, thin-bedded; beds fractured, calcite veinlets fill fractures; Sample CB-UT8, continuous	10.0	425.1
50. Limestone, dark-gray, very finely to medium-crystalline, argillaceous, thin-bedded; Sample CB-UT7, continuous	10.0	424.1

49.	Limestone, dark-gray, very finely to finely crystalline, argillaceous, thin-bedded, fossiliferous throughout with brachiopods and ostracodes; Sample CB-UT6, continuous.......	10.0	414.1
48.	Limestone, medium- to dark-gray, finely to medium-crystalline, argillaceous, thin-bedded; re-crystallized with abundant orangish-brown material in interstices of calcite grains; Sample CB-UT5, continuous......	10.0	404.1
47.	Limestone, medium- to dark-gray, finely to medium-crystalline, argillaceous, thin-bedded, numerous calcite veinlets fill cross-fractures; fossiliferous with brachiopods and leperditiid ostracodes; Sample CB-UT4, continuous........................	10.0	394.1
46.	Limestone, medium- to dark-gray, finely crystalline, argillaceous,		

	thin-bedded; fossiliferous throughout with brachiopods and leperditiid ostracodes; Sample CB-UT3, continuous.....	10.0	384.1
45.	Limestone, medium- to dark-gray, very finely to medium-crystalline, thin-bedded; fossiliferous throughout with brachiopods and leperditiid ostracodes; Sample CB-UT2, continuous....................	10.0	374.1
44.	Limestone, dark gray, very finely to medium-crystalline, argillaceous, thin-bedded, fossiliferous throughout with brachiopods and leperditiid ostracodes; Sample CB-UT1, continuous..................	10.0	364.1
43.	Covered interval along base of hill on west side of U.S. Route 220 to north of intersection with State Road 642; thickness estimated.........	10.0±	354.1
42.	Limestone, dark-gray, finely		

	crystalline, abundant euhedral quartz crystals and dolomitized oölites, medium- to thick-bedded; last resistant bed along State Road 642, forms ledge at top of cut at intersection of State Road 642 and U.S. Route 220; Sample CB-T6, continuous...	6.0	344.1
41.	Sandstone, olive-gray, fine-grained, calcareous, very argillaceous, thin-bedded; prominent 0.2-foot dark greenish-gray sandstone bed 0.6 foot above base of unit; upper 4 feet weathers shaly; Sample CB-T5, continuous.......	9.0	338.1
40.	Limestone, dark bluish-gray to black, very finely crystalline, argillaceous, thin-bedded, 3-4 feet exposed at base; largely covered along road; upper 2 feet exposed at intersection, limestone, dark-gray to olive-gray at top, finely crystalline		

with argillaceous, olive-
gray laminae, thin-to medium-
bedded, weathers platy; thick-
ness estimated; middle section
exposed in recent road work,
consists of an extensive
collapse breccia, no indi-
cation of fault movement; Sample
CB-T4B, top 2 feet; Sample CB-
T4A, basal 3-4 feet; Sample
CB-T4*, breccia................ 25.3 329.1

39. Shale, deeply weathered, lower
1 foot; overlain by 2.5-foot bed
limestone, dark-gray to black,
very finely crystalline, argil-
laceous; overlain by 0.5-1.0-
foot bed limestone, dark-gray
to black, medium-crystalline;
with pyritized pellets which
weather and give surface rusty
stain; overlain by limestone, dark
bluish-gray, very finely crystal-
line, thin- to medium-bedded,
appears rubbly; weathers platy;

fossiliferous with brachiopods, gastropods and leperditiid ostracodes; slight changes in attitude and minor folding in upper 6 feet; Sample CB-T3, continuous.................... 13.7 303.8

38. Limestone, medium-gray, very finely crystalline, very argillaceous, platy, mudcracked, weathers into stacks of polygonal plates, lower 2 feet; overlain by 2 feet of platy to fissile shale; overlain by limestone, dark bluish-gray to black, very finely crystalline, argillaceous, thin- to thick-bedded; top of unit becomes dolomitic, marked by prominent 0.5-foot bed forming ledge under 2-foot bed of dolomitic limestone which shows prominent subconchoidal fracture; Sample CB-T2C, upper 11 feet,

continuous; Sample CB-T2B, middle 11 feet, continuous; Sample CB-T2A, basal 11 feet, continuous......................	34.9	290.1
37. Limestone, dark bluish-gray, very finely crystalline, argillaceous, very thin- to thick-bedded, weathers platy; a few pods of limestone with abundant fossil detritus; leperditiid ostracodes abundant on some bedding surfaces; minor folding in middle of unit; top 0.5 foot weathers shaley; Sample CB-T1C, upper 10 feet; Sample CB-T1B, middle 10 feet; Sample CB-T1A, basal 10 feet..................	31.1	255.2

Wills Creek Formation (224.1 feet)

36. Limestone, dark bluish-gray, very finely crystalline, argillaceous, very thin- to thick-bedded, weathers to shale; laminated on weathered joint faces; thickness is a

	minimum, unit becomes obscured laterally by cover and is apparently slightly folded; Sample CB-WC15, continuous. Overlying resistant limestone beds which crop on hill and along road are taken as the basal beds of the Tonoloway Formation....................	14.0+	224.1
35.	Limestone, dark-gray, very finely crystalline, argillaceous, very thin-bedded with deeply weathered interbeds of shale, light olive-gray, calcareous; a few dark-gray, fissile shale interbeds; few concretionary layers; Sample CB-WC14C, upper 10 feet; Sample CB-WC14B, middle 10 feet; Sample CB-WC14A, basal 10 feet..	32.9	210.1
34.	Sandstone, light-gray, medium-grained, thick-bedded; overlain by very thin-bedded sandstone lenses with cal-		

	careous shale partings; minor drag folding; Sample CB-WC13, continuous......................	5.6	177.2
33.	Limestone, dark bluish-gray, medium-crystalline, arenaceous, argillaceous, very thin-bedded; fossiliferous with leperditiid ostracodes; interbedded platy to fissile, calcareous, arenaceous shale; Sample CB-WC12; continuous...............	11.6	171.6
32.	Siltstone, dark-gray, calcareous, arenaceous, medium- to thick-bedded, weathers olive gray; overlain by limestone, dark-gray, medium-crystalline, arenaceous, medium-bedded, with calcareous shale interbeds in upper part; fossiliferous with gastropods and ostracodes including leperditiid ostracodes; Sample CB-WC11B, upper 8 feet; Sample CB-WC11A, lower 8 feet	17.7	160.0
31.	Sandstone, dark-gray, medium-grained, calcareous, 0.9-foot		

	bed, upper 0.2 foot fossiliferous with leperditiid ostracodes; overlain by limestone, dark bluish-gray, very finely crystalline, argillaceous, occasional sandstone stringers, medium-bedded, weathers shaly and platy; Sample CB-WC10, continuous....	10.3	142.3
30.	Limestone, dark bluish-gray, very finely crystalline, argillaceous, silty, thin-bedded; interbeds of shale, dark bluish-gray, calcareous, platy; fissile, arenaceous stringers in middle of unit; Sample CB-WC9, continuous..	9.8	132.0
29.	Limestone, dark-gray, argillaceous, silty, single bed with 0.2-0.5-foot rusty weathered sandstone lens at top; Sample CB-WC8, continuous............	3.9	122.2
28.	Limestone, dark bluish-gray to black, very finely crystalline, argillaceous, with arena-		

	ceous stringers, platy, bedding wavy, small-scale cross-bedding; weathers ribby; sparsely fossiliferous with <u>Hormatoma</u> sp.; upper 2 feet mud-cracked, weathers to stacks of polygonal plates; Sample CB-WC7B, upper 8 feet; Sample CB-WC7A, basal 8 feet..............	16.5	118.3
27.	Sandstone, bluish-gray, fine- to medium-grained becoming argillaceous upward with sand-filled worm borings, basal 2 feet; overlain by shale and limestone, dark-gray, argillaceous, platy; thick-bedded and arenaceous in upper 4 feet; numerous arenaceous stringers throughout; Sample CB-WC6...........................	12.0	101.8
26.	Limestone, dark-gray to black, very finely crystalline, argillaceous, medium-bedded, weathers thin bedded and platy; 0.1-foot arenaceous stringer, 0.5 foot		

	above base; some scattered lenses, medium-crystalline limestone; Sample CB-WC5......	8.0	89.8
25.	Shale, dark-gray, calcareous, silty, weathers platy; few thin interbeds, limestone, dark-gray, very finely crystalline, fossiliferous with leperditiid ostracodes; upper 5 feet, mudcracked, weathers to stacks of polygonal plates; Sample CB-WC4...........	14.0	81.8
24.	Limestone, dark-gray to black, very finely crystalline, argillaceous, thin- to medium-bedded; a few medium-crystalline limestone stringers; Sample CB-WC3B, upper 10 feet; Sample CB-WC3A, basal 10 feet...	21.8	67.8
23.	Limestone, dark-gray, very finely crystalline, finely disseminated pyrite throughout, laminated, bedding wavy, very thin- to thick-bedded,		

	weathers ribby, upper 2-3 feet weathers shaly; Sample CB-WC2B, upper 9 feet; Sample CB-WC2A, lower 9 feet..........	18.0	46.0
22.	Covered interval, some deeply weathered shale visible in drainage ditch; no sample......	21.0	28.0
21.	Shale, medium-gray, with thin- to thick-interbeds of limestone, dark-gray, medium-crystalline, argillaceous; fossiliferous with abundant brachiopods and ostracodes; Sample CB-WC1......	7.0	7.0

Williamsport Sandstone (21 feet)

20.	Sandstone, light greenish-gray, fine-grained, thin- to thick-bedded; weathers reddish brown; 1.0-foot dark-gray shale bed, 2.0 feet above base; numerous shale partings in lower part, becomes more thick-bedded toward top; no sample.........	21.0	

Mifflintown Formation (131.8 feet+)

McKenzie Member (107.3 feet+)

19.	Shale, dark-gray, platy, with dark-gray siltstone interbeds up to 0.7 foot thick; grades upward into greenish-black mudstone; iron-stained quartz stringers in upper part; no sample..........................	14.0	126.3
18.	Shale, dark- to medium-gray; weathers brown to grayish brown; 0.1-0.3-foot interbeds of siltstone, weathers reddish brown; 0.2-foot bed of limestone, dark-gray, silty, medium-crystalline, fossiliferous with ostracodes, at top of interval; Sample CB-McK14, 0.2-foot bed at top of interval.....	5.9	112.3
17.	Shale, medium- to dark-gray, chippy to platy; weathers olive brown; with 0.5- and 0.7-foot beds of limestone, medium-gray, medium-crystalline, fossiliferous with		

	brachiopods and ostracodes at middle and top of interval, respectively; Sample CB-McK13, limestone beds at middle and top of interval...............	3.0	106.4
16.	Shale, medium- to dark-gray, weathers olive brown; with 0.2-0.3-foot interbeds of limestone, dark-gray, finely to medium-crystalline; weathers orangish brown; fossiliferous with brachiopods and ostracodes; Sample CB-McK12, limestone interbeds...........	1.9	103.4
15.	Shale, medium- to dark-gray; weathers olive brown; 1-foot bed of limestone, dark-gray, medium-crystalline, fossiliferous with ostracodes, 7 feet above base; Sample CB-McK11, 1-foot limestone bed.................	14.0	101.5
14.	Shale, medium- to dark-gray; numerous 0.2-foot interbeds of		

	limestone, medium-gray, finely crystalline; Sample CB-McK10, limestone interbeds........................	7.0	87.5
13.	Shale, medium-to dark-gray; numerous 0.1-to 0.7-foot interbeds of limestone, medium-to dark-gray, finely to medium-crystalline; moderately fossiliferous with brachiopods and ostracodes; weathers reddish brown; Sample CB-McK9, limestone interbeds......................	7.0	80.5
12.	Shale, medium- to dark-gray; 0.2-to 0.5-foot interbeds of limestone, medium- to dark-gray, finely to medium-crystalline, slightly argillaceous; moderately fossiliferous with brachiopods and ostracodes; weathers reddish brown; Sample CB-McK8, limestone interbeds..	3.8	73.5
11.	Limestone, medium- to dark-gray, finely to medium-crystalline,		

	slightly silty, thin-bedded; thin-interbeds of medium-gray shale; moderately fossiliferous with brachiopods, gastropods, and ostracodes; weathers reddish brown; Sample CB-McK7, limestone..	1.7	69.7
10.	Shale, medium- to dark-gray; 0.1- to 0.4-foot interbeds of limestone, medium-gray, finely to medium-crystalline, slightly silty; moderately fossiliferous with brachiopods and ostracodes; Sample CB-McK6, limestone interbeds......................	4.0	68.0
9.	Shale, medium- to dark-gray; weathers olive gray; interbedded limestone, medium- to dark-gray, dolomitic, finely to medium-crystalline; moderately fossiliferous with brachiopods, gastropods and ostracodes; weathers reddish brown; 2.2-foot bed of limestone marks base of interval; beds in interval rotated moderately;		

Sample CB-McK5, limestone interbeds.....................	8.5	64.0
The section is faulted at this stratigraphic horizon. Comparison with thickness for the Mifflintown Formation at Moyer Gap, Pendleton County, West Virginia and at Keyser Reservoir, Mineral County, West Virginia, indicates that 60 to 100 feet of section may be missing. The cumulative thickness of the units was extended across this interval for convenience.		
8. Siltstone, dark-gray, calcareous, thin-bedded; beds contorted and change dip radically (5-10° to 70-80°) as beds are traced eastward along the road; no sample..........................	6.0±	55.5
7. Shale, dark-gray, chippy to platy; 0.1- to 0.3-foot interbeds of calcareous siltstone, dark-gray, laminated; silty laminae stand out on		

	weathered surfaces, slightly cross-bedded; Sample CB-McK4, calcareous siltstone interbeds...........................	9.5	49.5
6.	Shale, olive-gray to dark-gray, platy; 0.2-foot ostracode coquina at base of interval; 0.6-foot bed of dark-gray silty limestone at top of interval; Sample CB-McK3, basal and uppermost limestone beds.....................	9.0	40.0
5.	Shale, dark-gray, platy; 0.3- and 0.5-foot beds of intraformational limestone conglomerate at middle and top of interval; matrix of conglomerates consists of dark-gray, medium-crystalline, ostracodal limestone; clasts in conglomerates consists of oblong plates of medium-gray, calcareous siltstone; limestone conglomerate		

in middle of interval overlain by 0.2-foot bed of oölitic limestone; Sample CB-McK2, conglomeratic and oölitic limestone......................	4.0	31.0
4. Shale, olive- to dark-gray, platy; with approximately 1.0-foot beds of intraformational limestone conglomerate at base, 2 feet above base, and at top of interval; conglomerate at base of interval marks base of McKenzie Member; Sample CB-McK1, conglomeratic limestone..	8.0	27.0

Cosner Gap Member (19.0 feet)

3. Shale, olive-gray, platy; fossiliferous with brachiopods and ostracodes; weathers light bluish gray; numerous arenaceous, dolomitic, limestone stringers in lower 5 feet; 0.3- and 0.7-foot beds of limestone, dark-gray, finely

crystalline, argillaceous, at 4.0 and 9.0 feet above base of interval; lower bed contains abundant small brachiopods; weathers reddish brown; Sample CB-CG3, upper 5 feet; Sample CB-CG2, lower 5 feet...	14.0	19.0
2. Shale, bluish-gray, arenaceous, with arenaceous, dolomitic stringers; overlain by shale, medium- to olive-gray, chippy; fossiliferous with brachiopods, ostracodes, pelecypods, trilobites; overlain by 0.5-foot bed of dolomite, light-gray, medium-to coarsely crystalline, calcareous; weathers orangish brown; _Parechmina postica_ and _Drepanellina clarki_ in shale immediately under bed of dolomite at top of interval; Sample CB-CG1, dolomite bed at top of interval.......	5.0	5.0

Lower hematitic member (5.5 feet)

1. Dolomite and siltstone with interbedded shale, and coarsely arenaceous, oölitic hematite; dolomite, light-gray, coarsely crystalline, thin- to medium-bedded, becomes shaly and arenaceous upward, basal 1.3 feet; overlain by 2.0 feet of siltstone, dark-gray, dolomitic, becomes coarsely arenaceous and with oölitic hematite upward, overlain by 0.7 foot of shale and sandstone with bands of coarsely and hematite arenaceous, oölitic hematite; overlain by 0.5 foot of dark-gray shale; overlain by 1.0 foot of dolomite with bands of coarsely-arenaceous, oölitic hematite; no sample............ 5.5

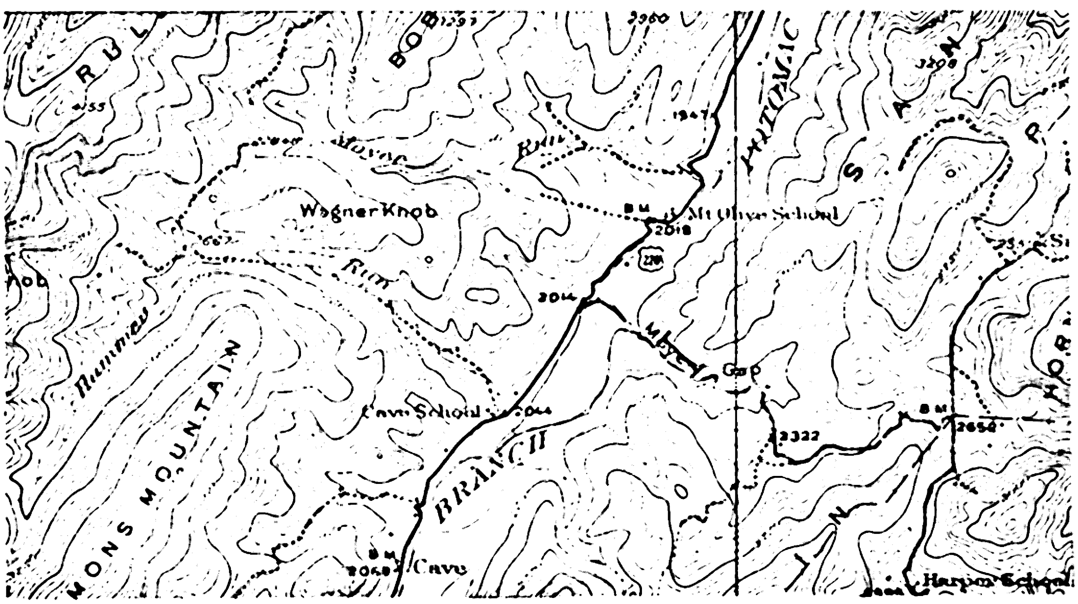
Rose Hill Formation (Not measured)

Grayish-green, fossiliferous shales; <u>Mastigobolbina typus</u>

identified in shale approxi-
mately 0.5 foot below over-
lying unit.

Moyer Gap Section

Location.--In southwest ninth of USGS 15-minute Circleville, West Virginia Quadrangle. This section is in Pendleton County, West Virginia, on the north side of State Route 25, 0.3 mile east from its intersection with U.S. Route 220.



	Thickness of Unit Feet	Total Thickness Feet
Williamsport Sandstone (16.0 feet)		
15. Sandstone, greenish-gray, fine-		

grained, thin- to thick-bedded; weathers light gray, forms resistant ridge at western end of exposure; no sample.

Mifflintown Formation (210.3 feet)

McKenzie Member (190.6 feet)

14.	Single 2-foot limestone bed at base of unit; interval up to Williamsport Sandstone largely covered by shale float; limestone, medium-gray, very finely to medium-crystalline, argillaceous, hematitic; very fossiliferous with brachiopods, gastropods, and ostracodes; Sample MG-14, basal 2-foot bed........................	75.6	205.6
13.	Limestone, dark-gray, finely to coarsely crystalline, argillaceous, medium-bedded; fossiliferous with brachiopods, ostracodes, and pelecypods; Sample MG-13, continuous......	10.0	130.0

12.	Limestone, dark - gray, very finely crystalline, thick-bedded; argillaceous toward top; fossiliferous with ostracodes throughout, brachiopods in middle and upper part; weathers slabby; Sample MG-12, continuous..................	10.0	120.0
11.	Covered interval; shale float; no sample....................	20.0	110.0
10.	Largely covered with shale float; a few resistant, thin beds of limestone, dark-gray to black, very fine crystalline, argillaceous to silty; fossiliferous with brachiopods; Sample MG-9, resistant limestone beds..............	10.0	90.0
9.	Shale float, lower 6 feet; overlain by limestone, dark-gray, very finely to finely crystalline, very thin- to thin-bedded; Sample MG-8, upper 4 feet................	10.0	80.0

8.	Limestone, dark-gray, very finely to finely crystalline, thin-bedded with numerous shale inter-beds; very fossiliferous with brachiopods, gastropods, and ostracodes; interval partially covered; Sample MG-7..............	10.0	70.0
7.	Limestone, dark-gray to black, finely crystalline, very platy to thin-bedded; fossiliferous with linguloid brachiopods and ostracodes; Sample MG-6........	10.0	60.0
6.	Shale with numerous thin inter-beds of limestone; shale, dark-gray, calcareous; limestone, dark-gray to black, silty, laminated; 1-foot intraformational lime-stone conglomerate 7.5 feet above base; overlain by platy limestone; Sample MG-5........	10.0	50.0
5.	Shale, dark-gray, chippy to platy; several thin inter-beds of siltstone, dark-gray to		

black, calcareous, in upper part; Sample MG-4; calcareous siltstone.....................	10.0	40.0
4. Shale, dark-gray, chippy to platy; thin interbeds of siltstone, dark-gray to black, calcareous; a few thin interbeds of limestone, dark-gray, finely crystalline in upper part; fossiliferous with brachipods, gastropods, and ostracodes; Sample MG-3, calcareous siltstone and limestone.....................	10.0	30.0
3. Siltstone, dark-gray to black, calcareous, irregularly bedded; interbedded, black fissile shale, and few pods of intraformational limestone conglomerate; upper 5 feet		

Cosner Gap Member (15 feet)

Shale, greenish-gray, chippy, fossiliferous with brachio-

	pods and ostracodes; several thin interbeds of limestone, dark-gray, silty, arenaceous, laminated, and dolomite, light-gray, coarsely crystalline; lower 5 feet; boundary between Cosner Gap and McKenzie members of the Mifflintown Formation is in the middle of this interval; Sample MG-2..	10.0	20.0
2.	Shale, greenish-gray, chippy; thin interbeds of limestone, medium-gray to dark-gray, finely to medium-crystalline, dolomitic, arenaceous; fossiliferous with brachiopods and ostracodes; Sample MG-1, limestone interbeds...............	10.0	10.0

Lower Hematitic Member (4.7 feet)

1. Sandstone, light-gray, medium-grained, slightly calcareous; with scattered oölitic hematite bands; fossiliferous with brachiopods at top; weathers

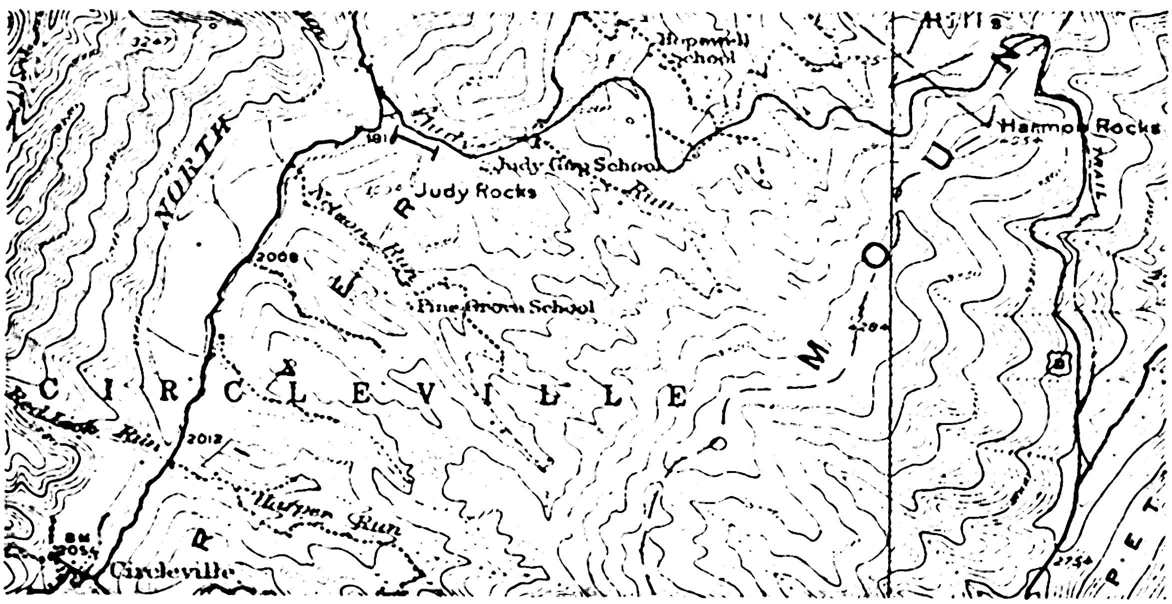
reddish brown,; upper part
weathers shaly; no sample..... 4.7

Rose Hill Formation (Not measured)

Grayish-green, fossiliferous shales; Mastigobolbina typus in shale approximately 1.0 foot below overlying unit.

Judy Gap Section

Location.--In the northwest ninth of the USGS 15-minute Circleville, West Virginia Quadrangle. This section is exposed in an old road-level quarry now used by the West Virginia State Highway Department as a service area. It is along U.S. Route 33, approximately 0.1 mile east from the junction with State Route 28.



	Thickness of Unit Feet	Total Thickness Feet
Keyser Limestone		
34. Limestone, light-gray, coarsely crystalline, massive, very crinoidal; quarried to road-level; exposed opposite highway sign approaching inter-section; Sample JG-33..........	12.7	630.1
33. Covered interval; quarried to road-level; lower 30 feet ex-posed in drainage ditch; similar to unit 32, grades upward into fissile shale; Keyser-Tonoloway contact not located; no sample..........................	163.0	617.4
Tonoloway Formation (183.2+)		
32. Limestone, dark bluish-gray, very finely to finely crystal-line, very thin-bedded; sparse-ly fossiliferous with brachio-pods; partially exposed on talus slope; Sample JG-32............	16.6	454.4

31.	Limestone, dark bluish-gray, very finely to finely crystalline, very thin-bedded, thin- to medium-bedded upward, with very thin clay partings; upper 15 feet very fossiliferous with brachiopods, bryozoans, and leperditiid ostracodes; weathers bluish gray; Sample JG-31, upper 10 feet, Sample JG-30, middle 10 feet, JG-29, lower 10 feet..................	32.0	437.8
30.	Covered interval; platy limestone float....................	47.2	405.8
29.	Limestone, dark bluish-gray, very finely crystalline, argillaceous; basal 3 feet, very thin- to thin-bedded; overlain by massive 5-foot bed; upper part platy and fossiliferous with gastropods and leperditiid ostracodes; Sample JG-28..................	15.3	358.6

28.	Shale, greenish-gray, calcareous, fissile; basal 0.9 foot; overlain by limestone, light greenish-gray, very finely crystalline, argillaceous, dolomitic, very thin-bedded; no sample........	1.5	343.3
27.	Limestone, dark bluish-gray, very finely crystalline, very thin-bedded, with shale partings; weathers light gray; thin-interbeds of very finely crystalline, dolomitic limestone; weathers yellowish gray; middle beds folded at base of cut; Sample JG-27, upper 10 feet; Sample JG-26, middle 10 feet; Sample JG-25, lower 10 feet........................	30.7	341.8
26.	Shale, dark-gray, calcareous; deep shoe-peg weathering; no sample......................	6.8	311.1
25.	Limestone, dark bluish-gray, very finely crystalline, thin-		

to medium-bedded, highly laminated; overlain by limestone, bluish-gray, very thin-bedded, laminated; weathers platy and shaly; Sample JG-24, upper 15 feet; Sample JG-23, lower 15 feet..................	33.1	304.3
Wills Creek Formation (271.2 feet)		
24. Limestone, dark bluish-gray, very finely to finely crystalline, slightly laminated, thin-bedded; weathers fissile to platy; Sample JG-22...........	13.2	271.2
23. Largely covered with shale float; dark-blue, calcareous, fissile shale at top; no sample........................	29.9	258.0
22. Limestone, dark-gray, argillaceous, platy to very thin-bedded, highly fractured; middle part largely covered with calcareous shale float; upper limestone beds contorted; no sample......................	17.0	228.1

21.	Limestone, dark-gray, medium-crystalline, argillaceous; fossiliferous with abundant leperditiid ostracodes; basal 0.2 foot; overlain by platy, argillaceous limestone; weathers shaly; upper part largely covered; Sample JG-21, basal bed...	14.0	211.1
20.	Largely covered; 0.3-foot bed limestone, dark-gray, very finely crystalline, argillaceous; in middle of interval; overlain by fissile shale; several thin beds of dark-gray, dense limestone at top; weathers light bluish-gray; no sample........	10.0	197.1
19.	Limestone, dark-gray, platy, very argillaceous, poorly exposed, basal 3 feet; overlain by limestone, medium-gray, finely crystalline, arenaceous, 1.5 feet; overlain by limestone, argillaceous, platy, deeply weathered, becomes		

	silty and thicker bedded in upper part; small cave about 10 feet above base; Sample JG-20........................	14.0	187.1
18.	Limestone, dark-gray, medium-crystalline, very thin-bedded, arenaceous, numerous calcite veinlets; fossiliferous with brachiopods and ostracodes; Sample JG-19......	2.0	173.1
17.	Lower 1.5 feet covered; overlain by limestone, bluish-gray, medium-crystalline, argillaceous, very thin-bedded; with olive-green clasts or clay galls; fossiliferous with leperditiid ostracodes; Sample JG-18........................	6.9	171.1
16.	Limestone, bluish-gray, finely crystalline, argillaceous, silty, very thin-bedded; fossiliferous with leperditiid ostracodes; basal 3 feet; upper part covered with calcareous shale float; interval		

	located on slope behind west end of Highway Commission barn; Sample JG-17, basal 3 feet.....	10.0	164.2
15.	Covered interval; calcareous shale and platy, argillaceous limestone float; no sample....	32.3	154.2
14.	Limestone, dark-gray, argillaceous, silty, single 3-foot bed at base of interval; overlain by 5 feet of deeply weathered, platy, argillaceous limestone and fissile, calcareous shale; overlain by limestone, medium-gray, finely crystalline, argillaceous, thin-bedded, with fissile shale partings; Sample JG-16, upper 3 feet; Sample JG-15, lower 3 feet.........................	11.4	121.9
13.	Covered interval; calcareous shale float; no sample........	7.8	110.5
12.	Shale, dark-gray, calcareous, platy to fissile upward; dark-gray, medium-crystalline lime-		

	stone lens, about 5 feet above base; fossiliferous with leperditiid ostracodes; upper part of interval partially covered; Sample JG-14, limestone lens...	14.7	102.7
11.	Covered interval; calcareous shale float; no sample........	28.0	88.0
10.	Limestone, dark-gray, very finely crystalline, argillaceous, very thin-bedded; weathers shaly and platy; upper 4 feet covered; Sample JG-13...	10.0	60.0
9.	Shale, light- to dark-gray calcareous, fissile to platy; upper part largely covered; Sample JG-12.........................	10.0	50.0
8.	Lower 5 feet, same as interval 7; overlain by shale, light-gray calcareous, fissile; some very thin, purplish-brown, fissile shale interbeds; Sample JG-11..................	10.0	40.0
7.	Limestone, dark-gray, very finely crystalline, argil-		

	laceous, thin-bedded, breaks blocky; very thin, purplish-brown, shale partings; Sample JG-10........................	10.0	30.0
6.	Limestone, dark-gray, very finely crystalline, argillaceous, thin-bedded, breaks blocky; interbedded papery shale; upper part largely covered; Sample JG-9.........................	10.0	20.0
5.	Limestone, bluish-gray, very finely crystalline, dense, slightly, argillaceous, thin-bedded with papery shale partings; several medium-crystalline limestone lenses in upper part; fossiliferous with brachiopods, gastropods, and ostracodes; Sample JG-8, lenses in upper part..........	10.0	10.0

Williamsport Sandstone (7.5 feet)

4. Sandstone, grayish-white, 2-foot bed; overlain by grayish-

green shale; overlain by 2.7-foot bed of siltstone, grayish-green to gray; weathers reddish brown; possible worm markings; no sample........... 7.5

Mifflintown Formation

McKenzie Member (65 feet+)

3. Largely covered; lower half of interval contains several thin beds of limestone, medium-gray, very finely to medium-crystalline; fossiliferous with brachiopods, ostracodes, and pelecypods; upper part consists of deeply weathered fissile shale with thin interbeds of sandstone, medium-gray, fine-grained, slightly calcareous; shale becomes arenaceous in upper 3 feet; Sample JG-7, upper 17 feet; Sample JG-6, lower 12 feet..... 29.3 65.0

2. Shale, dark-gray, slightly calcareous; weathers greenish to

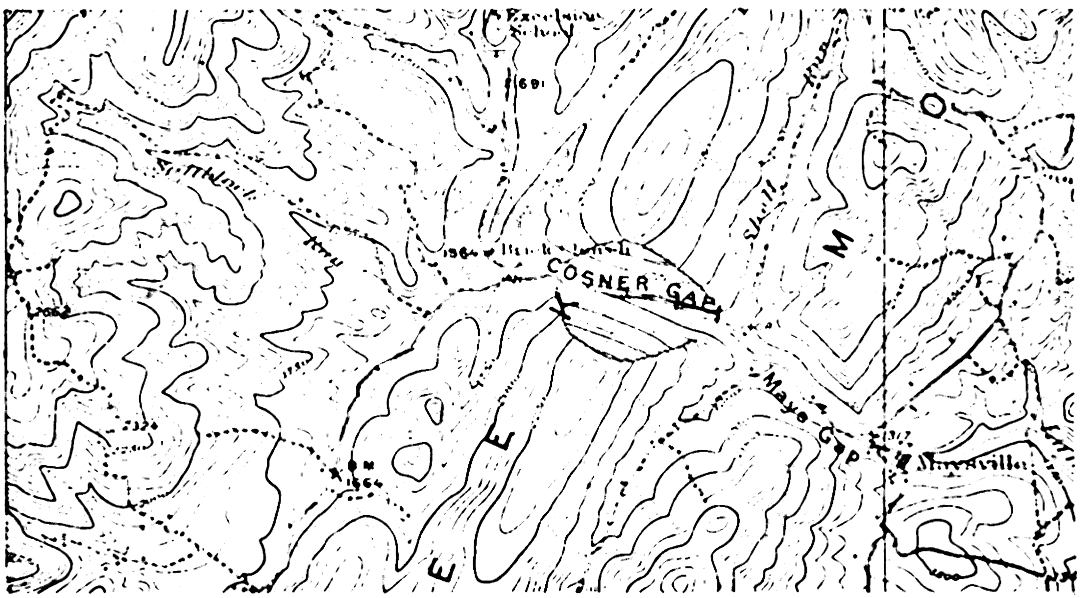
reddish brown; interbedded lime-
stone, medium-gray, very thin-
to thin-bedded; very fossili-
ferous with brachiopods and
ostracodes; Sample JG-5, upper
7.8 feet; Sample JG-4, middle 10
feet, Sample JG-3, lower 10 feet.. 27.8 35.7

1. Limestone, dark-gray, medium-
to coarsely crystalline, thin-
bedded, limonitic stains, cal-
cite vugs; upper 2 feet argil-
laceous and fossiliferous with
abundant brachiopods and ortho-
cerid cephalopods; Sample JG-2,
upper 2 feet; Sample JG-1,
lower 2 feet.................. 7.9 7.9

Remainder of section covered.

Cosner Gap Section

<u>Location</u>.--In the west-central ninth of the USGS 15-minute Greenland Gap, West Virginia Quadrangle. This section is 1.0 mile northwest of Maysville in Grant County, West Virginia, along State Route 42 at the eastern end of Cosner Gap.



	Thickness of Unit Feet	Total Thickness Feet
Mifflintown Formation		
McKenzie Member (26.7 feet+)		

4. Shale with interbedded siltstone and intraformational limestone conglomerate; shale, dark-gray, platy; weathers olive-gray; thin interbedded siltstone, dark-gray, calcareous; weathers light bluish gray; medium-bedded intraformational limestone conglomerates; matrix of conglomerates is limestone, medium-crystalline, very fossiliferous with ostracodes; clasts of conglomerates are oblong plates of limestone, dark-gray, very finely crystalline; conglomerates weather light gray with vari-colored clasts; remainder of section largely covered, not measured; Sample CG-McK1; 0.5-foot intraformational limestone conglomerate 21 feet above base of unit........................ 26.7 54.9

Cosner Gap Member (28.2 feet)

3. Shale with interbedded lime-

stone; shale, medium- to dark-gray, platy; 0.1- to 0.5-foot interbeds of limestone, medium-gray, medium-crystalline; fossiliferous with brachiopods , ostracodes, tentaculitids, and trilobites; top of interval marked by 0.9-foot bed of limestone, dark-gray, finely crystalline, oölitic; limestone weathers reddish brown; <u>Paraechmina spinosa</u> very abundant throughout this unit; Sample CG-CG9; oölitic limestone bed at top of interval; Sample CG-CG8, limestone bed 7 feet above base of interval; Sample CG-CG7, thin limestone beds 4.5 to 6 feet above base of interval; Sample CG-CG6, limestone bed 4 feet above base of interval..............	10.6	28.2
2. Shale with interbedded limestone and dolomite; shale, medium- to dark-gray; thin		

interbeds of limestone,
medium- to dark-gray, finely
to medium-crystalline, slightly
argillaceous; a few thin inter-
beds of dolomite, light-
gray, medium-crystalline; shales
and limestones fossiliferous
with brachiopods, ostracodes,
and trilobites; Drepanellina
clarki very abundant throughout
this unit; limestone interbeds
weather light gray; dolomite
interbeds weathers reddish
brown; Sample CG-CG5, limestone
bed 17 feet above base of inter-
val; Sample CG-CG4, dolomite bed
13.6 feet above base of inter-
val; Sample CG-CG3, limestone
bed 10.7 feet above base of
interval; Sample CG-CG2, lime
stone beds 4.3 to 4.9 feet above
base of interval; CG-CG1, lime-
stone bed 3.5 feet above base
of interval.................... 17.6 17.6

Lower hematitic member (10.2 feet)

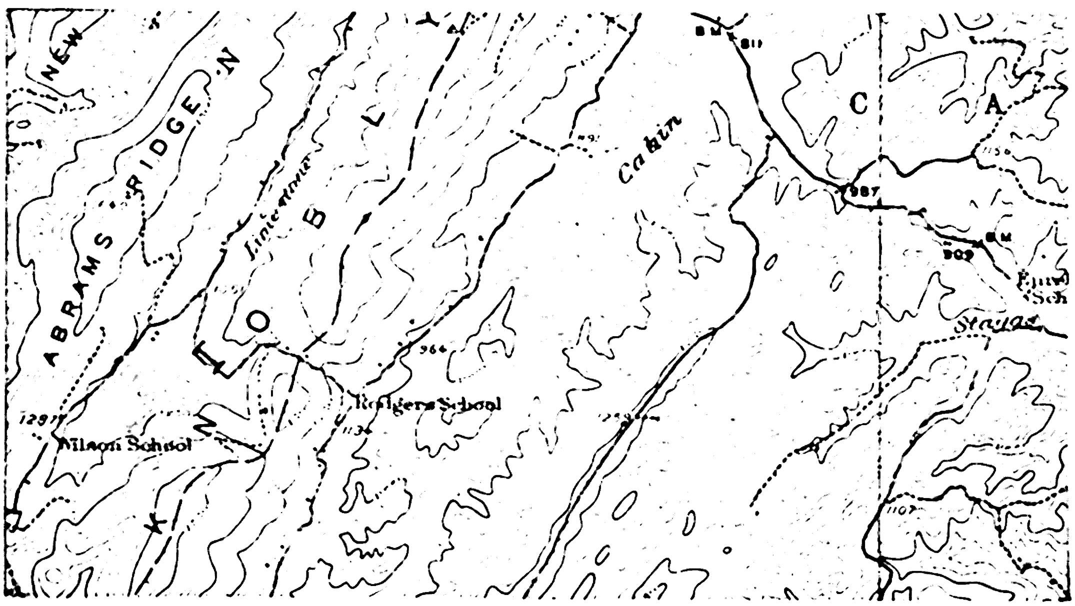
1. Silstone, dark-gray, thin-bedded with 0.4-foot band of oölitic hematite in middle and with arenaceous, hematitic limestone pods in upper part, basal 2 feet; overlain by shale; dark-gray, irregularly bedded with thin interbeds of sandstone, medium-gray, fine-grained, slightly calcareous; 5.7 feet; overlain by sandstone, grayish-brown, fine-grained, slightly calcareous, oölitic hematite throughout, with concentrated hematite band at base, 2.5-foot bed; top and bottom beds fossiliferous with brachiopods, and weather reddish brown, not sampled........................ 10.2

Rose Hill Formation (Not measured)

Shale, grayish-green; with interbedded siltstone.

Keyser Reservoir Section

Location.--In the west-central ninth of the USGS 15-minute Keyser, West Virginia-Maryland Quadrangle. This section is approximately 4 miles south of Keyser in Mineral County, West Virginia along State Route 14 opposite the Keyser City Reservoir.



	Thickness of Unit Feet	Total Thickness Feet
Wills Creek Formation (Not measured)		
Largely covered with shale float.		

Williamsport Sandstone (8.5 feet)

24.	Sandstone, medium-gray, fine-grained, thin-bedded, weathers yellowish brown, basal 4.5 feet; overlain by 2.5 feet of shale, reddish-gray to grayish-red; overlain by 1.5 feet sandstone, medium-gray, fine-grained, slightly calcareous, thin-bedded; weathers yellowish brown; no sample..........	8.5	

Mifflintown Formation (271.9 feet)

McKenzie Member (233.0 feet)

23.	Shale, yellowish-green, arenaceous; no sample.............	6.5	264.9
22.	Covered interval; soil and shale float; no sample........	24.0	258.4
21.	Largely covered with shale float; several medium-thick beds of limestone, dark-gray, medium-crystalline; limestones fossiliferous with brachiopods, coquinoid; Sample KR-McK19, limestones		

	in upper 3 feet; Sample KR-McK18, limestone bed 3 feet above base of interval....................	12.0	234.4
20.	Largely covered with shale float; several very thin beds of limestone, medium-gray, finely cyrstalline at middle and top of interval; fossiliferous with brachiopods and ostracodes, Sample KR-McK17, limestone beds...............	12.0	222.4
19.	Largely covered with shale float; several very thin beds of limestone, dark-gray, finely crystalline, in middle 4 feet of interval; fossiliferous with brachiopods and ostracodes; Sample KR-McK16, thin limestones...................	12.0	210.4
18.	Shale, deeply weathered, and largely covered; several lenses of limestone, medium-gray, finely crystalline, at base, middle, and top of inter-		

	val; fossiliferous with brachiopods and ostracodes; Sample KR-McK15, limestone lenses........................	6.0	198.4
17.	Shale, deeply weathered, and largely covered; 0.5-foot bed of limestone, medium-gray, finely crystal-line, 9 feet above base of interval; very fossiliferous with ostracodes; Sample KR-McK14, limestone bed......	12.0	192.4
16.	Shale, deeply weathered, and largely covered; lens of limestone, dark-gray, finely crystalline, 1 foot above base of interval; fossiliferous with ostracodes; Sample KR-McK13, limestone lens..........................	12.0	180.4
15.	Shale, deeply weathered, and largely covered; thin beds of limestone, medium-gray, finely crystalline,		

	3 feet above base and 1 foot below top of interval; very fossiliferous with brachiopods; Sample KR-McK12, limestone bed 1 foot below top of interval; Sample KR-McK11, limestone bed 3 feet above base of interval............	12.0	168.4
14.	Shale, deeply weathered, and largely covered; thin beds of limestone, medium-gray, finely crystalline, 5 to 6 feet above base of interval; very fossiliferous with ostracodes; Sample KR-McK10, thin limestone beds...	12.0	156.4
13.	Shale, deeply weathered, and largely covered; thin beds of limestone, medium-gray, finely crystalline, at base and top of interval; fossiliferous with ostracodes; Sample KR-McK9, thin limestone beds..........	12.0	144.4

12.	Shale, deeply weathered, and largely covered; no sample........................	18.0	132.4
11.	Shale, deeply weathered, and largely covered; several thin beds of limestone, dark-gray, finely crystalline; very fossiliferous with ostracodes; Sample KR-McK8, limestone beds..........................	12.5	114.4
10.	Shale, deeply weathered, and largely covered; numerous thin beds of limestone, medium- to dark-gray, finely to medium-crystalline; very fossiliferous with brachiopods and ostracodes; Sample KR-McK7; limestone beds...................	10.0	101.9
9.	Shale, dark-gray, chippy, with several thin beds of limestone, dark-gray, very finely crystalline, silty, cross-bedded, lower		

	part; thin beds of limestone, medium-gray, finely crystalline, at 5 and 8.5 feet above base of interval; very fossiliferous with brachiopods and ostracodes; Sample KR-McK6, limestone in upper half of interval....	10.0	91.9
8.	Shale, dark-gray, chippy; numerous thin beds of limestone, dark-gray, silty; fossiliferous with ostracodes; few thin intraformational limestone conglomerates; Sample KR-McK5, limestone in lower 5 feet..........................	10.0	81.9
7.	Shale, dark-gray, chippy; 0.2- and 0.5-beds of intraformational limestone conglomerate at 2 and 3 feet above base; several thin interbeds of limestone, dark-gray, silty; fossiliferous		

with ostracodes; Sample KR-McK4, silty and conglomeratic limestone........................	10.0	71.9
6. Shale, dark-gray, calcareous, chippy; numerous thin beds of intraformational limestone conglomerate; shale silty at middle of interval and platy at top of interval; about 60 percent of interval is shale; Sample KR-McK3, limestone conglomerates................	10.0	61.9
5. Shale, dark-gray, chippy; becomes silty, calcareous, and platy in upper half; numerous thin beds of limestone, dark-gray, very finely crystalline, in upper half; two 0.3-foot beds of intraformational limestone conglomerate in middle of interval; matrix of conglomerates, dark-gray, finely to medium-crystalline, clasts of conglomerates, limestone, dark-		

gray, finely crystalline, oblong, plate-like; Sample KR-McK2, limestones..........	10.0	51.9
4. Limestone, dark-gray, very finely crystalline, oölitic, basal 1.5 feet; overlain by shale, dark-gray, chippy, 2 medium-thick beds of intra-formational limestone conglomerate which thicken and thin rapidly; shale forms about 60 percent of interval; Sample KR-McK1B, limestone above basal bed; Sample KR-Mck1A, basalbed......................	10.0	41.9

Cosner Gap Member (31.9 feet)

3. Shale, dark-gray, chippy; numerous thin beds of limestone, medium-gray, medium-crystalline, many of which are brachiopod or ostracode coquinas; thick bed of dolomitic limestone, dark-gray, coarsely crystalline, 1

	foot above base; <u>Drepanellina clarki</u> collected from the base of this interval; Sample KR-CG2C, 0.5-foot coquina 1 foot below top; Sample KR-CG2B, limestone in middle of interval; Sample KR-CG2A, limestone in basal 1 foot	14.5	31.9
2.	Shale, dark-gray, arenaceous, lumpy at base of inerval, becomes calacareous and chippy upward; abundant marine fossils; weathers olive gray; 0.7-foot bed of limestone, medium- to dark-gray, dolomitic, 0.5-above base; 0.3-foot bed of limestone, dark-gray, coarsely crystalline, dolomitic, 3.5 feet above base; Samples KR-CG1B, calcareous shale 13.5 feet above base; Sample KR-CG1A, limestone bed 3.5 feet above base; Sample KR-CG1, limestone in basal 1.5 feet.....................	17.4	17.4

Lower hematitic member (7.0 feet)

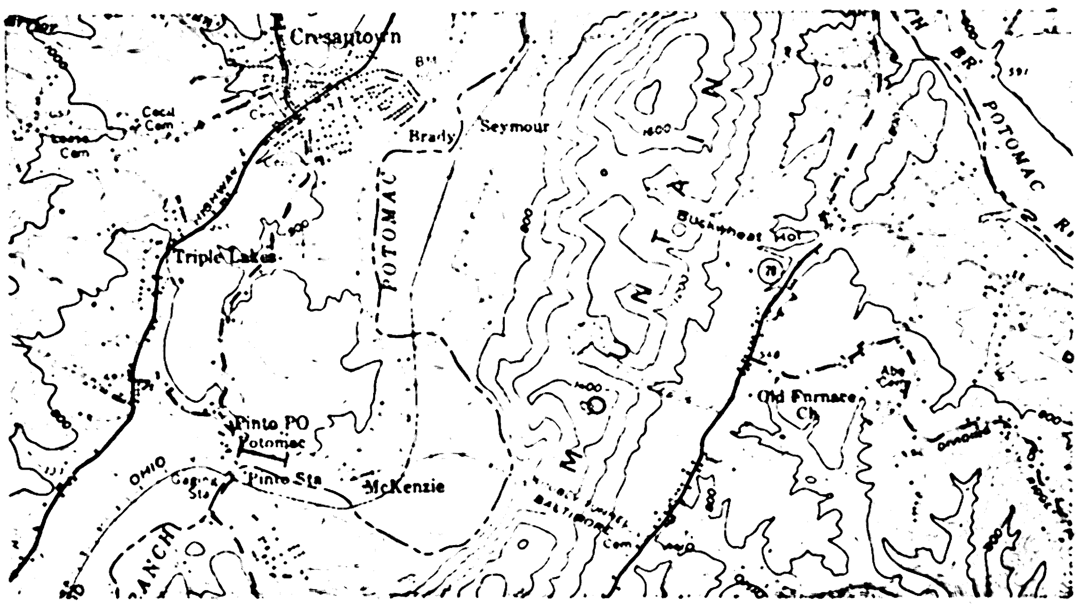
1.	Sandstone, medium-gray, fine- to medium-grained, calcareous; fossiliferous, with brachiopods; hematite bands in lower and upper parts; weathers yellowish brown; no sample.......	7.0

Rose Hill Formation (Not measured)

Shale and interbedded siltstone.

Pinto Section

Location.--In the south-central ninth of the USGS 15-minute Frostburg, Maryland-West Virginia-Pennsylvania Quadrangle. This section is approximately 0.5 mile southeast of Pinto Post Office along the tracks of the Baltimore and Ohio Railroad.



	Thickness of Unit Feet	Total Thickness Feet
Keyser Limestone (45 feet +)		
93. Limestone, dark-gray, very finely crystalline to finely		

crystalline, argillaceous, irregularly bedded; very fossiliferous with brachiopods, crinoid columnals, gastropods, and ostracodes; weathers yellowish gray to light gray; several thin beds of black chert in lower part; 5-foot interval at base and 7-foot interval 22 feet above base deeply weathered and covered with shale float; top of interval 19.7 feet from survey marker along side of railroad bed at western end of section, and 45 feet from center of road under trestle at western end of section; Sample P-K3, limestone 29 to 45 feet above base of interval; Sample P-K2, limestone 19 to 22 feet above base of interval; Sample P-K1, limestone 5 to 18 feet above base of interval............... 45.0 1136.6

Tonolway Formation (625.0 feet)

92.	Deeply weathered calcareous shale and limestone, largely covered. Keyser-Tonoloway contact placed 90 feet east of center of road which passes under railroad trestle at western end of cut following measurement by Swartz and Prouty (1923); contact not exposed presently..........	104.0	1091.6
91.	Limestone, light-gray, very finely to finely crystalline, argillaceous, platy; Sample P-T41..................	2.0	987.6
90.	Deeply weathered calcareous shale and limestone, largley covered; no sample............	32.5	985.6
89.	Limestone, light-gray, very finely crystalline, platy to very thin-bedded; deeply weathered, partially covered; no sample......................	10.0	953.1
88.	Limestone, olive-gray, very finely cyrstalline, argillaceous, very thin-bedded and		

	platy to thin-bedded; deeply weathered, no sample...........	13.2	943.1
87.	Limestone, dark-gray, very finely crystalline, medium-bedded; weathers light gray; Sample P-T40............	1.9	929.9
86.	Limestone, medium olive-gray, very finely crystalline, argillaceous, thin-bedded to platy; partially covered; no sample......................	11.0	928.0
85.	Limestone, olive-gray, very finely crystalline, argillaceous, thin- to medium-bedded; middle part laminated; weathers yellowish gray; Sample P-T39..................	4.7	917.0
84.	Covered interval; calcareous shale float; no sample.........................	6.1	912.3
83.	Shale, dark-gray, fissile; mottled white; overlain by limestone, dark-gray, very finely crystalline, argillaceous, very thin-bedded;		

	dark-gray, fissile shale interbeds; Sample P-T38.......	8.3	906.2
82.	Limestone, dark-gray, very finely crystalline, very thin- to medium-bedded upward; basal 3 to 4 feet very finely-laminated; small calcite laminae along bedding planes; cross-fractured with coarse calcite fillings; weathers tan to grayish yellow; Sample P-T37..................	10.7	897.9
81.	Interval largely covered with calcareous shale float; limestone, gray, very finely crystalline, argillaceous, platy; with fine calcite laminae; weathers yellowish brown; upper 2 feet; Sample P-T36..........	17.0	887.2
80.	Limestone, dark-gray, finely crystalline, platy; basal 2 to 3 feet with irregular argillaceous laminae which weather fluted; cross-fractured with		

	very coarse calcite fillings; weathers light bluish gray with grayish-brown laminae; Sample P-T35..................	3.3	870.2
79.	Limestone, medium olive-gray, very finely crystalline, arenaceous, oölitic; clay galls and small chert pebbles at base; deeply leached with unweathered argillaceous stringers and coarse, reddish-brown calcite filled cross-fractures at base; weathers grayish brown; Sample P-T34....	1.1	866.9
78.	Limestone, dark-gray, very finely crystalline, argillaceous, medium-bedded; weathers yellowish to orangish brown; solution cavities in toppart; cross-fractured with coarse calcite fillings; Sample P-T33..	1.9	865.8
77.	Limestone, grayish-black, finely crystalline, very thin-bedded, laminated; weathers platy and brownish gray; basal 6 feet;		

	overlain by shale, grayish-black, calcareous, very thin-bedded, very finely laminated; weathers fissile and yellowish to grayish brown; whole unit with coarse calcite filled fractures; leperditiid ostracodes 0.5 foot above base; Sample P-T32........................	9.1	863.9
76.	Limestone, dark-gray, very finely crystalline, carbonaceous; irregularly to regularly bedded upward; numerous cross-fractures filled with coarse calcite; weathers light gray; Sample P-T31........................	3.3	854.8
75.	Limestone, dark-gray, very finely to finely crystalline, fissile to platy; laminated, basal 1.5 feet; overlain by 3 0.5-0.6-foot beds of limestone, medium-gray, very finely crystal-		

line, with very thin shale partings; overlain by limestone, dark-gray very finely crystalline, dolomitic, medium- to thick-bedded with irregular stylolitic boundaries with bituminous filling; highly pitted; weathers yellowish brown; overlain by 2 feet of limestone, medium-gray, very finely crystalline, silty, very thin-bedded, platy, irregularly laminated; weathers yellowish brown; Sample P-T30........... 9.3 851.5

74. Limestone and interbedded shale; limestone, dark-gray, finely crystalline, laminated, medium- to very thin-bedded, weathers light gray; 2.5-foot bed of limestone 12 feet above base of interval; limestone 7-10 feet above base of interval fossiliferous with ostracodes and brachiopods; shale, grayish-

	black, fissile to platy, with coarse calcite veinlets; weathers brownish yellow to purplish gray; shale dominant in lower 7 feet; Sample P-T29..........	15.6	842.2
73.	Recess; reddish-brown residual soil, basal 2.5 feet; overlain by limestone, dark-gray, very finely crystalline, very dense, argillaceous, with dark-gray shale partings; weathers light brownish gray; overlain by 0.3-foot shale, grayish-brown, laminated; weathers orangish brown; Sample P-T28...	3.8	826.6
72.	Limestone, dark-gray, very finely crystalline, argillaceous, very thin- to medium-bedded; weathers platy in some units; top 0.2 foot weathers yellowish brown with solution cavities; unit		

	forms low pinnacle at top of cut; Sample P-T27..........	15.7	822.8
71.	Limestone, medium-gray, very finely crystalline argillaceous, dolomitic, medium-bedded, 3 beds separated by limestone, dark-gray, very finely crystalline, very thin-bedded to shaly; dolomitic limestone weathers orangish brown; limestone weathers grayish brown; dolomitic bed at base of unit solution pitted and recessed; middle and upper dolomitic bed stand out as ridges; Sample P-T26...........	6.3	807.1
70.	Limestone, dark-gray, very finely crystalline, argillaceous, very thin- to thin-bedded in lower part, becomes thick-bedded and thinly laminated upward; small black chert nodules in basal 1 foot;		

	middle 10 feet wavy bedded with clay partings; fossiliferous throughout with brachiopods, crinoid columnals, and ostracodes; Sample P-T25......	22.5	800.8
69.	Limestone, light-gray to yellowish-brown; mottled chalky; weathers orangish-brown; Sample P-T24...........	1.1	778.3
68.	Shale, dark purplish-gray, calcareous; basal part with thin interbeds of limestone, medium-gray, arenaceous, with a few very small chert nodules; sparsely fossiliferous with ostracodes; unit becomes shaly and platy upward; weathers gray to brown; Sample P-T23, basal 3 feet..................	6.1	777.2
67.	Limestone, brownish-gray, coarsely crystalline, 0.1- to 0.3-foot bed with shale wedge below; overlain by shale, dark-		

grayish-brown; weathers gray to light brown; very thin interbeds of dark-gray limestone, fossiliferous with brachiopods and ostracodes; unit forms recess in wall of cut; Sample P-T22, from basal limestone bed...... 3.2 771.1

66. Limestone, dark-gray, very finely crystalline, with finely crystalline limestone lenses, platy with very thin clay partings at base and thin shale partings upward, lower half of unit; overlain by limestone, grayish-brown to dark-gray, very finely crystalline, very thin-bedded with small fissile weathering units, becomes medium-bedded upward, weathers gray to grayish brown; Sample P-T21B, upper half of interval Sample P-T21A, lower half of interval.13.9 767.9

65.	Limestone, deeply weathered to yellowish brown residual soil zone; forms recess; no sample......................	1.0	754.0
64.	Shale, grayish-black, calcareous, vuggy; weathers yellowish brown; basal 2 feet; overlain by limestone, brownish-gray to grayish-black, very finely crystalline, argillaceous, platy to very thin-bedded; sandy on weathered surface; thin shale partings; bedding undulatory due to slight folding; fossiliferous with crinoid columnals, ostracodes, and tentaculitids; weathers grayish brown, Sample P-T19..................	15.7	753.0
63.	Recess in cut, filled with debris; no sample..............	3.5	737.3
62.	Limestone, dark-gray, very finely crystalline, argillaceous, thinly laminated,		

platy to medium-bedded upward; very thin shale partings in upper part; Weathers light gray to brownish gray; 2-foot recess about 1 foot above base of unit; Sample P-T17C, upper 10 feet; Sample P-T17B, middle 10 feet; Sample P-T17A, lower 10 feet	35.5	733.8
61. Limestone, dark-gray, very finely crystalline, thin-bedded, laminated, breaks irregularly; very thin shale partings; sparry calcite stringers and cross-veinlets throughout; weathers grayish brown; Sample P-T 16...	7.1	698.3
60. Limestone, bluish-gray, very finely crystalline, argillaceous, very thin-bedded, laminated; numerous cross-fractures filled with coarse calcite; sparsely fossiliferous		

with ostracodes; weathers
grayish brown; middle of unit
recessed with top and bottom
beds forming pinnacles at
top of cut; basal 0.5 foot
with white acicular crystals,
appears dolomitized with
argillaceous weathered blotches;
4.5 feet of purplish-weathering,
papery shale with thin limestone
interbeds, 28.9 feet above base;
1-foot bed of conglomeratic lime-
stone with small, elongate solution
cavities occurs below this shale;
limestone beds stand out in
relief in recess at 34.9, 38.5
and 40.7 feet above base of
interval, very coarse calcite
crystals encrust weathered sur-
faces of these beds; Sample
P-T15C, upper 25 feet; Sample
P-T15B, middle 25 feet; Sample
P-T15A, lower 25 feet......... 78.0 691.2

59. Limestone, very argillaceous,

	weathers to a reddish-yellow soil; forms deep recess in cut; no sample........................	0.9	613.2
58.	Shale, dark-gray, fissile; interbedded limestone, dark-gray, very finely crystalline, very thin-bedded, laminated; weathers gray to orangish brown; some purplish-brown shale in middle of unit; lower half of unit slightly recessed; Sample P-T13..................	15.1	612.3
57.	Dolomite, dark-gray, very finely crystalline, slightly calcareous, very thin- to thin-bedded; weathers orangish brown, with numerous solution cavities; 0.1-foot reddish-brown sandstone lens, 1.5 feet below top; Sample P-T12........................	7.9	597.2
56.	Shale, dark-gray, fissile; with thin interbeds of lime-stone, dark-gray, very finely		

	crystalline, argillaceous, weathers yellowish to grayish brown; unit slightly folded; 1-and 2-foot beds of limestone, dark-gray, with lenticular olive-gray limestone clasts at 30 and 37 feet above base; Sample P-T11B, upper 15 feet; Sample P-T11A, lower 15 feet........................	39.1	589.3
55.	Limestone, dark-gray, very finely crystalline, argillaceous, very thin-bedded; weathers light to yellowish gray; grades upward into platy limestone with interbeds of brownish-black fissile shale; 2-foot limestone bed in middle of unit; unit offset by 2 faults; Sample P-T10........	14.9	550.2
54.	Limestone, dark-gray, very finely crystalline, fissile to platy, with dark-gray shale		

	interbeds; grades upward into fissile shale with very thin, argillaceous limestone stringers; weathers yellowish brown; Sample P-T9....................	4.9	535.3
53.	Limestone, dark-gray to dark bluish-gray, very finely crystalline, platy; middle part solution pitted; weathers grayish to brownish yellow; Sample P-T8...	1.3	530.4
52.	Shale, light to medium-gray, calcareous; interbedded limestone, medium olive-gray, very finely crystalline, platy, laminated; weathers light gray to yellowish gray; upper part deeply weathered and forms recess in cut; Sample P-T7....................	7.3	529.1
51.	Limestone, dark-gray, very finely crystalline, very		

	thin to thin-bedded with interbedded shale, dark-gray, calcareous; weathers gray to yellowish brown; about 5 feet above tracks, beds are offset 2 feet by a fault; about 3 feet higher a second fault offsets beds about 1 foot; Sample P-T6....................	4.1	521.8
50.	Limestone, light- to medium-gray, very dense, dolomitic; forms a single bed of variable thickness; weathers yellowish gray; offset by same 2 faults as unit 51; Sample P-T5....................	0.9	517.7
49.	Shale, dark-gray, calcareous, platy; weathers light to medium gray; basal 3 feet; over lain by limestone, medium-gray, very finely crystalline, very thin-bedded, thinly laminated; weathers yellowish gray; overlain by limestone, dark-gray,		

	thin-bedded, with interbedded shale, dark-gray, thinly laminated; weathers light gray; upper beds undulatory; Sample P-T4....	18.1	516.8
48.	Limestone, light- to medium-gray, very finely crystalline, very thin-bedded, platy; weathers light to yellowish brown; offset by a fault; some beds pinched out below fault; Sample P-T3.....	10.7	498.7
47.	Limestone, dark-gray, very finely crystalline, argillaceous, thin-bedded at base and top, medium-bedded in middle; weathers light gray to grayish yellow; offset 4 feet by a fault about 4 feet above base of cut; Sample P-T2.......	10.7	488.0
46.	Limestone, dark-blue, very finely crystalline, thick-bedded to massive; contact with Wills Creek Formation somewhat gradational, basal foot is laminated and grades downward		

into papery shale; fault in lower part of cut; unit thinned to 5.7 feet below fault; Sample P-T1............	10.7	477.3

Wills Creek Formation (446.0 feet)

45. Limestone, dark-gray, very finely crystalline, capped above and below by deeply weathered intraformational breccia, basal 1 foot; overlain by limestone, dark-gray, very finely crystalline, argillaceous, very thin-bedded to platy, with fissile shale interbeds; grades upward into fissile shale; weathers banded; 2-foot bed of limestone capped by intraformational conglomerate, 13 feet above base of unit; Sample P-WC42B, argillaceous limestone in upper part; Sample P-WC42A, basal bed..........................	24.6	466.6
44. Limestone, dark-gray to grayish-		

	brown, very finely crystalline, argillaceous, platy, thinly laminated, with fissile, carbonaceous shale interbeds and thin arenaceous limestone stringers throughout unit; cross-veinlets of very coarse calcite in middle and upper part of unit; Sample P-WC41B, upper part of interval; Sample P-WC41A, basal 10 feet...........................	24.8	442.0
43.	Sandstone, light-gray, fine-grained, calcareous, basal 2 feet; overlain by 2 feet of thin-bedded, medium-gray limestone; overlain by fissile and platy calcareous shale with 2 thin beds of medium-gray limestone in middle; overlain by mudrock, dark-gray, calcareous; Sample P-WC40, basal sandstone bed...........	36.8	417.2

42.	Mudrock, dark-gray, very thick-bedded; massive and calcareous in middle of interval; several thin, reddish-brown weathering, arenaceous, medium-gray limestone stringers in lower part; 0.5-foot bed of dolomitic limestone, 3 feet below top of interval; Sample P-WC39.....................	26.5	380.4
41.	Limestone, dark-gray, very finely to finely crystalline, argillaceous, thin-bedded, coarsely banded with bluish-green shale partings; weathers reddish brown; Sample P-WC38....................	2.1	353.9
40.	Mudrock, dark-gray; lowest 4 feet of unit fissile and contains arenaceous, dark-gray, finely crystalline, limestone stringers; upper part weathers banded and splintery; Sample P-WC37.........................	10.9	351.8

39.	Limestone, dark-gray, very finely to finely-crystalline, argillaceous, medium-bedded; overlain by 0.7-foot bed of limestone, dark-gray, very finely crystalline, argillaceous, banded; weathers yellowish brown; Sample P-WC36..................	2.1	340.9
38.	Limestone, dark-gray, very finely crystalline, argillaceous, slightly arenaceous, thin-bedded with fissile, arenacous shale interbeds; upper part very fossiliferous with leperditiid ostracodes; Sample P-WC35.....	6.1	338.8
37.	Mudrock, medium-gray, calcareous, very thin-bedded, becomes thick-bedded upward; 2-foot residual soil zone about 6 feet above base; 0.9-foot bed of limestone, argillaceous, dolomitic, solution		

	pitted, deeply weathered orangish brown, 5 feet below top; 2 thin beds of limestone, light- to medium-gray, very finely to finely crystalline, slightly arenaceous, at top of interval; Sample P-WC34, from upper 2 feet..................	31.9	332.7
36.	Sandstone, brownish- to olive-gray, medium-grained, calcareous, very friable; weathers greenish gray to reddish brown; basal 1 foot; overlain by deeply weathered; thin-bedded, argillaceous limestone with thin to thick interbeds of fissile, carbonaceous shale; Sample P-WC33, basal 1 foot,.........	9.4	300.8
35.	Limestone, yellowish-brown, finely crystalline, arenaceous, argillaceous, platy; fossiliferous with ostracodes; grades upward into		

	fissile, calcareous shale with platy, argillaceous limestone interbeds; overlain by 1.5 feet of argillaceous limestone; Sample P-WC32, basal 1 foot.......	6.4	291.4
34.	Mudcrock, dark-gray, with calcareous sandstone stringers; weathers variegated; grades upward into limestone, dark-gray, arenaceous, argillaceous, shaly; fossiliferous with leperditiid ostracodes and shell hash; Sample P-WC31...	5.1	285.0
33.	Sandstone, brownish- to olive-gray, medium-grained, calcareous, weathers green to yellowish brown, basal 0.8 foot; overlain by 1-foot of limestone, dark-gray, argillaceous, platy, deeply weathered orangish brown; grades upward into shale, olive-gray, calcareous, fissile; overlain by a thick bed of mudrock, dark-gray, arenaceous,		

	with sandstone stringers, weathers green to dark reddish brown; Sample P-WC30, basal 0.8 foot.................	6.5	279.9
32.	Mudrock, dark-gray, arenaceous; basal 0.7 foot; overlain 0.5-foot bed of sandstone, medium-gray, medium-grained, calcareous, silty; overlain by shale, dark-gray to carbonaceous, arenaceous, fissile, with thin interbeds of argillaceous limestone and calcareous sandstone stringers; 1-foot bed of mudrock at top; weathers variegated; Sample P-WC29, basal 1 foot..........	9.1	273.4
31.	Limestone, dark-gray, very finely to finely crystalline, slightly arenaceous, thin-bedded with papery shale partings; becomes dolomitic, platy, and laminated upward; upper part weathers orangish brown; P-WC28.................	4.4	259.9

30.	Sandstone, light olive-gray, fine- to medium-grained, slightly calcareous, argillaceous, 0.4-foot bed; overlain by mudrock, dark-gray, calcareous, arenaceous in lower part; weathers variegated; Sample P-WC27, basal 0.4 foot......................	3.7	258.2
29.	Limestone, light- to dark-gray, very finely crystalline, argillaceous, platy to thin-bedded; becomes dolomitic and laminated upward, with thin interbeds of gray, calcareous shale; upper part weathers orangish to yellowish brown; vuggy throughout; Sample P-WC 26..........................	5.0	256.2
28.	Shale, dark-gray, with interbedded limestone, medium- to dark-gray, very finely crystalline, argillaceous, slightly arenaceous; overlain		

	by 1.5 feet of mudrock, olive-gray, calcareous; Sample P-WC25...	6.1	251.2
27.	Mudrock, medium-gray, calcareous, dolomitic; weathers orangish brown to bluish gray; no sample...............	2.9	245.1
26.	Shale, deeply weathered in recess, basal 2 feet; overlain by shale, dark-gray, calcareous, fissile to platy; grades upward into limestone, dark-gray very finely crystalline, thinly laminated, vuggy; Sample P-WC23.................	8.2	242.2
25.	Limestone, dark-gray, finely crystalline, basal 1 foot; overlain by shale, dark-gray, with interbedded limestone, dark-gray, very finely crystalline, argillaceous, arenaceous, thick- to very thin-bedded upward; Sample P-WC22.......................	4.9	234.0

24.	Limestone, dark-gray, very finely crystalline, dolomitic, thin-bedded, becomes dolomitic and shaly upward; weathers orange to reddish brown; Sample P-WC21..................	1.8	229.1
23.	Mudrock, dark-gray, calcareous, variegated; orange to reddish-brown, platy to fissile shale in upper part; Sample P-WC20...	10.7	227.3
22.	Limestone, dark-gray, very finely crystalline, dolomitic, thin- to thickbedded with interbedded papery shale; fossiliferous with leperditiid ostracodes; Sample P-WC19.........................	3.0	216.6
21.	Shale, dark-gray, calcareous, very thin-bedded, laminated, with thin interbeds of arenaceous limestone; cross-fractures filled with pink calcite; basal 2 feet; overlain by mudrock,		

	dark-gray, calcareous, weathers variegated; thin, rusty-brown limestone lenses in lower 3 feet of mudrock; Sample P-WC17, basal 5 feet....................	13.1	213.6
20.	Shale, purple, 0.1-foot bed at base; overlain by limestone, dark-gray, finely crystalline, argillaceous, deeply weathered rusty yellow; no sample...	3.9	200.5
19.	Mudrock, dark-gray, calcareous; weathers variegated; Sample P-WC15.........................	7.1	196.6
18.	Shale, dark-gray, calcareous, laminated; interbeds of purplish, arenaceous shale; weathers yellow to grayish brown; overlain by limestone, dark-gray, medium-crystalline; very fossiliferous with leperditiid ostracodes; weathers with red, hematitic blotches;		

	Sample P-WC14.................	8.0	189.5
17.	Limestone, dark-gray, very finely to finely crystal-line, thin- to thick-bed-ded with fissile shale partings; fossiliferous with leperditiid ostracodes; Sam-ple P-WC13....................	1.6	181.5
16.	Mudrock, dark-gray, cal-careous; grades upward into arenaceous limestone and interbedded shale; no sample........................	3.1	179.9
15.	Covered interval; site of col-lapsed cement tunnel; no sample........................	15.2	176.8
14.	Limestone, medium-gray, very finely crystalline, argillaceous, thin-bedded with thin- to thick inter-beds of shale, dark-gray, calcareous, fissile; shale weathers purplish brown to greenish yellow; thin		

	vertical stringers of white calcite in the shale; Sample P-WC10....................	14.7	161.6
13.	Mudrock, dark-gray, calcareous; Sample P-WC9.........	1.7	146.9
12.	Limestone, dark-gray, very finely crystalline, very thin- to thin-bedded; finely disseminated pyrite throughout; weathers yellowish orange; very thin- to thin interbeds of shale, grayish-black, calcareous, arenaceous, fissile to platy, thinly laminated; Sample P-WC8....................	26.1	145.2
11.	Limestone, dark-gray, very finely crystalline, vuggy, thin-bedded; weathers pale yellowish brown; thin interbeds of slightly folded, calcareous shale; Sample P-WC7...	15.0	119.1
10.	Shale, dark-gray, calcareous, platy to fissile; 1-foot bed of limestone, dark-gray,		

very finely crstalline, slightly argillaceous, in middle of unit; weathers rusty yellow; Sample P-WC6.........................	5.1	104.1
9. Shale, dark-gray, calcareous, platy; very thin interbeds of limestone, dark-gray; overlain by mudrock, dark gray, with nodular pyrite encrustations on upper surface; weathers variegated; Sample P-WC5..........	14.9	99.0
8. Shale, olive-gray, calcareous, platy mudcracked; minor beds of dark-gray mudrock; numerous interbeds of limestone, dark-gray, argillaceous, thin-bedded; unit formerly quarried for cement rock by tunneling; no sample..........	27.1	84.1
7. Mudrock, dark-gray, calcareous, thick-bedded; weathers variegated; overlain by limestone, dark-gray, very finely crystalline, argillaceous, med-		

	ium-bedded; Sample P-WC3.......	7.9	57.0
6.	Limestone, dark-gray, very finely crystalline, argillaceous, very thin-bedded, with thin interbeds of dark-gray calcareous shale; very fossiliferous with brachiopods, crinoid columnals, and ostracodes; Sample P-WC2.......	3.4	49.1
5.	Mudrock, dark-gray, calcareous, slightly arenaceous, massive; weathers variegated; very thin interbeds of fissile shale; thin interbeds of limestone, dark-gray, very finely crystalline, argillaceous, weathers reddish brown; top beds of unit mudcracked; Sample P-WC1B, upper 10 feet; Sample P-WC1A, basal 10 feet...	25.1	45.7

Williamsport Sandstone (20.6 feet)

Upper member

4. Shale, grayish-green, arenaceous;

2-foot bed of grayish-green, fine-grained sandstone in middle of interval; no sample........................	4.6	20.6
Cedar Cliff Member		
3. Residual clay, orangish-yellow; 0.1- and 1-foot beds of limestone, dark bluish-gray, very finely to finely crystalline, argillaceous, at 1.5 and 2.5 feet above base of interval; fossiliferous with leperditiid ostracodes; weathers brown to orangish brown; Sample P-CC2, 1-foot bed 2.5 feet above base; Sample P-CC1, 0.1-foot bed 1.5 feet above base................	8.0	16.0
Lower member		
2. Sandstone, light-gray, fine-grained, medium-bedded, no sample........................	8.0	8.0

Mifflintown Formation

McKenzie Member (34.1 feet +)

1. Shale, dark-gray, slightly calcareous, platy; becomes arenaceous in upper few feet; few thin beds of limestone, dark-gray, finely crystalline; abundantly fossiliferous with ostracodes; Sample P-McK3, limestone bed 19.7 feet below base of Williamsport; Sample P-McK2, limestone bed 22.8 feet below base of Williamsport; Sample McK1, limestone 34.1 feet below base of Williamsport. Remainder of Mifflintown Formation exposed but intensely drag-folded and faulted; not measured.

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SILURIAN CONODONTS FROM THE WILLS MOUNTAIN ANTICLINE

by

Charles Thomas Helfrich

(ABSTRACT)

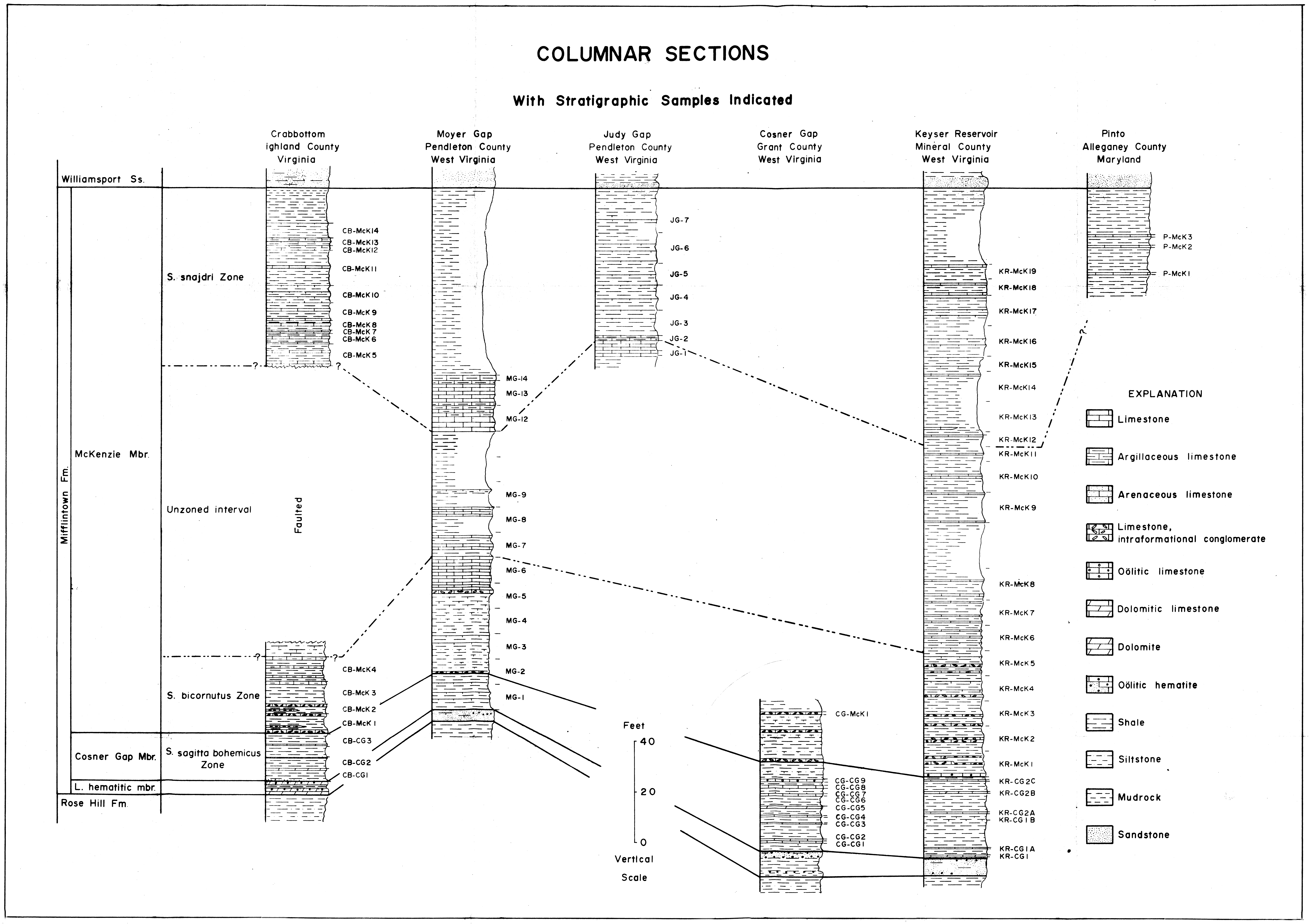
Condodont biostratigraphy has been established for complete sections of the Mifflintown, Wills Creek, and Tonoloway formations along the Wills Mountain anticline in the Central Appalachians. Beds in the Central Appalachians formerly called the Rochester Formation have been renamed the Cosner Gap Member of the Mifflintown Formation. The type section of the unit is at Cosner Gap, northwest of Maysville, Granty Count, West Virginia. Use of the name, Rochester Formation is restricted to the New York section.

The succession of conodont faunas described for these formations range from latest Wenlock through Pridoli in age. The fauna includes 46 form species assignable to the form genera Hindeodella, Ligonodina, Lonchodina, Neoprioniodus, Ozarkodina, Panderodus, Plectospathodus, Spathognathodus, and Trichonodella. Sixteen new form species are described and twelve of these are

named: *Ligonodina brevis*, *Ozarkodina edithae mariae*, *O. typica intermedia*, *O. serrata*, *O. sinuosa*, *O. ziegleri crassatoides*, *Spathognathodus bicornutus*, *S. primus highlandensis*, *S. primus multidentatus*, *S. tillmani*, *S. walliseri*, and *Synprioniodina lowryi*. One platform species, possibly representing a new form genus, occurs in the upper Tonoloway Formation. The important European forms *Spathognathodus sagitta bohemicus*. *S. snajdri*, *S. crispus*, and *S. steinhornensis eosteinhornensis*, are reported for the first time from the Central Appalachians. Eleven multi-element conodont species are recognized using open nomenclature.

Spathognathodus primus and *Spathognathodus sagitta bohemicus* lineages are recognized in the fauna and are important in delimiting six local concurrent range zones. Three zones are described for the Mifflintown Formation. The *Spathognathodus sagitta bohemicus* Zone is restricted to the Cosner Gap Member. The *Spathognathodus bicornutus* Zone is restricted to the lower third and the *Spathognathodus snajdri* Zone to the upper third of the McKenzie Member. No zone has been determined for the middle third of the McKenzie Member. Three zones are also described for the Wills Creek and Tonoloway formations. The *Spathognathodus tillmani* Zone spans the lower half of the Wills Creek Formation. The *Spathognathodus crispus* Zone spans the upper half of the Wills Creek Formation and the lower half of the Tonoloway Formation. The *Spathognathodus steinhornensis eosteinhornensis* Zone spans the upper Tonoloway Formation and supplementary samples indicate that it spans all or nearly all of the Keyser Limestone. The Gedinne form *Icriodus woschmidti* does not appear lower than the base of the New Creek Limestone or, possibly, the upper few feet of the Keyser Limestone.

The faunas of the *S. sagitta bohemicus*, *S. snajdri*, *S. crispus*, and *S. steinhornensis eosteinhornensis* zones correlate with the *sagitta*, *snajdri* horizon of the *siluricus*, *crispus*, and *eosteinhornensis* zones of Walliser. The *S. bicornutus* and *S. tillmani* zones are tentatively correlated with Walliser's *crassa* and *latialatus* zones. The *ploeckensis* Zone of Walliser was not identified, but its stratigraphic position would be similar to that of the unzoned interval of the middle third of the McKenzie Member of the Mifflintown Formation.


COLUMNAR SECTIONS
With Stratigraphic Samples Indicated
Crabbottom
ighland County
Virginia
Moyer Gap
Pendleton County
West Virginia
Judy Gap
Pendleton County
West Virginia
Cosner Gap
Grant County
West Virginia
Keyser Reservoir
Mineral County
West Virginia
Pinto
Alleganey County
Maryland
Williamsport Ss.
Mifflintown Fm.
McKenzie Mbr.
Cosner Gap Mbr.
L. hematitic mbr.
Rose Hill Fm.
S. snajdri Zone
Unzoned interval
S. bicornutus Zone
S. sagitta bohemicus Zone
Faulted
CB-McK14
CB-McK13
CB-McK12
CB-McK11
CB-McK10
CB-McK9
CB-McK8
CB-McK7
CB-McK6
CB-McK5
CB-McK4
CB-McK3
CB-McK2
CB-McK1
CB-CG3
CB-CG2
CB-CG1
MG-14
MG-13
MG-12
MG-9
MG-8
MG-7
MG-6
MG-5
MG-4
MG-3
MG-2
MG-1
JG-7
JG-6
JG-5
JG-4
JG-3
JG-2
JG-1
CG-McK1
CG-CG9
CG-CG8
CG-CG7
CG-CG6
CG-CG5
CG-CG4
CG-CG3
CG-CG2
CG-CG1
KR-McK19
KR-McK18
KR-McK17
KR-McK16
KR-McK15
KR-McK14
KR-McK13
KR-McK12
KR-McK11
KR-McK10
KR-McK9
KR-McK8
KR-McK7
KR-McK6
KR-McK5
KR-McK4
KR-McK3
KR-McK2
KR-McK1
KR-CG2C
KR-CG2B
KR-CG2A
KR-CG1B
KR-CG1A
KR-CG1
P-McK3
P-McK2
P-McK1
Feet
40
20
0
Vertical
Scale
EXPLANATION
Limestone
Argillaceous limestone
Arenaceous limestone
Limestone, intraformational conglomerate
Oölitic limestone
Dolomitic limestone
Dolomite
Oölitic hematite
Shale
Siltstone
Mudrock
Sandstone

COLUMNAR SECTIONS

With Stratigraphic Samples Indicated

Table I

	Stratigraphic Range and Abundances of Elements of Proposed Multi-element Species	Rose Hill Fm.	Mifflintown Fm.			Williamsport Ss.	Number of Specimens
			Lower Hematitic Mbr.	Cosner Gap Mbr.	McKenzie Mbr.		
Group I	Spathognathodus sagitta bohemicus						452
	Ozarkodina edithae mariae n. ssp.						87
Group II	Spathognathodus bicornutus n. sp.						922
	Ozarkodina ziegleri crassatoides n. ssp.						229
	Ligonodina brevis n. sp.						96
	Lonchodina? greilingi						67
	Synprioniodina lowryi n. sp.						100
	Trichonodella inconstans						51
Group III	Spathognathodus snajdri						93
	Ozarkodina serrata n. sp.						43
	Ligonodina n. sp.						11
	Plectospathodus? n. sp.						19
	Synprioniodina n. sp.						3
	Trichonodella n. sp.						2
Group IV	Spathognathodus primus primus						799
	Ozarkodina typica typica						329
	Ligonodina "silurica"						1163
	Plectospathodus extensus						600
	Neoprioniodus excavatus						555
	Trichonodella excavata						565
Group V	Ozarkodina aequalis						123
	Ozarkodina tenuiramea						814
	Lonchodina walliseri						431
Group VI	(Spathognathodus primus primus)						
	(Ozarkodina typica typica)						
	Hindeodella confluens						128
	Plectospathodus flexuosus						110
	Synprioniodina bicurvata						221
	Trichonodella symmetrica						88

Form element range greater than range of multi-element species.

Table II.

Stratigraphic Range and Abundances of Elements of Proposed Multi-element Species		Williamsport Ss.	Wills Creek Fm.	Tonoloway Fm.	Keyser Fm.	Number of specimens
Group V	Ozarkodina sinuosa n. sp.					68
Group V	Lonchodina walliseri					64
Group VI	(Spathognathodus primus primus)					
Group VI	(Ozarkodina typica typica)					
Group VI	Hindeodella confluens					13
Group VI	Plectospathodus flexuosus					8
Group VI	Synprioniodina bicurvata					18
Group VI	Trichonodella symmetrica					11
Group VII	Spathognathodus primus multidentatus n. ssp.					123
Group VII	Ozarkodina typica intermedia n. ssp.					44
Group VII	Ligonodina "silurica"					167
Group VII	Plectospathodus extensus					76
Group VII	Neoprioniodus excavatus					57
Group VII	Trichonodella excavata					59
Group VIII	Spathognathodus tillmani n. sp.					36
Group VIII	Ozarkodina ziegleri crassatoides n. ssp.					6
Group VIII	Ligonodina brevis n. sp.					3
Group VIII	Lonchodina? greilingi					7
Group VIII	Synprioniodina lowryi					2
Group VIII	Trichonodella inconstans					17
Group IX	Spathognathodus primus highlandensis n. ssp.					61
Group IX	Ozarkodina typica intermedia n. ssp.					35
Group IX	Ligonodina "silurica"					33
Group IX	Plectospathodus extensus					31
Group IX	Neoprioniodus excavatus					12
Group IX	Trichonodella excavata					18
Group X	Spathognathodus crispus					137
Group X	Ozarkodina ortuformis					34
Group X	Ligonodina brevis n. sp.					123
Group X	Lonchodina? greilingi					59
Group X	Synprioniodina lowryi n. sp.					19
Group X	Trichonodella inconstans					33
Group XI	Spathognathodus steinhornensis eosteinhornensis					449
Group XI	Ozarkodina typica denckmanni					116
Group XI	Hindeodella priscilla					57
Group XI	Plectospathodus alternatus					32
Group XI	Synprioniodina bicurvata					43
Group XI	Trichonodella symmetrica					12

Form element range greater than range of multi-element species.

Table III

Stratigraphic Abundance of Conodonts by Samples Mifflintown Formation

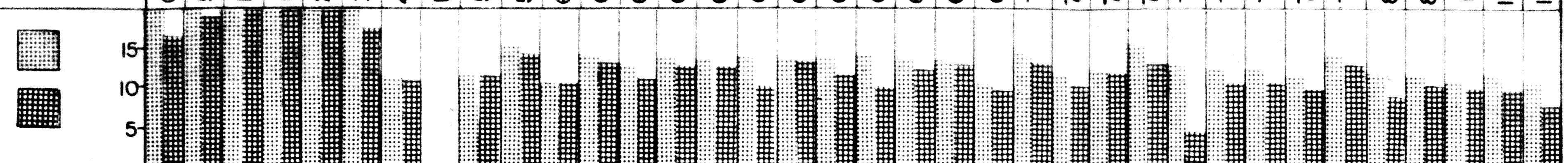
Bulk sample species index		CB-CG1	CB-CG2	CB-CG3	CB-McK1	CB-McK2	CB-McK3	CB-McK4	Fault	CB-McK5	CB-McK5A	CB-McK5B	CB-McK5C	CB-McK6	CB-McK6A	CB-McK6B	CB-McK6C	CB-McK6D	CB-McK7	CB-McK7A	CB-McK7B	CB-McK7C	CB-McK8	CB-McK8A	CB-McK8B	CB-McK8C	CB-McK9	CB-McK9A	CB-McK9B	CB-McK9C	CB-McK9D	CB-McK9E	CB-McK10	CB-McK11	CB-McK12	CB-McK13	CB-McK14	Total specimens per species
		Crabbottom Section																																				
		Cosner Gap Mbr.			McKenzie Mbr.																																	
	Sample Number	CB-CG1	CB-CG2	CB-CG3	CB-McK1	CB-McK2	CB-McK3	CB-McK4		CB-McK5	CB-McK5A	CB-McK5B	CB-McK5C	CB-McK6	CB-McK6A	CB-McK6B	CB-McK6C	CB-McK6D	CB-McK7	CB-McK7A	CB-McK7B	CB-McK7C	CB-McK8	CB-McK8A	CB-McK8B	CB-McK8C	CB-McK9	CB-McK9A	CB-McK9B	CB-McK9C	CB-McK9D	CB-McK9E	CB-McK10	CB-McK11	CB-McK12	CB-McK13	CB-McK14	
	Bulk Sample Museum Number—VPIL	1300	1301	1302	1303	1304	1305	1306		1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	
	Measurements in feet	0-5	5-10	10-19	19-27	27-31	31-40	40-49.5	Fault	55.5-64.0	55.5-57.7	60.0-61.0	63.5-63.7	64.0-68.0	64.0-64.3	65.1-65.5	66.5-66.7	67.0-67.1	68.0-69.7	68.0-68.2	68.4-69.0	69.5-69.7	69.7-73.5	70.3-70.5	71.3-71.9	73.3-73.5	73.5-80.5	74.5-74.6	75.5-76.2	76.7-77.7	78.3-78.4	78.8-79.0	80.5-87.5	87.5-101.5	101.5-103.4	103.4-106.4	106.4-112.3	
	Sample Weight (lbs.) / Weight Digested (lbs.)																																					
A	Hindeodella confluens		9	2										2	4	1	10	9		3				2			4		2	5	11	18						82
B	" equidentata	2	6	1																																		9
D	Ligonodina brevis n. sp.						2	7																														9
E	" "silurica"	2								3	4	8	35	43	10	31	116	129	9	25	13	75	9	35	20		34	14	9	23	128	61	18	12				866
F	" n. sp.															1	4	1						5														11
H	Lonchodina walliseri						1				4	3	22	8	6	6	32	49		10	8	33	6	17	11		8	2	9	4	44	28	2	1				314
I	? greilingi				2		9	4																														15
J	Neoprioniodus excavatus	2	4							1	3	4	11	22	2	15	46	50	2	10	2	33	6	9	10	2	32	3	6	9	55	19	4	7	3	1		373
K	" multiformis																																					
L	Ozarkodina aequalis	5	3																																			8
M	" edithae mariae n. ssp.		21	17																																		38
O	" serrata n. sp.													1	1	4	7	1	1		1	5		11	2													34
Q	" tenuiramea										1	2	29	32	12	37	92	107	2	7	9	35	9	11	14		15	7	12	9	47	33	11	4	2			539
T	" typica typica												5	1	9	23	35	36	1	7	1	7	3	2			7	2	7	11	17	29	3	10	5	1	14	243
U	" ziegleri crassatoides n. ssp.				14	5	20	10																														49
V	Panderodus simplex	3	11	1																																		15
X	Plectospathodus extensus	2	13	1			5			1				50	6	12	40	53	2	10	1	12	4	12	8		7	2	5	3	25	25	10		3			312
Y	" flexuosus		8	1									1	9		4	11	9				3			2				1	6	8	7						70
Z	? n. sp.													1			2	1	2			7		5	1													19
AA	Spathognathodus bicornutus n. sp.				28	31	51	22																														132
EE	" primus primus		9	3	1		1			1	5	3	9	28	16		44	53	2	11	11	8	3	11	7	11	13	8	16	13	43	23	8	30	8	2	45	446
FF	" sagitta bohemicus		47	57																																		104
GG	" snajdri											1	2	4	2		14	4	5	4	10	11	3	9	6			1	1									77
JJ	" walliseri n. sp.		1																																			1
KK	" sp.																																					
LL	Synprioniodina bicurvata		16	11	3		4					1		4		7	12	13		4	1	2		4	1		8	1	1	11	20	12		3	1		12	152
MM	" lowryi n. sp.				4			7																														11
NN	" n. sp.													1			2																					3
OO	" sp.			1																																		1
PP	Trichonodella excavata		1	2						2		5	12	14	2	14	39	37	2	6	6	35	8	16	11	2	29	4	10	11	46	25	14	5	2		1	361
QQ	" inconstans				3	5	5	2																														15
RR	" symmetrica	1		2									2	3		4	12	5		3		1					2	1	1	6	5	10	3	2			1	64
SS	" n. sp.																2																					2
TT	" sp.																																					
	Total specimens per sample	17	156	99	55	41	98	52		8	17	27	128	223	70	159	520	557	28	100	63	267	51	149	93	15	159	45	80	111	449	290	73	74	24	4	73	4375

Table IV

Stratigraphic Abundance of Conodonts by Samples, Mifflintown Formation

Moyer Gap Section

Bulk sample species index	Species	MG-1	MG-CG1	MG-CG2	MG-CG3	MG-CG4	MG-CG5	MG-2	MG-3	MG-4	MG-5	MG-6	MG-7	MG-8	MG-9	MG-12	MG-13	MG-14	Total specimens per species
	Member	Cosner Gap Mbr.						McKenzie Mbr.											
	Bulk Sample Museum Number–VPIL	1335	1336	1337	1338	1339	1340	1341			1342	1343	1344	1345		1346	1347	1348	
	Measurements in feet	0-10	2.1-2.6	3.0-3.1	4.5-5.0	9.0-9.2	11.0-11.1	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	110-120	120-130	130-132	
	Sample Weight (lbs.) / Weight Digested (lbs.)																		
A	Hindeodella confluens	2				2	4												8
B	" equidentata	11	22	10		1	3						5						52
D	Ligonodina brevis n. sp.										6	1							7
E	" "silurica"												12	22		7	5	13	59
F	" n. sp.																		
H	Lonchodina walliseri		2			1							8	12		3	5	5	36
I	" ? greilingi																		
J	Neoprioniodus excavatus	5	6	4	2		1						8	16		6	3	4	55
K	" multiformis	1					2	1											4
L	Ozarkodina aequalis	8	16	8	5	3	2												42
M	" edithae mariae n. ssp.				1	2	7												10
O	" serrata n. sp.																	1	1
Q	" tenuiramea												21	36		15	15	10	97
T	" typica typica	6											5	5		4	2	7	29
U	" ziegleri crassatoides n. ssp.										15	2							17
V	Panderodus simplex	20			1														21
X	Plectospathodus extensus	7	20	5	2		2				4		22	12		11	8	5	98
Y	" flexuosus			2		2	1						1						6
Z	" ? n. sp.																		
AA	Spathognathodus bicornutus n. sp.										72	13							85
EE	" primus primus	4					1						33	20		19	9	17	103
FF	" sagitta bohemicus			2		4	146												152
GG	" snajdri															1		1	2
JJ	" walliseri n. sp.		1	2	4	1													8
KK	" sp.																		
LL	Synprioniodina bicurvata	4				1	1						8				2	2	18
MM	" lowryi n. sp.										5								5
NN	" n. sp.																		
OO	" sp.																		
PP	Trichonodella excavata	8	7	4	4	1	1						13	17		10	4	2	71
QQ	" inconstans										10								10
RR	" symmetrica	1				1	2						2						6
SS	" n. sp.																		
TT	" sp.						1												1
	Total specimens per sample	77	74	37	19	19	174	1			112	16	138	140		76	53	67	1003

Judy Gap Section (McKenzie Mbr.)

Bulk sample species index	Species	JG-1	JG-2	JG-3	JG-4	JG-5	JG-6	JG-7	Total specimens per species
	Bulk Sample Museum Number–VPIL	1349	1350	1351	1352	1353	1354	1355	
	Measurements in feet	0.0-2.0	5.9-7.9	7.9-17.9	17.9-27.9	27.9-35.7	35.7-47.7	47.7-65.0	
A	Hindeodella confluens			1	2	2	1		6
B	" equidentata								
D	Ligonodina brevis n. sp.								
E	" "silurica"	3	1	2	28		6	14	54
F	" n. sp.								
H	Lonchodina walliseri		1	4	14	2		9	30
I	" ? greilingi								
J	Neoprioniodus excavatus		1	2	7	1	2	10	23
K	" multiformis								
L	Ozarkodina aequalis								
M	" edithae mariae n. ssp.								
O	" serrata n. sp.		1	1					2
Q	" tenuiramea		5	2	6	2	12		27
T	" typica typica	1		1	5	1	4		12
U	" ziegleri crassatoides n. ssp.								
V	Panderodus simplex								
X	Plectospathodus extensus			4	5	1	2	6	18
Y	" flexuosus			3					3
Z	" ? n. sp.								
AA	Spathognathodus bicornutus n. sp.								
EE	" primus primus	7	4	6	10	5		2	34
FF	" sagitta bohemicus								
GG	" snajdri		3	1					4
JJ	" walliseri n. sp.								
KK	" sp.								
LL	Synprioniodina bicurvata		1	1	3			2	7
MM	" lowryi n. sp.								
NN	" n. sp.								
OO	" sp.								
PP	Trichonodella excavata		2	4	10	4	1	5	26
QQ	" inconstans								
RR	" symmetrica							1	1
SS	" n. sp.								
TT	" sp.								
	Total specimens per sample	11	19	32	90	18	28	49	247

Cosner Gap Section

Bulk sample species index	Species	CG-CG1	CG-CG2	CG-CG3	CG-CG4	CG-CG5	CG-CG6	CG-CG7	CG-CG8	CG-CG9	CG-McK1	Total specimens per species
	Member	Cosner Gap Mbr.									McKenzie Mbr.	
	Bulk Sample Museum Number–VPIL	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	
	Measurements in feet	3.5-3.6	4.3-4.8	10.7-10.8	13.6-14.0	17.0-17.5	21.5-22	22.0-23.5	24.5-24.9	27.2-28.2	49.2-49.7	
A	Hindeodella confluens						6	17	1			24
B	" equidentata	3	10	4	8	2	7	2	5	1		42
D	Ligonodina brevis n. sp.										29	29
E	" "silurica"											
F	" n. sp.											
H	Lonchodina walliseri								4			4
I	" ? greilingi										25	25
J	Neoprioniodus excavatus	2	2		5		1			1		11
K	" multiformis											
L	Ozarkodina aequalis	16	11	3	11	4	12	5	4			66
M	" edithae mariae n. ssp.							43	4	3		50
O	" serrata n. sp.											
Q	" tenuiramea											
T	" typica typica						11		2			13
U	" ziegleri crassatoides n. ssp.										60	60
V	Panderodus simplex	1	5			1	4					11
X	Plectospathodus extensus	7	14		11	3	9	2	3		1	50
Y	" flexuosus						9	12	1	1		23
Z	" ? n. sp.											
AA	Spathognathodus bicornutus n. sp.										154	154
EE	" primus primus				2		9	1	9		1	22
FF	" sagitta bohemicus							142	32	22		196
GG	" snajdri											
JJ	" walliseri n. sp.				1	2	2					5
KK	" sp.	2										2
LL	Synprioniodina bicurvata						6	17	4	1	5	33
MM	" lowryi n. sp.										25	25
NN	" n. sp.											
OO	" sp.											
PP	Trichonodella excavata	2	5	1	3		1	3	4	2		21
QQ	" inconstans										4	4
RR	" symmetrica						2	7				9
SS	" n. sp.											
TT	" sp.											
	Total specimens per sample	33	47	8	41	12	79	251	73	31	304	879

Keyser Reservoir Section

Bulk sample species index	Species	KR-CG1	KR-CG1A	KR-CG1B	KR-CG2A	KR-CG2B	KR-CG2C	KR-McK1	KR-McK2	KR-McK3	KR-McK4	KR-McK5	KR-McK6	KR-McK7	KR-McK8	KR-McK9	KR-McK10	KR-McK11	KR-McK12	KR-McK13	KR-McK14	KR-McK15	KR-McK16	KR-McK17	KR-McK18	KR-McK19	Total specimens per species
	Member	Cosner Gap Mbr.						McKenzie Mbr.																			
	Bulk Sample Museum Number–VPIL		1366			1367	1368			1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	
	Measurements in feet	0.0-1.5	3.5-3.8	13.5-17.3	17.3-17.4	22.3-27.3	29.4-29.9	31.9-41.9	41.9-51.9	51.9-61.9	61.9-71.9	71.9-81.9	81.9-91.9	91.9-101.9	101.9-114.4	132.4-144.4	149.4-150.4	159.4-160.0	166.8-167.4	169.4-169.6	189.4-189.6	192.4-198.4	202.4-206.4	216.4-222.4	225.4-225.7	231.4-234.4	
A	Hindeodella confluens																				2		4	1			7
B	" equidentata		5										3														8
D	Ligonodina brevis n. sp.											34	14														48
E	" "silurica"												29	5	5	12	16	2	6	15	20	9	28	6	16	5	174
F	" n. sp.																										
H	Lonchodina walliseri												10	2		3	7	3	3	10	5	2					45
I	" ? greilingi											24	3														27
J	Neoprioniodus excavatus		13				1						27	2	7	2	4		1	5	10	1	8	6	4		91
K	" multiformis																										
L	Ozarkodina aequalis		4			3																					7
M	" edithae mariae n. ssp.																										
O	" serrata n. sp.																		1		4	1					6
Q	" tenuiramea												24	3	6	26	14		14	24	13	3	11	3	2		143
T	" typica typica					1					1		8				1			1	3		3	3	8		29
U	" ziegleri crassatoides n. ssp.										2	101															103
V	Panderodus simplex		3																								3
X	Plectospathodus extensus		11			3							25	1	3	9	10		5	12	13	5	14	6	3		120
Y	" flexuosus																				1		2	1	4		8
Z	" ? n. sp.																		1								1
AA	Spathognathodus bicornutus n. sp.									1	14	536															551
EE	" primus primus					2	1				1	22	62	4	2		3	1	2	16	10	2	5	12	28	4	177
FF	" sagitta bohemicus																										
GG	" snajdri																		5		3	2					10
JJ	" walliseri n. sp.																										
KK	" sp.																										
LL	Synprioniodina bicurvata											1	2	1	1		1						3				9
MM	" lowryi n. sp.											55	4														59
NN	" n. sp.																				2						2
OO	" sp.																										
PP	Trichonodella excavata		2			1						2	13	4	3	7	8	1	6	15	7	2	6	4	1	2	84
QQ	" inconstans											12	10														22
RR	" symmetrica					1								1							1				3		6
SS	" n. sp.																										
TT	" sp.																										
	Total specimens per sample		38			11	2			1	18	787	234	23	27	59	64	7	44	98	94	27	84	42	69	11	1740

Pinto Section (McKenzie Mbr.)

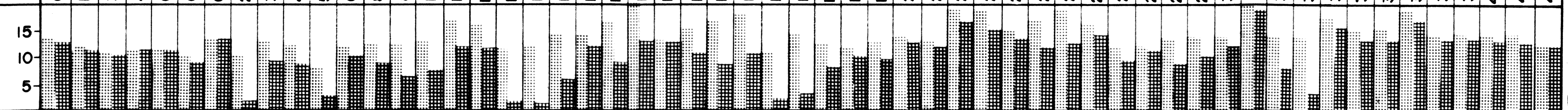
Bulk sample species index	Species	P-McK1	P-McK2	P-McK3	Total specimens per species
	Bulk Sample Museum Number–VPIL	1386	1387		
	Measurements in feet	0.0-0.1	11.3-11.5	14.4-14.6	
A	Hindeodella confluens	1			1
B	" equidentata				
D	Ligonodina brevis n. sp.				
E	" "silurica"	8	2		10
F	" n. sp.				
H	Lonchodina walliseri	2			2
I	" ? greilingi				
J	Neoprioniodus excavatus	2			2
K	" multiformis				
L	Ozarkodina aequalis				
M	" edithae mariae n. ssp.				
O	" serrata n. sp.				
Q	" tenuiramea	8			8
T	" typica typica	1	2		3
U	" ziegleri crassatoides n. ssp.				
V	Panderodus simplex				
X	Plectospathodus extensus	2			2
Y	" flexuosus				
Z	" ? n. sp.				
AA	Spathognathodus bicornutus n. sp.				
EE	" primus primus	8	9		17
FF	" sagitta bohemicus				
GG	" snajdri				
JJ	" walliseri n. sp.				
KK	" sp.				
LL	Synprioniodina bicurvata	2			2
MM	" lowryi n. sp.				
NN	" n. sp.				
OO	" sp.				
PP	Trichonodella excavata	2			2
QQ	" inconstans				
RR	" symmetrica	1	1		2
SS	" n. sp.				
TT	" sp.				
	Total specimens per sample	37	14		51

Table V

Stratigraphic Abundance of Conodonts by Samples

Crabbottom Section

Sample Weight (lbs.) / Weight Digested (lbs.)



Wills Creek Formation

Bulk sample species index	Species	CB-WC1	CB-WC1A	CB-WC1B	CB-WC1C	CB-WC1D	CB-WC1DL	CB-WC1DU	CB-WC2A	CB-WC2B	CB-WC3A	CB-WC3B	CB-WC4	CB-WC5	CB-WC6	CB-WC7A	CB-WC7AL	CB-WC7AU	CB-WC7B	CB-WC8	CB-WC9	CB-WC10	CB-WC10A	CB-WC10B	CB-WC11A	CB-WC11B	CB-WC11BL	CB-WC11BU	CB-WC12	CB-WC13	CB-WC14A	CB-WC14B	CB-WC14C	CB-WC15
	Bulk Sample Museum Number–VPIL	1388	1389		1390	1391	1392	1393					1394			1395	1396	1397	1398		1399	1400		1401		1402		1403						1404
	Measurements in feet	0-7	1.0-2.5	3.0-3.5	4.0-4.5	6.5-7.0	6.5-6.7	6.7-7.0	28.0-37.0	35.0-46.0	46.0-56.0	56.0-67.8	67.8-81.8	81.8-89.8	89.8-101.8	101.8-109.8	101.8-105.8	105.8-109.8	109.8-118.3	118.3-122.2	122.2-132.0	132.0-142.3	132.0-137.0	137.0-142.3	142.3-150.3	150.3-160.3	150.3-155.3	155.3-160.0	160.0-171.6	171.6-177.2	177.2-187.2	187.2-197.2	197.2-210.1	210.1-224.1
A	Hindeodella confluens					1		1										1				1												
B	" equidentata							1														1												
C	" priscilla																																	
D	Ligonodina brevis n. sp.		3														13	6			1	1				6		2						2
E	" "silurica"	11			4	49	4	58								9	8	10				1		11										
G	Lonchodina detorta																																	
H	" walliseri	4			1	13	1	19										4						1										
I	" ? greilingi	7																2				1				2		1						2
J	Neoprioniodus excavatus	6			2	27	1	15									2	3						1										
N	Ozarkodina ortuformis																	1								2								1
P	" sinuosa n. sp.	3			3	16	1	22										1						7										
R	" typica denckmanni																																	
S	" " intermedia n. ssp.	6			2	15		11					1					6						5										
U	" ziegleri crassatoides n. ssp.	6																																
V	Panderodus simplex																																	
W	Plectospathodus alternatus																																	
X	" extensus	6			2	21	3	32									2	6						4		2								
Y	" flexuosus					5		1																										
BB	Spathognathodus crispus																		1															
CC	" primus highlandensis n. ssp.																	2								3								
DD	" " multidentatus n. ssp.	5			1	22	5	29					2			1	1	9																
EE	" " primus	19	2													7	5					4				4								
HH	" steinhornensis eosteinhornensis																																	
II	" tillmani n. sp.				2	13	13	1					2				2																	
LL	Synprioniodina bicurvata					4		2										1				1												1
MM	" lowryi n. sp.		1															1																
PP	Trichonodella excavata	3			4	23		20								1	2	1						2										
QQ	" inconstans	4	3														1	5	3															
RR	" symmetrica					5		1																										
UU	Gen. et sp. indet. A																																	
VV	" " " " B																																	
WW	" " " " C																																	
XX	N. gen. et n. sp.																																	
	Total specimens per sample	80	9		21	214	28	213					5			18	36	59	4		1	10		31		19		3						6

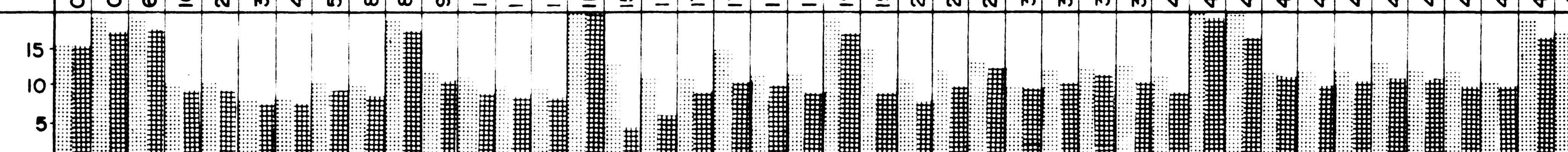
Tonoloway Formation

Bulk sample species index	Species	CB-T1A	CB-T1AL	CB-T1AU	CB-T1B	CB-T1BL	CB-T1BU	CB-T1C	CB-T2A	CB-T2B	CB-T2C	CB-T3	CB-T4A	CB-T4*	CB-T4B	CB-T5	CB-T6	CB-UT1	CB-UT2	CB-UT3	CB-UT4	CB-UT5	CB-UT6	CB-UT7	CB-UT8	Total specimens per species
	Bulk Sample Museum Number–VPIL	1405			1406	1407	1408	1409	1410	1411	1412			1413	1414			1415	1416	1417	1418	1419	1420	1421	1422	
	Measurements in feet	224.1-234.1	224.1-229.1	229.1-234.1	234.1-244.1	234.1-239.1	239.1-244.1	244.1-255.2	255.2-266.2	266.2-277.2	277.2-290.1	290.1-303.8	303.8-306.8	Breccia	324.1-329.1	329.1-338.1	338.1-344.1	354.1-364.1	364.1-374.1	374.1-384.1	384.1-394.1	394.1-404.1	404.1-414.1	414.1-424.1	424.1-434.1	
A	Hindeodella confluens														1											5
B	" equidentata																									2
C	" priscilla													5				3	3	5	4	3				23
D	Ligonodina brevis n. sp.					4																				38
E	" "silurica"																									165
G	Lonchodina detorta																									
H	" walliseri																									43
I	" ? greilingi					1																				16
J	Neoprioniodus excavatus																									57
N	Ozarkodina ortuformis						1																			5
P	" sinuosa n. sp.				1																					54
R	" typica denckmanni													12					12	15	6	3	3	4		55
S	" " intermedia n. ssp.	1			1																					48
U	" ziegleri crassatoides n. ssp.																									6
V	Panderodus simplex														2											2
W	Plectospathodus alternatus																		2	2	2				2	8
X	" extensus				3	2									1											84
Y	" flexuosus																									6
BB	Spathognathodus crispus									3					8				2	11						25
CC	" primus highlandensis n. ssp.	2			8	4																				19
DD	" " multidentatus n. ssp.																									75
EE	" " primus																		1							42
HH	" steinhornensis eosteinhornensis													11				48	49	25	7	9	20	10	23	202
II	" tillmani n. sp.																									33
LL	Synprioniodina bicurvata														2			2		3		1			2	19
MM	" lowryi n. sp.													1					1							4
PP	Trichonodella excavata																									56
QQ	" inconstans				1	2												1								20
RR	" symmetrica				1									3												10
UU	Gen. et sp. indet. A							1																		1
VV	" " " " B	7							1		1															9
WW	" " " " C										1															1
XX	N. gen. et n. sp.																									
	Total specimens per sample	10			15	13	1	1	1	3	2			32	14			54	70	61	19	16	23	14	27	1133

Table VI

Stratigraphic Abundance of Conodonts by Samples — Judy Gap Section

Sample Weight (lbs.) / Weight Digested (lbs.)



Wills Creek Formation

Bulk sample species index	Sample Number	JG-8	JG-8A	JG-8B	JG-9	JG-10	JG-11	JG-12	JG-13	JG-14	JG-14A	JG-14B	JG-15	JG-16	JG-16A	JG-16B	JG-17	JG-18	JG-19	JG-19R	JG-20	JG-21A	JG-21AR	JG-21B	JG-22
	Bulk Sample Museum Number—VPIL	1423	1424	1425	1426					1427	1428			1429	1430	1431			1432	1433				1434	
	Measurements in feet	0-10	0-6	6-10	10-20	20-30	30-40	40-50	50-60	88-102.6	88-92	98-102.6	110.5-113.5	115.9-121.9	115.9-118.9	118.9-121.9	154.2-164.2	164.2-171	171-173	171-173	173-187	197.1-197.3	197.1-197.3	197.3-211.1	257.9-271.1
A	Hindeodella confluens	3		2												1				2					
B	" equidentata																								
C	" priscilla																								
D	Ligonodina brevis n. sp.									4	1			9	3	60								2	
E	" "silurica"	8		5							3				3				1	7					
G	Lonchodina detorta																								
H	" walliseri	1		1												5			2	2					
I	Lonchodina? greilingi									6				4		28				1				2	
J	Neoprioniodus excavatus	2		4												1			1						
N	Ozarkodina ortuformis													2		23			1						
P	" sinuosa n. sp.	6		2											1					5					
R	" typica denckmanni																								
S	" " intermedia n. ssp.	3		1										3		12			2	8					
V	Panderodus simplex																								
W	Plectospathodus alternatus																								
X	" extensus	2		2							2			2		2			1	3					
Y	" flexuosus															2									
BB	Spathognathodus crispus													32		72									
CC	" primus highlandensis n. ssp.									2				13					2					2	
DD	" " multidentatus n. ssp.	17	1	10	1														8						
EE	" " primus	8								1									19						
HH	" steinhornensis eosteinhornensis																								
II	" tillmani n. sp.	1		3																					
LL	Synprioniodina bicurvata	1														6									
MM	" lowryi n. sp.															11			1						
PP	Trichconodella excavata	2		3						1						4				6					
QQ	" inconstans	1												1	1	20			1					2	
RR	" symmetrica	2														1			1						
UU	Gen. et sp. indet. A																								
VV	" " " " B																								
WW	" " " " C																								
XX	N. gen. et n. sp.																								
	Total specimens per sample	57	1	33	1					14	6			66	8	248			40	34				8	

Tonoloway Formation

Bulk sample species index	Sample Number	JG-23	JG-24	JG-25	JG-26	JG-27	JG-28	JG-29	JG-29A	JG-29B	JG-30	JG-30A	JG-30B	JG-31	JG-31A	JG-31B	JG-32	JG-32A	JG-32B	Total specimens per species
	Bulk Sample Museum Number—VPIL							1435	1436	1437							1438	1439	1440	
	Measurements in feet	271.1-286.2	286.2-304.3	311.1-321.1	321.1-331.1	331.1-341.7	343.2-358.6	405.8-415.8	405.8-410.8	410.5-415.8	415.8-425.8	415.8-420.8	420.8-425.8	425.8-437.8	425.8-430.8	430.8-437.8	437.8-454.5	437.8-445.8	445.8-454.5	
A	Hindeodella confluens																			8
B	" equidentata																			
C	" priscilla							2	2								1	2		7
D	Ligonodina brevis n. sp.																			79
E	" "silurica"																			27
G	Lonchodina detorta																			
H	" walliseri																			11
I	Lonchodina? greilingi							4												45
J	Neoprioniodus excavatus																			8
N	Ozarkodina ortuformis							2												28
P	" sinuosa n. sp.																			14
R	" typica denckmanni							3		3							2	3	3	14
S	" " intermedia n. ssp.							2												31
V	Panderodus simplex																			
W	Plectospathodus alternatus								1	2								2		5
X	" extensus																			14
Y	" flexuosus																			2
BB	Spathognathodus crispus																			104
CC	" primus highlandensis n. ssp.																			19
DD	" " multidentatus n. ssp.																			37
EE	" " primus																			28
HH	" steinhornensis eosteinhornensis							7	6	15							8	7	23	66
II	" tillmani n. sp.																			4
LL	Synprioniodina bicurvata									2									1	10
MM	" lowryi n. sp.																			12
PP	Trichconodella excavata																			16
QQ	" inconstans							2												28
RR	" symmetrica								1	1							1			7
UU	Gen. et sp. indet. A																			
VV	" " " " B																			
WW	" " " " C																			
XX	N. gen. et n. sp.																			
	Total specimens per sample							22	10	23							12	14	27	624

Table VII

Bulk sample species index	Stratigraphic Abundance of Conodonts by Samples	Pinto Section																																										
		Williamsport Ss. Cedar Cliff Mbr.		Wills Creek Formation																																								
	Sample Number	P-CC1	P-CC2	P-WC1A	P-WC1B	P-WC2	P-WC3	P-WC5	P-WC6	P-WC7	P-WC8	P-WC9	P-WC10	P-WC13	P-WC14	P-WC15	P-WC17	P-WC19	P-WC20	P-WC21	P-WC22	P-WC22A	P-WC22B	P-WC23	P-WC25	P-WC26	P-WC27	P-WC28	P-WC29	P-WC30	P-WC31	P-WC32	P-WC33	P-WC34	P-WC35	P-WC36	P-WC37	P-WC38	P-WC39	P-WC40	P-WC41A	P-WC41B	P-WC42A	P-WC42B
	Bulk Sample Museum Number—VPIL																				1441	1442	1443																					
	Measurements in feet	9.5-9.6	10.5-11.5	20.6-30.6	35.7-45.7	47.5-49.1	49.1-57.0	84.1-99.0	99.0-104.1	104.1-119.1	119.1-145.2	145.2-146.9	146.9-161.6	179.9-181.5	181.5-189.5	189.5-196.6	200.5-205.5	213.6-216.6	216.6-227.3	227.3-229.1	229.1-234.0	229.1-230.1	231.6-233.3	234.0-242.2	245.1-251.2	251.2-256.2	256.2-256.6	259.9-264.3	264.3-265.3	273.4-274.2	279.9-285.0	285.0-286.0	291.4-292.4	330.7-332.7	332.7-338.8	338.8-340.1	340.9-351.8	351.8-353.9	353.9-380.4	380.4-417.2	417.2-418.2	418.2-442.0	442.0-444.0	456.6-466.6
A	Hindeodella confluens																																											
B	" equidentata																																											
C	" priscilla																																											
D	Ligonodina brevis n. sp.																				9																							
E	" "silurica"																					3	5																					
G	Lonchodina detorta																																											
H	" walliseri																				1																							
I	" ? greilingi																				5																							
J	Neoprioniodus excavatus																				2	2																						
N	Ozarkodina ortuformis																				1																							
P	" sinuosa n. sp.																																											
R	" typica denckmanni																																											
S	" " intermedia																						1																					
U	" ziegleri crassatoides n. ssp.																																											
V	Panderodus simplex																																											
W	Plectospathodus alternatus																																											
X	" extensus																				6		3																					
Y	" flexuosus																																											
BB	Spathognathodus crispus																				1		7																					
CC	" primus highlandensis n. ssp.																				10		13																					
DD	" " multidentatus n. ssp.																				1	10																						
EE	" " primus																				1																							
HH	" steinhornensis eosteinhornensis																																											
II	" tillmani n. sp.																																											
LL	Synprioniodina bicurvata																				1		1																					
MM	" lowryi																				4		1																					
PP	Trichonodella excavata																				3		2																					
QQ	" inconstans																				2																							
RR	" symmetrica																																											
UU	Gen. et sp. indet. A																																											
VV	" " " " B																																											
WW	" " " " C																																											
XX	N. gen. et n. sp.																																											
	Total specimens per sample																				47	15	33																					

Bulk sample species index	Stratigraphic Abundance of Conodonts by Samples	Pinto Section																																																	Total specimens per species
		Tonoloway Formation																																																	
	Sample Number	P-T1	P-T2	P-T3	P-T4	P-T5	P-T6	P-T7	P-T8	P-T9	P-T10	P-T11A	P-T11B	P-T12	P-T13	P-T15A	P-T15B	P-T15C	P-T16	P-T17A	P-T17B	P-T17C	P-T19	P-T19A	P-T19B	P-T19C	P-T21A	P-T21AR	P-T21B	P-T21BR	P-T22	P-T23	P-T24	P-T25	P-T26	P-T27	P-T28	P-T29	P-T30	P-T31	P-T32	P-T33	P-T34	P-T35	P-T36	P-T37	P-T38	P-T39	P-T40	P-T41	
	Bulk Sample Museum Number—VPIL																						1444	1445	1446	1447	1448	1449	1450	1451	1452			1453																	
	Measurements in feet	466.6-477.3	477.3-488.0	488.0-498.7	498.7-516.8	516.8-517.7	517.7-521.8	521.8-529.1	529.1-530.4	530.4-535.3	535.3-550.2	550.2-565.2	574.3-589.3	589.3-597.2	597.2-612.3	613.2-639.2	639.2-665.2	665.2-691.2	691.2-698.3	698.3-708.3	711.0-721.0	723.8-733.8	737.3-753.0	739.3-739.6	745.3-746.3	750.0-751.0	754.0-761.0	754.0-761.0	761.0-767.9	761.0-767.9	767.9-768.2	771.1-774.1	777.2-778.3	778.3-800.8	800.8-807.1	807.1-822.8	822.8-826.6	826.6-842.2	842.2-851.5	851.5-854.8	854.8-863.9	863.9-865.8	865.8-866.9	866.9-870.2	870.2-887.2	887.2-897.9	897.9-906.2	912.3-917.0	928.0-929.9	985.6-987.6	
A	Hindeodella confluens																						6																												6
B	" equidentata																						2	16	2	6		1																							27
C	" priscilla																																																		9
D	Ligonodina brevis n. sp.																																																		8
E	" "silurica"																									1																									1
G	Lonchodina detorta																						9																												10
H	" walliseri																																																		5
I	" ? greilingi																																																		4
J	Neoprioniodus excavatus																																																		1
N	Ozarkodina ortuformis																																																		
P	" sinuosa n. sp.																						18	17	4	10	1	1	1	5																					57
R	" typica denckmanni																																																		1
S	" " intermedia																																																		
U	" ziegleri crassatoides n. ssp.																						3			8			20																						31
V	Panderodus simplex																						6	6	2	3	2																								19
W	Plectospathodus alternatus																						6					1																							16
X	" extensus																																																		
Y	" flexuosus																																																		8
BB	Spathognathodus crispus																																																		23
CC	" primus highlandensis n. ssp.																																																		11
DD	" " multidentatus n. ssp.																						7		2																										10
EE	" " primus																						48	25	24	26	3	5	3	23	3			1																	161
HH	" steinhornensis eosteinhornensis																																																		
II	" tillmani n. sp.																						9	7		3		4		3																					28
LL	Synprioniodina bicurvata																																																		5
MM	" lowryi																																																		5
PP	Trichonodella excavata																																																		2
QQ	" inconstans																						3	1		2																									6
RR	" symmetrica																																																		
UU	Gen. et sp. indet. A																																																		
VV	" " " " B																																																		
WW	" " " " C																												5																					5
XX	N. gen. et n. sp.																																																		
	Total specimens per sample																						117	72	34	59	6	12	24	36	3			1																	459

Table VIII

Formation	Mifflintown Fm.				Williams-port Ss.	Wills Creek Fm.		Tonoloway Fm.
	Cosner Gap Mbr.	McKenzie Mbr.						
Species / Concurrent Range Zone	Spathognathodus sagitta bohemicus	Spathognatodus bicornutus	Unzoned interval	Spathognathodus snajdri	No data	Spathognathodus tillmani	Spathognathodus crispus	Spathognathodus steinhornensis eosteinhornensis
Hindeodella confluens	—	—	—	—	—	—	—	
" equidentata	—	—	—	—	—	—	—	
" priscilla								—
Ligonodina brevis n. sp.		—	—	—	—	—	—	
" "silurica"	—	—	—	—		—	—	
" n. sp.				—				
Lonchodina detorta								—
" walliseri	—	—	—	—	—	—	—	
" ? greilingi		—	—	—	—	—	—	
Neoprioniodus excavatus	—	—	—	—	—	—	—	
" multiformis	—							
Ozarkodina aequalis	—							
" edithae mariae n. ssp.	—							
" ortuformis							—	
" serrata				—				
" sinuosa n. sp.						—		
" tenuiramea		—	—	—				
" typica denckmanni								—
" " intermedia n. ssp.						—		
" " typica	—	—	—	—	—			
" ziegleri crassatoides n. ssp.		—	—	—	—	—		
Panderodus simplex	—	—	—	—	—	—	—	—
Plectospathodus alternatus								—
" extensus	—	—	—	—	—	—	—	—
" flexuosus	—	—	—	—	—	—		
" ? n. sp.				—				
Spathognathodus bicornutus n. sp.		—						
" crispus							—	—
" primus highlandensis n. ssp.							—	
" " multidentatus n. ssp.						—		
" " primus	—	—	—	—	—	—	—	—
" sagitta bohemicus	—							
" snajdri				—				
" steinhornensis eosteinhornensis								—
" tillmani n. sp.						—		
" walliseri n. sp.	—							
" sp.	—							
Synprioniodina bicurvata	—	—	—	—	—	—	—	—
" lowryi n. sp.		—	—	—	—	—	—	
" n. sp.				—				
" sp.	—							
Trichonodella excavata	—	—	—	—	—	—	—	
" inconstans		—	—	—	—	—	—	
" symmetrica	—	—	—	—	—	—	—	—
" n. sp.				—				
" sp.	—							
N. gen. et n. sp.								—
Gen. et sp. indet. A							—	
" " " " B							—	
" " " " C							—	