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THE TAXONOMY, ONTOGENY, BIOSTRATIGRAPHY AND
PALEOECOLOGY OF THE EDENIAN (UPPER ORDOVICIAN)
OSTRACODS OF THE OHIO VALLEY.

University of Cincinnati, Ph.D., 1973
Paleontology

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THE TAXONOMY, ONTOGENY, BIOSTRATIGRAPHY AND
PALEOECOLOGY OF THE EDENIAN (UPPER ORDOVICIAN)

OSTRACODS OF THE OHIO VALLEY

A dissertation submitted to the

Division of Graduate Studies
of the University of Cincinnati

in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

in the Department of Geological Sciences
of the Graduate School of Arts and Sciences

1972

by

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November 30 1972

I hereby recommend that the thesis prepared under my supervision by Steven M. Warshauer

entitled The Taxonomy, Ontogeny, Biostratigraphy and
Paleoecology of the Edenian (Upper Ordovician)
Ostracods of the Ohio Valley

be accepted as fulfilling this part of the requirements for the degree of Doctor of Philosophy

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TABLE OF CONTENTS

	Page
ABSTRACT.....	1
INTRODUCTION.....	3
ACKNOWLEDGMENTS.....	4
STRATIGRAPHY.....	5
Historical survey.....	5
Petrology of the Kope Formation.....	8
COLLECTING LOCALITIES.....	12
General statement.....	12
Moffett Road.....	12
Rapid Run.....	14
Newport.....	14
I-71.....	15
Rabbit Hash.....	15
Boltz Lake.....	16
Twelvemile Creek.....	16
U.S. 27.....	17
Duck Creek.....	17
Kope Hollow.....	17
White Swan Run.....	18
West Fork Creek.....	18
TECHNIQUES.....	20
Sample processing.....	20
Photography.....	21

Data processing.....	21
FAUNAL ANALYSIS	
The ostracod fauna.....	23
Method of analysis.....	24
Results.....	28
Ostracod biostratigraphy.....	43
Paleoecology.....	44
ABBREVIATIONS USED IN THIS WORK.....	49
SYSTEMATIC PALEONTOLOGY.....	
Order Palaeocopida Henningsmoen, 1953.....	50
Suborder Beyrichiocopina Scott, 1961.....	50
Superfamily Drepanellacea Ulrich and Bassler, 1923.....	50
Family Bolliidae Boucek, 1936.....	50
Genus <u>Bollia</u> Jones and Holl, 1886.....	50
<u>Bollia persulcata</u> (Ulrich), 1879.....	50
Genus <u>Warthinia</u> Spivey, 1939.....	58
<u>Warthinia nodosa</u> (Ulrich), 1890.....	59
Genus <u>Parenthatia</u> Kay, 1940.....	67
<u>Parenthatia rabbithashensis</u> n. sp.....	67
Family Richinidae Scott, 1961.....	73
Genus <u>Jonesella</u> Ulrich, 1890.....	74
<u>Jonesella crepidiformis</u> (Ulrich), 1879.....	75
<u>Jonesella interrupta</u> n. sp.....	80
<u>Jonesella tumida</u> n. sp.....	85
Genus <u>Pseudulrichia</u> Schmidt, 1941.....	90

<u>Pseudulrichia byrnesi</u> (Miller), 1874.....	91
Family Aechminidae Boucek, 1936.....	96
Genus <u>Aechmina</u> Jones and Holl, 1869.....	96
<u>Aechmina</u> sp. A.....	96
<u>Aechmina</u> sp. B.....	100
<u>Aechmina</u> sp. C.....	101
Superfamily Hollinacea Swartz, 1936.....	102
Family Tetradellidae Swartz, 1936.....	102
Subfamily Glossomorphitinae Hessland, 1953.....	102
Genus <u>Ctenobolbina</u> Ulrich, 1890.....	102
<u>Ctenobolbina ciliata</u> (Emmons), 1855.....	102
<u>Ctenobolbina</u> cf. <u>alata</u> Ulrich, 1890.....	112
Family Eurychilinidae Ulrich and Bassler, 1923.....	113
Genus <u>Euprimitia</u> Ulrich and Bassler, 1923.....	113
<u>Euprimitia minuta</u> Keenan, 1951.....	113
<u>Euprimitia</u> sp.....	115
Family Ctenonotellidae Schmidt, 1941.....	116
Genus <u>Ceratopsis</u> Ulrich, 1894.....	117
<u>Ceratopsis chambersi</u> (Miller), 1874.....	117
<u>Ceratopsis</u> cf. <u>intermedia</u> Ulrich, 1894.....	127
Superfamily Oepikellacea Jaanusson, 1957.....	128
Family Aparchitidae Jones, 1901.....	128
Genus <u>Aparchites</u> Jones, 1889.....	128
<u>Aparchites minutissimus</u> (Hall), 1871.....	128
Suborder Eridostraca Adamczak, 1961.....	135

Family Eridoconchidae Henningsmoen, 1953.....	135
Genus <u>Americoncha</u> Schallreuter, 1968.....	135
<u>Americoncha marginata</u> (Ulrich), 1890.....	135
<u>Americoncha</u> aff. <u>A. bifurcata</u> (Copeland), 1965.....	139
Suborder Kloedenellocopina Scott, 1961.....	143
Superfamily Leperditellacea Ulrich and Bassler, 1923.....	143
Family Leperditellidae Ulrich and Bassler, 1923.....	143
Genus <u>Milleratia</u> Swartz, 1936.....	143
<u>Milleratia kopensis</u> n. sp.....	143
<u>Milleratia rudis</u> (Ulrich), 1890.....	147
<u>Milleratia shideleri</u> Levinson, 1951.....	150
Genus <u>Pseudoprimitiella</u> n. gen.....	153
<u>Pseudoprimitiella unicornis</u> (Ulrich), 1879.....	153
<u>Pseudoprimitiella reticulata</u> n. sp.....	157
Genus <u>Schmidtella</u> Ulrich, 1894.....	162
<u>Schmidtella claypolei</u> (Jones), 1890.....	162
Genus <u>Platamonaria</u> n. gen.....	165
<u>Platamonaria bicava</u> (Ulrich and Bassler), 1923.....	166
Suborder indeterminate.....	170
Family indeterminate.....	170
Genus <u>Ambitella</u> n. gen.....	170
<u>Ambitella unispinifera</u> n. sp.....	170
Genus <u>Cincinnatiiconcha</u> n. sp.....	178
<u>Cincinnatiiconcha pedigera</u> (Ulrich), 1890.....	178
Genus " <u>Primitiella</u> " Ulrich, 1894.....	184

<u>"Primitiella" whitfieldi</u> (Jones), 1890.....	184
Order Podocopida Muller, 1884.....	188
Suborder Metacopina Sylvester-Bradley, 1961.....	188
Superfamily Healdiacea Harlton, 1933.....	188
Family Bairdiocyprididae Shaver, 1961.....	188
Genus <u>Cytherellina</u> Jones and Holl, 1869.....	188
<u>Cytherellina cylindrica</u> (Hall), 1871.....	188
<u>Cytherellina granti</u> (Ulrich), 1894.....	194
Family Krausellidae Berdan, 1961.....	196
Genus <u>Krausella</u> Ulrich, 1894.....	196
<u>Krausella</u> sp.....	196
Order indeterminate.....	197
Ostracod indet. A.....	197
Ostracod indet. B.....	197
Ostracod indet. C.....	198
Ostracod indet. D.....	198
Ostracod indet. E.....	199

LIST OF TEXT FIGURES

	Page
Text Fig. 1. Correlation of Edenian nomenclature.....	9
Text Fig. 2. Nomenclature and approximate lateral relations between Champlainian and Cincinnati lithostrati- graphic units of the Cincinnati area.....	11
Text Fig. 3. Map of collecting localities.....	13
Text Fig. 4. Summary chart of Edenian ostracod occurrences.....	26-27
Text Fig. 5. Q-mode dendrogram (U.P.G.M.) based on calculation of the Jaccard similarity coefficients for 86 Edenian samples coded by the straight occurrence method.....	30-31
Text Fig. 6. Q-mode dendrogram (U.P.G.M.) based on calculation of the Otsuka similarity coefficients for 86 Edenian samples coded by the straight occurrence method.....	32-33
Text Fig. 7. Q-mode dendrogram (U.P.G.M.) based on calculation of the Jaccard similarity coefficients for 86 Edenian samples normalized by the moving average method.....	34-35
Text Fig. 8. Q-mode dendrogram (U.P.G.M.) based on calculation of the Otsuka similarity coefficients for 86 Edenian samples normalized by the moving average method.....	36-37
Text Fig. 9. Q-mode dendrogram (U.P.G.M.) based on calculation	

of the Jaccard similarity coefficients for 86 Edenian samples normalized by the range method of Cheetham and Deboo.....	39-40
Text Fig. 10. Q-mode dendrogram (U.P.G.M.) based on calculation of the Otsuka similarity coeffic- ients for 86 Edenian samples normalized by the range method of Cheetham and Deboo.....	41-42
Text Fig. 11. Chart of samples reordered by zones.....	45-46
Text Fig. 12. Size dispersion diagram of <u>Bollia persulcata</u> (Ulrich).....	54
Text Fig. 13. Size dispersion diagram of <u>Warthinia nodosa</u>	63
Text Fig. 14. Size dispersion diagram of <u>Parenthatia</u> <u>rabbithashensis</u> n. sp.....	70
Text Fig. 15. Size dispersion diagram of <u>Jonesella crepidi-</u> <u>formis</u> (Ulrich).....	79
Text Fig. 16. Size dispersion diagram of <u>Jonesella</u> <u>interrupta</u> n. sp.....	84
Text Fig. 17. Illustration showing position of the lobes and sulci on an Adult technomorph of <u>Ctenobolbina</u> <u>ciliata</u> (Emmons).....	104
Text Fig. 18. Size dispersion diagram of <u>Ctenobolbina ciliata</u> (Emmons).....	109
Text Fig. 19. Size dispersion diagram of <u>Ceratopsis chambersi</u> (Miller).....	122
Text Fig. 20. Size dispersion diagram of <u>Aparchites</u>	

	<u>minutissimus</u> (Hall).....	131
Text Fig. 21. Size dispersion diagram of <u>Ambitella</u>		
	<u>unispinifera</u> n. sp.....	175
Text Fig. 22. Size dispersion diagram of <u>Cincinnati-concha</u>		
	<u>pedigera</u> (Ulrich).....	182

LIST OF TABLES

	Page
Table 1. Statistical summary of measurements (in mm) for 37 specimens of <u>Bollia persulcata</u> from sample 9-4.....	53
Table 2. Statistical summary of measurements (in mm) for 58 specimens of <u>Warthinia nodosa</u> from sample 2-7.....	62
Table 3. Measurements (in mm) of Holotype and 23 Paratypes of <u>Parenthatia rabbithashensis</u> from sample 5-23.....	69
Table 4. Statistical summary of measurements (in mm) for 25 specimens of <u>Jonesella crepidiformis</u> from sample 2-7..	78
Table 5. Measurements (in mm) of Holotype and 15 Paratypes of <u>Jonesella interrupta</u> from sample 2-1.....	83
Table 6. Measurements (in mm) of Holotype and 10 Paratypes of <u>Jonesella tumida</u> from several samples.....	89
Table 7. Measurements (in mm) of the Lectotype and 10 Paralectotypes of <u>Pseudulrichia byrnesi</u>	94
Table 8. Measurements (in mm) of <u>Aechmina</u> sp. A.....	98
Table 9. Measurements (in mm) of <u>Aechmina</u> sp. B.....	98
Table 10. Statistical summary of measurements (in mm) for 78 specimens of <u>Ctenobolbina ciliata</u> from sample 12-1....	106
Table 11. Measurements (in mm) of ? <u>Euprimitia minuta</u> from sample 8-2.....	114
Table 12. Statistical summary of measurements (in mm) for 63 specimens of <u>Ceratopsis chambersi</u> from sample 12-1....	120
Table 13. Statistical summary of measurements (in mm) for 44	

specimens of <u>Aparchites minutissimus</u> from sample 2-2.....	130
Table 14. Measurements (in mm) of <u>Americoncha marginata</u> from sample 2-28.....	138
Table 15. Measurements (in mm) of <u>Americoncha</u> aff. <u>A.</u> <u>bifurcata</u> from sample 1-40.....	140
Table 16. Measurements (in mm) of 9 specimens of <u>Milleratia</u> <u>kopensis</u>	146
Table 17. Measurements (in mm) of 17 specimens of <u>Milleratia</u> <u>rudis</u> from sample 1-42.....	149
Table 18. Measurements of 5 specimens of <u>Milleratia shideleri</u> from sample 2-13.....	152
Table 19. Measurements (in mm) of the 14 measurable specimens of <u>Pseudoprimitiella unicornis</u>	156
Table 20. Measurements (in mm) of the Holotype and 9 Paratypes of <u>Pseudoprimitiella reticulata</u>	160
Table 21. Measurements (in mm) for 7 specimens of <u>Schmidtella claypolei</u>	163
Table 22. Measurements (in mm) of 11 specimens of <u>Platamonaria</u> <u>bicava</u>	169
Table 23. Measurements (in mm) of the Holotype and 11 Paratypes of <u>Ambitella unispinifera</u> from sample 2-32..	173
Table 24. Statistical summary of measurements (in mm) for 30 specimens of <u>Cincinnatiiconcha pedigera</u> from sample 5-2.....	188

Table 25. Measurements (in mm) of 11 specimens of <u>"Primitiella" whitfieldi</u> from sample 2-1.....	185
Table 26. Measurements (in mm) of 12 specimens of <u>"Cytherellina cylindrica"</u> from sample 7-3.....	191
Table 27. Measurements (in mm) of 15 specimens of <u>"Cytherellina granti"</u> from sample 1-57.....	196

ABSTRACT

This investigation describes the taxonomy, ontogeny, biostratigraphy and paleoecology of the Edenian ostracods of the Ohio Valley. Studies of the ostracods from this classical area and unit (the lowermost Upper Ordovician type standard for North America) have not been undertaken since the 1890's. Since that time many new concepts pertaining to the study of ostracods have been developed.

Approximately 12,000 specimens were recovered and studied from 132 processed samples collected from 12 localities within a 1,500 square mile area of southwestern Ohio and northern Kentucky.

Thirty seven ostracod species, distributed among 20 genera and 13 families are described. Four new genera: Ambitella, Cincinnati-cha, Platamonaria, Pseudoprimitiella, and six new species: Ambitella unispinifera, Jonesella interrupta, Jonesella tumida, Milleratia kopensis, Parenthatia rabbithashensis, Pseudoprimitiella reticulata, are included in the descriptions. The family Richinidae Scott (1961) has been emended to include Jonesella, Vogdesella and any other Paleocene with a "U"-shaped lobe and no marginal or adventral structures. Jonesella Ulrich (1890) has also been emended and several previously described species have been removed from the genus. Leperditia bivertex Ulrich (1879) the type species of Pseudulrichia Schmidt (1941) has been found to be a junior subjective synonym of Leperditia bynesi Miller (1874) thereby changing the concept of the genus Pseudulrichia, a member of the Richinidae. Ceratopsis chambersi (Miller), 1874) was discovered to exhibit infravelar antral dimorphism and has therefore been removed from the nondimorphic Quadrijugatoridae Kesling and Hussey

(1953) to the Ctenonotellidae Schmidt (1941). Likewise, Beyrichia ciliata Emmons, (1855), the type species of Ctenobolbina Ulrich (1890) is now proven to be sexually dimorphic.

Analysis of the temporal and spatial distribution of the ostracods was accomplished through the use of binary Q-mode cluster analysis. The Jaccard, Dice and Otsuka coefficients of association were used throughout. Clustering was executed by use of the unweighted pair-group method.

A tripartite zonation for the Edenian Stage, based on the clustered ranges of 35 widely occurring species of ostracods, has been developed. A new term, Polythetic Range Zone, has been coined to describe the type of zone obtained by this method. The Polythetic Range Zones of the Edenian are coincident with the Kope Formation at Cincinnati but transgress into the underlying and overlying formations as one goes east and west of the City. Therefore, while the Point Pleasant-Kope and the Kope-Fairview boundaries are used to define the Edenian Stage at Cincinnati, they cannot be used at localities outside of the type area.

Mega-environmental pressures on the ostracod fauna of the Kope Formation, as reflected by diversity levels, have been deemed steady for the entire depositional period. This conclusion was reached by testing (Chi-square) the significance of change in the diversity levels against a rectangular distribution. Minor changes in the ostracod communities are felt to reflect micro-environmental changes that cannot be delineated by presence-absence analysis.

INTRODUCTION

With the notable exception of the four ostracod species described in papers by Ulrich and Bassler (1923), Keenan (1951), Levinson (1951) and Copeland (1965), the previously described faunal elements of the type Edenian were recognized between 1855 and 1894 by Emmons (1855), Hall (1871), Miller (1874), Jones (1890) and Ulrich (1879, 1890, 1894). Since that time many new concepts pertaining to the paleobiology of fossil ostracods have been developed. Most important is the recognition of polymorphism in ostracod species due to a stepwise ontogeny (Ecdysis) and the development of sexual dimorphism. Both of these factors have increased the array of specific variability to the point where investigators have, on various occasions, assigned conspecific juveniles and adults or males and females to different species. It is with these problems in mind that the ostracods of the type Edenian have been either redescribed or described for the first time.

In addition, the Edenian Stage has never been successfully subdivided into regionally effective biostratigraphic zones. A preliminary investigation of the Edenian (Warshauer, 1969) indicated that, due to their great abundance and ease of recovery, the ostracods offered an excellent basis for zonation.

This is then a first attempt at understanding the taxonomy, ontogeny, biostratigraphy and paleoecology of the ostracods from the North American Upper Ordovician type standard.

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I am also grateful to Mr. Frederick J. Collier of the United States National Museum and Dr. Eugene S. Richardson of the Field Museum of Natural History for the loan of type material; Dr. Joseph E. Hazel of the United States Geological Survey for the cluster analysis program (U.S.G.S. A243); Dr. Douglas M. Lorenz of the United States National Museum for the sample residues from Moffett Road.

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STRATIGRAPHY

Historical survey.--The Edenian rocks of Cincinnati, Ohio, were first delineated as a separate lithologic entity by Orton in 1873. He divided the strata at Cincinnati into three divisions, which, in ascending order, are the River Quarry Beds, the Middle or Eden Shales and the Hill Quarry Beds. The Eden Shales were defined as the 250 feet of shaley rock (only 10% limestone) intercalated between the limey (20%-40% limestone) River Quarry and Hill Quarry Beds. Eden Park, in the eastern portion of Cincinnati, was designated as the type section. Miller (1881) felt that the Eden Shales were a correlative of the Utica Slates of New York. Therefore, he replaced the term Eden with Utica Group.

Nickles (1902) divided the Utica of Cincinnati into three bryozoan zones, the Lower Utica or Asidopora newberryi beds, the Middle Utica or Batostoma jamesi beds and the Upper Utica or Dekayella ulrichi beds. It is important to note that these zones were not based on the restricted occurrences of these bryozoans but rather on zones of maximum abundance. For example, Nickles states that Dekayella ulrichi, the Upper Utica zone fossil, is very abundant in the Upper Utica but "occurs plentifully in the Middle Utica" (p. 73). Therefore, the mere presence or absence of a particular bryozoan is not indicative of a particular zone.

Foerste (1905) resurrected Orton's term, Eden, and described the Fulton Beds as the thin (4-5 feet) dark shales bearing Triarthrus becki, at the base of the Eden. In addition, Foerste extended the use of the name Garrard, originally used to describe the unfossiliferous Upper

Eden Beds of Central Kentucky, to include the extremely fossiliferous Upper Eden of Ohio. Bassler (1906) correlated Foerste's Fulton Beds with the Utica of New York and gave geographical names to Nickles' bryozoan zones, namely, in ascending order, Economy, Southgate and McMicken and considered them to be members of the Eden Formation.

In 1916, Fenneman divided the Eden Group into two unequal shale units, the thin Utica below and the thick Latonia above. Fenneman used the term Latonia in order to be in agreement with the terminology used in the manuscript copy of Ulrich and Bassler's United States Geological Survey Cincinnati Folio. Unfortunately, this ill-fated folio was never published. Caster, Dalve and Pope (1955) used the term Latonia as a formational name and divided the unit into three members, the Economy, Southgate and McMicken, and included the Fulton Beds in the basal Economy. Sweet et al (1959) revived the term Eden as a formational name and lumped the Fulton-Economy into one member. This consolidation of names was felt to be imperative because the Fulton and the Economy are lithologically indistinguishable.

In 1964, Weiss and Sweet defined the Kope Formation as the basal Cincinnati unit lying conformably between the Point Pleasant Formation (Middle Ordovician) and the overlying, unnamed, shaley limestone. Lithologically, the Kope Formation consists of shales and mudstones interspersed with sparse beds and lenses of limestone. The shales and mudstones comprise more than 85% of the unit. Moving logs of the clastic ratio (mudstone and shale/limestone) computed for each succeeding three foot interval shows the Kope to have a mean clastic ratio between 2.5 and 3.8. This high clastic content helps to distinguish the Kope

from the underlying unit which has a mean clastic ratio of 1.0 and the overlying unit which has a mean clastic ratio of 0.5. In the vicinity of Cincinnati, the Kope Formation is coincident with the Edenian Stage but transgresses into the Maysvillian Stage to the north and east of the Cincinnati area (Weiss and Sweet, 1964). The Kope is, therefore, purely a lithostratigraphic term and except for the area of Cincinnati, Ohio, has no time connotation.

The previous dual use of the term Eden for both a formational and stadial name was the main impetus behind the erection of the Kope Formation. The members of the Edenian shales-Fulton, Economy, Southgate and McMicken, proposed as bryozoan zones by Nickles (1902) and given geographic names by Bassler (1906), have been rejected as members of the Kope Formation because of their biostratigraphic rather than lithostratigraphic basis.

The only lithostratigraphic member recognized for the Kope Formation is the Grand Avenue Member, proposed by J.P. Ford (1967). This member is located in the upper portion of the Kope Formation and consists of approximately eleven feet of closely spaced limestone and shale beds (each terrigenous unit is no more than two feet thick) with a clastic ratio generally lower than that typical of the Kope. In fact, the Grand Avenue Member is lithologically similar to the overlying Fairview Formation and may represent an early incursion of the environment represented by the Fairview.

In 1969 Anstey and Fowler suggested that the Eden Shale should be retained as a lithostratigraphic term and the name Kope Formation should be dropped. This suggestion was based on an erroneous conception that,

due to newly discovered correlations with the New York Trentonian, the Eden was no longer a valid stadial name and could be used lithostratigraphically without undue confusion. However, as presently proposed by Sweet and Bergstrom (1971), the Edenian should be retained as a stadial name and the Upper Trenton Cobourgian Stage should be suppressed.

Therefore, I am using the term Kope Formation, as defined by Weiss and Sweet (1964), to refer to the shaley rocks of mostly Edenian age in the Ohio Valley. In addition, the Grand Avenue Member (Ford, 1967) is not employed as similar intervals of increased limestone occurrence have been observed at various stratigraphic levels within the Kope. Anstey and Fowler (1969) have reported three such intervals in the Kope Formation on the western limb of the Cincinnati Arch. I have observed the same phenomenon on the eastern portion of the Arch (i.e. Kope Hollow). However, due to slumping, the exact number of limey intervals occurring on the eastern side of the Arch are not known.

Text figure 1 is a summary of the stratigraphic terms discussed in this survey. The relationship of the Kope Formation and the Edenian Stage to the surrounding rocks is shown in Text figure 2. For a more complete discussion of Cincinnati nomenclature, see Weiss and Norman (1960), Weiss, Norman, Edwards and Sharp (1965), Peck (1966) and Sweet and Bergstrom (1971).

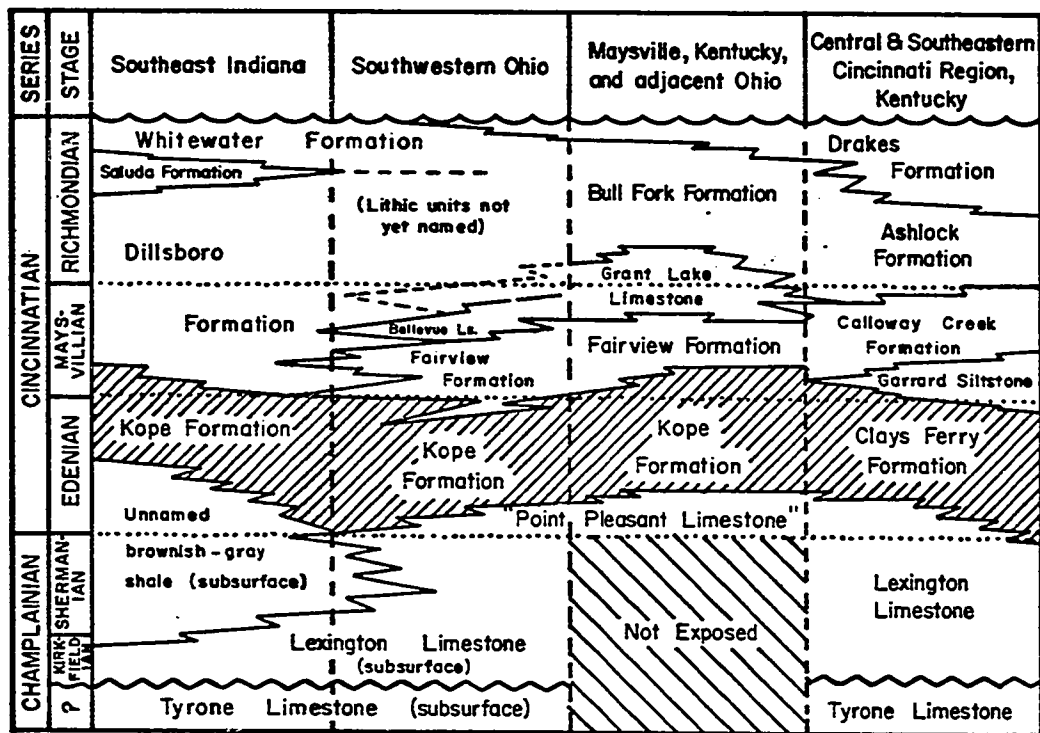
Petrology of the Kope Formation.--Petrologic investigations of the Kope mudstones and shales (Scotford, 1965; Bassarab, 1965; Bassarab and Huff, 1969) indicate that they consist mainly of illite, chlorite, vermiculite, quartz, calcite, and dolomite with trace amounts of pyrite, feldspar, kaolinite and mixed illite/montmorillonite. An upward decrease in the

SYSTEM	ORDOVICIAN			Champion?	SERIES	EDENIAN			Maysvillian	STAGE
	Cincinnati Beds					Eden Division				
Orton 1873	Hill Quarry Beds	Middle (Eden) Shales			River Quarry Beds					
		Utica Group				Trenton Group				
Miller 1881	Hudson River Group	Utica Group			Point Pleasant Beds					
Nickles 19C?	Mt Hope Beds	Lower Utica	Middle Utica	Upper Utica		Point Pleasant Beds				
Foerste 1905	Mt Hope Beds	Lower Eden	Middle Eden	Garrard	Point Pleasant Beds					
Bassler 1906	Mt Hope Member	Economy Member	Southgate Member	McMicken Member		Point Pleasant Formation				
Fenneman 1916	Mt Hope Member	Eden Group			Cynthiana Formation					
Caster Dalve & Pope 1955	Mt Hope Member	Economy Member	Southgate Member	McMicken Member		Pt. Pleasant or River Quarry Beds				
Sweet Turco & Warner & Wilkie 1959	Fairview Formation	Economy Member	Southgate Member	McMicken Member	Point Pleasant Formation					
Weiss & Sweet 1964	Unnamed Unit	Kope Formation				Point Pleasant				
Ford 1967	Fairview Formation	Kope Formation			River Quarry Beds					
Anstey & Fowler 1969	Dillsboro Formation	Eden Shale				Lexington Limestone				
This Report	Fairview Formation	Kope Formation			Point Pleasant Formation					
		Polythetic Range Zones								
								A		
								B		
								C		

Text Fig. 1.--Correlation of Edenian nomenclature.

chlorite/vermiculite ratio reported by Bassarab and Huff (1969) has since been found to be non significant (Booth and Osborne, 1971). Therefore, the compositional parameters of the clastics are remarkably uniform for the entire formation. Scotford (1965) suggests that this is due to the uniform, low energy nature of the depositional environment during Kope time.

The limestones of the Kope Formation and associated units have been studied on many different occasions (Weiss and Norman, 1960; Weiss et al., 1956; Ford, 1967; Osborne, 1967, 1969, 1970, 1971; Anstey and Fowler, 1969). Approximately 10 different types of limestone have been reported. All of them are biogenetic, consisting of broken fossils, and form discontinuous beds and lenses. The discontinuous nature of the carbonates is easily observed in the field and indicates syndeposition of the clastics and nonclastics. Energy required for fragmentation of the fossils most probably originated from recurrent storms.



Text Fig. 2--Nomenclature and approximate lateral relations between Champlainian and Cincinnati lithostratigraphic units of the Cincinnati Region. (from Sweet and Bergstrom, 1971)

COLLECTING LOCALITIES

General Statement.--The following locality descriptions are based upon United States Geological Survey topographic maps of the 7.5 minute series. Longitude and latitude are indicative of the base of each section and are given to the nearest second. The number in parentheses that follows each sample number is the elevation above the base of the section at which the particular sample was collected. Text-figure 3 is a generalized index map of the localities.

Although Moffett Road is the only complete section of the Kope Formation presently studied, several shorter sections have been employed in constructing composite sections. In particular, localities 3, 8 and 9 describe a complete Kope section with 9 being the basal beds, 3 the middle and 8 the upper. Similarly, sections 10 and 11 are representative of a complete Kope section, with 10 being the basal and middle beds and 11 the upper.

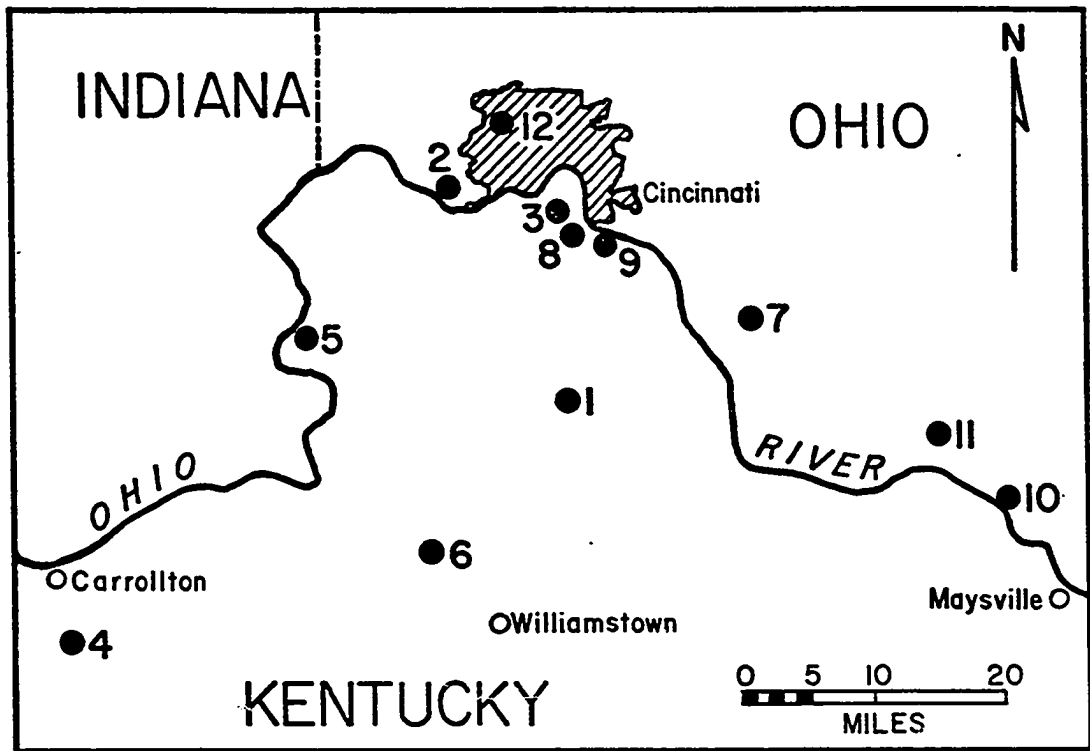
1) Moffett Road

Location--DeMossville Quadrangle, Kenton County, Kentucky.

Longitude 84° 28'

Latitude 38° 52' 05"

The section begins in a creek north of a bridge over Moffett Road, 1/2 mile west of Kenton Kentucky and crops out along Moffett Road for 3/5 of a mile. Included in the section are the upper 50 feet of the Point Pleasant Formation, the entire Kope formation (250 feet) and 33 feet of the Fairview Formation. However, weathering and slumping have severely limited the number of usable samples collected from this locality.



Text Fig. 3--Map of collecting localities.

1. Moffett Road
2. Rapid Run
3. Newport
4. I-71
5. Rabbit Hash
6. Boltz Lake
7. 12 Mile Creek
8. U.S. 27
9. Duck Creek
10. Kope Hollow
11. White Swan Run
12. West Fork Creek

Samples.--1-1(0), 1-12(5'4"), 1-31(15'11"), 1-32(16'2"), 1-34(17'3"), 1-40(23'9"), 1-42(26'8"), 1-47(33'11"), 1-54(37'), 1-57(39'4"), 1-78(49'2"), 1-95(59'2"), 1-129(70'5"), 1-149(79'9"), 1-171(91'), 1-176(151'9"), 1-192(191'3"), 1-211(199'6"), 1-243(210'), 1-249(211'9"), 1-294(224'1"), 1-328(241').

2) Rapid Run

Location.--Burlington Quadrangle, Hamilton County, Ohio.

Longitude 84° 40' 01"

Latitude 39° 06' 10"

Outcroppings of bedrock initiate at a ford across Rapid Run 1/5 of a mile north of U.S. 50. The section consists of approximately 200 feet of the Kope Formation exposed along 1.5 miles of creek bed. It is estimated that only the bottom 30 feet of the unit is missing. The rest of the Formation is well exposed, up to and including the Kope-Fairview contact.

Samples.--2-1(0'), 2-2(15'), 2-3(20'), 2-4(25'), 2-5(30'), 2-6(35'), 2-7(40'), 2-8(45'), 2-9(50'), 2-10(55'), 2-11(60'), 2-13(65'), 2-15(75'), 2-17(85'), 2-19(95'), 2-21(105'), 2-24(115'), 2-26(125'), 2-29(145'), 2-31(155'), 2-33(165'), 2-35(175'), 2-37(185'), 2-38(190'), 2-39(195').

3) Newport

Location.--Newport Quadrangle, Campbell County, Kentucky.

Longitude 84° 28' 10"

Latitude 39° 05' 04"

The section begins at the base of the northern most outcrop behind the newest portion of the shopping center (located on Carothers

Road; the older portion of the shopping center faces U.S. 27). Approximately 185 feet of section has been reported to occur here (Weiss, Norman, Edwards and Sharp, 1965), including the Kope-Fairview contact. Weathering has masked the contact and made collecting the uppermost interval impossible.

Samples.--3-1(0'), 3-1A(30'3"), 3-2(34'3"), 3-3(66'1").

4) I-71

Location.--Campbellsburg Quadrangle, Carroll County, Kentucky.

Longitude 85° 09' 40"

Latitude 38° 37' 05"

The measured strata can be found in the second high road cut 3/10 miles southwest of the English interchange on the west bound lane of Interstate 71. Included in the section are the upper 40 feet of the Kope Formation and the Kope-Fairview contact.

Samples.--4-1(40'), 4-3(30'), 4-5(20'), 4-7(10'), 4-9(0').

5) Rabbit Hash

Location.--Rising Sun Quadrangle, Boone County, Kentucky.

Longitude 84° 50' 45"

Latitude 38° 56' 25"

The section is located in an unnamed creek that flows parallel to Kentucky Route 536. Bedrock outcroppings begin 1/10 of a mile east of the Rabbit Hash general store and continue up the creek to the Kope-Fairview contact. The contact is best exposed in the southernmost branch of the creek and occurs 128'6" above the base of the section.

Samples.--5-1(0'), 5-2(5'), 5-3(10'), 5-4(15'), 5-5(20'), 5-7(30'),

5-8(35'), 5-9(40'), 5-11(50'), 5-13A(58'), 5-15(68'6"), 5-17(80'), 5-19(85'0"), 5-21(98'3"), 5-23(110'), 5-24(120'), 5-27(126'6"), 5-29(128'6").

6) Boltz Lake Spillway

Location.--Williamstown Quadrangle, Grant County, Kentucky.

Longitude 84° 37' 05"

Latitude 38° 42' 25"

The upper part of the Kope Formation, including the contact with the Fairview Formation, is exposed in the spillway (Arnolds Creek) to Boltz Lake. However, only 50'5" of the Kope is present.

Samples.--6-1(0'), 6-2(5'), 6-3(10'), 6-4(15'), 6-5(19'5"), 6-5A(19'9"), 6-6(25'), 6-7(29'8"), 6-8(34'6"), 6-9A(36'5"), 6-9(39'4"), 6-10(44'9"), 6-11(50'), 6-12(50'5"), 6-14(50'9"), 6-13(54'6").

7) Twelvemile Creek

Location.--New Richmond and Laurel Quadrangles, Clermont County, Ohio.

Longitude 84° 15' 25"

Latitude 38° 58'

Basal Kope beds can be found in Twelvemile Creek 1/2 mile east of Ohio Route 132. At this locality, 93'1" of the Kope Formation overlies approximately 30' of the Point Pleasant Formation. The Kope exposure consists of several outcrops along one mile of creek bed.

Samples.--7-1(3"), 7-3(10'), 7-5(20'), 7-5A(23'), 7-7(30'), 7-9(40'), 7-11(50'), 7-13(60'), 7-15(70'), 7-17(80'), 7-19(90'), 7-20(93').

8) U.S. 27

Location.--Newport Quadrangle, Campbell County, Kentucky.

Longitude 84° 27' 50"

Latitude 39° 04'

The section consists of a steep cliff located at the intersection of U.S. 27 and Kentucky State Route 1632. Only the upper 13' of the Kope Formation, up to the Fairview contact, is exposed.

Samples.--8-1(0)', 8-2(5'), 8-3(10'), 8-4(13").

9) Duck Creek

Locality.--Newport Quadrangle, Campbell County, Kentucky.

Longitude 84° 25' 17"

Latitude 39° 02' 29"

The Point Pleasant-Kope contact is located in Duck Creek 2/10 of a mile south of Kentucky Route 8. Although most of the Kope Formation seems to be present, weathering has limited collecting to the bottom 26' of the Kope.

Samples.--9-4(1'6"), 9-6(11'6"), 9-8(21'6"), 9-9(26'6").

10) Kope Hollow

Location.--Higginsport and Russellville Quadrangles, Brown County, Ohio.

Longitude 83° 52' 43"

Latitude 38° 45' 50"

Kope Hollow is located in the eastern portion of Levanna, Ohio, adjacent to U.S. 52. The Point Pleasant-Kope contact can be found 300' north of the highway and outcroppings continue up the hollow for approximately 9/10 of a mile. In total, 200 feet of the Kope Formation is

exposed. However, the Kope-Fairview contact is not included in the section.

Samples.--10-4(3'3"), 10-6(13'3"), 10-6A(17'), 10-8(23'3"), 10-10(33'3"), 10-12(43'3"), 10-14(53'3"), 10-16(63'3"), 10-18(73'3"), 10-20(85'3"), 10-22(93'3"), 10-25(113'3"), 10-26(123'3"), 10-28(133'3"), 10-30(143'3"), 10-32(153'3"), 10-34(163'3"), 10-36(175'3"), 10-38(188'3"), 10-40(203'3").

11) White Swan Run

Location.--Higginsport Quadrangle, Brown County, Ohio.

Longitude 83° 56' 45"

Latitude 38° 50' 35"

White Swan Run is the name given to a previously unnamed tributary of White Oak Creek by Weiss, Norman, Edwards and Sharp(1965). The creek enters into White Oak Creek just north of the mouth of Cochran Run. Approximately 165' of the Kope Formation is exposed in White Swan Run. Included in the section is the Kope-Fairview contact. However, for the purposes of this study only the upper 45' of the Kope Formation was sampled.

Samples.--11-1(45'), 11-4(35'), 11-8(25'), 11-10(10'), 11-12(0').

12) West Fork Creek, Mt. Airy Forest

Location.--Cincinnati West Quadrangle, Hamilton County, Ohio.

Longitude 84° 34' 20"

Latitude 39° 09' 45"

Only one sample was obtained from this locality on the west bank of West Fork Creek, 50 yards northwest of the intersection of Diehl Road

and West Fork Roads. The sample was taken 198' below the contact with the overlying Fairview Formation.

Sample.--12-1.

TECHNIQUES

Sample Processing.--Recovery of the ostracod specimens from the Kope mudstones was accomplished by a 10 step process in which each sample was:

1. weighted (approximately 500 g.).
2. oven dried for approximately 12 hours (at 95° C).
3. covered with Stoddards Solvent, a commercial dry cleaning agent.
(Note: Stoddards Solvent will eventually crack plastic vessels)
4. let stand for approximately 8 hours.
5. Stoddards Solvent decanted and water added (4 parts water to 1 part sediment).
6. let stand for approximately 8 hours.
7. boiled in water for 1.25 hours.
8. air cooled for 1 hour.
9. wet sieved in number 10 (2,000 microns) and number 140 (105 microns) standard sieves.
10. residues oven dried at 95° C.

All of the samples were treated in this manner with the exception of the ones from Moffett Road. Those samples were obtained as processed residues from Dr. D. M. Lorenz of the United States National Museum. He processed them in Oleum and then wet sieved them in number 20 (841 microns) and number 170 (88 microns) mesh screens.

Residues were quickly scanned under a binocular microscope to ascertain the abundance of ostracod material. Empirical studies indicated that, due to an overall low diversity and dominance, only 75 specimens were needed from each sample to insure a representative suite.

The samples were then split (using a micro-splitter) to a workable size and the entire fraction was picked. This step was to insure the recovery of both the large and small species. Of the 132 samples processed in this manner, only 86 were rich enough to supply the needed 75 specimens. However, many of the 86 samples contained hundreds of specimens. Approximately 12,000 specimens were recovered in this way.

Several limestone samples (only 10% of the unit) were crushed and the fragments scanned for ostracods. This method was extremely slow, tedious and supplied very few specimens. In addition, the specimens that were recovered failed to differ from those in the surrounding mudstones. Therefore, this report deals directly with only the ostracods of the Kope mudstones but by inference the limestones as well.

Photography.--Due to the large range in specimen size (length, 0.17-2.10 mm), several different photographic systems were employed. Larger specimens were photographed with a Leitz Aristophot II with either a 50 or 24 mm lens. Small and intermediate specimens were photographed with a Zeiss Photo-microscope II equipped with a pinhole diaphragm in the manner of Fournier (1954, 1956).

Specimens were prepared for photography by first staining them with a water soluble green ink, to impart an even base, and then whitened with sublimated ammonium chloride. Several fine grained films, Adox KB-14 and Kodak Panatomic-X, were used throughout.

Data processing.--The cluster analysis program used in this work was a version of U.S.G.S. Program A243 modified by the present author to run on the University of Cincinnati IBM system 360/65. Statistical parameters were calculated with either a Wang 500 programmable calculator

or a University Computing Corporation remote conversational terminal.

FAUNAL ANALYSIS

The ostracod fauna.--Thirty seven species of ostracods were recovered from the 132 processed samples. The species present are as follows:

Aechmina sp. A

Aechmina sp. B

Aechmina sp. C

Ambitella unispinifera n. sp.

Americoncha aff. A. bifurcata (Copeland, 1965)

Americoncha marginata (Ulrich, 1890)

Aparchites minutissimus (Hall, 1871)

Bollia persulcata (Ulrich, 1879)

Ceratopsis chambersi (Miller, 1874)

Ceratopsis cf. intermedia Ulrich, 1890

Cincinnatiiconcha pedigera (Ulrich, 1890)

Ctenobolbina cf. alata (Ulrich, 1890)

Ctenobolbina ciliata (Emmons, 1855)

Cytherellina cylindrica (Hall, 1871)

Cytherellina granti (Ulrich, 1894)

Euprimitia minuta Keenan, 1951

Euprimitia sp.

Jonesella crepidiformis (Ulrich, 1879)

Jonesella interrupta n. sp.

Jonesella tumida n. sp.

Krausella sp.

Milleratia kopensis n. sp.

Milleratia rudis (Ulrich, 1890)

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ods of analysis were available but, for the most part, relied upon relative abundance data for the comparison of samples. The use of some form of presence-absence analysis was felt to be imperative as preservational peculiarities made the acquisition of relative percentage data impossible. Foremost among the problems associated with counting numbers of specimens was the severe fragmentation found in almost all of the samples. In addition, selective preservation (some species are pyritized, others are recrystallized and some the combination of the two) was suspected of causing numerical inequalities.

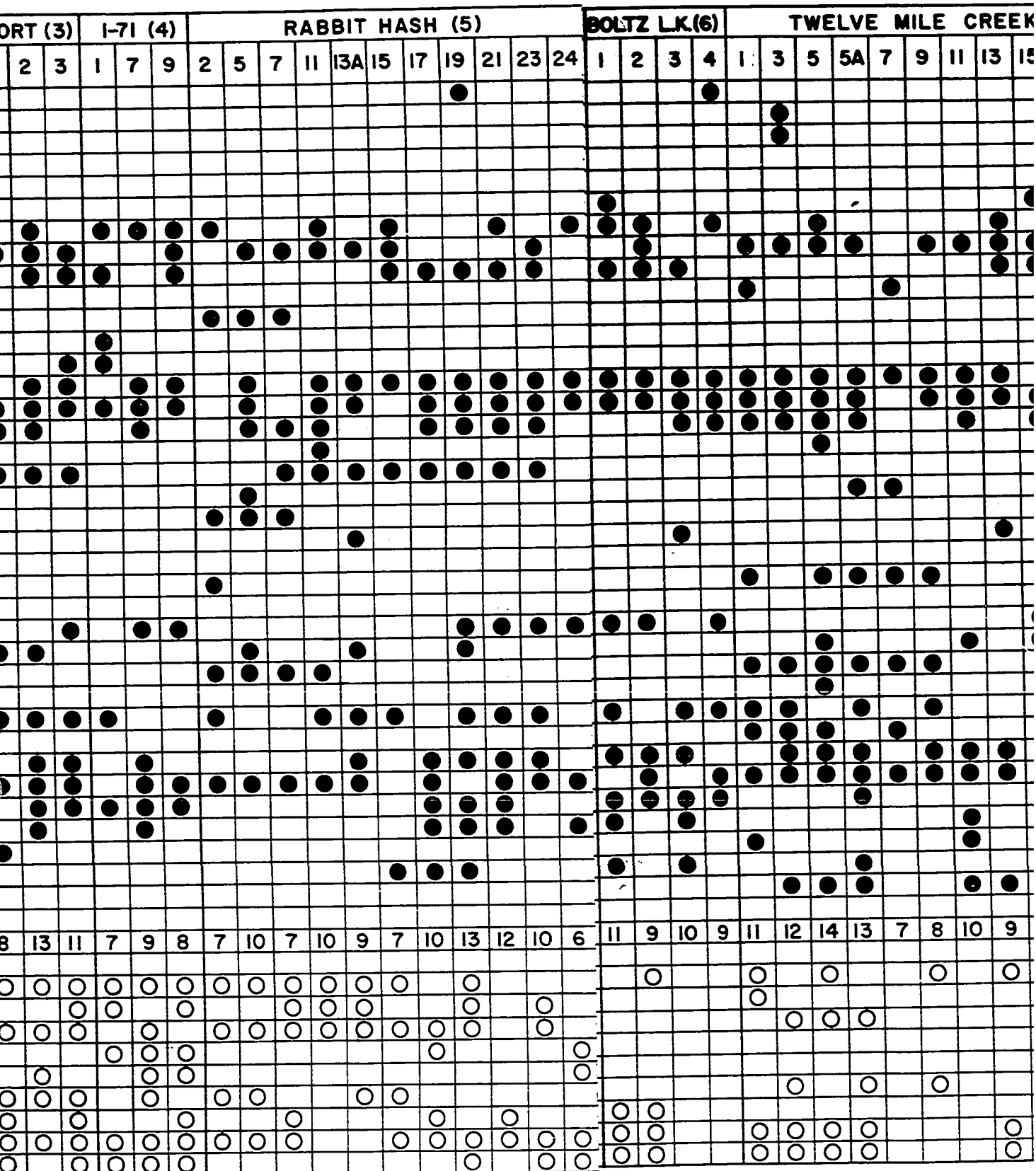
Several different methods of handling the species occurrence data were attempted. They are as follows:

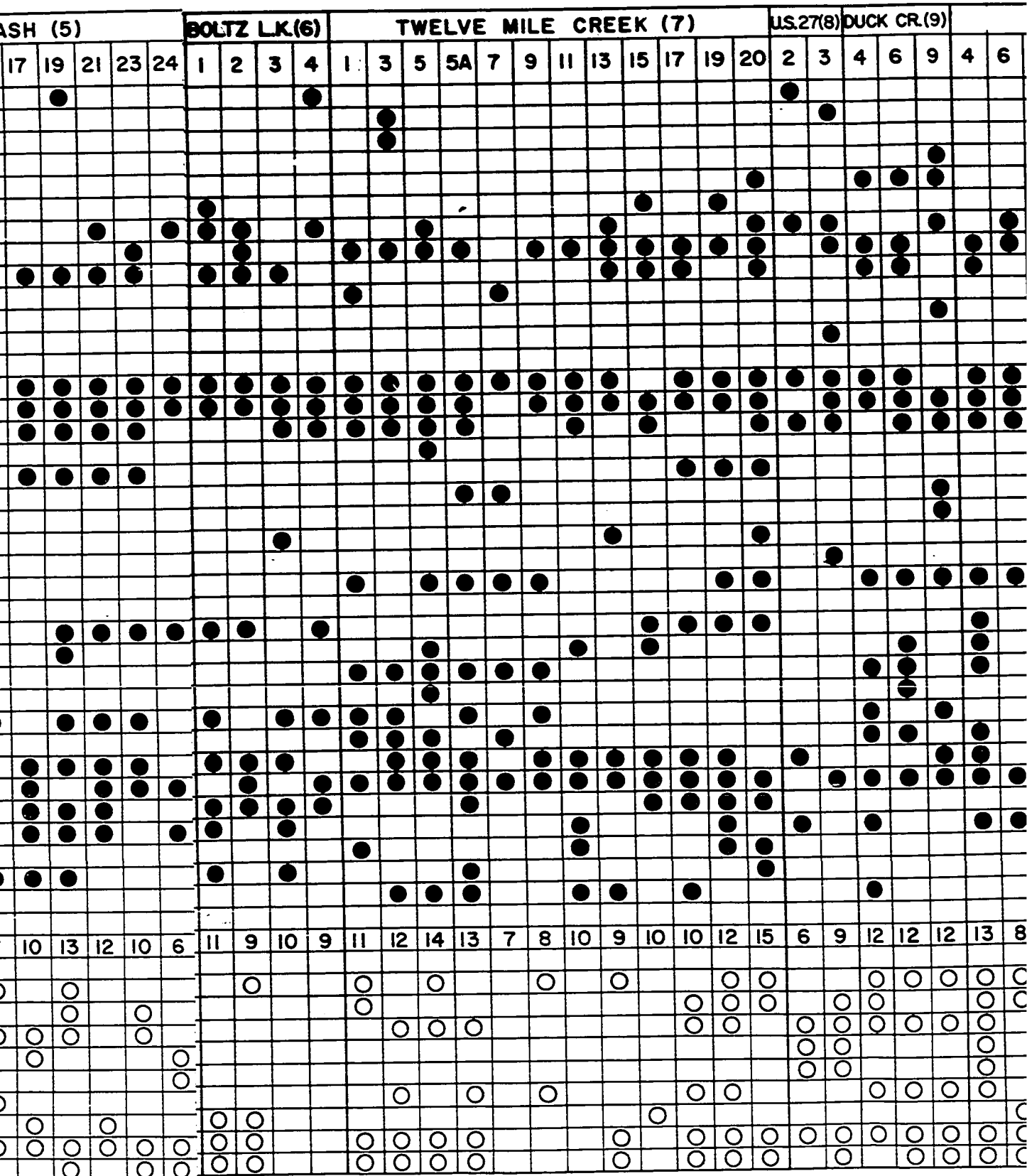
1. Straight occurrence method. In this method one simply codes the occurrence of each species for the samples that it actually occurs in (text fig. 4 is a summary of ostracod occurrences). There is no averaging of the ostracod occurrences. This type of data array has successfully been used to analyze paleoecologic associations in recent and subrecent faunas (Kaesler, 1966; Maddocks, 1966; Valentine and Peddicord, 1967; Mello and Buzas, 1968).
2. Moving average method. This is an attempt at averaging the occurrence of species in adjacent samples. The averaging is accomplished by simply adding to any given sample the species that occur directly above or below it, but otherwise not in the sample. Use of this technique would negate sampling errors caused by small sample sizes. Therefore, the probability of missing a species occurrence would be greatly reduced.
3. Range method. This biostratigraphic technique was developed by

Text Fig. 4--Matrix of Edenian ostracod occurrences. Dots simply represent the presence of each species. Diversity (S) is the total number of species occurring in each sample.

Locality		MOFFETT ROAD (I)																		
Species	Sample no.	31	32	34	40	42	47	54	57	78	95	129	149	171	249	294	1	2	4	
1. Aechmina sp. A																				
2. Aechmina sp. B																				
3. Aechmina sp. C																				
4. Ambitella unispinifera			●											●						
5. Americoncha aff. bifurcata			●		●	●	●			●									●	
6. Americoncha marginata														●						
7. Aparchites minutissimus		●	●			●								●			●	●		
8. Bollia persulcata		●	●		●		●	●		●	●	●	●	●	●	●				
9. Ceratopsis chambersi											●	●	●	●	●	●				
10. Ceratopsis cf. intermedia																				
11. Cincinnaticoncha pedigera				●	●		●	●									●	●	●	
12. Ctenobolbina cf. alata															●	●				
13. Ctenobolbina ciliata		●										●		●		●				
14. Cytherellina cylindrica			●				●	●			●	●	●	●	●	●	●	●	●	●
15. Cytherellina granti		●					●	●	●	●	●	●	●	●	●	●	●	●	●	●
16. Euprimitia minuta			●	●	●		●		●				●				●	●	●	●
17. Euprimitia sp.																				
18. Jonesella crepidiformis														●				●	●	●
19. Jonesella interrupta					●	●	●	●	●	●	●							●	●	●
20. Jonesella tumida		●		●	●													●	●	●
21. Krausella sp.																				●
22. Milleratia kopensis															●	●				
23. Milleratia rudis		●	●	●	●	●	●			●										
24. Milleratia shideleri																				
25. Parenthatia rabbithashensis										●				●						●
26. Platamonaria bicava											●	●		●						
27. Primitiella whitfieldi		●	●	●	●	●	●	●			●	●						●	●	●
28. Pseudoprimitiella unicornis		●							●											
29. Pseudoprimitiella reticulata			●	●		●	●	●		●	●	●			●	●	●	●	●	●
30. Pseudulrichia byrnesi			●																	
31. Schmidtella claypolei							●	●		●							●	●	●	●
32. Warthinia nodosa		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
33. Ostracod indet. A						●														
34. Ostracod indet. B			●																●	
35. Ostracod indet. C																				
36. Ostracod indet. D																				
37. Ostracod indet. E																				
Diversity (S)		9	12	7	9	8	12	9	5	9	9	9	8	9	7	10	11	10	10	10
Associated Fauna																				
39. Brachiopods				○	○		○		○	○	○	○	○		○	○	○	○	○	○
40. Bryozoans					○						○	○	○	○	○	○	○	○	○	○
41. Trilobites					○					○	○							○	○	○
42. Pelecypods													○		○	○				
43. Gastropods													○		○	○				
44. Pelmatozoans											○								○	○
45. Graptolites																			○	○
46. Conodonts		○	○				○		○	○		○	○		○	○	○	○	○	○
47. Scolecodonts									○	○		○	○							

D RUN (2)								NEWPORT (3)				I-71 (4)			RABBIT HASH (5)								BOLT						
15	17	21	24	26	33	35	37	38	1A	1	2	3	1	7	9	2	5	7	11	13A	15	17	19	21	23	24	1		
					●																								
●			●	●			●	●	●		●	●	●	●	●	●		●	●	●		●			●	●	●	●	●
●	●	●			●	●	●	●	●		●	●	●		●		●	●	●	●	●	●		●	●	●	●	●	●
					●			●					●			●	●	●											
●	●	●		●	●	●		●			●	●		●	●		●		●	●	●	●	●	●	●	●	●	●	●
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						●	●	●								●					●								
●	●	●	●							●	●	●	●	●				●		●	●	●		●	●	●	●	●	●
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●		●	●	●	●			●	●		●	●		●	●				●		●	●	●	●	●	●	●	●	●
●	●	●		●	●						●	●		●	●					●	●	●	●	●	●	●	●	●	●
●	●	●	●	●	●																●	●	●						●
																						●	●	●					●
13	10	12	8	10	12	8	8	10	11	8	13	11	7	9	8	7	10	7	10	9	7	10	13	12	10	6	11		
○	○	○	○	○	○	○	○	○		○	○	○	○	○	○	○	○	○	○	○	○		○						
	○	○		○	○	○	○	○				○	○		○	○		○	○	○	○		○		○				
		○	○	○	○			○	○	○	○	○		○	○		○	○	○	○	○	○	○		○				
				○				○			○			○	○														
○		○								○	○	○		○		○	○			○	○								○
○				○						○		○		○		○				○		○							○
○			○			○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
				○		○	○	○	○	○		○		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○





Cheetham and Deboo (1963) and later adopted for use in cluster analysis by Hazel (1970, 1971). In the range method samples are normalized by adding a given species to every sample occurring between the end points of that species range, whether or not the species actually occurs in each of the samples. Normalization of the samples is separately arrived at for each of the stratigraphic sections. We are therefore not comparing just the isolated occurrences of each species, but are simultaneously examining the ranges of all the included species.

Theoretically, any zonation based on this method would be the result of more information than would one based solely on the occurrence of a single "Index Species." As a zonation based on the method would be polythetic in nature, no single species name can be applied. Therefore, a new term, Polythetic Range Zone, is herein suggested to describe this type of biostratigraphic unit.

Q-mode (sample by sample) cluster analysis was then applied to each of the three data arrays. Comparison of the samples was then initiated by the use of three separate similarity coefficients, the Jaccard, Dice and Otsuka. Clustering was executed by the unweighted pair-group method (U.P.G.M.). For an explanation of cluster analysis and similarity coefficients see the excellent accounts given by Bonham-Carter (1967), Valentine and Peddicord (1967), Mello and Buzas (1968), Cheetham and Hazel (1969) and Hazel (1970, 1971).

Results.--Critical study of the nine dendrograms (3 data arrays X 3 similarity coefficients) generated by the foregoing analysis revealed the following:

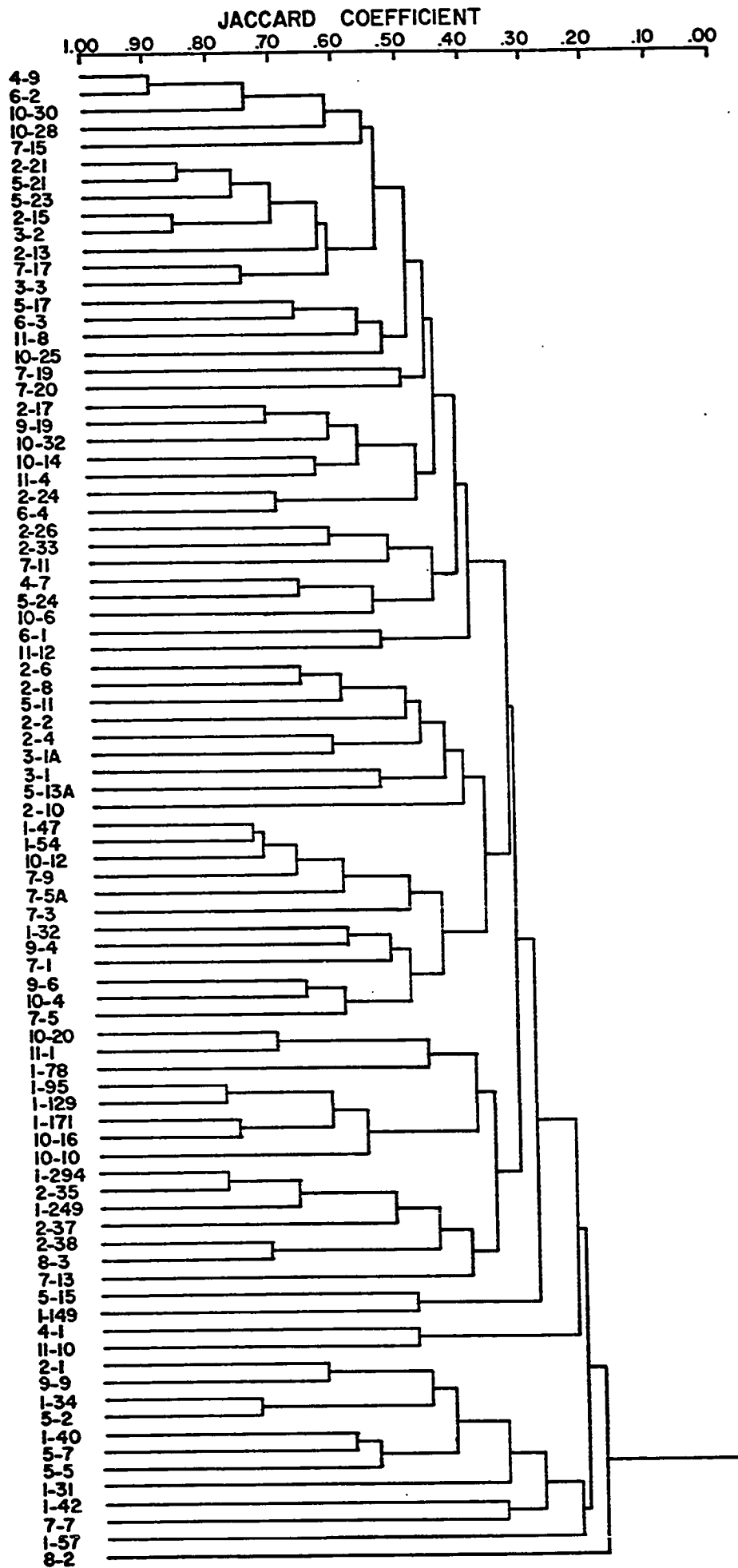
1. Examination of the data arrays and matrices for the straight occur-

rence method failed to delineate any meaningful relationship between the clusters (text-fig. 5 and 6). As previously stated, this type of analyses has successfully been applied to ecological studies of recent and subrecent faunas. However, in each of these cases the investigators were dealing with a two dimensional system and did not have the time factor to deal with. In the present investigation, a three dimensional system, it is felt that faunal changes due to niche and species evolution have masked the type of ecologic relationship normally definable by presence-absence studies.

Another indication of the failure of the occurrence method to define ecozones is the non-replicability of the results. That is, each of the 3 similarity coefficients generated a different dendrogram. (Dendrograms calculated with the Dice Coefficient were always intermediate in clustering level to those calculated with the Jaccard and Otsuka Coefficients. Therefore, the Dice based dendrograms have not been illustrated).

2. Dendrograms (text figs. 7 and 8) based on the moving average data array have consistently defined 2 major clusters. Perusal of the raw data reveals the relationship of these clusters to be biostratigraphic in nature. The lower cluster is indicative of a lower Eden zone and the upper cluster of an upper zone. Use of the different similarity coefficients slightly changed the ordering of samples within clusters but did not alter the relationships between clusters. In fact, all three dendrograms are remarkably similar, differing mostly in the level of clustering (Otsuka coefficient clustered at the highest level, Jaccard lowest and the Dice intermediate).

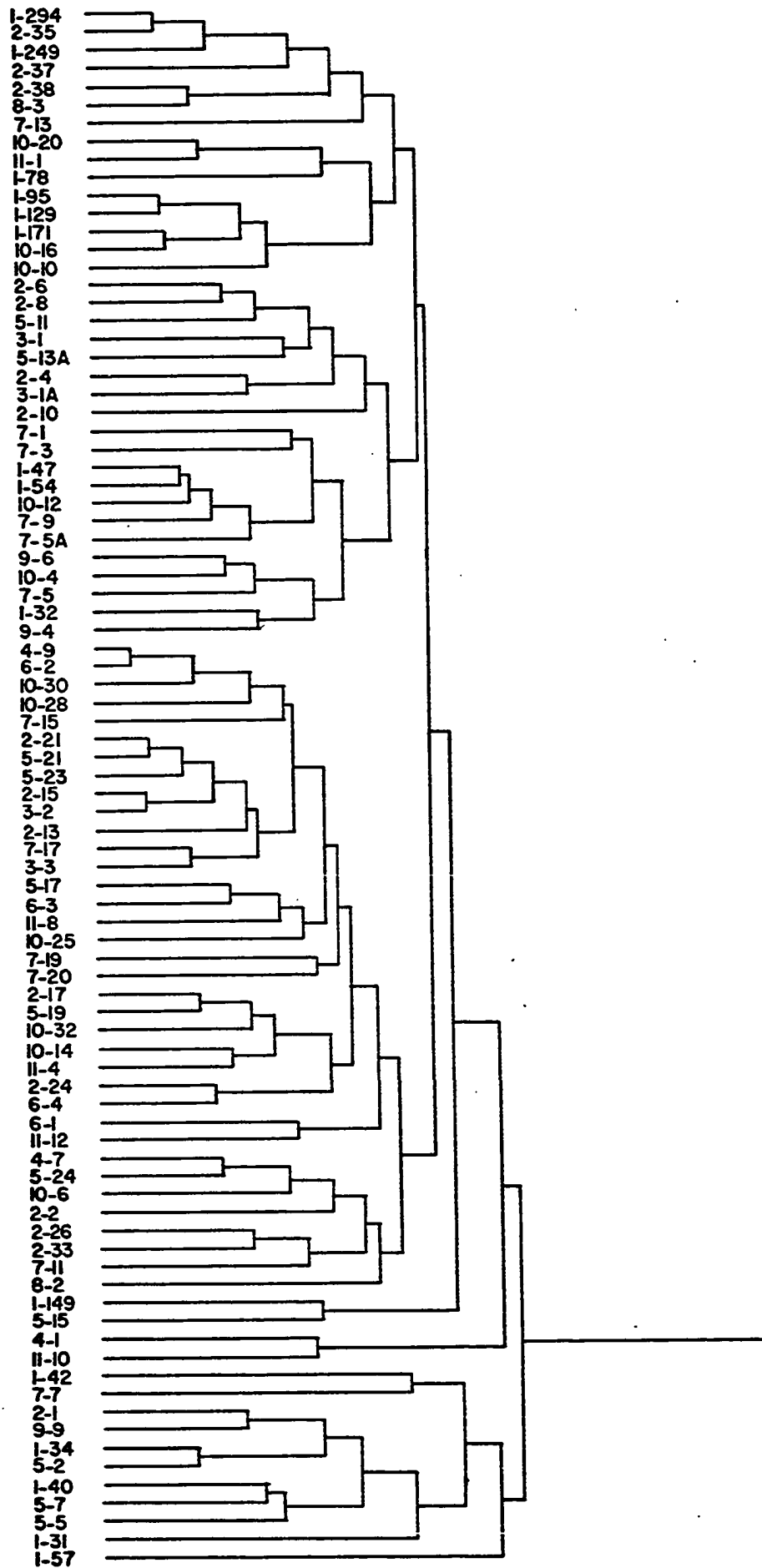
Text Fig. 5--Q-mode dendrogram (U.P.G.M.) based on calculations of the Jaccard similarity coefficients for 86 Edenian samples. The samples contain 37 ostracod species and were coded by the straight occurrence method.



Text Fig. 6--Q-mode dendrogram (U.P.G.M.) based on calculations of the Otsuke similarity coefficients for 86 Edenian samples. The samples contain 37 ostracod species and were coded by the straight occurrence method.

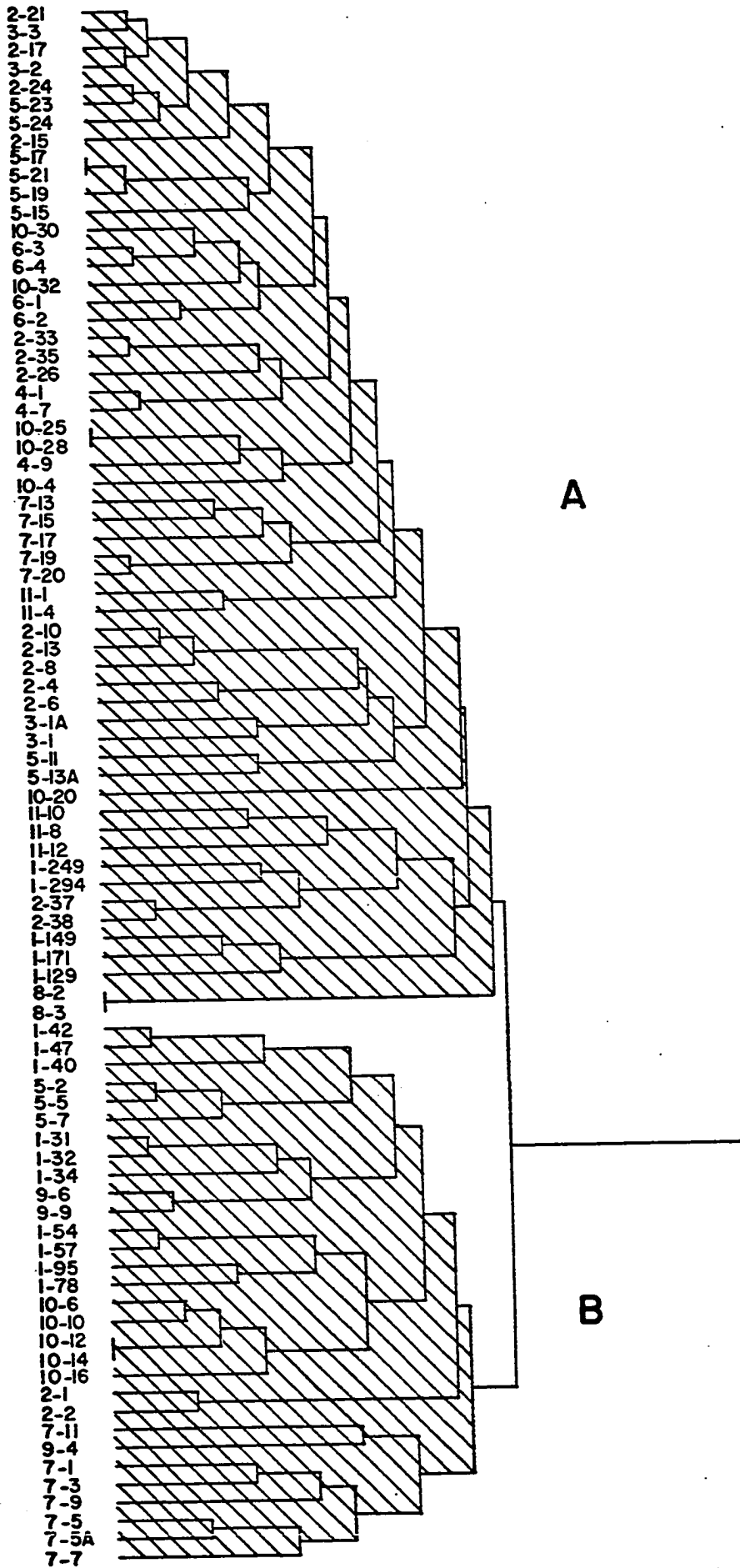
OTSUKA COEFFICIENT

1.0 .90 .80 .70 .60 .50 .40 .30 .20 .10 .00

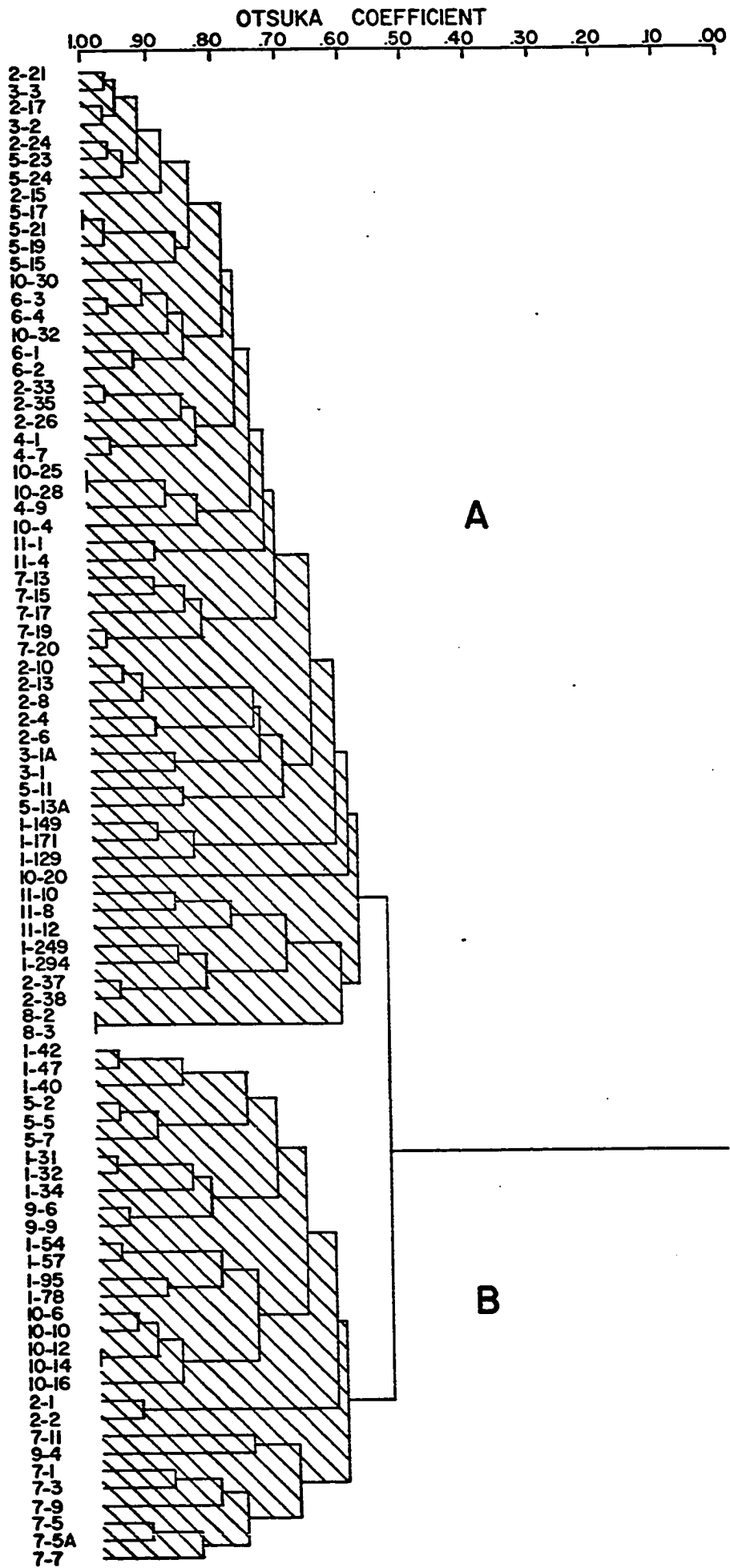


Text Fig. 7--Q-mode dendrogram (U.P.G.M.) based on calculations of the Jaccard similarity coefficients for 86 Edenian samples. The samples contain 37 ostracod species and have been normalized by the moving average method.

JACCARD COEFFICIENT
 1.00 .90 .80 .70 .60 .50 .40 .30 .20 .10 .00



Text Fig. 8--Q-mode dendrogram (U.P.G.M.) based on calculations of the Otsuka similarity coefficients for 86 Edenian samples. The samples contain 37 ostracod species and have been normalized by the moving average method.



A

B

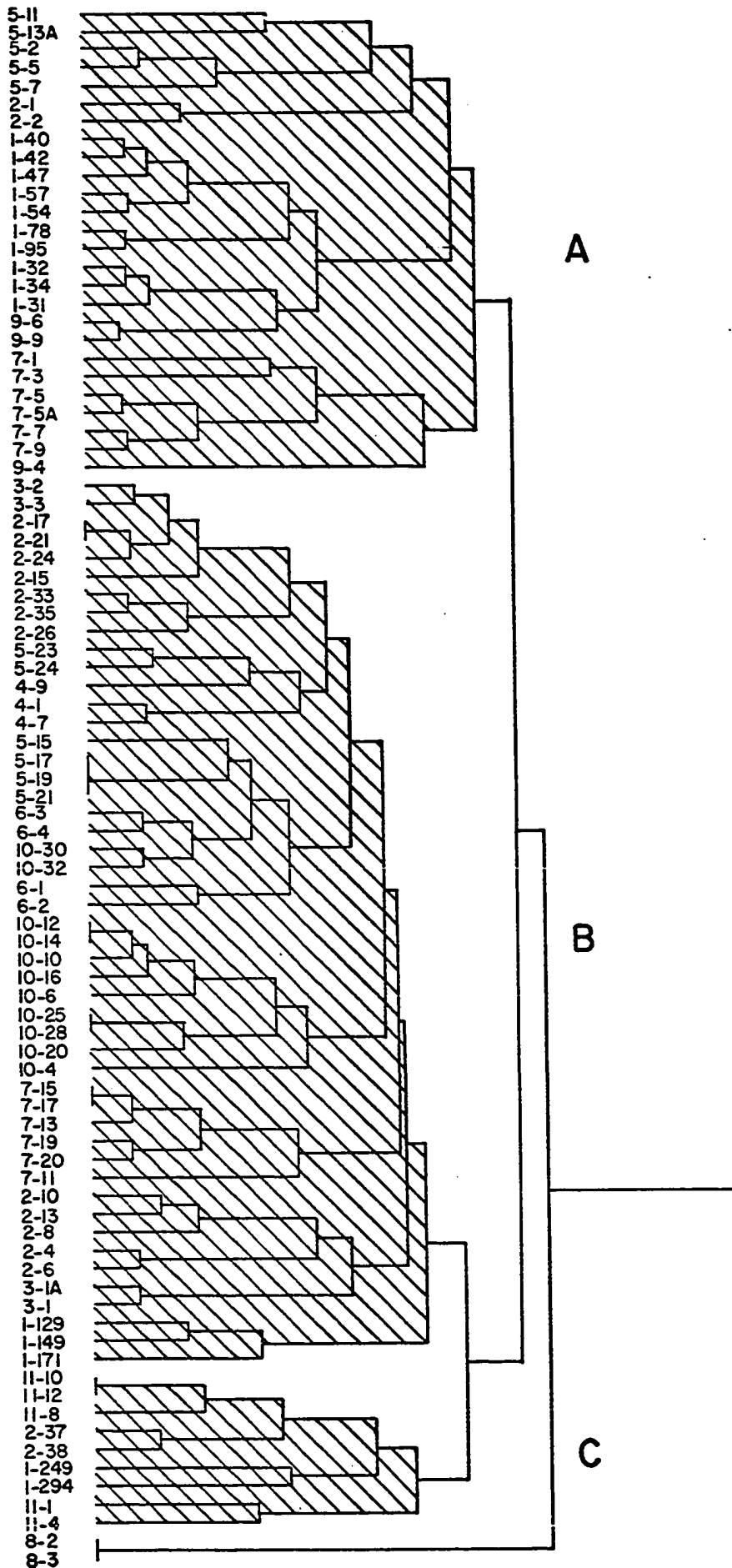
3. Cluster diagrams (text figs. 9 and 10) generated for the range method data array consistently define 2 major clusters, 4 subclusters and a pair of samples that cluster late (samples 8-2 and 8-3, at the bottom of the dendrograms). All of the samples found in the uppermost major cluster occur in the basal Kope in and around Cincinnati. The lower subdivision of this major grouping consists of, with the exception of one sample, 9-4, samples from locality 7. This sub-cluster most probably reflects geographic similarity and adds no biostratigraphic information. Therefore, the upper major cluster cannot be subdivided and must be considered as one unit, herein termed Polythetic Range Zone A. This is not the case, however, with the 2 subclusters of the lower major cluster. In the lower large cluster, the upper and largest subgrouping (Polythetic Range Zone B) consists of samples found in the middle Kope of the Cincinnati area. The lower subcluster (P.R.Z. C) consists of samples from the uppermost Kope.

We have then a tripartite zonation for the Kope Formation at Cincinnati delineated by cluster analysis in a reversed stratigraphic order. That is, P.R.Z. A, the lowest biostratigraphic unit is found at the top of the dendrogram and P.R.Z. C, the uppermost biostratigraphic unit, is found at the bottom of the dendrogram. Polythetic Range Zone B, the middle unit, is found in the middle of the dendrogram. As this method (Range Method) offers a greater resolution (3 zones) than does the moving average method (2 zones) it will be adopted for biostratigraphic purposes.

Samples 8-2 and 8-3, the samples that clustered late, and therefore had a low similarity when compared to the rest of the samples, were

Text Fig. 9--Q-mode dendrogram (U.P.G.M.) based on calculations of the Jaccard similarity coefficients for 86 Edenian samples. The samples contain 35 ostracod species and have been normalized by the range method of Cheetham and Deboo. Polythetic Range Zones A, B and C appear in reversed stratigraphic order.

JACCARD COEFFICIENT
 1.00 .90 .80 .70 .60 .50 .40 .30 .20 .10 .00

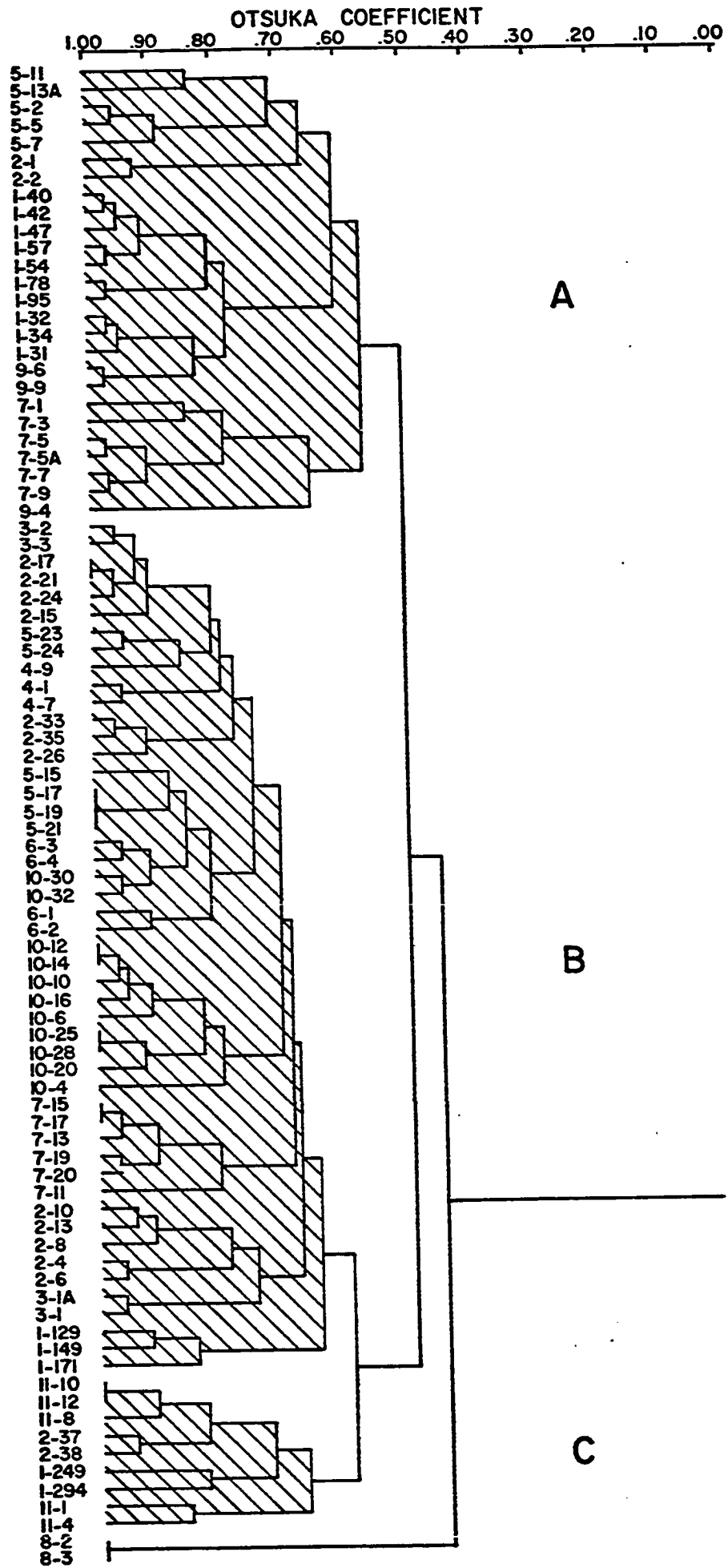


A

B

C

Text Fig. 10--Q-mode dendrogram (U.P.G.M.) based on calculations of the Otsuka similarity coefficients for 86 Edenian samples. The samples contain 35 ostracod species and have been normalized by the range method of Cheetham and Deboo. Polythetic Range Zones A, B and C appear in reversed stratigraphic order.



reexamined and found to be extremely weathered. The only ostracods preserved were coarsely pyritized. It is felt that selective preservation of the specimens may have caused these samples to be seemingly aberrant.

Text Fig. 1 shows the relationship of the three Polythetic Range Zones to the Kope Formation at Cincinnati.

Ostracod biostratigraphy.--The three Polythetic Range Zones delineated in the aforementioned fashion occur within the confines of the Kope Formation at Cincinnati and are therefore coincident with the Edenian Stage. However, as one goes east and west of the type area the three zones are no longer bounded by the Point Pleasant-Kope and Kope-Fairview contacts.

At Kope Hollow (section 10), the easternmost outcrop sampled, the Point Pleasant-Kope contact occurs within Polythetic Range Zone B, the middle Eden zone. The upper Point Pleasant Formation in Kope Hollow, which is conformable with the lower Kope, must therefore be lower to middle Edenian (P.R.Z. A and B) in age. This is in agreement with a conodont based correlation depicted by Sweet and Bergstrom (1971) and reillustrated in this report (text fig. 2). Sweet and Bergstrom included the upper Kope Formation of the Maysville area in the lower Maysvillian Stage. Thus far, the ostracod correlations indicate that the Kope-Fairview boundary at White Swan Run (section 11), the easternmost upper Kope sampled, is equivalent to the Edenian-Maysvillian boundary. It may be that as one traverses the 15 miles from White Swan Run to Maysville the formational boundary becomes younger.

In the southern (section 6, Boltz Lake) and westernmost (section

4, I-71 and section 5, Rabbit Hash) outcrops, the Kope-Fairview contact occurs in Polythetic Range Zone B. The lower Fairview Formation in NW Kentucky, which rests conformably on the Kope Formation, must therefore be middle to upper Edenian (P.R.Z. B and C) in age. This correlation is not in agreement with Sweet and Bergstrom (1971) for they have included the Kope-Fairview boundary of S E Indiana in the Maysvillian Stage. No information is yet available regarding the placement of the lower Kope boundary for the western side of the Cincinnati Arch.

This tripartite zonation of the Edenian Stage has thus revealed the time-transgressive nature of the Point Pleasant, Kope and Fairview formations. Whether or not these zones will be effective in correlating between major lithotopes remains to be investigated.

Text figure 11 is a reordering of the samples by the zones in which they occur.

Paleoecology.--Paleoecologic investigations of the Kope Formation have been undertaken by several authors (Weiss et al., 1965; Anstey and Fowler, 1969). In general the Kope is thought to represent a stable epicontinental sea with water depths variously estimated as between 1 (Hofman, 1966) and 25 meters (Bucher, 1919), based on ripple amplitudes, and greater than 20 meters, based on bryozoan growth forms (Anstey and Fowler, 1969). However, the Kope is interpreted by all of the authors to represent a deeper water facies than does the surrounding Point Pleasant and Fairview formations.

Bottom topography of the Kope sea most probably was one of low swells and swales (Ford, 1967; Anstey and Fowler, 1969). The higher areas, by virtue of more sunlight and less terrigenous influence, would

Text Fig. 11--Suggested biostratigraphic positions of the samples within Polythetic Range Zones A, B and C. Placement of the samples is based upon the relationships delineated by Q-mode cluster analysis. The height of the zone rectangles has no time connotation.

LOCALITY 1-II ZONE	Moffett Road	Rapid Run	Newport	1-71	Rabbit Hash	Boltz Lake	Twelve Mile Creek	U.S. 27	Duck Creek	Kope Hollow	White Swan Run
C	1-294 1-249	2-38 2-37						8-3 8-2			11-1 11-12
		2-35		4-1 4-9	5-24	6-4 6-1	7-20			10-32 10-4	
B			3-3 3-1								
	1-171 1-129	2-4			5-15		7-11				
A		2-2 2-1			5-13A		7-9		9-9 9-4		
	1-95 1-31				5-2		7-1				

 Exposed but not sampled

 Covered interval

tend to be the sites for the localized development of extremely large populations of benthonic organisms (Anstey and Fowler, 1969). Biogenic material generated by these organisms would leak off of the mound areas onto the surrounding muds. In addition, occasional storms would destroy entire communities and distribute the skeletal material over large areas. For the most part, however, the organism-derived sediment would be limited to the topographic highs where it formed. Shifting of the subaqueous highs over time would account for the changes in vertical and lateral occurrences of the carbonate beds (Ford, 1967; Anstey and Fowler, 1969).

Several investigators have described a steady shallowing of water conditions in the upper Kope. This interpretation has been based on decreasing ripple amplitudes (Hofman, 1966), increasing limestone occurrences (Ford, 1967, Anstey and Fowler, 1969) and increasing bryozoan diversities (Anstey and Fowler, 1969) towards the top of the Kope.

However, the ostracod communities do not display any significant (at 0.05 probability) change in diversity levels. This hypothesis (H_0 =no change) was tested by using a Chi-square test to compare diversity values, S (number of species in each sample), for all of the samples against a rectangular distribution. The calculated Chi-square value for the diversity indices ($N=86$, $\bar{X}=9.6$, Range=5-15, $s^2=4.9$, $s=2.2$) was found to be within the range of acceptance (with $N-1$ or 85 degrees of freedom) and the null hypothesis was therefore accepted. Steady environmental pressures, as reflected by ostracod diversity and clay mineralogy (Scotford, 1964; Booth and Osborne, 1971) have been in effect for the entire Kope interval. If the Fairview and Point

Pleasant formations do represent shallower environments than does the Kope, the shoaling conditions must have rapidly stopped and started at the respective lower and upper contacts.

ABBREVIATIONS USED IN THIS WORK

Museums

U.S.N.M.--United States National Museum.

U.C.--Field Museum of Natural History.

U.C.G.M.--University of Cincinnati Geological Museum.

Statistical

N_L --number of length measurements.

\bar{X}_L --mean of length measurements.

R_L --observed range of the length measurements.

s^2_L --variance of the length measurements.

s_L --standard deviation of the length measurements.

N_H --number of height measurements.

\bar{X}_H --mean of height measurements.

R_H --observed range of the height measurements.

s^2_H --variance of the heights measurements.

s_H --standard deviation of the height measurements.

$N_{H/L}$ --number of height/length ratios calculated.

$\bar{X}_{H/L}$ --mean of height/length ratios.

$R_{H/L}$ --observed range of height/length ratios.

$s^2_{H/L}$ --variance of height/length ratios.

$s_{H/L}$ --standard deviation of the height/length ratios.

Miscellaneous

U.P.G.M. --Unweighted Pair Group Method.

P.R.Z.--Polythetic Range Zone.

SYSTEMATIC PALEONTOLOGY

Subclass Ostrocooda Latreille, 1890

Order Palaeocopida Henningsmoen, 1953

Suborder Beyrichicopina Scott, 1961

Superfamily Drepanellacea Ulrich and Bassler, 1923

Family Bolliidae Boucek, 1936

Genus Bollia Jones and Holl, 1886Bollia persulcata (Ulrich)

Pl. 1, Figs. 1-5

- 1879 Beyrichia persulcata Ulrich, E.O., Cincinnati Soc. Nat. Hist. Jour. 2(1):12, Pl. 7, Fig. 6.
- 1890 Beyrichia buchiana ? Jones, T.R., [not Beyrichia buchiana Jones. 1855] Geol. Soc. London, Quart. Jour., 46:16, Pl. 3, Fig. 25.
- 1890 Bollia persulcata (Ulrich), Ulrich, E.O., Cincinnati Soc. Nat. Hist., Jour. 13(3):116, Text Fig. 3, a-d.
- 1951 Bollia persulcata (Ulrich), Keenan, J.E., Jour. Paleontology 25:564, Pl. 78, Figs. 2,3.
- 1965 Bollia persulcata [?] (Ulrich), Copeland, M.J., Geol. Surv. Canada, Bull. 127:8, Pl. 11, Figs. 9,11.

Diagnosis.--A Bollia with L2 separated into a lobe and a knob by a deep horizontal furrow; L1 commonly constricted; velar ridge discontinuous, absent from mid-ventral area.

Description of adults.--The valves are equal in size and sub-rectangular in lateral view. Greatest height (exclusive of struc-

tures projecting above the hingeline) is just anterior to L1. Greatest length is at the mid-height and the greatest thickness is located at the mid-portion of L2. Hingeline is straight, approximately 90% of the greatest length. Dorsum is orthocline. The ventral margin ranges from slightly convex to straight and is subparallel to the dorsal margin. Anterior margin is strongly convex and well rounded. The posterior margin is weakly convex and sub-perpendicular. Anterior cardinal angle is obtuse (approximately 140°), and the posterior cardinal angle is acute (approximately 85°). A prominent velate ridge parallels the marginal rim around the anterior and posterior portions of the free margins. Velate ridge coalesces with the marginal rim in a centro-ventral position, leaving a hiatus between the anterior and posterior portions of the ridge. The velate ridge is extremely wide and conceals the marginal rim, thereby forming a false border on the anterior and posterior portions of the valve. Velate ridge is reflected on the interior of the valve as two deep channels, one posterior and the other anterior. Anterior and posterior portions of the marginal rim are separated from the velate ridge by a narrow canaliculus. L1 is extremely variable: straight, medianly inflated or medianly constricted. L1 joins L2 ventro-medianly, forming a "U" shaped ridge. Ventro-median portion of the ridge is constricted. L2 is slightly longer than L1 and has its dorsal third separated into a hemispherical to sub-oblong knob by a deep furrow. The dorsal portion of both lobes projects above the hinge line. L1 and L2 are reflected on the interior of the valves as deep grooves. The dorsal

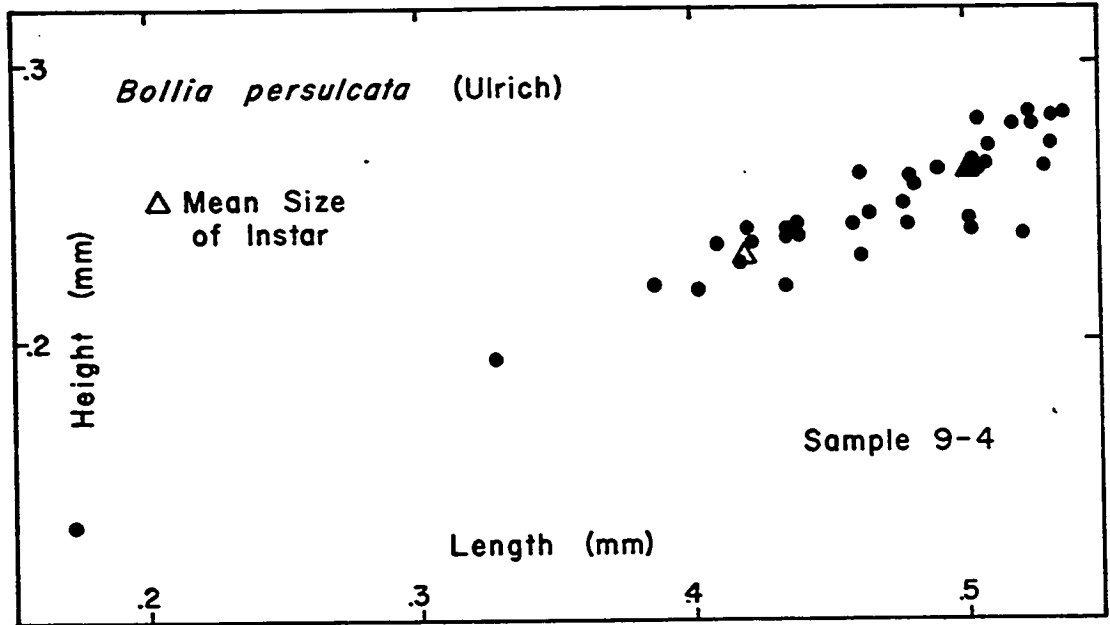
knob is reflected internally as a deep, wide pit. Ventral portion of the "U" shaped ridge is not reflected internally. S2 is deep and long, extending almost to the ventral border. S2 is reflected internally as a long, high ridge. The surface of the valves ranges from smooth to finely granulose. Hingement is by a dorsal groove in the right valve and a denticulate bar in the left valve.

Measurements.--See table 1 for a statistical summary of the measurements for 37 specimens from sample 9-4.

Ontogeny.--A study of the size dispersion diagram (text fig. 12) indicates the existence of at least 4 growth stages, the Adult, Adult-1, Adult-2 and Adult-3. Changes in morphology during ontogeny are made manifest in several ways. Most obvious are the changes in the ornament of the valves. In the Adult-2, the smallest instar to be well enough preserved for critical study, the central "U" shaped ridge projects higher off the valve surface in relation to the velate ridge than it does in the Adult. In addition, the constricted centro-vental portion of the "U" shaped ridge is extremely narrow and tubular. This portion of the ridge, which in reality connects L1 and L2, increases in girth through ontogeny although it never reaches the thickness of the lobes. L1 has a very strong constriction at about the same level as the furrow in L2. L1 does not project above the hingeline while L2 barely does. The dorsal portion of L2 is developed into a well rounded knob. This knob shows a tendency to become elongate through ontogeny, although some of the Adults have sub-rounded knobs.

Table 1--Statistical summary of measurements (in mm) for 37 specimens of Bollia persulcata from sample 9-4.

Statistic	Adult	Adult-1	Adult-2	Adult-3
N L	25	10	1	1
\bar{X} L	.500	.421	.329	.173
R L	.459-.538	.387-.442	----	----
s^2 L	.001	.000	----	----
s L	.024	.018	----	----
N H	25	10	1	1
\bar{X} H	.260	.232	----	----
R H	.231-.282	.220-.241	----	----
s^2 H	.000	.000	----	----
s H	.015	.009	----	----
N H/L	25	10	1	1
\bar{X} H/L	.520	.550	.593	.780
R H/L	.479-.563	.512-.573	----	----
s^2 H/L	.001	.000	----	----
s H/L	.023	.018	----	----



Text Fig. 12--Size dispersion diagram of Bollia persulcata (Ulrich).

The Adult-1, as expected, reveals intermediate development between the Adult-2 and the Adult. L1 exhibits a higher degree of constriction than does the Adult but less than the Adult-2. Limited evidence also exists for a change in valve shape during ontogeny (see table 1 for the H/L ratio data). The valves are highest in the juveniles but become relatively longer through ontogeny. However, the limited material makes the testing of the statistical significance of this change impossible.

Discussion.--Bollia persulcata most closely resembles B. ridicula Keenan, 1951, from the Maquoketa Shale of Missouri. B. persulcata differs from B. ridicula by lacking a small node in front of the postero-dorsal corner. In addition, the velate and central ridges of B. ridicula are higher and narrower than in B. persulcata. B. persulcata differs from all other species of the genus, except for B. ridicula, by the existence of a deep furrow separating L2 into two distinct parts, a lobe and a knob.

The specimen identified as Beyrichia buchiana by Jones, (1890), was originally placed in synonymy with B. persulcata by Ulrich and Bassler in 1908. However, it is evident that even Jones doubted his original assignment for he placed a question mark after the trivial name. Jones had good cause for his doubt, for as stated by Ulrich and Bassler, (1908), Jones' specimen was simply a partially covered B. persulcata. Examination of the type figure shows this to be the case. The specimen is exposed from the anterior border to just posterior of L2.

Keenan (1951) did not describe B. persulcata but did include photographs of one Adult and one Juvenile from the base of the Edenian at Cincinnati. These were the first photographs of the species ever published, and are therefore included in the synonymy.

In 1965, Copeland figured 2 specimens of B. persulcata from the Lake Timiskaming area of Ontario. Both of the specimens are partially covered by matrix and are extremely difficult to study. In spite of these difficulties, the specimens bear a great resemblance to the juveniles of B. persulcata. This resemblance is particularly great in the development of the lobes and in the large Height/Length ratio. However, in absolute size, the Ontario specimens are more like the Adults of the present study. This discrepancy in absolute size is most probably due to ecological factors and cannot be used as a taxobasis.

Occurrence.--Recovered from 61 samples and occurred in Polythetic Range Zones A, B and C.

This species has been reported from the Edenian, Maysvillian and Richmondian of the Cincinnati Area (Bassler, 1915; Bassler and Kellett, 1934; Keenan, 1951) and the Middle Ordovician Liskeard Formation of Lake Timiskaming, Ontario (Copeland, 1965).

Types.--Figured specimens

U.C.G.M. 41325

U.C.G.M. 40794

U.C.G.M. 40795

U.C.G.M. 40796

U.C.G.M. 40797

Measured specimens (1 slide with 36 specimens)

U.C.G.M. 40793

Genus Warthinia Spivey

- 1939 Warthinia Spivey, R. C., Jour. Paleontology, 13:167.
1963 Warthinia Spivey, Guber, A. L., Unpub. Ph.D. Thesis, Univ. of Illinois, P. 56.

Type species.--The type species is Primitia nodosa Ulrich, by the original designation of Spivey in 1939.

Discussion.--The genus Warthinia was originally described by Spivey (1939, P. 167) as follows:

Small equivalved Ostracoda with long, straight hinge, finely reticulate surface and more or less distinct border. Primarily with four, but sometimes only three, nodes; one node located on each side of short sulcus, and other node (or nodes) on posteroventral and ventral surface. The genus shows some variation in the development of ornamentation, some specimens have relatively weak nodes and border, while others have much heavier borders, and spines on the nodes.

In 1961, Scott, Wainwright and Hessland placed Warthinia questionably into synonymy with Ulrichia, a binodose form. However, Guber, in 1963, resurrected and emended the generic name Warthinia to include only trinodose, finely reticulate species. Guber became suspicious about the exact number of nodes occurring on U. nodosa when he recovered no examples of quadrinodose forms among the hundreds of specimens studied from the type area. Consequently, Guber

had I. G. Sohn of the United States Geologic Survey reexamine the types of U. nodosa. This species had originally been described (Ulrich, 1890) as being either trinodose or quadrinodose. The types were all found to be trinodose with no indication of any quadrinodose individuals. Subsequent examination of the types (cotypes, U.S.N.M. 41552, 2 specimens) by the present writer reaffirm Sohn's observations. Warthinia is thereby restricted to trinodose Bolliidae.

Warthinia nodosa (Ulrich)

Pl. 1, Figs. 6-9

- 1890 Primitia nodosa Ulrich, E.O., Cincinnati Soc. Nat. Hist., Jour., 13(3):134, Pl.10, Figs 11a-b, 12a-b.
- 1891 Ulrichia nodosa (Ulrich), Ulrich, E.O., Cincinnati Soc. Nat. Hist., Jour., 13(4):203.
- 1939 Warthinia nodosa (Ulrich), Spivey, R.C., Jour. Paleontology, 13:167, Pl. 21, Figs. 3-6.
- 1941 Ulrichia nodosa nodosa (Ulrich), Schmidt, E.A., Senckenb. Naturf. Gesell., abh. 454, P. 57.
- 1941 Ulrichia nodosa paupera (Ulrich), Schmidt, E. A., Senckenb. Naturf. Gesell., abh. 454, P. 57, Pl. 4, Figs. 30-31.
- 1951 Kiesowia nodosa (Ulrich), Keenan, J.E., Jour. Paleontology, 25:560, Pl. 78, Fig. 6.
- 1965 [?] Ulrichia nodosa (Ulrich), Burr, J.H. and Swain, F.M., Minnesota Geol. Surv., Sp-3, P. 14, Pl. 4, Figs. 2a-b,3.
- 1970 Ulrichia nodosa (Ulrich), Copeland, M.J., Geol. Surv. Canada,

Bull. 187, P. 18, Pl.4, Figs. 3,4.

Diagnosis.--A finely reticulate Warthinia with a well formed ventral lobe connecting the three nodes; the three nodes are extremely variable, may be spinose, conical or rounded.

Description.--The valves are semicircular in lateral view and are subequal in size. Right valve is slightly larger than the left valve. Greatest height is usually at the mid-length and rarely anterior or posterior to the mid-length. Greatest length is dorsal to the mid-height and the greatest thickness is ventral to the mid-height. Dorsal margin is straight to slightly convex and is approximately 80% of the greatest length. Ventral margin is convex and grades laterally into the convex anterior and posterior margins. Posterior margin more bluntly convex than the anterior. Cardinal angles are obtuse and subequal, the anterior cardinal angle is approximately 140° and the posterior approximately 145° . A well developed velate ridge parallels the marginal rim around the entire free margin. The velate ridge and the marginal rim coalesce at the antero-dorsal and postero-dorsal corners. A wide, shallow canaliculus with weakly developed longitudinal striae is formed between the velate ridge and the marginal rim. The canaliculus is well developed around the entire contact margin. Three large nodes appear on the lateral surface of the valves. The largest of the three lateral nodes is located in a postero-dorsal position and varies from being low and rounded to elongate and pointed. When pointed, the nodes are posteriorly inclined. The antero-dorsal node is smaller than the

postero-dorsal. Antero-ventral node is slightly larger than the antero-dorsal. Antero-dorsal and antero-ventral nodes are not as variable in shape as is the postero-dorsal node. All three of the nodes are ventrally connected by a low swelling of the lateral valve surface. S2 is moderately deep, short and located between the antero-dorsal and postero-dorsal nodes. The three nodes, connecting lobe and velate ridge are internally reflected as corresponding depressions. S2 is reflected as a prominence. Exterior surface of the valves is finely reticulate. Reticulation not well developed on the nodes and is absent from the velate ridge. Dorsum is slightly epicline. Right valve over-reaches the left valve at the cardinal corners. No hinge structure was observed.

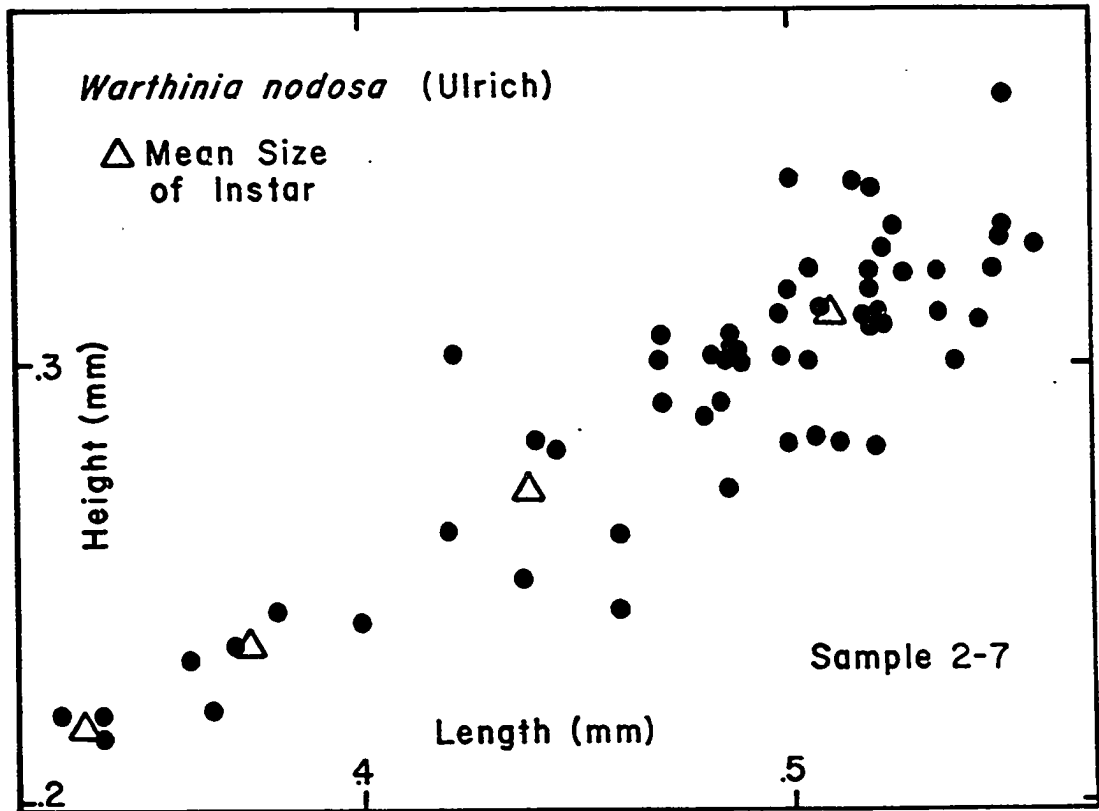
Measurements.--See table 2 for a statistical summary of the measurements for 58 specimens from sample 2-7.

Ontogeny.--In addition to the changes in absolute and relative size (there is a trend towards a decrease in the Height/Length ratio through ontogeny) revealed by the size dispersion diagram (text-Fig. 13) and table 2, there is also a change in the morphology of the nodes in the three pre-adult stages thus far recovered. This change is made manifest by the development of spines on the dorsal nodes. The spines occur one per node and are posteriorly directed. Due to their delicate nature, the short thin spines are commonly broken and therefore difficult to study. No other ontogenetic changes have thus far been delineated.

Discussion.--The posterior-anterior orientation employed in this

Table 2--Statistical summary of measurements for 58 specimens of Warthinia nodosa from sample 2-7 (in mm).

Statistic	Adult	Adult-1	Adult-2	Adult-3
N L	43	7	5	3
\bar{X} L	.510	.440	.375	.337
R L	.470-.558	.420-.460	.360-.400	.332-.341
s^2 L	.001	.000	.000	.000
s L	.024	.016	.016	.005
N H	43	7	5	3
\bar{X} H	.309	.269	.234	.219
R H	.270-.360	.242-.300	.220-.242	.215-.222
s^2 H	.000	.000	.000	.000
s H	.018	.018	.009	.004
N H/L	43	7	5	3
\bar{X} H/L	.604	.612	.624	.648
R H/L	.538-.680	.527-.714	.602-.647	.632-.668
s^2 H/L	.001	.003	.000	.000
s H/L	.031	.058	.020	.018



Text Fig. 13—Size dispersion diagram of *Warthinia nodosa* (Ulrich).

paper is opposite to that previously used. However, the location of S2 coupled with the inclination of the spines and pointed nodes indicates a reversed orientation.

Warthinia nodosa closely resembles several species of Warthinia from the Maquoketa Shale of Missouri. W. verrucosa (Kay) differs from W. nodosa by having a more prominent, punctate, velate ridge and a sharp posteriorly directed spine on the antero-dorsal node of the Adults. Ulrichia saccula Burr and Swain, from the Maquoketa of Iowa, is very similar to W. nodosa but is more coarsely punctate. However, a more detailed study may prove U. saccula to be conspecific with W. nodosa.

The specimens of Ulrichia nodosa figured by Burr and Swain (1965) are poorly preserved and therefore placed questionable into synonymy.

Schmidt (1941) erected two subspecies for Ulrichia nodosa, Ulrichia nodosa paupera and Ulrichia nodosa nodosa. The former was initiated for the typical three node form and the latter for the four node variant described by Ulrich (1890). As previously stated, no quadrinodose individuals were found to occur in either the cotypes or in the thousands of topotypic specimens subsequently studied. It is therefore felt that quadrinodose specimens of Warthinia nodosa do not exist and that Ulrich most probably misinterpreted the ventral connecting lobe as a node. In this respect, it is interesting to note that while Schmidt figured a specimen of the trinodose variety, he did not figure a quadrinodose form.

The great variation in the shape of the postero-dorsal node forms a continuous series from low and rounded to conical and spinose. While the spinose individuals were restricted to the pre-adult instars, many of the Adults bear conical and pointed nodes. These observations are consistent with those made by Guber (1963, p. 46) who found that among five hundred specimens studied only the pre-adult specimens had spinose nodes. This loss of structure during ontogenetic development is an unusual situation among ostracods, where the rule is that structures are intensified during ontogeny. Any explanation for this strange development must be highly speculative. However, ecological factors must be ruled out as all of the variants can be recovered from the same sample.

Occurrence.—Found in 85 samples and occurs in Polythetic Range Zones A, B and C.

This species has also been reported from the Edenian through Richmondian of the Cincinnati area (Bassler and Kellett, 1934), the Upper Ordovician English Head and Vaureal formations of Anticosti Island (Bassler, 1927; Copeland, 1970), the Richmondian Maquoketa Shale of Iowa (Spivey, 1939) and the Middle Ordovician Dubuque Formation of Minnesota (Burr and Swain, 1965).

Types.—Figured specimens

U.C.G.M. 40164

U.C.G.M. 40165

U.C.G.M. 40166

U.C.G.M. 40893

Measured specimens

U.C.G.M. 40894 (55 specimens on 1 slide)

Genus Parenthatia Kay, 1940

Parenthatia rabbithashensis n. sp.

Pl. 1, Fig. 10

Holotype.--An Adult left valve, U.C.G.M. 40897.

Type locality.--Rabbit Hash Section, Boone County, Kentucky, sample 5-23.

Type stratum.--Kope Formation, Edenian Stage, 18.5 feet below the contact with the overlying Fairview Formation.

Derivation of the name.--rabbithashensis, in honor of Rabbit Hash, Kentucky, the type locality.

Material.--The following descriptive work is based upon 24 specimens, the holotype and 23 paratypes from sample 5-23. However, many good specimens from other samples were also given a cursory examination.

Diagnosis.--A Parenthatia with a ridge surrounding the entire lateral surface of the valve; area inside of ridge marked by a centrally located, none punctate, "Y" shaped swelling.

Description.--The valves are equal in size and subrectangular in lateral view. Greatest length is ventral of the midheight and the greatest height is anterior to the midlength. Greatest thickness is centrally located. Dorsal margin is straight and is approximately 70% of the greatest length. Ventral margin is straight and sub-parallel to the dorsal margin. Ventral margin grades into the convex anterior and posterior margins. Anterior margin more bluntly rounded than the posterior. Cardinal angles are obtuse and

indistinctly developed. Anterior cardinal angle is more sharply defined but smaller than the posterior cardinal angle. A well formed ridge completely encircles the lateral surface of the valve. Anterior portion of the ridge is well defined and separated from the anterior free margin by a narrow channel. The ridge is narrow and rounded on the anterior, antero-dorsal and ventral portions. Ridge is moderately wide on the posterior extremity. However, the ridge is extremely wide on the postero-dorsal portion. At this portion, a sloping surface occurs between the dorsal margin and the crest of the ridge. The lateral surface of the valve adjacent to the ridge is depressed while the central area is inflated. Entire area inside the encircling ridge is coarsely punctate with the exception of the centrally located, horizontally disposed, "Y" shaped ridge. The bifurcating portion of the ridge faces posterior. S2, the interior of the valve and hingement were not observed.

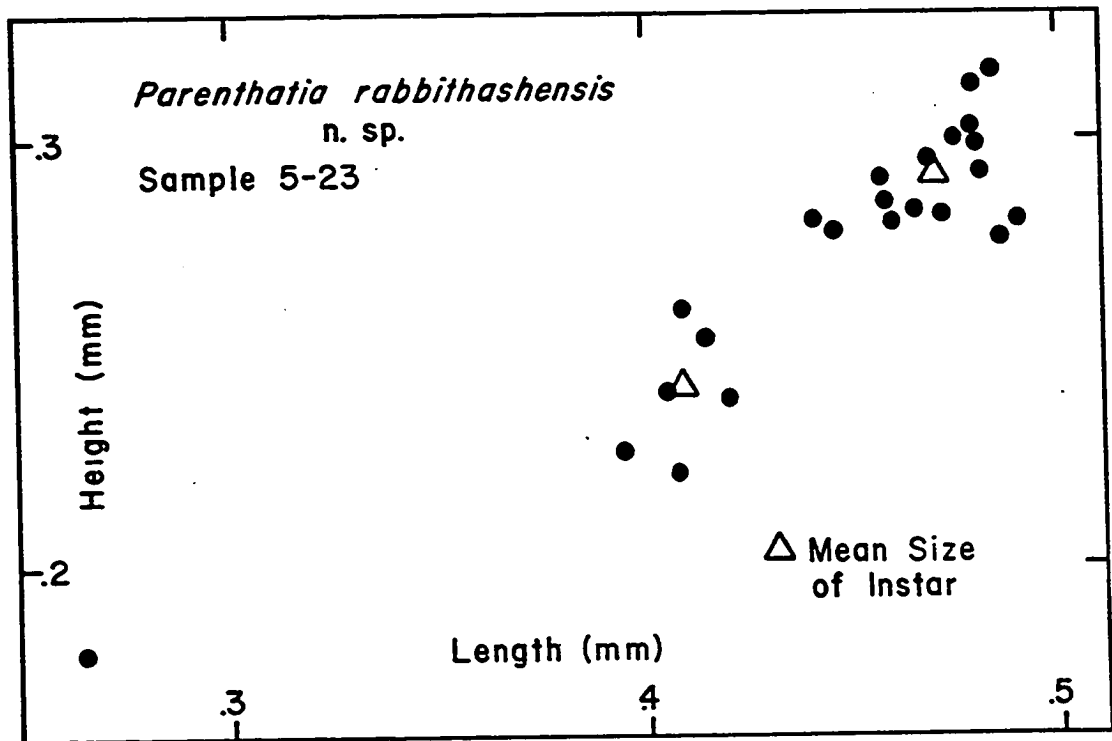
Measurements.--See table 3 for the measurements of the holotype and 23 paratypes.

Ontogeny.--Examination of the size dispersion diagram (Text-Fig. 14) reveals the existence of at least three different growth stages, the Adult, Adult-1 and the Adult-x. The smallest instar yet recovered, the Adult-x, is widely separated from the Adult-1 and may represent either the Adult-2 or the Adult-3. In addition, this specimen is coarsely recrystallized, thereby masking most of the morphologic features. The remaining growth stages, the Adult and the Adult-1 differ in relative (Adults are relatively shorter,

Table 3—Measurements of Holotype and 23 Paratypes of Parenthatia
rabbithashensis from sample 5-23 (in mm).

U.C.G.M. no.	Length	Height	Comments
40897 *	.487	.276	Left valve
40898	.485	.315	Left valve
40899	.421	.238	Left valve
40900	.480	.312	Left valve
40901	.473	.280	Left valve
40902	.410	.260	Right valve
40903	.405	.240	Right valve
40904	.481	.298	Right valve
40905	.395	.225	Left valve
40906	.440	.280	Right valve
40907	.445	.278	Left valve
40908	.491	.280	Right valve
40909	.475	.300	Left valve
40910	.481	.302	Right valve
40911	.265	.180	Carapace
40912	.465	.280	Left valve
40913	.409	.221	Left valve
40914	.458	.290	Left valve
40915	.465	.281	Left valve
40916	.482	.292	Left valve
40917	.471	.295	Right valve
40918	---	.260	Right valve
40919	.415	.252	Right valve
40920	.460	.280	Right valve

* Holotype



Text Fig. 14--Size dispersion diagram of Parenthatia rabbithashensis n. sp.

Height/Length ratio=.615, than are the Adult-1 specimens, Height/Length ratio=.584) and absolute size but not in morphology.

Discussion.--Parenthatia rabbithashensis differs from the other species of the genus by having a ridge encircling the entire lateral surface. P. punctata (Ulrich, 1890) and P. camerata Kay, 1940 do not have the ridge developed on the dorsal border. In addition, P. rabbithashensis has a non-punctate swelling developed in the center of the valve and is lacking S2.

I have, at this time, serious doubts as to whether or not Parenthatia belongs to the Bolliidae. These doubts stem from the low degree of morphologic similarity between P. punctata, P. rabbithashensis and the true bolliids. P. camerata, however, exhibits a greater degree of similarity with the true bolliids, but may represent another genus. This type of taxonomic question will best be answered by a much needed revision of the family and will not be dealt with now.

Occurrence.--Found in 29 samples and occurs in Polythetic Range Zones A, B and C.

Types.--Holotype

U.C.G.M. 40897

Paratypes

U.C.G.M. 40898

U.C.G.M. 40899

U.C.G.M. 40900

U.C.G.M. 40901

U.C.G.M. 40902

U.C.G.M. 40903

U.C.G.M. 40904

U.C.G.M. 40905

U.C.G.M. 40906

U.C.G.M. 40907

U.C.G.M. 40908

U.C.G.M. 40909

U.C.G.M. 40910

U.C.G.M. 40911

U.C.G.M. 40912

U.C.G.M. 40913

U.C.G.M. 40914

U.C.G.M. 40915

U.C.G.M. 40916

U.C.G.M. 40917

U.C.G.M. 40918

U.C.G.M. 40919

U.C.G.M. 40920

Family Richinidae Scott, 1961 Emend.

Diagnosis.--Subovate with two dorsomedial nodes, nodes may be elongate and ventrally connected to form a "U" shaped ridge; posterior node may develop into a dorsally directed horn; S2 separates the nodes; hingeline shorter than greatest length; cardinal angles distinct to indistinct; surface smooth, reticulate or granulose; marginal rim lacking; dimorphism unknown.

Included Genera.

Crescentilla Barrande, 1872

Jonesella Ulrich, 1890

Parulrichia Schmidt, 1941

Pseudulrichia Schmidt, 1941

Richina Coryell and Malkin, 1936

Vogdesella Baker, 1924

Discussion.--The above revision was deemed necessary in order to accomodate Jonesella and the closely allied Vogdesella into the Richinidae. Inclusion of these genera into the family was made imperative by the discovery of a new species, Jonesella interrupta, intermediate in morphology between Jonesella crepidiformis (type species of Jonesella) and Pseudulrichia bynesi (type species of Pseudulrichia). Therefore, the "U" shaped ridge of J. crepidiformis can be seen to originate in P. bynesi as two separate structures, a wide anterior lobe and a centrodorsal horn. These structures become much narrower and more sharply defined in J. interrupta and finally merge into a single element in J. crepidiformis. In addition,

ontogenetic studies reveal that J. crepidiformis passes through a J. interrupta like stage during its development. This developmental continuum indicates a relationship of at least a familial level.

Vogdesella was equated with Jonesella in part Q of the Treatise on Invertebrate Paleontology. However, the small, poorly defined and anteriorly restricted "U" shaped ridge of Vogdesella is a legitimate generic taxobasis and the name should be retained.

Genus Jonesella Ulrich, Emend.

- 1890 Jonesella Ulrich, E. O., Cincinnati Soc. Nat. Hist., Jour., 13:12.
- 1894 Jonesella Ulrich, Ulrich, E. O., Minnesota Geol. and Nat. Hist. Surv., 3(2):667
- 1910 Jonesella Ulrich, Grabau, A. W., and Shimer, H. W., North American Index Fossils, p. 349
- 1923 Jonesella Ulrich, Ulrich, E. O. and Bassler, R. S., Maryland Geol. Surv., Silurian Vol., P. 301.

Type species.--Leperditia crepidiformis, by the original designation of Ulrich in 1890.

Diagnosis.--Granulose Richinidae bearing a variously modified, sharply defined, "U" shaped ridge; ridge located in the anterior portion of the valve, occupies over 50% of the valve surface; ridge may be continuous or interrupted in centro-ventral portion; centro-dorsal portion of the ridge may be modified into a sharp horn; ventral most portion of the "U" shaped ridge comes to within 10-25% of the ventral

margin; a low hemispherical node, or a relic of the node, appears on the floor of S2, adjacent to the antero-dorsal portion of the ridge.

Included species.

Leperditia crepidiformis Ulrich, 1890

Jonesella interrupta n. sp.

Jonesella tumida n. sp.

Discussion.--Several species previously included in Jonesella have been subsequently removed to other genera. J. obscura Ulrich, 1894, from the middle Ordovician of Minnesota, has been designated as the type species of Vogdesella Baker, 1924. J. crassa Ulrich, 1890 also from the middle Ordovician of Minnesota, has been found to be conspecific with technomorphs of Dilobella fulcrata (Ulrich, 1894) (Kay, 1940; Jaanusson, 1966). J. pedigera Ulrich, 1890, from the Edenian of the Cincinnati area is herein designated as the type species of Cincinnatiiconcha, n. gen. Lastly, J. digitata Ulrich, 1890, from the Richmondian of Kentucky, most probably represents a species of the genus Wabiella Copeland, 1965.

Jonesella crepidiformis (Ulrich)

Pl. 1, Figs. 11-13

- 1879 Leperditia crepidiformis Ulrich, E. O., Cincinnati Soc. Nat. Hist., Jour., 2(1):10, Pl. 7, Figs. 3,3a.
- 1890 Jonesella crepidiformis (Ulrich), Ulrich, E. O., Cincinnati Soc. Nat. Hist., Journ., 13 (3):122, Pl. 7, Figs. 8a,b,c.
- 1894 Jonesella crepidiformis (Ulrich), Ulrich, E. O., Minnesota

Geol. and Nat. Hist. Surv., 3(2):667, Text-Figs. 47,a-c, 1897,
(advance edition, 1894, fide Bassler and Kellett, 1934).

(Figure reproduced from Ulrich, 1890.)

1911 Jonesella crepidiformis (Ulrich), Wade, A., Geol. Soc. London,
Quart. Jour., 67:451, Text-Fig. a-c.

1924 Jonesella crepidiformis (Ulrich), Foerste, A.F., Canada Geol.
Surv., Mem. 138, P. 254, Pl. 45, Fig. 7. (Figure reproduced
from Ulrich, 1890)

1961 Jonesella crepidiformis (Ulrich), Scott, H.W. and Hessland, I.,
Treatise on Invertebrate Paleontology, Pt. Q, P. 132, Fig. 64,
No. 2, Lawrence, Kansas. (Figure reproduced from Ulrich, 1890)

Diagnosis.--A Jonesella with a narrow, well defined, continuous "U"
shaped ridge; anterior sulcal node also well developed.

Description of Adults.--The valves are equal in size and subovate in
lateral view. Greatest height is usually anterior of the midlength,
rarely at or posterior to the mid-length. Greatest thickness is
sub-centrally located. Dorsal margin is straight and approximately
70% of the greatest length. Ventral margin is convex and grades into
the convex anterior and posterior margins. Anterior margin is more
tumid than the posterior. Cardinal angles are obtuse, subequal and
sharply defined. The anterior cardinal angle is approximately 130°
and the posterior approximately 150°. A narrow, well developed,
tubular in cross section, "U" shaped ridge occupies the anterior por-
tion of the valve and covers over 50% of the valve surface. Dorsal
extremities of the ridge extend above the hingeline. The ventral

most portion of the ridge extends to within 10% of the ventral margin. In addition, there is a slight sag in the centro-ventral portion of the ridge. S2 is large and occurs on the interior of the "U" shaped ridge. A low hemispherical node is located on the floor of S2 adjacent to the antero-dorsal limb of the ridge. The "U" shaped ridge and sulcal node are both reflected on the interior of the valve as a groove and associated circular depression. S2 is reflected as a raised area between the two lobes. Surface of the valve is granulose. No hingement was observed.

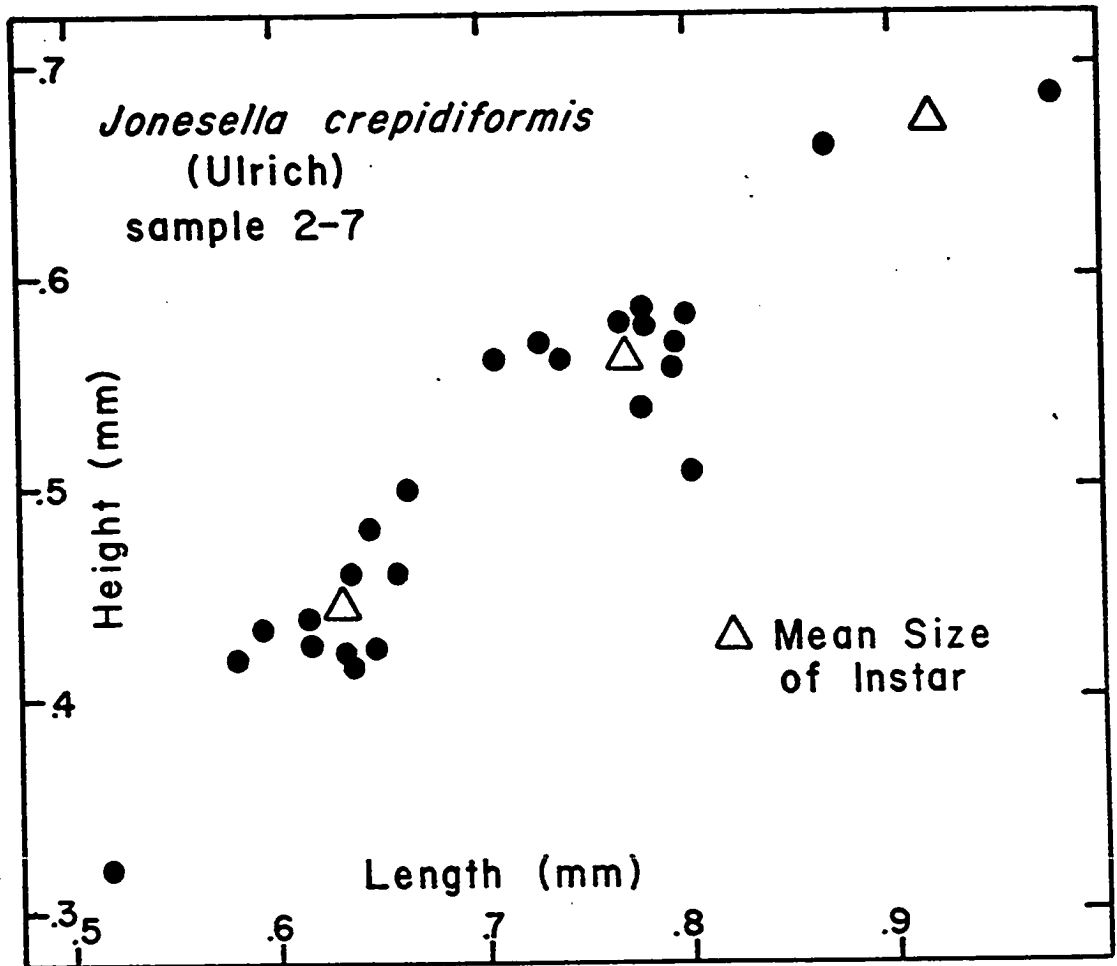
Measurements.--See table 4 for a statistical summary of 25 specimens from sample 2-7.

Ontogeny.--Although the material is limited, an examination of the size dispersion diagram (Text-Fig. 15) none the less indicates the existence of at least four growth stages, the Adult, Adult-1, Adult-2 and the Adult-3. This change in absolute size reflected by the diagram is also accompanied by a change in relative size and lobal morphology. The Adult-3 and Adult-2 are lower than the Adult-1 and Adult and display a progressive gain in height through ontogeny (data limited, see table 4 for H/L ratio values). This condition is opposite to what is generally observed in Paleocope ontogeny.

Development of the "U" shaped ridge can be followed from a two piece, poorly defined, structure with a wide ventral gap in the Adult-3, through the Adult-2 stage, where the ventral gap closes somewhat and the two ridges become more pronounced. In the Adult-1 and the Adult the ridge is extremely pronounced and the only indication of the

Table 4--Statistical summary of measurements for 25 specimens of Jonesella crepidiformis from sample 2-7 (in mm).

Statistic	Adult	Adult-1	Adult-2	Adult-3
N L	2	11	11	1
\bar{X} L	.922	.771	.631	.520
R L	.865-.980	.705-.810	.580-.665	---
s^2 L	---	.001	.001	---
s L	---	.032	.027	---
N H	2	11	11	1
\bar{X} H	.672	.562	.444	.320
R H	.660-.685	.510-.580	.418-.500	---
s^2 H	---	.000	.001	---
s H	---	.021	.027	---
N H/L	2	11	11	1
\bar{X} H/L	.731	.730	.703	.615
R H/L	.698-.763	.629-.794	.653-.751	---
s^2 H/L	---	.002	.001	---
s H/L	---	.045	.036	---



Text Fig. 15—Size dispersion diagram of Jonesella crepidiformis (Ulrich).

juvenile gap is the centro-ventral sag occurring in most of the specimens.

Discussion.--J. crepidiformis differs from J. interrupta by having a continuous "U" shaped ridge and lacking the dorsal horn. J. crepidiformis differs from J. tumida by the narrowness of its ridge and the presence of a well differentiated sulcal node.

The diagnosis of Jonesella given in part Q of the Treatise on Invertebrate Paleontology (P. 132) is, in reality, a description of J. crepidiformis and was therefore included in the specific synonymy.

Occurrence.--Found in 28 samples and occurred in Polythetic Range Zones A and B.

This species has also been reported from the Sheguiandah Formation of Ontario (Foerste, 1924).

Types.--Figured specimens

U.C.G.M. 40167

U.C.G.M. 40856

U.C.G.M. 40857

Jonesella interrupta n. sp.

Pl. 2, Figs. 1-6

Holotype.--An Adult right valve, U.C.G.M. 40168.

Type locality.--Rapid Run Section, Hamilton County, Ohio, Sample 2-1.

Type stratum.--Kope Formation, Edenian Stage, 197 feet below the contact with the Maysvillian Fairview Formation.

Derivation of the Name.--interrupta, refers to the interrupted nature

of the "U" shaped jonesellid ridge.

Material.--The following descriptive work is based upon sixteen complete specimens, the holotype and fifteen paratypes, from sample 2-1 and a single paratype from sample 1-40. Specimens were available from other samples but were, for the most part, broken and corroded.

Diagnosis.-- A Jonesella with a ventral gap in the "U" shaped ridge; dorso-central portion of the ridge modified into a large, sharp postero-dorsally directed horn.

Description of Adults.--The valves are equal in size and subovate in lateral view. Greatest height is at the mid-length and the greatest length is just ventral of the mid-height. Greatest thickness occurs in a subcentral position. The hingeline is straight and is approximately 65% of the greatest length. Ventral margin is convex and grades into the convex anterior and posterior margins. Posterior margin is more broadly rounded than the anterior. Cardinal angles are sharply defined, obtuse and subequal. Anterior cardinal angle is approximately 135° and the posterior cardinal angle approximately 140° . L1 is narrow, geniculate and tubular in cross section. L1 begins subcentrally, proceeds anteriorly and bends sharply towards the dorsal border. Dorsal extremity of L1 is rounded and extends above the hingeline. A low hemispherical swelling (anterior sulcal node) occurs midway on the posterior side of L1. L2 is shorter than L1, tubular in cross section and horn shaped. L2 is separated from L1 by a deep subcentral sulcus. Dorsal extremity of L2 is pointed, posteriorly directed and extends above the dorsal margin. Ventral

most portion of L1 extends to within 25% of the ventral border. S2 is large and occupies the area between L1 and L2. L1, L2 and the sulcal node are reflected on the interior of the valve as elongate and rounded depressions. S2 is reflected as a raised area between L1 and L2. The surface of the valve is granulose. No hingement was observed.

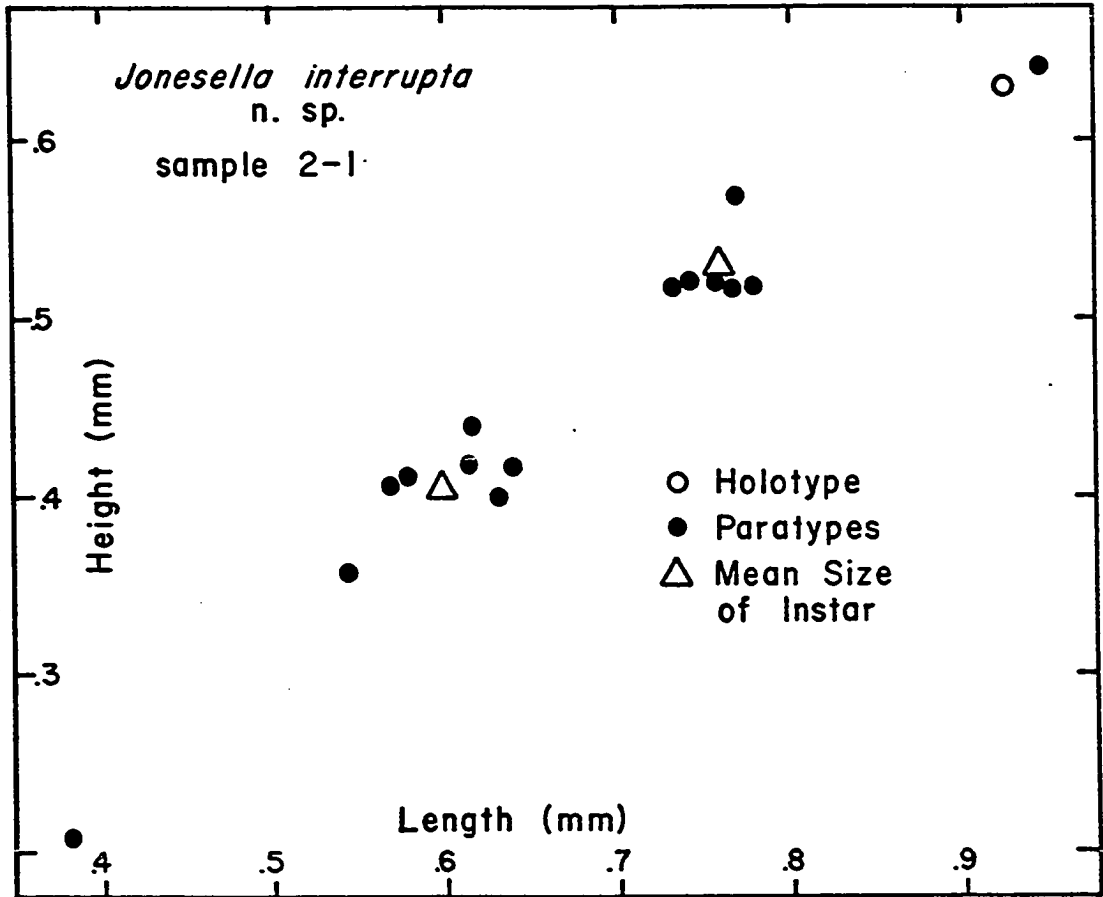
Measurements.--See table 5 for measurements of the Holotype and 15 Paratypes from sample 2-1.

Ontogeny.--Four growth stages, the Adult, Adult-1, Adult-2 and the Adult-3 were recovered during the present work. The paucity of material representing the Adult and the Adult-3 (see table 5) makes the analysis of the ontogenetic development quite tenuous. However, as presently understood, changes are limited, in addition to changes in absolute size, to the degree in which L1 and L2 are developed. In the Adult-3, the smallest instar recovered, L1 is without the geniculation and associated ventral portion. Therefore, L1 and L2 are approximately of the same length. The lobes are not as well defined as in the Adults and are subquadrate in cross section. L2 has already developed its horn like shape, however, the proximal portion is not yet as pointed as in the Adults. The Adult-2 is like the Adult-3 but with more tubular lobes and a geniculate L1. The horizontal section of L1 is poorly developed and the sulcal node consists of a swelling on L1 that does not contact the floor of S2. Complete development of L1 occurs in the Adult-1, causing this stage to closely resemble the Adult.

Table 5--Measurements of Holotype and 15 Paratypes of Jonesella interrupta from sample 2-1 (in mm).

U.C.G.M. no.	Length	Height	Height/Length	Comments
40168 *	.925	.628	.678	Right valve
40169	.547	.360	.658	Carapace
40858	.570	.408	.715	Left valve
40859	.621	.440	.708	Left valve
40860	.633	.400	.631	Carapace
40861	.735	.518	.704	Left valve
40862	.770	.571	.741	Left valve
40863	.615	.423	.687	Carapace
40864	.580	.410	.706	Right valve
40865	.642	.420	.654	Right valve
40866	.385	.211	.548	Carapace
40867	.758	.522	.688	Right valve
40868	.780	.520	.666	Right valve
40869	.945	.642	.679	Right valve
40870	.762	.521	.683	Right valve
40871	.738	.518	.701	Right valve

* Holotype



Text Fig. 16--Size dispersion diagram of *Jonesella interrupta* n. sp.

Paratypes

U.C.G.M. 40169
U.C.G.M. 40858
U.C.G.M. 40859
U.C.G.M. 40860
U.C.G.M. 40861
U.C.G.M. 49862
U.C.G.M. 40863
U.C.G.M. 40864
U.C.G.M. 40865
U.C.G.M. 40866
U.C.G.M. 40867
U.C.G.M. 40868
U.C.G.M. 40869
U.C.G.M. 40870
U.C.G.M. 40871
U.C.G.M. 40872

Jonesella tumida n. sp.

Pl. 1, Figs. 14-17

Holotype.--An Adult? right valve, U.C.G.M. 40873.

Type locality.--Moffett Road Section, Kenton County, Kentucky, Sample 1-40.

Type stratum.--Kope Formation, Edenian Stage, 23 feet 9 inches above the contact with the Middle Ordovician (Shermanian?) Point Pleasant

Formation.

Derivation of the Name.--tumida, refers to the tumid nature of the "U" shaped ridge.

Material.--The total material thus far recovered consists of fifteen specimens, all of them free valves, and approximately thirty fragments.

Diagnosis.--A Jonesella with a wide tumid "U" shaped ridge; ridge is subquadrate in cross section; a narrow channel occurs on the ventral most margin of the "U" shaped ridge; sulcal node consists of a large swelling on the posterior side of Ll.

Description.--The valves are equal in size and subovate in lateral view. Greatest height is just anterior of the mid-length and the greatest length is just ventral of the mid-height. Greatest thickness is subcentrally located. The hingeline is straight and is approximately 75% of the greatest length. Ventral margin is broadly convex and grades into the convex anterior and posterior margins. Anterior margin is more tumid than the posterior. Cardinal angles are both obtuse and subequal, approximately 130°. "U" shaped ridge is tumid, wide and subquadrate in cross section. Dorsal extremities of the ridge are rounded and extend above the hingeline. Anterior portion extends higher above the hingeline than does the posterior. Postero-ventral area of the ridge developed into a low posteriorly directed extension. A narrow channel occurs on the ventral margin of the ridge. The channel is concealed from lateral view by the sharp ventral edge of the "U" shaped ridge. The sulcal node is developed

as a general swelling on the antero-dorsal portion of Ll. Ventral most portion of the ridge extends to within 15% of the ventral margin. S2 occupies the area in the center of the ridge. The "U" shaped ridge is reflected on the interior of the valve as a wide groove and S2 is reflected as the raised area in the center of the groove. Surface of the valve is granulose. No hingement was observed.

Measurements.--See table 6 for the measurements of the holotype and 10 paratypes of Jonesella tumida.

Discussion.--As no large number of specimens was recovered from any one sample, a size dispersion diagram could not be obtained. However, if the largest specimens thus far obtained are taken to be the Adults, then the ultimate and penultimate stages possess a channel on the ventral edge of the "U" shaped lobe. However, the smallest specimen recovered (U.C.G.M. 40878) does not have the channel developed. In addition, the ridge of this small specimen occupies most of the valve surface.

When I originally recovered specimens of J. tumida, I felt that they might represent heteromorphs of J. crepidiformis. Since then, several factors have convinced me that we are dealing with two discrete species. Firstly, J. tumida and J. crepidiformis do not generally occur together, and are in fact, both found in only one of the samples, 5-7. Secondly, J. crepidiformis is longer ranging than is J. tumida. J. crepidiformis is found in Polythetic Range Zones A and B while J. tumida occurs only in Zone A. Thirdly, and most importantly, both species have their own separate growth stages, a

condition that would not be achieved if one was simply the dimorph of the other.

J. tumida differs from the other described species of Jonesella by the tumid nature of the "U" shaped ridge and the postero-ventral extension of the ridge.

Occurrence.--Found in 9 samples and restricted to Polythetic Range Zone A.

Types.--Holotype

U.C.G.M. 40873

Paratypes

U.C.G.M. 40874

U.C.G.M. 40875

U.C.G.M. 40876

U.C.G.M. 40877

U.C.G.M. 40878

U.C.G.M. 40879

U.C.G.M. 40880

U.C.G.M. 40881

U.C.G.M. 40882

U.C.G.M. 40883

Table 6--Measurements of Holotype and 10 Paratypes of Jonesella tumida from several samples (in mm).

U.C.G.M. no.	Length	Height	Valve	Sample no.
40873 *	.742	.525	Right	1-40
40874	.623	.428	Right	1-34
40875	.562	.411	Left	1-34
40876	.612	.443	Right	1-34
40877	.625	.451	Left	5-2
40878	Broken	.340	Right	5-2
40879	.665	.460	Left	5-2
40880	.600	.425	Left	5-2
40881	.680	.485	Left	2-1
40882	.721	.520	Right	2-1
40883	.717	.490	Left	2-1

*Holotype

Genus Pseudulrichia Schmidt, Emend.

1941 Pseudulrichia Schmidt, E. A., Senckenberg. Naturforsch. Ges.

Abh. 454, P. 59.

Type species.--Leperditia byrnesi Miller, 1874, the senior subjective synonym of Leperditia bivertex Ulrich, 1879.

Diagnosis.--Finely granulose to smooth Richinidae with two large, well defined lobes; lobes gently merge into valve just dorsal of the mid-height; L1 wide, curving and adjacent to the anterior margin; dorsal portion of L1 may be rounded or bulbous, may extend above hingeline; L2 located just posterior of the mid-length and may be modified into a large dorsal or dorso-laterally directed horn; L2 may also be rounded and bear a small dorsal spine; L2 invariably extends above the hingeline; S2 deeply incised and occupies area between L1 and L2.

Included species.--Leperditia byrnesi Miller, 1874

Primitia spinata Burr and Swain, 1965

Pseudulrichia norvegica Henningsmoen, 1954

Discussion.--Examination of the type specimens of Leperditia byrnesi Miller, 1874 (U.C. 8823) and Leperditia bivertex Ulrich, 1879 (U.S.N.M. 41365) reveals them to be conspecific. Therefore, L. bivertex, the type species of Pseudulrichia Schmidt, 1941, is a junior subjective synonym of L. byrnesi. The type species of Pseudulrichia must then bear the name of the senior subjective synonym, L. byrnesi. This change in type species greatly affects the concept of the genus Pseudulrichia for L. bivertex was based upon a broken, partially embedded specimen of L. byrnesi. The dorsal nodes attributed to Pseudulrichia

by Schmidt are, in reality, the dorsal portion of the anterior lobe and the base of a broken postero-dorsal horn. Concealed from view by the rock matrix are the hingeline, anterior and posterior margins.

Several of the species originally included in the genus must now be removed as they do not comply with the present emended concept. These species are, Beyrichia bipunctata Jones and Holl, 1865, Ulrichia girvanensis Jones, 1893 and Ulrichia furcata, Boucek, 1936. All of these forms share the occurrence of two rounded, centrally located, nodes. The exact systematic position of these species is presently not known, although they most probably represent a new genus.

Ulrichia marrii and Ulrichia nicholsoni, two species described and figured by Jones in 1893 may belong to Pseudulrichia. However, the original illustrations leave much to be desired and the whereabouts of the holotypes are not known. Due to these factors, neither of the species are being included in the genus.

Pseudulrichia byrnesi (Miller)

Pl. 2, Figs. 7-11

- 1874 Leperditia byrnesi Miller, S.A., Cincinnati Quart. Jour. Sci., 1:123, Text Fig. 10.
- 1879 Leperditia bivertex Ulrich, E. O., Cincinnati Soc. Nat. Hist. Jour., 2:11, Pl. 7, Figs. 5,5a.
- 1890 Aechmina byrnesi (Miller), Jones, T.R., Geol. Soc. London, Quart. Jour., 46:12, Pl. 3, Figs. 9-11.

Diagnosis.--A Pseudulrichia with L1 developed into a rounded lobe

that does not extend above the hingeline; L2 developed into a large postero-dorsally directed horn.

Description.--The valves are equal in size and subelliptical in lateral view. Greatest height is located at or posterior to the mid-length. Greatest length is just dorsal to the mid-height and the greatest thickness is sub-centrally located. Dorsal margin is straight and is approximately 70% of the greatest length. Ventral margin is convex and grades into the convex anterior and posterior margins. Anterior margin is more bluntly rounded than the posterior. Cardinal angles are both obtuse and poorly defined. However, the posterior cardinal angle is more sharply defined than the anterior. L1 is located just posterior of the anterior margin. L1 is curved, convex side facing posterior, and dorsally rounded. Anterior, dorsal and posterior boundaries of L1 are all moderately well defined. Ventral boundary of L1 is poorly defined and merges into the adventral surface of the valve. L2 is horn like and pointed. Proximal portion of the horn initiates in a centro-dorsal position. Distal portion of the horn extends above the hingeline and is posteriorly directed. S2 is deep, moderately wide and occupies the area between L1 and L2. Surface of the valve is coarsely granulose. No hingement was observed.

Measurements.--See table 7 for the measurements of the lectotype and 9 paralectotypes.

Discussion.--I have chosen a lectotype from among the eleven cotypes deposited in the Field Museum of Natural History. The specimen chosen was the largest and therefore has the greatest probability of

representing an Adult form. In addition, most of the other specimens were poorly preserved and did not exhibit all of the critical taxobases.

Miller (1874) in his original work on the species described the type locality as follows:

This species is found within a range of from 7 to 14 feet above low water-mark, under the bank of the Ohio River in the First Ward of Cincinnati. (P.123)

This would place the type occurrence as being within the Point Pleasant Formation of Middle Ordovician age.

In 1890 Ulrich assigned L. byrnesi questionably to the genus Dicranella. Likewise, in the same year Jones assigned it to Aechmina. However, Pseudulrichia byrnesi cannot be included in either genus for Dicranella is restricted to species possessing a well developed velate ridge and Aechmina for forms with only one dorsal horn and no anterior lobe.

Pseudulrichia spinata (Burr and Swain), from the Dubuque Formation of Minnesota, differs from P. byrnesi by lacking the large centro-dorsal horn. Instead, P. spinata possesses a dorsal spine originating from the apex of a rounded L2. P. norvegica Henningsmoen, from the Upper Ordovician of the Oslo region, has the dorsal most portion of L1 developed into a bulbous protuberance. In all other respects, P. norvegica closely resembles P. byrnesi.

For a discussion of Leperditia bivertex Ulrich, the junior

Table 7--Measurements of the Lectotype and 10 Paralectotypes of
Pseudulrichia byrnesi (in mm).

U.C. no.	Length	Height	Comment
8823 A *	1.202	.779	Right valve
8823 B	.990	---	Right valve
8823 C	.942	.670	Left valve
8823 D	1.020	.685	Left valve
8823 E	1.000	---	Right valve
8823 F	1.022	.718	Right valve
8823 G	1.037	.672	Left valve
8823 H	1.031	---	Left valve
8823 I	1.155	---	Left valve
8823 J	1.050	---	Right valve
8823 K	---	---	Right valve

* Lectotype

--- No information, due to either breakage or calcitic
overgrowths.

subjective synonym of P. byrnesi, see the section on the genus

Pseudulrichia.

Occurrence.--Found in 9 samples and occurs in Polythetic Range Zones A and B.

Millers types are from the Point Pleasant Formation of the Cincinnati area and represent the only other known occurrence of the species.

Types.--Lectotype

U.C. 8823A

Paralectotypes

U.C. 8823B

U.C. 8823C

U.C. 8823D

U.C. 8823E

U.C. 8823F

U.C. 8823G

U.C. 8823H

U.C. 8823I

U.C. 8823J

U.C. 8823K

Figured specimens

U.C.G.M. 40895

U.C.G.M. 40896

Family Aechminidae Boucek, 1936

Genus Aechmina Jones and Holl, 1869

Aechmina sp. A

Pl. 6, Figs. 1, 2

Description.--The valves are equal in size and sub-elliptical in lateral view. Greatest length of the valves is ventral to the mid height and the greatest height is anterior to the mid-line. The greatest thickness is in a centro-dorsal position. Dorsal margin is straight and is approximately 70% of the greatest length. Ventral margin is broadly convex and grades into the convex anterior and posterior margins; the anterior margin is more tumid than the posterior. Anterior and posterior cardinal angles are obtuse and sub-equal. The lateral surface of the valves are coarsely granulose. A single large dorsal spine arises from the centro-dorsal surface of the valves approximately 40% of the distance from the anterior cardinal corners. The spine is straight and slightly posteriorly directed. In length, the spine is approximately 60% of the greatest height. Small spine bases or papillae rim the posterior surface parallel to the free margin and in a velar position. A possibility exists that the papillae rim the entire free margin. No hinge structures were observed.

Measurements.--See table 8 for the measurements of the six measurable specimens.

Discussion.--Only 9 specimens were recovered from the present

samples. Of these, 3 were disarticulated valves and 6 were either pyritized or coarsely recrystallized carapaces. Due to breakage, only 1 valve (U.C.G.M. 40161) and 5 carapaces were sufficiently complete to allow measurement. The posterior papillae were observed on only one of the disarticulated valves (U.C.G.M. 40161). However, several of the recrystallized specimens exhibit some evidence for the existence of fine papillae rimming the entire free margin. The existence of these fine structures must remain questionable as the coarse recrystallization tends to make the task of differentiating morphologic traits from calcitic overgrowths extremely difficult.

The specimens of Aechmina sp. A show some similarity to A. maquoketensis Keenan (1951) from the Upper Ordovician Maquoketa Shale of Missouri. They differ in that A. maquoketensis has a thicker centro-dorsal spine and no postero-marginal papillae. In addition, A. maquoketensis has a depressed area surrounding the base of the centro-dorsal spine and no postero-marginal papillae. In addition, A. maquoketensis has a depressed area surrounding the base of the centro-dorsal spine and curved rows of small nodes covering the entire valve surface.

Aechmina sp. A shows a striking resemblance to A. richmondensis Ulrich and Bassler, an Upper Ordovician form from the Elkhorn Formation (?) of Indiana. My investigation of the type material of A. richmondensis (U.S.N.M. 82410) suggests that A. richmondensis is also characterized by possession of a row of spines parallel to the free margin. However, the type material consists of one slide with three specimens,

Table 8--Measurements (in mm) of Aechmina sp. A.

U.C.G.M. no.	Length	Height	Width	Hingeline	Spine	Sample no.
40161	.762	.453	----	.660	.261	2-28
40162	.701	.340	.282	.541	.182	2-36
40768	.240	.120	----	.201	----	4-5
40769	.619	.325	.220	.250	.185	5-19
40770	.259	.140	.120	.130	----	6-4
40771	.556	.300	.179	.478	----	8-2

Table 9--Measurements (in mm) of Aechmina sp. B.

U.C.G.M. no	Length	Height	Hingeline	Spine	Sample no.
40772	.405	.390	----	.301	2-10
40773	.250	.240	.200	.150	7-3

none of which is marked as the Holotype and all of which are either recrystallized carapaces or calcitic stienkerns. A problem arises from the fact that only one of the specimens clearly shows the development of the marginal spines. The other two specimens are more coarsely recrystallized and offer only tentative evidence as to the existence of these structures. In addition, the specimen showing the best development of the marginal spines is also the smallest and has the shortest dorso-median spine. Whether or not this is simply a juvenile of A. richmondensis or a different species remains to be investigated. At present, the only recognizable difference between the two species is that Aechmina sp. A. has a granulose surface and A. richmondensis a smooth one.

Occurrence.--Aechmina sp. A is limited to Polythetic Range Zones B and C. and occurred in 4 samples.

Types.--Figured specimens

U.C.G.M. 40161

U.C.G.M. 40162

Measured specimens

U.C.G.M. 40768

U.C.G.M. 40769

U.C.G.M. 40770

U.C.G.M. 40771

Aechmina sp. B.

Pl. 6, Figs. 4-6

Description.---The valves are equal in size and semi-circular in lateral view. Greatest length is at mid-height and greatest height is at mid-length. The length is slightly longer than the height. Dorsal margin is straight and in the smaller specimens is approximately 80% of the greatest length. The convex ventral, anterior and posterior margins grade continually into one another and cannot be separated. Cardinal corners are obtuse and sub-equal. The surface area of the valves is granulose, which may be due to coarse recrystallization. A slightly posteriorly directed spine arises from the dorso-median portion of the valves and is approximately 70% as long as the greatest height. On the larger specimens, the spines are tumid near the proximal portion but rapidly constricts 60% of the distance to the distal end. The smaller specimens have narrow, relatively long spines with no constrictions. No hinge structures were observed.

Measurements.---See table 9 for the measurements of the two measurable specimens.

Discussion.---Of the three specimens (all recrystallized carapaces) of Aechmina sp. B. recovered during this investigation, only two were complete enough to be measured. The other specimen was broken and overgrown by secondary deposits of calcite. Even the complete specimens are coarsely preserved and show evidence of crushing.

This species differs from all other species of Aechmina in its sub-circular outline. Unfortunately, the distinct possibility exists that I am not dealing with a true animal taxon but may, in fact, be

dealing with an artifact of preservation, in which case, these specimens could be considered broken, weathered specimens of some other species of Aechmina. The problem will not be solved until better material is recovered.

Occurrence.--Aechmina sp. B was found in three samples from Polythetic Range Zone B.

Types.--Figured specimens

U.C.G.M. 40773

U.C.G.M. 40772

Aechmina sp. C

Pl. 6, Fig. 3

Discussion.--These two incomplete specimens are being treated as a separate taxonomic entity for the following reasons. Firstly, the dorso-median spines are more tumid than either of the preceeding species of Aechmina. Secondly, the anterior marginal surface is papillous, versus a papillous posterior margin for Aechmina sp. A. Lastly, the surface of the valves appears to be smooth. Breakage of the valves prevents the examination of the posterior and ventral margins. Therefore, the possibility exists that these specimens belong to either a previously described Edenian Aechmina or to some unknown representative of the genus.

Occurrence.--Aechmina sp. C. occurred in one sample from Polythetic Zone A.

Types.--Figured specimen

U.C.G.M. 40774

Superfamily Hollinacea Swartz, 1936

Family Tetradellidae Swartz, 1936

Subfamily Glossomorphae Hessland, 1953

Genus Ctenobolbina Ulrich, 1890

Type species.--Beyrichia ciliata Emmons, 1855

Ctenobolbina ciliata (Emmons)

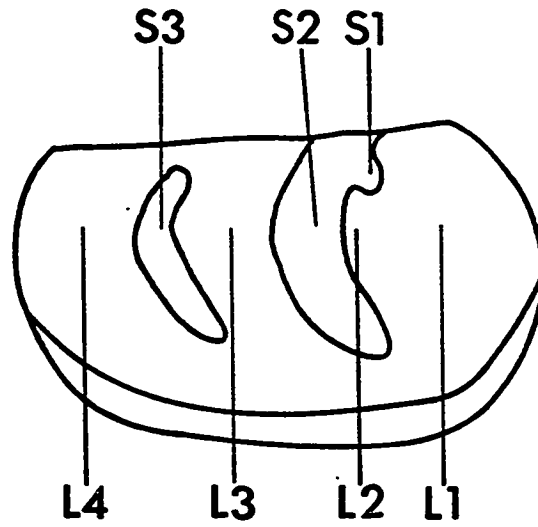
Pl. 3, Figs. 1-5, Pl. 4, Figs. 1-3

- 1855 Beyrichia ciliata Emmons, E., American Geology, 1(2):219,
Text-Fig. 74C. Lesley, J. P., 1889, Geol. Surv. Pennsylvania
Rept., P. 4, P. 89, Text-Fig. 3b.
- 1890 Beyrichia ciliata Emmons, Jones, T. R., Geol. Soc. London,
Quart. Jour., 46:19, Pl. 3, Figs. 12-16, Pl. 4, Figs.
16-18.
- 1890 Ctenobolbina ciliata (Emmons), Ulrich, E. O., Cincinnati
Soc. Nat. Hist., 13:108, Pl. 7, Figs. 1a-b.
- 1890 Ctenobolbina bispinosa Ulrich, E. O., Cincinnati Soc. Nat.
Hist., 13:110, Pl. 7, Fig. 6.
- 1911 [NOT] Ctenobolbina ciliata (Emmons) Wade, A., Geol. Soc.
London, Quart. Jour., 67:452, Pl. 36, Fig. 6.
- 1951 Ctenobolbina bispinosa Ulrich, Keenen, J. E., Jour. Pale-
ontology 25:564, Pl. 78, Fig. 1.

Diagnosis.--A Ctenobolbina with two large curved sulci, S2 and S3,
and one severely reduced sulcus, S1; Incipient S1 is located on the

antero-dorsal portion of L1; S2 is deep, wide and extends to the dorsal border; S3 is shallow and does not extend to dorsal border; ventral portion of prominent L3 rarely has a small laterally directed spur; commonly no spur occurs.

Description of Adult Technomorphs.---The valves are subrectangular in lateral view and are equal in size. Greatest height occurs just anterior to S1 and the greatest length occurs just dorsal to the mid-height. The thickest portion of the valve is coincident with the mid height of L3. Dorsum is straight, approximately 75% of the greatest length, and slightly epicline. Ventral margin is straight and sub-parallel to the dorsal margin. Anterior and posterior margins are both convex, with the anterior being more broadly rounded than the posterior. Cardinal angles are both obtuse, with the anterior being greater (ca. 145°) and more sharply defined than the posterior (ca. 135°). L1 is bulbous and subrounded, with the dorsal portion extending above the hingeline. A shallow reentrant occupies the postero-dorsal corner of L1; this reentrant represents a reduced S1 (see text-Fig 17). L2 is also poorly developed and is simply a small extension of L1. L2 is separated from L3 by a wide, deep, curving (concave towards the anterior of the valve) and long (extends from the hingeline 75% of the distance to the dorsal edge of the velate frill) sulcus, S2. L3 is long, prominent and convex. Ventral portion of L3 may have a small laterally directed spur, which is often broken, leaving a circular base. L3 is separated from L4 by a wide shallow sulcus, S3. S3 is restricted to the mid portion of the valve and does



Text Fig. 17—Illustration showing the position of the lobes and sulci on an Adult Technomorph of *Ctenobolbina ciliata* (Emmons).

not extend to the hingeline. L4 is extremely wide and joins with L3 dorsally. All of the lobes are joined by a ventral connecting lobe. The surface of the lobes and sulci is coarsely papillate, with the exception of S2, which is smooth. A narrow, concave velate frill extends from the ventral portion of the anterior margin across the adventral surface to the ventral portion of the poster margin. The surface of the frill is striato-reticulate and has faint radiating ribs. The subvelar field consists of a narrow canaliculus situated between the inner side of the frill and a row of marginal spines. No hingement was observed.

Description of Heteromorphs.--The heteromorphs are like the Adult technomorphs in every way except in the development of the dimorphic characters. In the Heteromorphs the frill is wide, convex and develops an anterior frill funnel on the mid anterior margin. Additionally, the Heteromorphic frill is positioned higher on the valve flank than in the Technomorph. The distal edge of the velate frill actually consists of two low ridges, the inner one lined with spines, separated by a narrow channel; this is visible only on well-preserved specimens. The infravelar antrum is deep, long and wide. The outer antral fence consists of the inner surface of the velate frill, while the inner antral fence consists of a marginal ridge with superimposed spines.

Measurements.--See table 10 for a statistical summary of the measurements of the 78 specimens from sample 12-1.

Ontogeny.--The size dispersion diagram (Text-Fig. 18) indicates the

Table 10--Statistical summary of measurements for 78 specimens of Ctenobolbina ciliata from sample

12-1 (in mm).

Statistic	Adult		Adult-1	Adult-2	Adult-3
	Technomorph	Heteromorph			
N L	26	17	22	10	3
\bar{X} L	1.776	1.759	1.453	1.179	.896
R L	1.619-1.925	1.650-1.930	1.340-1.542	1.102-1.255	.865-.922
s^2 L	.006	.005	.003	.002	.001
s L	.078	.068	.059	.044	.029
N H	26	17	22	10	3
\bar{X} H	1.035	1.044	.819	.654	.559
R H	.901-1.135	.953-1.145	.758-.865	.620-.702	.535-.582
s^2 H	.003	.003	.001	.001	.001
s H	.057	.052	.036	.029	.027
N H/L	26	17	22	10	3
\bar{X} H/L	.582	.593	.563	.555	.624
R H/L	.517-.612	.558-.635	.511-.609	.504-.603	.594-.647
s^2 H/L	.000	.001	.001	.001	.001
s H/L	.021	.023	.025	.031	.027

existence of at least four growth stages, the Adult, Adult-1, Adult-2, and the Adult-3. The smallest of these instars, the Adult-3, is subelliptical in lateral view. Throughout the remainder of ontogeny, the species becomes progressively more rectangular.

The Adult-3 has two spines, a lateral spine located at the base of L3 and a dorsal spine initiating from the postero-dorsal portion of L3. Both of the spines are posteriorly inclined. They occur in the Adult-2 and the Adult-1 as well, but, in the Adult, the dorsal spine is lost and the lateral one only rarely occurs as a spur-like spine. The trisulcate condition found in the Adults originates in the Adult-2 and increases in developmental intensity during the Adult-1. However, the Adult-3 does not have S3 yet developed and is therefore bisulcate. L3 may be recognized as an elongate, raised area just posterior to S2.

No velar structures are recognizable in the Adult-3. In the Adult-2, however, a row of low spines develops on the adventral surface. This row of spines occurs in the penultimate stage and eventually develops into the velate frill of the Adults. In addition to the velar spines, the Adult-1 has a lateromarginal bend developed.

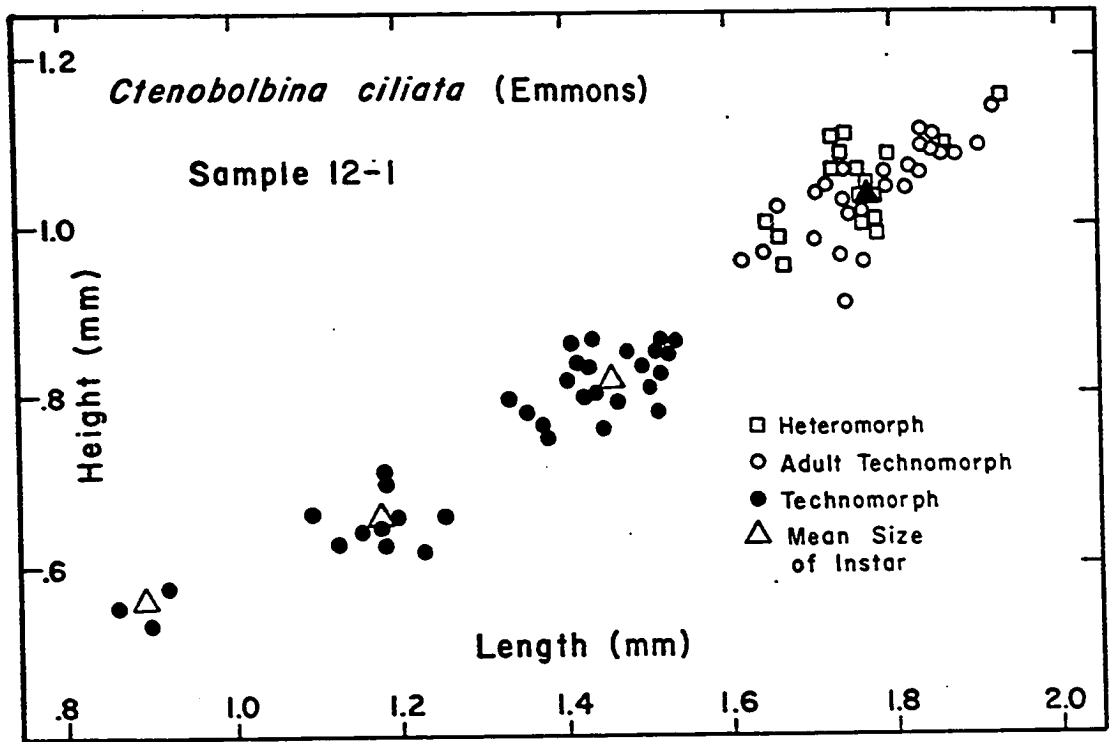
All of the instars are coarsely pappilose.

Discussion.--The velate frill of the Heteromorphic valve is located in a position corresponding to the histial flange of other species. However, as no additional adventral structure (in addition to the marginal spines) occurs on the Heteromorph, this character must be considered velar in origin. This shift of the velum from the adventral to

the histial area was made necessary in order to accommodate the wide infravelar antrum. According to Jaanusson (1966), the lack of a true histium would disqualify Ctenobolbina from the subfamily Glossomorphytinae. Schallreuter (1966), on the other hand, definitely includes Ctenobolbina in his concept of the subfamily. Additionally, Jaanusson admits that this group is poorly understood and needs further revision. Therefore, Ctenobolbina is provisionally being included in the Glossomorphytinae until this subfamily is better understood.

I have examined the cotypes (U.S.N.M. 41490) of Ctenobolbina bispinosa Ulrich, 1890, and have found them to be identical with the juveniles of C. ciliata. Therefore, C. bispinosa is a junior subjective synonym of C. ciliata and is herein placed into synonymy with it. Conversely, the specimen assigned to C. ciliata by Wade (1911) is not identical to C. ciliata and may, in fact, represent some other genus.

The holotype (U.C. 52000) of C. tumifrons (Hall, 1871), a species previously placed into synonymy with C. ciliata (Ulrich, 1890; Bassler and Kellett, 1934), was observed to differ by having a more deeply incised S2 and a narrower, more pronounced L3, which does not lose its ventral definition by merging into the connecting lobe. The label included in the box with the small slab of limestone bearing the holotype reads "...Eden Formation, Cincinnati Ohio." However, an old label attached to the slab itself reads "Beryichia tumifrons, Cincinnati gr., Oxford O." Specimens of Quadrijugator sp. occur on the slab. As this genus is not presently known (in the Cincinnati area) from rocks older than Richmondian, this slab is



Text Fig. 18—Size dispersion diagram of Ctenobolbina ciliata (Emmons).

most certainly not from the Edenian. While some Richmondian rocks do outcrop in the westernmost portion of Cincinnati, they are extremely well exposed in the area around Oxford, Ohio. Therefore, C. tumifrons is certainly Richmondian in age and the holotype most probably originates from Oxford.

The holotype of C. emaciata Ulrich, 1890 (U.S.N.M. 41325), from the Maquoketa Formation at Savannah, Illinois was observed to have a shallow S3 and a bifurcating S2. This dorsal bifurcation forms a mammelose protuberance on the dorsal portion of the lateral surface. In addition, the anterior most limb of the bifurcation is much wider and deeper than the posterior portion.

Examination of the cotypes of C. hammelli Miller and Faber, 1894 (U.C.G.M. 1322; U.C. 21709), from the Richmondian of Versailles, Indiana, reveals that species to be intermediate between C. tumifrons and C. emaciata, in that it has a pronounced L3 and a bifurcating S2. However, the posterior most limb of the bifurcation is not as well developed as in C. emaciata.

Cotypes of C. alata Ulrich, 1890 (U.S.N.M. 41489), from the Edenian of Cincinnati, were found to differ from C. ciliata by the development of extremely large, lateral, alate processes.

The cotypes of C. duryi Miller, 1874 (U.C. 8878), from the Maysvillian at Cincinnati, were observed to be unisulcate (no indication of S1 or S3) and may represent a species of the genus Hesslandella Henningsmoen, 1953. Unfortunately, the type material is badly corroded and difficult to study.

C. curta Ulrich, 1890, a supposed Edenian form with no available types, may simply represent a juvenile of C. ciliata or C. alata in which the dorsal spine has become aligned with L3, giving the illusion of a projecting lobe. See Ulrich's type figure (1890, Pl. 7, Fig. 2) for a further comparison.

Occurrence.--Found in 11 samples and ranges from Polythetic Range Zones A-C.

This species has also been reported from the upper Utica Shale at Green Island and Menands, New York (Reudemann, 1901) and the Pholadomorpha zone of the Lorraine Formation of Quebec (Foerste, 1924).

Types.--Figured specimens

U.C.G.M. 40838

U.C.G.M. 40839

U.C.G.M. 40840

U.C.G.M. 40843

U.C.G.M. 40844

U.C.G.M. 40846

U.C.G.M. 40847

U.C.G.M. 40848

Measured specimens

U.C.G.M. 40841 (1 slide with 35 specimens)

U.C.G.M. 40842 (1 slide with 34 specimens)

Ctenobolbina cf. alata Ulrich

Pl. 4, Figs. 4-7

1890 Ctenobolbina alata Ulrich, E. O., Cincinnati Soc. Nat. Hist.
 Jour., 13: 110, Pl. 7, Figs. 4a-c.

Discussion.--Although eleven specimens of this species were recovered, none of them were sufficiently complete for definite identification. However, these fragmental specimens were distinguished from C. ciliata by the occurrence of a large alate process. This was deemed possible for as presently understood, C. alata is the only member of the genus with this character. In all other aspects, including the occurrence of an infravelar antrum in the heteromorphs, C. alata closely resembles C. ciliata.

Measurements.--Due to the fact that none of the present specimens were measurable, I measured the only properly oriented cotype (U.S.N.M. 41489, consists of six specimens permanently glued to a single slide). The specimen is 1.822 mm in length and .920 mm in height.

Occurrence.--Found in 8 samples from Polythetic Range Zones B and C.

This species has not been reported to occur in any rocks other than the Edenian of the Cincinnati area.

Types.--Cotypes

U.S.N.M. 41489 (six specimens on one slide)

Figured specimens

U.S.G.M. 40850

U.C.G.M. 40851

Family Eurychilinidae Ulrich and Bassler, 1923

Genus Euprimitia Ulrich and Bassler, 1923

?Euprimitia minuta Keenan

Pl. 6, Fig. 7

1951 Euprimitia minuta, Keenan, J. E., Jour. Paleontology, 25:568,
Pl. 78, Fig. 17.

Discussion.--This small species is represented by specimens that are either pyritized or recrystallized. Both modes of preservation are gross and have tended to mask the morphologic characters. Identification was made possible by the limited recovery of some good material. A complete description was presented by Keenan (1951).

Measurements.--See table 11 for the measurements of 12 specimens from sample 8-2.

Occurrence.--Found in 56 samples and occurs in Polythetic Range Zones A, B and C.

This species has also been reported from the upper Ordovician Maquoketa Shale of Missouri (Keenan, 1951).

Types.--Figured specimen

U.C.G.M. 40852

Measured specimen

U.C.G.M. 40853 (11 specimens on 1 slide)

Table 11--Measurements of ?Euprimitia minuta from Sample 8-2 (in mm).

U.C.G.M. no.	Box no.	Length	Height	Comments
40852	---	.321	.175	pyritized carapace
40853	1	.325	.162	pyritized carapace
40853	2	.240	.139	pyritized carapace
40853	3	.280	.141	pyritized carapace
40853	4	.335	.163	recrystallized carapace
40853	5	.321	.159	recrystallized carapace
40853	6	.324	.180	recrystallized carapace
40853	7	.341	.160	pyritized carapace
40853	8	.339	.181	pyritized carapace
40853	10	.304	.140	pyritized carapace
40853	11	.307	.180	pyritized carapace
40853	12	.300	.160	pyritized carapace

?Euprimitia sp.

Pl. 6, Fig. 8

Discussion.--Four specimens of a species closely resembling ?Euprimitia minuta were recovered during the present sampling. These specimens differ from ?E. minuta by being more elongate and possessing a relatively large dorsal node. The node, in addition to the poorly defined pre-sulcal node, is situated between the anterior dorsal corner and S2. In addition, the marginal rim is not as well developed as in ?E. minuta.

Measurements.--The figured specimen, and only measurable one, is .380 mm in length and .172 mm in height.

Occurrence.--Found in 2 samples from Polythetic Range Zone A.

Types.--Figured specimen

U.C.G.M. 40854

Family Ctenonotellidae Schmidt, 1941

Subfamily uncertain

Discussion.--Schallreuter (1966) in his review of the Ctenonotellidae recognized three subfamilies, the Ctenonotellinae Schmidt, 1941, the Wehrliinae Schallreuter, 1965 and the Steusloffinae Schallreuter, 1966. Tallinnella Opik, 1937, a genus considered closely related to Ceratopsis Ulrich, 1894, by the present author, was included in the Ctenonotellinae. However, Jaanusson (1972, personal communication) has informed me that new material indicates Ctenonotella, the type genus of the family, is in reality a Piretillid. Therefore, the non Piretillid genera included in the Ctenonotellinae must be removed from the subfamily and the subfamily removed from the Ctenonotellidae. A new subfamily, or at least a redistribution of the genera into the two valid subfamilies, must now be established for Kiesowia Ulrich and Bassler, 1908, Tallinnella Opik, 1937, Tetrada Neckaja, 1958, Quadritia Schallreuter, 1966 and Ceratopsis Ulrich, 1894. This undertaking is beyond the scope of the present study as all of the genera involved, with the exception of Ceratopsis, are restricted to Europe and have not been adequately described. Lacking first hand knowledge of the morphologic characteristics, I feel that a familial revision would be, at best, a tenuous approximation.

Genus Ceratopsis Ulrich, 1894

Type species.--Beyrichia chambersi Miller, 1874

Ceratopsis chambersi (Miller)

Pl. 5, Figs. 1-7

- 1874 Beyrichia chambersi Miller, S.A., Cincinnati Quart. Jour. Sci. 1:234, Text-Fig. 27. Cumings, E. R., 1908, (as Ceratopsis chambersi), Indiana Geol. and Nat. Hist. Surv., 32nd. Ann. Rept., P. 1042, Pl. 53, Figs. 1, 1a (figures are reproduced from Hall and Whitefield, 1875).
- 1875 Beyrichia chambersi [?] Miller, Hall, J., and Whitfield, R. P. Ohio Geol. Surv., 2(2):104, Pl. 4, Figs. 11-12. Bassler, R.S., 1919 (as Ceratopsis chambersi), Maryland Geol. Surv., Cambrian and Silurian Vol., P. 369, Pl. 55, Fig. 34.
- 1894 [Non] Ceratopsis chambersi (Miller), Ulrich, E. O., Minnesota Geol. and Nat. Hist. Surv., 3(2):676, Pl. 46, Figs. 19-22, 1897 (advance edition, 1894, fide Bassler and Kellett, 1934).
- 1951 Ceratopsis chambersi (Miller), Keenan, J.E., Jour. Paleont., 25:564, Pl. 78, Fig. 7.

Diagnosis.--A Ceratopsis with an elongate sub-conical speral process; Lateromarginal flange well developed in the Adults; Infravelar antral dimorphism present, Technomorphs with narrow concave velar frill, Heteromorphs with wide convex frill.

Description of Adult Technomorphs.--The valves are equal in size and subelliptical in lateral view. Greatest length is slightly dorsal to the mid-length and the greatest length is slightly dorsal to the

mid-height. Greatest thickness is coincident with the central portion of the lateromarginal flange. Hingeline is slightly convex and is approximately 85% of the greatest length. Ventral margin is strongly convex and grades into the convex anterior and posterior margins. The anterior margin is more bluntly rounded than the posterior. Cardinal angles are obtuse and subequal, approximately 130° . Velate frill is narrow and concave, present on the anterior and ventral portions of the valve but lacking on the posterior. Velate frill and the marginal rim are sub-parallel around the entire free margin and coalesce at the antero-dorsal and postero-dorsal cardinal corners. A wide prominent canaliculus is developed around the entire free margin between the velate frill and the marginal rim. In lateral view the marginal rim is concealed by the velate frill around the entire margin. L1 is prominent and modified into a large sub-conical speral process. The edge of the process is serrated into comb like teeth. Distally the speral process is sharp and directed postero-dorsally. L2 is short, narrow, inclined posteriorly, and does not reach the dorsal margin. Dorsal-most portion of L2 is separated from the rest of the lobe by a shallow horizontal sulcus. The separated portion consists of a small hemispherical node of translucent calcite and may represent an eyespot. L2 is inclined posteriorly and is separated from L1 by a narrow shallow sulcus (S1) and from L3 by a wide deep sulcus (S2). L3 is long, narrow and extends to the dorsal margin. L3 is curved, with the concave side facing anteriorly, and separated from L2 by a wide deep sulcus. L3 and L4 are separated by

a wide extremely shallow sulcus. L4 is wide, not very well defined, and grades into the posterior and postero-dorsal margins. All of the lobes are ventrally connected by an acute latero-marginal bend. The crest of the bend is sharply defined and sags ventrally, creating a lateromarginal flange. A hemi-conical channel is formed beneath the lateromarginal flange in a supra-velar position. The lateromarginal flange is parallel to the velate frill around the anterior and antero-ventral margins but coalesces with the velate frill on the posterior margin. S1 is narrow, shallow and joins S2 dorsally. S2 is wide, deep and extends approximately 75% of the way to the ventral margin. S2 is curved with the concave side facing anterior. S3 is extremely shallow and poorly defined. Entire surface of the valves, including the velum, is finely reticulate. No hingement was observed.

Description of Hetermorphs.--The heteromorphs are like the Adult technomorphs in every way except in the development of the velate frill. In the heteromorphs, the frill is extremely wide, convex and distally recurved, thereby forming an elongate dolonal antrum. In addition, faint radiating ribs are present on the lateral surface of the frill. Examination of the one nearly complete carapace indicates that the right and left frill borders do not meet, thereby creating a gap around the entire ventral margin.

Measurements.--See table 12 for a statistical summary of the measurements of 63 specimens from sample 12-1.

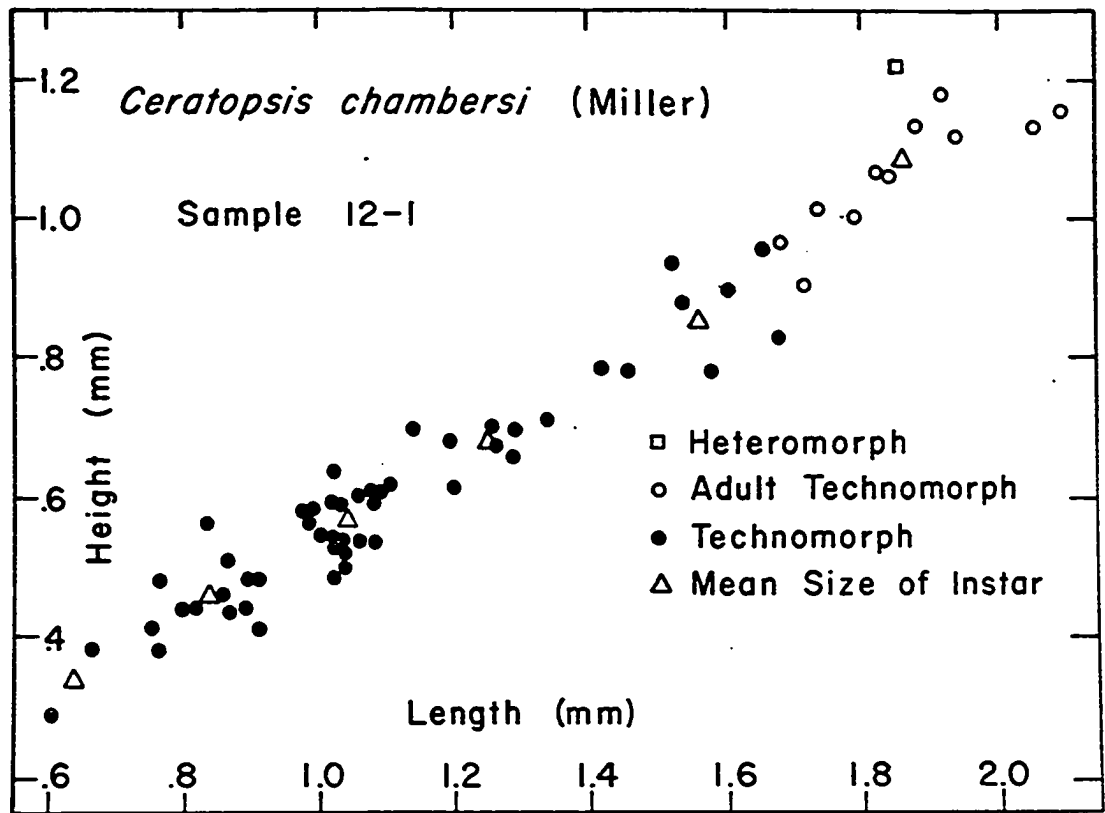
Ontogeny.--Examination of the size dispersion diagram (text fig. 19) reveals the existence of at least 6 growth stages, the Adult, Adult-1,

Table 12--Statistical summary of measurements (in mm) of 63 specimens of Ceratopsis chambersi from

sample 12-1.

Statistic	Adult	Adult-1	Adult-2	Adult-3	Adult-4	Adult-5
N L	12	8	8	20	13	2
\bar{X} L	1.863	1.558	1.248	1.037	.841	.637
R L	1.678-2.100	1.420-1.681	1.141-1.340	.975-1.105	.752-.911	.630-.665
s^2 L	.017	.008	.004	.001	.003	-----
s L	.129	.091	.065	.037	.057	-----
N H	12	8	8	20	13	2
\bar{X} H	1.083	.857	.679	.567	.456	.335
R H	.910-1.219	.779-.961	.610-.715	.480-.639	.381-.563	.290-.380
s^2 H	.009	.005	.001	.002	.002	-----
s H	.095	.074	.033	.042	.047	-----
N H/L	12	8	8	20	13	2
\bar{X} H/L	.581	.546	.546	.546	.543	.523
R H/L	.528-.659	.493-.618	.508-.613	.472-.628	.450-.674	.475-.571
s^2 H/L	.001	.002	.001	.002	.003	-----
s H/L	.035	.043	.034	.041	.058	-----

Adult-2, Adult-3, Adult-4 and Adult-5. The earliest stage, the Adult-5, is bisulcate with S2 being more strongly developed than S1. No latero-marginal bend or flange is yet developed. In fact, the latero-marginal surface of the valves is convex, and as in the Adults, finely reticulate. The velar structure is limited to a low ridge on the adventral surface but lacking on the anterior. A strongly developed marginal ridge is parallel to the entire free margin and is not concealed by the velar ridge. Calculation of the H/L ratio (table 12) demonstrates that the Adult-5 is lower than in the Adult. However, this factor must remain tenuous as the smaller specimens are rare and therefore poorly represented. The H/L ratios for the Adult-1--Adult-4 is very constant and does not change until the Adult stage is attained. There is also an ontogenetic change in the lateral outline of the valves. In the Adult-5 the greatest height is located in an extreme anterior position. During the rest of ontogeny the greatest height moves progressively away from the anterior border until, in the Adult, it is just anterior to the mid-length. The Adult-4 is trisulcate and has a velate ridge developed on both the anterior and ventral borders. These conditions also occur in the Adult-3 and the Adult-2, although they do show a steady increase in the intensity of development of the lobes and sulci. A very close similarity exists between the Adult and the Adult-1, the most obvious difference being the occurrence of the lateromarginal flange in the Adult but not in the Adult-1. In fact, the occurrence of the lateromarginal flange was the unique criterion used to differentiate the Adult and the



Text Fig. 19--Size dispersion diagram of *Ceratopsis chambersi* (Miller).

Adult-1 for the size dispersion diagram. The Adult-1, however, does have a lateromarginal bend (sometimes acutely developed) developed and therefore differs from the earlier instars. Another difference between the Adult and Adult-1 is in the development of the velar frill: in the Adult-1, the frill conceals the marginal rim ventrally but not anteriorly, while in the Adult, the frill conceals the entire marginal rim.

Discussion.--In his original description of the species in 1874, Miller reported the following:

I first found it in the excavation for Columbia Ave.,
in Cincinnati, about 150 feet above low water mark;
(p. 234)

This would fix the original occurrence as being in the shales of the type Edenian. However, Miller further wrote:

Subsequently I found it at Richmond Indiana, in
the upper part of the Cincinnati Group. (p. 234)

A cursory examination of specimens of Ceratopsis from the Richmondian of Indiana reveals differences in morphology of at least a specific nature. Therefore, I am reserving the name Ceratopsis chambersi for forms identical to the Edenian specimens herein described. This restriction is made necessary as the whereabouts of the holotype is presently unknown. Furthermore, no other species of Ceratopsis, with the exception of C. intermedia, a form without the large spiral process described by Miller (1874), have been recovered during the present extensive sampling of the Edenian in its

type area. Accordingly, the identification of the specimens described and poorly figured by Hall and Whitefield (1875) from the Richmondian near Waynesville, Ohio, have been questioned in the synonymy. In 1890, Ulrich reported and figured C. chambersi from the Middle Ordovician Decorah Shale of Minneapolis and Cannon Falls, Minnesota. Examination of topotype material reveals that this species is also distinct from C. chambersi sensu strictu. As far as can yet be ascertained, the Trentonian and Richmondian specimens previously assigned to C. chambersi are distinct and separate entities, differing from C. chambersi in the development of the dimorphic characters and the disposition of the speral process. Further information as to the nature of these specimens must await future investigation.

Ceratopsis chambersi differs from the other described Cincinnati members of the genus, C. intermedia and C. oculifera, by the extreme development of the speral process. In C. intermedia, the process is short and subtriangular while in C. oculifera, it is short and circular. More important, however, C. chambersi exhibits velar dimorphism. Thus far no sexual dimorphism has been reported for C. intermedia, C. oculifera or any other described member of the genus. Admittedly though, the heteromorphs of C. chambersi are rare and fragile, thereby making them unknown until the present study. This delicate nature of the valves could also explain the lack of heteromorphic valves for the other described species of Ceratopsis.

Examination of the holotype (U.S.N.M. 41335) of C. robusta Ulrich, from the Richmondian of Minnesota, reveals a great similarity

between that specimen and the Adult-1 of C. chambersi. In particular, both forms have a lateromarginal bend but no lateromarginal flange. Whether or not the holotype of C. robusta represents an Adult of a paedomorphic derivative of C. chambersi or simply the juvenile of some Richmondian species remains to be investigated.

Keenan (1951) figured but did not describe C. chambersi from the base of the Edenian at Cincinnati. This was the first photograph of the species ever to be published and for that reason was included in the synonymy. All previous figures were merely inaccurate generalized drawings.

Occurrence.--Found in 52 samples (mostly as isolated spiral processes) and occurs in Polythetic Range Zones A, B and C.

C. chambersi has also been reported from the Richmondian Liberty Formation of Richmond and Versailles, Indiana (Cummings, 1908), the Upper Ordovician Indian Lateral beds of Albany County, New York (Ruedemann, 1912), the Eden division of the Martinsburg Shale of Pennsylvania and Maryland (Bassler, 1919) and the Middle to Upper Ordovician Utica and Lorraine Formations of New York (Ruedemann, 1926).

Types.--Figured Specimens

U.C.G.M. 40171

U.C.G.M. 40812

U.C.G.M. 40816

U.C.G.M. 40817

U.C.G.M. 40818

U.C.G.M. 40819

U.C.G.M. 40820

Measured Specimens

U.C.G.M. 40814 (47 specimens on one slide)

U.C.G.M. 40815 (9 specimens on one slide)

Ceratopsis cf. intermedia Ulrich

Pl. 6, Fig. 17

1894 Ceratopsis intermedia Ulrich, E. O., Geol. Minnesota, 3(2):676,
1897 (advance edition, 1894, fide Bassler and Kellett, 1934).

Discussion.--Two specimens of this species were recovered from the Twelve Mile Creek Section. Both of the specimens were poorly preserved and extremely overgrown with secondary calcite. Due to these factors, the identification has been given a "cf." designation.

It is interesting to note that illustrations of C. intermedia have never been previously published.

Measurements.--The figured specimen is 1.885 mm. long and approximately (due to poor preservation) 1.120 mm. high.

Occurrence.--Found in 2 samples from Polythetic Range Zone A.

This species has also been reported from the Middle Ordovician Point Pleasant Formation (Cynthiana) of the Cincinnati area (Ulrich, 1894) and the Middle to Upper Ordovician Clays Ferry formation of central and north-central Kentucky (Berdan, 1970).

Types.--Figured Specimen

U.C.G.M. 40821

Superfamily Oepikellacea Jaanusson, 1957

Family Aparchitidae Jones, 1901

Genus Aparchites Jones, 1889? Aparchites minutissimus (Hall)

Pl. 6, Figs. 9-13

- 1871 Leperditia (Isochilina) minutissimus Hall, J., New York State Mus. Nat. Hist., 24th Ann. Rept., P. 231 Pl. 8, Fig. 13, 1872, (advance sheets, 1871, fide Bassler and Kellett, 1934); Hall, J., and Whitfield, R.P., 1875, Geol. Surv. Ohio, Rept., 2(2):102, Pl. 4, Fig. 4; Bassler, R. S., 1919, (as Aparchites minutissimus), Maryland Geol. Surv., Cambrian and Ordovician Vol., P. 366, Pl. 55, Fig. 5.
- 1899 Aparchites minutissimus (Hall), Ulrich, Geol. and Nat. Hist. Surv. Canada, Contr. to the Micro-Paleontology of the Cambro-Silurian Rocks of Canada, Pt. 2, P. 49, Pl. 9, Fig. 5.
- 1926 Aparchites minutissimus (Hall), Ruedemann, R., New York State Mus., Bull., 272:138, Pl. 23, Figs. 1-2.

Diagnosis.--An Aparchites with no velar structures; character of lateral surface variable, may have a prominent node developed in the central portion of the valve.

Description of Adults.--The valves are equal in size and sub-elliptical in lateral view. Greatest height of the valves is slightly anterior to the midlength and the greatest length is slightly dorsal to the mid-height. Greatest thickness is sub-centrally located. Dorsal margin is straight and is approximately 60% of the greatest

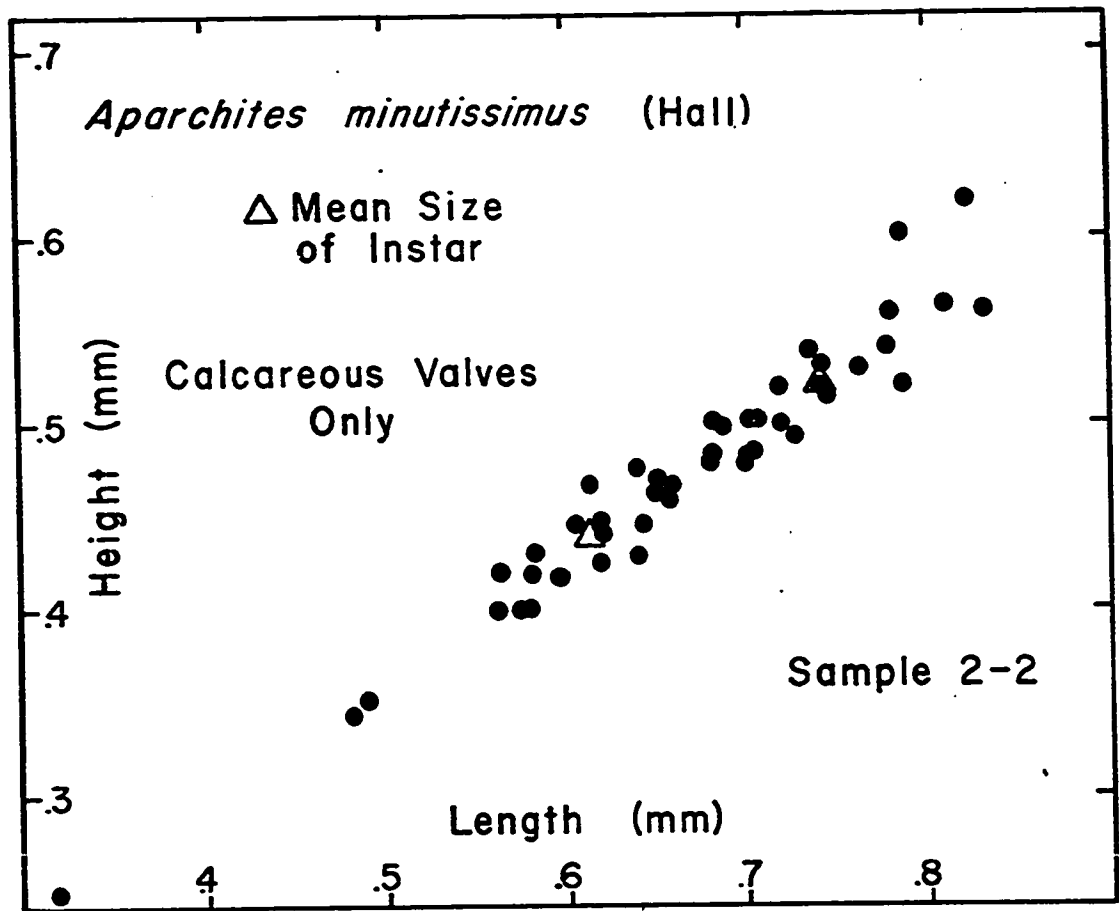
length. Ventral margin is strongly convex and grades into the convex anterior and posterior margins. The anterior margin is rounded in outline; the posterior margin is elliptical. Cardinal angles are obtuse and sub-equal (approximately 135°). Surface of the valves is finely granulose. Lateral surface of the valves is generally evenly convex but rarely has a sub-central prominence. The entire free margin (anterior, ventral and posterior) has a thickened, rounded edge. Hingement is rarely preserved, and consists of a dorsal bar in the right valve and a groove in the left valve. The bar may be denticulate, but poor preservation makes this extremely difficult to observe.

Measurements.--See table 13 for a statistical summary of the measurements for 44 specimens from sample 2-2.

Ontogeny.--The size dispersion diagram (text-fig. 20) for the 44 specimens of Aparchites minutissimus demonstrates the existence of at least four stages, the Adult, Adult-1, Adult-2 and the Adult-3. The unclear instar clusters for the Adult and the Adult-1 can be explained by a mixing of populations, an extremely variable genotype or a combination of the two. Morphologic change during ontogeny is limited to a change in relative shape. A study of the statistics for the height/length ratio (table 13) shows the juveniles to be higher in relation to length than are the adults. Admittedly, there is only limited evidence for this condition, as the Adult-2 and Adult-3 instars are not very well represented. A difference also exists in the position of the greatest height. In the Adult-2 and Adult-3 it is at the mid-length and in the Adult-1 and Adult it is anterior to

Table 13—Statistical summary of measurements (in mm) for 44 specimens of Aparchites minutissimus from sample 2-2.

Statistic	Adult	Adult-1	Adult-2	Adult-3
N L	22	19	2	1
\bar{X} L	.743	.615	.485	.322
R L	.680-.829	.562-.659	.480-.490	-----
s ² L	.002	.001	----	----
s L	.046	.033	----	----
N H	22	19	2	1
\bar{X} H	.525	.437	.347	.240
R H	.480-.561	.400-.478	.342-.352	-----
s ² H	.001	.001	----	----
s H	.037	.023	----	----
N H/L	22	19	2	1
\bar{X} H/L	.702	.711	.715	.745
R H/L	.614-.764	.672-.749	.713-.718	----
s ² H/L	.001	.000	----	----
s H/L	.032	.021	----	----



Text Fig. 20--Size dispersion diagram of Aparchites minutissimus (Hall).

the mid-length.

Discussion.--The lack of velar structures makes the assignment of this species to the genus Aparchites extremely tenuous. However, the taxonomic confusion presently surrounding Aparchites makes this assignment necessary until a better understanding of the genus is attained. When this occurs, Aparchites minutissimus will most certainly be placed in some new genus.

The great variation in lateral valve morphology observed by Ulrich in 1889 is also present in my material. In addition, the variant with the sub-central prominence is rare and restricted to pyritized specimens only. However, within the pyritized specimens a complete gradation exists from specimens with a smooth lateral surface to those with a large sub-central prominence. The possibility exists that the pyritized specimens belong to a different species than do the specimens preserved as calcareous valves. Unfortunately, crude preservation makes the critical comparison of the pyritized carapaces with the calcareous valves futile. They have been lumped together as one species on the basis of their similar lateral shapes. If the variant with the central prominence is indeed a different species from the smooth specimens, A. minutissimus must be restricted to the specimens with the central prominence. This restriction is based on Hall's original description, the relevant part of which follows:

Surface of the valve smooth, rising into an obtusely pointed prominence at the anterior third of the length:

(P.231)

however, Hall made no indication as to whether or not the types were pyritized and the whereabouts of the Holotype is not known.

Examination of the Cotypes (U.S.N.M. 41302, U.S.N.M. 41303) of Aparchites minutissimus var. trentonensis Ulrich, 1894, from the Middle Ordovician of Minnesota, show that variety to be different from A. minutissimus sensu stricta. The Minnesota variety differs by having indistinct cardinal corners, a blunt anterior margin and a sinuous dorsum. A. minutissimus differs from all other species presently classified with Aparchites by its tendency to have a centrally located prominence.

Occurrence.--Found in 38 samples and occurs in Polythetic Range Zones A, B, and C.

This species has been reported from the Richmondian of Stoney Mountain, Manitoba (Ulrich, 1889), the upper Ordovician Vaureal Formation of Anticosti Island (Bassler, 1927), the upper Ordovician Martinsburg Shale of Pennsylvania and Maryland (Bassler, 1919) and the middle to upper Ordovician Utica and Lorraine Formations of New York (Ruedemann, 1926).

Types.--Figured specimens

U.C.G.M. 40173

U.C.G.M. 40788

U.C.G.M. 40789

U.C.G.M. 40790

U.C.G.M. 40791

Measured specimens (39 specimens on one slide)

U.C.G.M 40787

Suborder Eridostraca Adamczak, 1961

Family Eridoconchidae Henningsmoen, 1953

Genus Americanconcha Schallreuter, 1968Americanconcha marginata (Ulrich)

Pl. 7, Figs. 1, 2, 4

- 1890 Placentula marginata Ulrich, Ulrich, E. O., Cincinnati Soc. Nat. Hist., 13:124, Pl. 10, Figs. 13a,b,c.
- 1951 [Non]Eridoconcha marginata (Ulrich), Keenan, J.E., Jour. Paleont., 25:566, Pl. 79, Figs. 13-15.
- 1961 [Non]Eridoconcha marginata (Ulrich), Swain, F.M., Cornell, J.R. and Hanson, D.L., Jour. Paleont., 35:361, Pl. 48, Figs. 9a,b.
- 1965 [Non]Eridoconcha marginata (Ulrich), Burr, J.H., and Swain, F.M., Minnesota Geol. Surv., SP-3, P. 18, Pl. 5, Figs. 6-20, 22-23.

Diagnosis.--A subquadrate Americanconcha with a short, shallow and non-bifurcating sulcus restricted to the most dorsal portion of the umbo; Umbo low, does not extend far above the hingeline; wide adventral structure conceals the contact margin.

Description.--The valves are equal in size and subquadrate in lateral view. Greatest height is just anterior of the sulcus and the greatest length is slightly ventral of the mid-height. Greatest thickness is centrally located. The hingeline is straight and is approximately 75% of the greatest length. The ventral margin is broadly convex and grades into the subequally convex anterior

and posterior margins. Cardinal angles are obtuse and subequal. An adventral ridge parallels the free margin along its entire extent. The adventral ridge and free margin coalesce at the anterior and posterior cardinal corner. Umbo is divided into two lobes by a short and shallow sulcus. Anterior lobe extends higher above the hingeline than does the posterior lobe. The free margin of each succeeding smaller valve abuts the adventral structure of the larger. The wide adventral ridge conceals the contact margin on the largest of the growth stages. No hingement was observed.

Measurements.—See table 14 for the measurements of the 8 measurable specimens from sample 2-28.

Discussion.—Examination of the holotype of A. marginata reveals it to closely resemble A. multiannulata (Levinson), from the Richmondian of Ohio and Indiana, differing from it by having a shorter, shallower sulcus and a more pronounced subquadrate outline. In addition, the adventral structure of A. marginata is extremely wide and tends to conceal the free margin of the larger valves. This adventral character does not occur in A. multiannulata or, in fact, any other member of the genus.

The specimens described as Eridoconcha marginata from the Maquoketa Formation of Iowa and Missouri (Keenen, 1951; Swain, Cornell and Hansen, 1961; Burr and Swain, 1965), are more closely related to A. multiannulata. These specimens differ from A. multiannulata by the occurrence of a bifurcating sulcus and probably represent a new species. This relationship was also suggested by

Schallreuter (1968).

Occurrence.--Present in 7 samples and occurs in Polythetic Range Zones A and B.

Ulrich's holotype is from the Maysvillian (Corryville) of Cincinnati and represents the only other known occurrence of the species.

Types.--Holotype

U.S.N.M. 41364

Figured Specimens

U.C.G.M. 40174

U.C.G.M. 40822

Measured Specimens

U.C.G.M. 40823

U.C.G.M. 40824

U.C.G.M. 40825

U.C.G.M. 40826

U.C.G.M. 40827

U.C.G.M. 40828

U.C.G.M. 40829

Table 14—Measurements of Americanoncha marginata from sample 2-28
(in mm).

U.C.G.M. no.	Length	Height	No. of Retained Instars
40174	.475	.360	2
40822 *	.482	.560	3
40823	.492	.362	2
40824	.470	.339	2
40825	.495	.360	2
40826	.485	.342	2
40827	.463	.319	2
40828	.380	.260	2
40829	.450	.301	2

* Due to breakage of the anterior margin, measurement of the length is approximate.

Americoncha aff. A. bifurcata (Copeland)

Pl. 7, Figs. 5-7

1965 Eridoconcha bifurcata Copeland, Copeland, M.J., Geol. Surv.
Canada, Bull. 127:38, Pl. 7, Fig. 7.

Diagnosis.--An Americoncha with an extremely high umbo; sulcus short and slit-like; adventral structure present but poorly defined.

Description.--The valves are equal in size and sub-elliptical in lateral view. Greatest height is just anterior to the sulcus and the greatest length is just ventral to the mid height. The hingeline is straight and is approximately 55% of the greatest length. Cardinal angles are poorly defined. Ventral margin is broadly convex and grades into the convex anterior and posterior margins. Anterior margin is slightly more tumid than the posterior. A wide, poorly defined adventral structure is parallel to the entire free margin. The adventral structure and the free margin coalesce at the anterior and posterior cardinal corners. The high umbo is divided into two lobes by a shallow slitlike sulcus. Anterior lobe extends higher above the hingeline than does the posterior lobe. The free margin of each succeeding valve abuts the dorsal portion of the adventral structure of the larger valve. Surface of the valves is coarsely granulose. No hingement was observed.

Measurements.--See table 15 for measurements of the 8 measurable specimens from sample 1-40.

Discussion.--Americoncha aff. A. bifurcata differs from all other members of the genus by the occurrence of a wide, poorly defined

Table 15—Measurements of Americanoncha aff. A. bifurcata from sample 1-40 (in mm).

U.C.G.M. no.	Length	Height	No. of Retained Instars
40830	.642	.520	3
40831	.641	.460	2
40832	.472	.220	1
40833	.420	.261	1
40834	.500	.363	2
40835	.600	.449	2
40836	.410	.300	2
40837	.498	.322	1

adventral structure. The present specimens have been only questionably assigned to A. bifurcata because of the poor preservation of the Canadian specimens. In addition, Copeland's figure of Eridoconcha bifurcata suggests the existence of a small node in the ventral portion of the sulcus. If this structure is present, and is not merely an artifact of poor preservation, the Edenian specimens would constitute a new species.

The small number of specimens recovered during the present study thwarted any attempt at an ontogenetic study of this species. However, there is some indication that the larger valves do not have as high an umbo as do the smaller valves. This would cause a specimen retaining three valves to be much higher in relation to length than a specimen retaining only 2 valves. Specimens displaying only 2 instars may retain either the Adult and the Adult-1 or the Adult-1 and the Adult-2.

Occurrence.--Found in 13 samples and occurred in Polythetic Range Zones A and B.

The type occurrence of A. bifurcata is in the Middle Ordovician Liskeard Formation of Lake Timiskaming, Ontario (Copeland, 1965).

Types.--Figured Specimens

U.C.G.M. 40830

U.C.G.M. 40831

U.C.G.M. 40832

Measured Specimens

U.C.G.M. 40833

U.C.G.M. 40834

U.C.G.M. 40835

U.C.G.M. 40836

U.C.G.M. 40837

Suborder Kloedenellocopina Scott, 1961

Superfamily Leperditellacea Ulrich and Bassler, 1923

Family Leperditellidae Ulrich and Bassler, 1923

Genus Milleratia Swartz, 1936

Milleratia kopensis, n. sp.

Pl. 7, Figs. 8, 9

Holotype.--An Adult? right valve, U.C.G.M. 40175.

Type locality.--United States Route 27 section, Campbell County, Kentucky, sample 8-2a.

Type stratum.--Kope Formation, Edenian Stage, 11 feet below the contact with the overlying (Maysvillian) Fairview Formation.

Derivation of the name.--kopensis, named for its occurrence in the Kope Formation.

Material.--The following descriptive work is based upon 9 complete valves, the holotype and 8 paratypes, and approximately 11 fragments.

Diagnosis.--A coarsely punctate Milleratia; velate ridge and subvelar channel are well defined; a large subcentrally located node occurs in S2.

Description.--The valves are equal in size and subovate in lateral view. Greatest height is posterior to the mid-length and the greatest length is slightly ventral to the midheight. Greatest thickness is located posterior to the midlength. Dorsal margin is umbonate and conceals the hingeline. Hingeline is straight and is approximately 60% of the greatest length. Ventral margin is broadly convex and grades into the convex anterior and posterior margins. Posterior

margin is more bluntly rounded than the anterior margin. Cardinal angles are obtuse and subequal. The anterior cardinal angle is approximately 145° and the posterior 140° . Dorsal umbo is divided into two lobes by S2. Posterior lobe extends higher above the hinge-line than does the anterior lobe. S2 is slightly anterior of the mid-line, moderately deep and extends 35% of the distance to the venter. At the ventral most extension, S2 bifurcates and encompasses a large poorly defined node (Some of the smaller specimens exhibit a well defined node and a narrower, shallower S2. These discrepancies might be indicative of another species or might simply represent ontogenetic changes). A prominent velate ridge is developed subparallel to the free margin. Free margin extends past the velate ridge on the antero-ventral, ventral and postero-ventral margins. Velate ridge and free margin coalesce just ventral of the anterior and posterior cardinal corners. A fairly deep, wide channel is developed between the free margin and the velate ridge. Lateral surface of the valve, within the confines of the velate ridge, is coarsely punctate. The velate ridge, subvelar channel and subcentral node are granulose to smooth. No hingement was observed.

Measurements.--See table 16 for the measurements of the holotype and 8 paratypes.

Discussion.--This species most closely resembles Milleratia mica Copeland, 1965, from the Middle Ordovician Liskeard Formation of Ontario, but differs in having a pronounced velate ridge instead of just an angular interruption of the valve convexity. Milleratia

anteroextensa Kraft, from the Middle Ordovician Edinburg Formation of Virginia, has "faintly" punctate instars and "faintly" punctate to smooth Adults. M. kopensis, on the other hand, has coarsely punctate Adults. Eridoconcha punctata Keenan, from the Upper Ordovician Maquoketa Shale of Missouri, superficially resembles M. kopensis. However, E. punctata is lacking a velate ridge, a character common to all true members of the genus Milleratia, and most probably represents some new genus. (Investigation of the type material of E. punctata by the present author reveals that E. punctata does not retain instars and is therefore not a true member of the genus Eridoconcha.)

Occurrence.--Found in 8 samples and occurs in Polythetic Range Zones B and C.

Types.--Holotype

U.C.G.M. 40175

Paratypes

U.C.G.M. 40942

U.C.G.M. 40943

U.C.G.M. 40944

U.C.G.M. 40945

U.C.G.M. 40946

U.C.G.M. 40947

U.C.G.M. 40948

U.C.G.M. 40949

Table 16--Measurements of 9 specimens of Milleratia kopensis (in mm).

U.C.G.M. no.	Sample no.	Length	Height	Valve
40175 *	8-2a	.765	.479	Right
40942	8-3	.562	.380	Right
40943	2-38	.535	.357	Left
40944	2-38	.640	.422	Left
40945	2-37	.581	.495	Left
40946	2-35	.620	.415	Left
40947	1-294	.662	.452	Left
40948	1-249	.661	.440	Left
40949	1-249	.670	.442	Right

* Holotype

Millerartia rudis (Ulrich)

Pl. 7, Fig. 10

- 1890 Primitia rudis Ulrich, E.O., Cincinnati Soc. Nat. Hist., Jour.
13:136, Pl. 10, Text Figs. 8a-c.
- 1926 [?] Primitia rudis Ulrich, Ruedemann, R., New York State Mus.
Bull. 272, P. 139, Pl. 23, Figs. 3-5.

Diagnosis.--A Millerartia with a moderate to coarsely granulose lateral surface; S2 bifurcates and surrounds a poorly defined subcentral node; velate ridge present but not sharply defined; velate ridge and subvelar channel smooth to moderately granulose.

Description.--The valves are equal in size and subovate in lateral view. Greatest height is posterior to the mid-length and the greatest length is at the mid-height. Greatest thickness is located posterior to the mid-length. Dorsal margin is umbonate and conceals the hingeline. Hingeline is straight and is approximately 60% of the greatest length. Ventral margin is broadly convex and grades into the convex anterior and posterior margins. Anterior margin is subelliptical in shape and the posterior margin is broadly rounded. Cardinal angles are both obtuse. The anterior cardinal angle is poorly defined and the posterior cardinal angle is sharply defined. Dorsal umbo is divided into two lobes by S2. Posterior lobe is wider and extends higher above the hingeline than does the anterior lobe. S2 is anterior of the mid-line, moderately deep and extends approximately 25% of the distance to the venter. At ventral most portion S2 bifurcates and encircles a large poorly defined subcentral node. A poorly

defined velate ridge is developed subparallel to the free margin. Free margin extends past the velate ridge on the antero-ventral, ventral and postero-ventral margins. Velate ridge and free margin coalesce just ventral of the anterior and posterior cardinal corners. A fairly deep, wide channel is developed between the free margin and the velate ridge. Lateral surface of the valve, within the confines of the velate ridge, is moderately to coarsely granulose. The velate ridge and subvelar channel are smooth to finely granulose. No hinge-ment was observed.

Measurements.--See table 17 for the measurements of 17 specimens from sample 1-40.

Discussion.--Examination of the holotype of Milleratia rudis (U.S.N.M. 41345) has revealed it to be very similar to M. kopensis but differing by displaying a granulose lateral surface instead of a punctate one. In addition, the posterior portion of the umbo in M. rudis appears to be higher than in M. kopensis, although this factor must remain questionable until more Adult specimens of M. kopensis are obtained.

I have also studied the Plesiotype of M. rudis (U.S.N.M. 34536) described and figured by Reudemann (1926) from the Utica Shale near Rome New York. This specimen is an external mould and is un-identifiable. Therefore, I have questionably included Reudemann's identification in the synonymy.

Occurrence.--Found in 25 samples from Polythetic Range Zones A and B.

In addition to its original occurrence in the Edenian of the Cincinnati area, M. rudis has also been reported from the Utica of

Table 17--Measurements of 17 specimens of Milleratia rudis from sample 1-42 (in mm).

U.C.G.M. no.	Box no.	Length	Height	Valve
40955	—	.740	.500	Left
40956	1	.795	.560	Left
40956	2	.660	.462	Right
40956	3	.720	.481	Right
40956	4	.622	.435	Left
40956	5	.732	.497	Right
40956	6	.720	.483	Left
40956	7	.745	.460	Left
40956	8	.721	.482	Right
40956	9	.642	.425	Left
40956	10	.658	.440	Right
40956	11	.681	.480	Right
40956	12	.660	.481	Left
40956	13	.658	.460	Left
40956	14	.660	.457	Left
40956	15	.668	.443	Left
40956	16	.602	.480	Left

New York (Reudemann, 1926).

Types.--Figured specimen

U.C.G.M. 40955

Measured specimens

U.C.G.M. 40956 (16 specimens on 1 slide)

Milleratia shideleri Levinson

Pl. 7, Fig. 11

1951 Milleratia shideleri, Levinson, S.A., Jour. Paleont., 25:559,

Pl. 77, Figs. 2a-c.

Discussion.--Sixteen specimens referable to Milleratia shideleri were recovered during the present sampling. Examination of the holotype (U.S.N.M. 116364) indicates that the present material compares very favorably with the type, including the development of the sharply defined supravolar depression. For a more complete description and discussion of this species, see Levinson, 1951.

Measurements.--See table 18 for measurements of the five measurable specimens.

Occurrence.--Found in 3 samples from Polythetic Range Zone B.

This is the first occurrence of this species in rocks as old as Edenian. Previously, M. shideleri was thought to be restricted to the Richmondian, Elkhorn Formation (Levinson, 1951).

Types.--Figured specimen

U.C.G.M. 40950

Measured specimens

U.C.G.M. 40951

U.C.G.M. 40952

U.C.G.M. 40953

U.C.G.M. 40954

Table 18—Measurements for 5 specimens of Milleratia shideleri from sample 2-13 (in mm).

U.C.G.M. no.	Length	Height	Valve
40950	.701	.453	Right
40951	.720	.465	Right
40952	.585	.383	Right
40953	.660	.440	Right
40954	.382	.260	Right

Pseudoprimitiella n. gen.

Type species.--Pseudoprimitiella reticulata n. sp.

Derivation of the name.--Pseudoprimitiella, meaning a false Primitiella.

Diagnosis.--Valves are subrectangular in lateral view; dorsal border straight to slightly concave; ventral border slightly convex to subparallel with the dorsal border; anterior and posterior borders may be subequal or either may be higher than the other; anterior and posterior lateral surface is inflated, S2 occurs between inflated ends, is wide and poorly to sharply defined; posterior modified into a posterior or postero-laterally directed spine; valve surface may be smooth, granulose, papillose, punctate or reticulate.

Included species.--Leperditia unicornis Ulrich, 1879

Primitiella huilensis Copeland, 1970

Pseudoprimitiella reticulata n. sp.

Discussion.--Guber and Jaanusson (1964) restricted the generic name Primitiella to those species exhibiting monotiolepidid dimorphism and an anterior strangular process. The genus Pseudoprimitiella is herein being established for unispinose, non monotiolepidid "Primitiellids." As presently understood this new genus is a member of the family Leperditellidae Ulrich and Bassler, 1906.

Pseudoprimitiella unicornis (Ulrich)

Pl. 7, Figs. 12-15

1879 Leperditia unicornis Ulrich, E.O., Cincinnati Soc. Nat. Hist.

- Jour., 2(1):10, Pl. 7, Figs. 4-4b
- 1889 [Non] Aparchites unicornis (Ulrich), Ulrich, E.O., Geol. and Nat. Hist. Surv. Canada, Contr. Canada Micro-paleontology, Pt. 2, P. 50, Pl. 9, Fig. 11.
- 1890 [Non] Primitia unicornis (Ulrich), Jones, T.R., Geol. Soc. London, Quart. Jour., 46:7, Pl. 4, Figs. 8-13.
- 1894 Primitiella unicornis (Ulrich), Ulrich, E. O., Minnesota Geol. and Nat. Hist. Surv., 3(2):649, P. 43, Figs. 75-77, 1897 (advance edition, 1894, fide Bassler and Kellett, 1934).
- 1911 [Non] Primitiella unicornis (Ulrich), Wade, A., Geol. Soc. London, Quart. Jour., 67:452, Pl. 36, Figs. 4-5.
- 1926 [?] Primitiella unicornis (Ulrich), Ruedemann, R., New York State Mus., Bull., 272:137, Pl. 23, Fig. 6.
- 1951 Primitiella unicornis (Ulrich), Keenan, J.E., Jour. Paleontology, 25: 568, Pl. 78, Fig. 5, Pl. 79, Figs. 38-39.
- 1965 [Non] Primitiella unicornis (Ulrich), Burr, J.H. and Swain, F. M., Minnesota Geol. Surv., SP-3, P. 22, Pl. 2, Figs. 21-25, Pl. 5, Figs. 1-10.

Diagnosis.--A Pseudoprimitiella with a relatively large height/length ratio; lateral surface of the valve is granulose with scattered pits; postero ventral spine is inclined postero-laterally; S2 is wide and poorly defined.

Description.--Valves are subrectangular in lateral view. Greatest height is anterior to the mid-length and the greatest length is ventral to the mid-height. Greatest thickness, with the exception of

the spine, is anterior to the mid-length. Dorsal margin is straight to slightly concave and is approximately 80% of the greatest length. Ventral margin is slightly convex and is subparallel to the dorsal margin. Anterior margin is strongly convex and the posterior margin is bluntly convex. Cardinal angles are obtuse. Anterior cardinal angle is larger and less well defined than the posterior cardinal angle. An indistinct marginal rim extends around the entire free margin. Anterior and posterior portions of the valve are more tumid than the median portion, thereby forming a wide, poorly defined S2. Posterior portion of the valve is modified into a postero-laterally directed postero-ventral spine. Spine occurs near but not on the posterior boundary. Surface of the valves smooth to granulose, with occasional small pits scattered on the lateral surface. No hingement was observed.

Measurements.--See table 19 for the measurements of the 14 measurable specimens.

Ontogeny.--Although the scarcity of measurable specimens made the acquisition of a size dispersion diagram impossible, one ontogenetic trend could be observed. The smaller specimens were observed to be suboval in shape with the greatest height being adjacent to the anterior border. As the animals grew larger the anterior and posterior extremities became subequal, giving the valves a subrectangular shape.

Discussion.--Examination of the newly recovered material plus the holotype (U.S.N.M. 41467) reveals that Pseudoprimitiella unicornis differs from the other members of the genus by being noticeably higher

Table 19--Measurements of the 14 measurable specimens of
Pseudoprimitiella unicornis (in mm).

U.C.G.M. no.	Sample no.	Length	Height	Valve
40964	9-6	.781	.465	Right
40965	9-6	.742	.440	Left
40966	9-6	.583	.362	Right
40967	9-6	.320	.205	Right
40968	7-5	.245	.162	Right
41301	9-6	.361	.225	Right
41302	9-6	.522	.328	Right
41303	7-5	.547	.320	Right
41304	7-5	.861	.482	Right
41305	7-5	.755	.440	Right
41306	7-5	.391	.235	Right
41307	7-5	.242	.140	Right
41308	7-5	.370	.227	Left
41309	7-5	.320	.200	Right

in relation to length and displaying subequal extremities. In addition, the ventral spine is not oriented directly posterior as it is in the other species and the lateral surface of the valves is not reticulate, as in P. reticulata, or papillose, as in P. huilensis.

The references given a Non designation in the present synonymy all share several characteristics in common. Firstly, they are not equal ended; all of them have the greatest height in a posterior position. Additionally, the figures are all more elongate than P. unicornis. In general, the lateral shape of the valves is more similar to either the new species, P. reticulata, or the species described by Copeland in 1970, P. huilensis.

Ruedemann's 1926 identification was given a questionable citation as the figure leaves some doubt in my mind as to whether or not the specimens are conspecific.

Occurrence.--Found in 4 samples and restricted to Polythetic Range Zone A.

In addition to its occurrence in the basal Edenian of the Ohio Valley, P. unicornis has also been reported from the top of the Trenton (Point Pleasant Formation) at Cincinnati (Bassler and Kellett, 1934) and from the Maquoketa Shale of Missouri (Keenan, 1951). Due to the factors discussed above, all other reported occurrences are highly suspect.

Types.--Figured specimen

U.C.G.M. 40964

U.C.G.M. 40965

U.C.G.M. 40967

U.C.G.M. 40968

Measured specimens

U.C.G.M. 41301

U.C.G.M. 41302

U.C.G.M. 41303

U.C.G.M. 41304

U.C.G.M. 41305

U.C.G.M. 41306

U.C.G.M. 41307

U.C.G.M. 41308

U.C.G.M. 41309

Pseudoprimitiella reticulata n. sp.

Pl. 7, Figs. 16-18

Holotype.--A recrystallized Adult? carapace, U.C.G.M. 41319.

Type locality.--Moffett Road Section, Kenton County, Kentucky, sample 1-32.

Type stratum.--Kope Formation, Edenian Stage, 16 feet 2 inches above the contact with the Middle Ordovician (Shermanian?) Point Pleasant Formation.

Derivation of the name.--reticulata, refers to the reticulate nature of the valve surface.

Material.--The following descriptive work is based upon the holotype and 10 paratypes from 3 separate samples (see table). Many specimens

were studied from other samples, but these were, for the most part, broken and unmeasurable.

Description.--The valves are subrectangular in lateral view and seem to be equal in size (very few articulated valves were recovered). Location of the greatest height is variable, the ends may be equal or the greatest height can be posterior of the mid-length. Greatest length is slightly ventral of the mid-height. Greatest thickness, with the exception of the postero-ventral spine, is anterior of the mid-length. Dorsal margin is straight to slightly concave and is approximately 65% of the greatest length. Ventral margin is slightly convex and subparallel to the dorsal margin. Anterior margin is strongly convex and posterior margin is bluntly convex. Cardinal angles are both obtuse and poorly defined. Anterior cardinal angle is greater than the posterior. Anterior and posterior portions of the valve are much more tumid and sharply differentiated than the median portion, thereby forming a wide, well defined S2. Posterior portion of the valve is modified into a spine that points directly posteriorly. A wide channel occurs on the posterior border between the inside of the spine and the contact margin. The spine and associated channel are not necessarily of the same size on each valve of a single carapace. A poorly defined adductor pit occurs in a subcentral position. Surface of the valve is finely reticulate. No hingement was observed.

Measurements.--See table 20 for the measurements of the holotype and 10 paratypes.

Table 20--Measurements of the Holotype and 9 Paratypes of
Pseudoprimitiella reticulata (in mm).

U.C.G.M. no.	Sample no.	Length	Height	Comments
40176	2-28	.618	.320	Right valve
41310	7-3	.995	.505	Right valve
41311	7-3	.705	.360	Left valve
41312	7-3	.700	.360	Right valve
41313	7-3	.702	.341	Right valve
41314	7-3	.688	.361	Right valve
41315	7-3	.755	.362	Left valve
41316	7-3	.708	.365	Carapace
41317	7-3	.940	.420	Carapace
41318	10-6a	.762	.380	Left valve
41319 *	1-32	.935	.500	Carapace

* Holotype

Discussion.--Pseudoprimitiella reticulata differs from the other members of the genus, P. unicornis and P. huilensis, by the fine reticulation of the valve surface. In addition, it differs from P. unicornis by being considerably narrower and having its spine oriented directly posterior, not postero-laterally. Furthermore, the spine is located on the posterior boundary in P. reticulata just anterior of the boundary in P. unicornis.

P. reticulata differs from P. huilensis by lacking the papillae and scattered punctae.

Occurrence.--Found in 52 samples and occurs in Polythetic Range Zones A, B and C.

Types.--Holotype

U.C.G.M. 41319

Paratypes

U.C.G.M. 40176

U.C.G.M. 41310

U.C.G.M. 41311

U.C.G.M. 41312

U.C.G.M. 41313

U.C.G.M. 41314

U.C.G.M. 41315

U.C.G.M. 41316

U.C.G.M. 41317

U.C.G.M. 41318

Genus Schmidtella Ulrich, 1894

Schmidtella claypolei (Jones)

Pl. 6, Fig. 16

1890 Leperditia claypolei Jones, T.R., Geol. Soc. London, Quart. Jour., 46:25, Pl. 3, Figs. 17a-c.

Description.--The valves are subovate in lateral view and unequal in size. Left valve is larger than the right and overlaps it on the dorsal border. Greatest height is anterior to the mid-length and the greatest length is at the mid-height. Dorsum is slightly epicline and umbonate. Greatest thickness is at the umbo. Remainder of the valve surface slopes away from the umbo. Carapace is narrowest adjacent to the free margin. Hingeline is short and undefined. Cardinal corners are rounded. Valve surface is either smooth or finely granulate. No hingement was observed.

Measurements.--See table 21 for the measurements of 11 specimens (in mm).

Discussion.--Critical study of this species was greatly hindered by the poor preservation of the specimens. For the most part, the material consists of either coarsely recrystallized or pyritized carapaces. The few free valves recovered were inevitably broken.

Schmidtella claypolei exhibits a high degree of similarity with several of the species described by Ulrich (1894) from the Trenton of Minnesota. Examination of the holotypes of these species reveals the following; S. brevis (Holotype U.S.N.M. 41299) differs from S. claypolei by having its zone of greatest thickness

Table 21--Measurements for 7 specimens of Schmidtella claypolei
(in mm).

U.C.G.M. no.	Sample no.	Length	Height	Comments
40957	6-3	.561	.397	Recrystallized Cara.
40958	3-2	.600	.402	Recrystallized Cara.
40959	6-3	.560	.363	Recrystallized Cara.
40960	6-3	.600	.425	Recrystallized Cara.
40961	6-3	.542	.400	Recrystallized Cara.
40962	6-11	.620	.400	Pyritized Carapace
40963	8-2	.465	.321	Recrystallized Cara.

subcentrally located instead of at the dorsal umbo. S. incompta (Holotype 41298) has an orthocline dorsum and distinct cardinal angles in comparison to the slightly epicline dorsum and indistinct cardinal angles of S. claypolei. S. affinis (Holotype U.S.N.M. 41296) possesses a strongly epicline dorsum, thereby causing the umbo to be extremely high. S. claypolei, on the other hand, has a low poorly defined umbo.

Occurrence.--Found in 42 samples and occurs in Polythetic Range Zones A, B and C.

This species has never been reported from any rocks other than the Edenian of the Cincinnati area.

Types.--Figured specimens

U.C.G.M. 40957

Measured specimens

U.C.G.M. 40958

U.C.G.M. 40959

U.C.G.M. 40960

U.C.G.M. 40961

U.C.G.M. 40962

U.C.G.M. 40963

Genus Platamonaria n. gen.

Type species.--Octonaria bicava Ulrich and Bassler, 1923.

Derivation of the name.--Platamonaria, from platamon, meaning a broad flat area. Refers to the broad, bisulcate, triangular lateral surface of the valve.

Diagnosis.--This genus is presently monotypic and therefore has the characters of the type species.

Discussion.--Swartz, in his 1932 revision of the Thlipsuridae (P.55) discussed Octonaria bicava and stated:

This species is not suggestive of any of the other described species of Octonaria, and besides having an incorrect outline, lacks a true marginal flange, unless the overlapping enlargement be considered as such. Its relationship to Octonaria is also made questionable because of its age, as it is an Ordovician species, whereas the earliest known normal species are from the Middle Silurian.

Subsequent investigation of this species by the present author reveals it to be a Palecope with close affinities to the Leperditellid genus Schmidtella. This statement is based upon the occurrence of a straight hingeline (concealed by the dorsal umbo) and cardiform cross section. The bisulcate condition of the lateral surface is an anomolous situation among the Leperditellidae. However, it is felt that this character is of secondary importance and

the shape of the valve and hingeline are of primary importance.

Platamonaria bicava (Ulrich and Bassler)

Pl. 6, Figs. 14, 15

1923 Octonaria bicava Ulrich, E. O. and Bassler, R. S., Maryland Geol. Surv., Silurian Vol., P. 317, Fig. 23, Nos. 3-4.

1934 Octonaria bicava Ulrich and Bassler, Bassler, R. S., and Kellett, B., Geol. Soc. America Special Paper No. 1, P. 36, Fig. 16, Nos. 3-4. (Figures reproduced from Ulrich and Bassler, 1923)

Diagnosis.--A cardiform Paleocope with two deep curving sulci restricted to a subcentrally located triangular platform.

Description.--The valves are suboval in lateral view and are subequal in size. The left valve is slightly smaller than the right. Greatest height is slightly anterior to the midlength and the greatest length is ventral to the midheight. Greatest thickness is subcentrally located. Dorsal margin is sinuous, with the umbo extending above the hingeline. Hinge is straight and is approximately 60% of the greatest length. Ventral margin is broadly convex and grades into the convex anterior and posterior margins. Anterior margin is more tumid than the posterior. Cardinal angles are obtuse, poorly defined and subequal. The center of the valve is raised into a subtriangular platform, leaving a narrow flange bordering the entire free margin. Two deep, elongate depressions occupy the center of the platform. Anterior depression is longer than the posterior and is curved with

the convex side facing the anterior. Posterior depression is only slightly curved and has the convex side also facing the anterior. Surface of the valve is smooth. There is a groove in the hingeline of the right valve. No hinge structure was observed in the left valve.

Measurements.--See table 22 for the measurements of 11 specimens.

Discussion.--I have examined the ten cotypes (U.S.N.M. 41699) and have found them to be in complete agreement with the present material. For a further discussion of this species, see the section on the genus

Platamonaria.

Occurrence.--Found in 17 samples and occurred in Polythetic Range Zones A and B.

This species has never been reported from rocks other than the Edenian of the Cincinnati area.

Types.--Figured specimens

U.C.G.M. 40179

U.C.G.M. 40921

Measured specimens

U.C.G.M. 40923

U.C.G.M. 40924

U.C.G.M. 40925

U.C.G.M. 40926

U.C.G.M. 40927

U.C.G.M. 40928

U.C.G.M. 40929

U.C.G.M. 40930

Table 22--Measurements of 11 specimens of *Platamonaria bicava* (in mm).

U.C.G.M. no.	Sample no.	Length	Height	Comments
40179	3-2a	.602	.462	Left valve
40921	1-171	.545	.406	Right valve
40922	2-14	.622	.460	Left valve
40923	2-14	.548	.430	Right valve
40924	2-14	---	.438	Right valve
40925	2-14	.561	.440	Left valve
40926	7-15	.510	.420	Carapace
40927	7-15	.542	.400	Carapace
40928	7-15	.525	.405	Right valve
40929	7-15	.570	.418	Carapace
40930	7-15	.581	.404	Carapace

---No information, due to breakage..

Suborder indeterminate

Family indeterminate

Genus Ambitella n. gen.

Type Species.--Ambitella unispinifera n. sp.

Derivation of the Name.--from ambitus, meaning encircling or surrounding, refers to the encircling ridge.

Diagnosis.--This genus is presently monotypic and therefore has the characters of the type species.

Discussion.--Examination of the dorsal margins of the larger specimens suggests that an anterior strangular process may be present.

Unfortunately, this type of projecting structure is subject to rapid weathering on disarticulated valves and therefore cannot yet be verified. If, when better material is available, the anterior strangular process and domiciliar dimorphism are proven to be present, Ambitella will most probably be placed in the Family Monotiopleuridae Guber and Jaanusson, 1964. Until that time Ambitella must remain of unknown systematic affinities.

Ambitella unispinifera n. sp.

Pl. 8, Figs. 7-10

Holotype.--An Adult right valve, U.C.G.M. 40775.

Type Locality.--Moffett Road Section, Kenton County, Kentucky, sample 1-32.

Type Stratum.--Kope Formation, Edenian Stage, 16 feet, 2 inches above the contact with the Middle Ordovician (Shermanian?) Point Pleasant

Formation.

Derivation of the Name.--unispinifera, meaning bearing one spine, referring to the well developed posterior spine.

Material.--The material consists of 12 technomorphic valves, of which four are adults and eight are juveniles. In addition, there are 12 identifiable fragments.

Diagnosis.--Valves are subrectangular in lateral view; a well developed ridge encircles the entire lateral surface, ridge terminates in a posteriorly directed spine; S2 small and round, subcentrally located; a small node occurs just anterior to S2.

Description of Adults.--The valves seem to be equal in size and are subrectangular in lateral view. Greatest length occurs at the mid-height and the greatest height is constant for the middle 80% of the valves. Greatest thickness of the valves is located on the antero-dorsal margin. Dorsal margin is slightly concave and flares upward just posterior to the anterior cardinal corner. Dorsum is orthocline. Ventral margin is slightly convex and sub-parallel to the dorsal margin. Anterior and posterior margins are both convex, the anterior being more tumid than the posterior. Cardinal angles are both obtuse, the anterior being greater and more clearly defined than the posterior. A well developed ridge circumscribes the entire lateral surface of the valves. The ridge initiates at the postero-ventral corner and encircles the valve in a clockwise direction. A slight sag occurs in the ridge just anterior to the postero-dorsal corner. At the antero-dorsal corner, the crest of the ridge is

highest, making this the thickest part of the valve and causing the ridge to slightly overhang the lateral surface of the valve. On the venter, the ridge is tubular and is extended into a well developed, posteriorly directed spine. The surface of the valve is steeply inclined from the hingeline and anterior contact margins to the crest of the ridge on the dorsal and anterior portions, causing the ridge to be widest in these areas. A slight depression is present on the inclined surface of the valve just posterior to the anterior cardinal corner. Anterior, posterior and ventral portions of the ridge are reflected internally by a shallow channel. Dorsal portion is not reflected internally. The lateral surface of the valve is well below the crest of the ridge. Areas nearest the ridge are depressed while the central portion is slightly inflated. S2 consists of a round pit located on the ventral side of the dorsal portion of the ridge just anterior to the mid-line. S2 is reflected on the interior of the valve as a small boss. Just anterior to S2 is a low node. The node is reflected on the interior of the valve as a shallow pit. The valve surface is coarsely granulose. Dorsal hinge structure of the right valve apparently consists of a central groove bounded anteriorly by a subtriangular callus. Anterior contact margin of both valves has a faint groove extending from the anterior cardinal corner to the ventral margin. No groove was observed on the ventral or posterior margins of either valve. Dorsal hinge structures of the left valve unknown.

Measurements.--See table 23 for the measurements of the 12 measurable

Table 23--Measurements of Holotype and 11 Paratypes of Ambitella unispinifera from sample 2-32 (in mm).

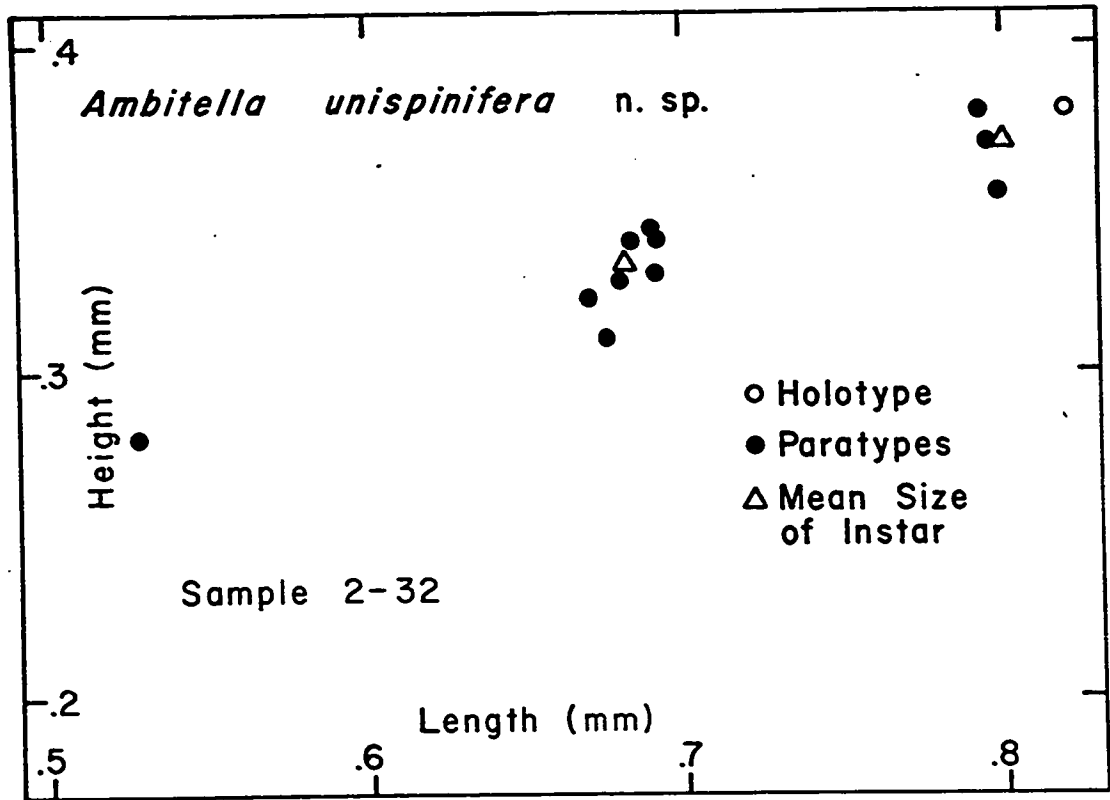
U.C.G.M. no.	Length	Height	Hingeline	Height/Length
40775 *	.821	.380	.622	.463
40776	.675	.310	.520	.459
40777	.681	.329	.500	.483
40778	.692	.330	.510	.477
40779	.800	.355	.600	.44
40780	.529	.281	.420	.531
40781	.692	.340	.520	.491
40782	.691	.339	.495	.491
40783	.670	.322	---	.481
40784	.796	.369	---	.601
40785	.683	.340	---	.498
40786	.793	.380	---	.479

* Holotype

specimens of Ambitella unispinifera from sample 2-32 (in mm).

Ontogeny.--Examination of the size dispersion diagram (text fig. 21) indicates the existence of at least three growth stages, the Adult, Adult-1 and Adult-2. Ontogenetic change from the Adult-1 to the Adult is limited to a change in absolute and relative proportions, with the Adult-1 being higher in relation to length than the Adult (\bar{X} of the H/L ratio for the 4 Adult specimens = .463, \bar{X} of the H/L ratio for the 7 Adult-1 specimens = .483). No other morphologic changes were observed. However, absolute and relative size changes between the Adult-1 and the Adult-2 (H/L ratio for the 1 specimen of the Adult-2 = .531) are accompanied by other changes in valve morphology. Firstly, the lateral outline of the valve changes, being suboval in the Adult-2 and sub-rectangular in the larger instars. Secondly, the encircling ridge is not fully developed in the Adult-2, being limited to the anterior, ventral and posterior margins, with no indication of it on the dorsal margin, thereby forming a "J" shaped ridge, the ridge is not very well defined on either the antero-ventral corner or the entire posterior margin. The subcentral S2 and the posteriorly directed spine are well formed and located in the same relative position as on the larger specimens. No hinge structures were observed on the smaller specimens.

Discussion.--Of the four Adult specimens recovered, three were right valves and one a left valve. Unfortunately, weathering of the valves made the interpretation of the hinge structures extremely difficult. In addition, the entire dorsal hinge area of one of the right valves



Text Fig. 21—Size dispersion diagram of Ambitella unispinifera n. sp.

is covered with extraneous fossil material, and the anterior cardinal corner of the single left valve is broken. No further investigation of the hinge structures was therefore deemed possible.

As previously stated, the systematic position of this genus and species is unknown. There is, however, a striking resemblance between the Adult-2 instar of A. unispinifera and the Adult of another species, Cincinnati-concha pedigera (Pl. 8, Figs. 1-6), in the development of the "J" shaped ridge and the posteriorly directed spine. Differences do exist in the location of S2 and the lateral shape of the valves. Therefore, no relationship between the two species is currently being proposed.

Occurrence.--Found in 3 samples and is restricted to Polythetic Range Zones A and B.

Types.--Holotype

U.C.G.M. 40775

Paratypes

U.C.G.M. 40766

U.C.G.M. 40777

U.C.G.M. 40778

U.C.G.M. 40779

U.C.G.M. 40780

U.C.G.M. 40781

U.C.G.M. 40782

U.C.G.M. 40783

U.C.G.M. 40783

U.C.G.M. 40784

U.C.G.M. 40785

U.C.G.M. 40786

Genus Cincinnati n. gen.

Type species.--Jonesella pedigera Ulrich, 1890.

Derivation of the name.--Cincinnati, named in honor of Cincinnati, Ohio.

Diagnosis.--This genus is presently monotypic and therefore has the characters of the type species.

Discussion.--The single species presently assigned to this genus has previously been placed in the genus Jonesella. However, the elongate rectangular shape coupled with the "J" shaped ridge and narrow marginal rim definitely exclude Cincinnati pedigera from Jonesella and, in fact, any other genus. Until more work is carried out on Lower Paleozoic ostracod faunas, Cincinnati must remain of unknown systematic affinities.

Cincinnati pedigera (Ulrich)

Pl. 8, Figs. 1-6

- 1890 Jonesella pedigera Ulrich, E. O., Cincinnati Soc. Nat. Hist., 13(3):122, Pl. 7, Figs. 9a-b.
- 1894 Jonesella pedigera Ulrich, Ulrich, E. O., Minnesota Geol. and Nat. Hist. Surv., 3(2):667, Text Fig. 47, d-e.
- 1926 Jonesella pedigera Ulrich, Ruedemann, R., New York State Mus., Bull., No. 272, P. 140, Pl. 23, Figs. 13-15

Diagnosis.--A subrectangular Paleocene with a horizontally disposed "J" shaped ridge; posterior portion of the ridge developed into a large spine.

Description of Adults.--The valves are equal in size and elongate sub-rectangular in lateral view. Greatest height is located posterior to the mid-length and the greatest length is at the mid-height. Dorsal margin is straight and is approximately 85% of the greatest length. Ventral margin is slightly convex and grades into the convex anterior and posterior margins. Posterior margin is higher and therefore more broadly rounded than the anterior. Cardinal angles are obtuse and unequal. The anterior cardinal angle is approximately 150° and the posterior 125° . Lateral surface of the valves contains a horizontally disposed "J" shaped ridge. The ridge begins as a swelling on the antero-dorsal portion of the valve, bends antero-ventrally and finally posteriorly along the adventral surface. Posterior extremity of the ridge is raised off of the valve surface and modified into a posteriorly directed lateral spine. The area of the valve surrounding the ventral portion of the ridge is slightly depressed below the surface of the valve. S2 is wide, shallow and indistinct. S2 is located just posterior of the antero-dorsal portion of the "J" shaped ridge. The "J" shaped ridge, depressed area around the ridge and S2 are internally reflected. An indistinct marginal rim extends around the entire contact margin. Surface of the valves is smooth to finely granulose. No hingement was observed.

Measurements.--See table 24 for a statistical summary of the measurements of the 30 measurable specimens from sample 5-2.

Ontogeny.--Study of the size dispersion diagram (text fig 22) reveals the existence of at least seven growth stages, the Adult, Adult-1,

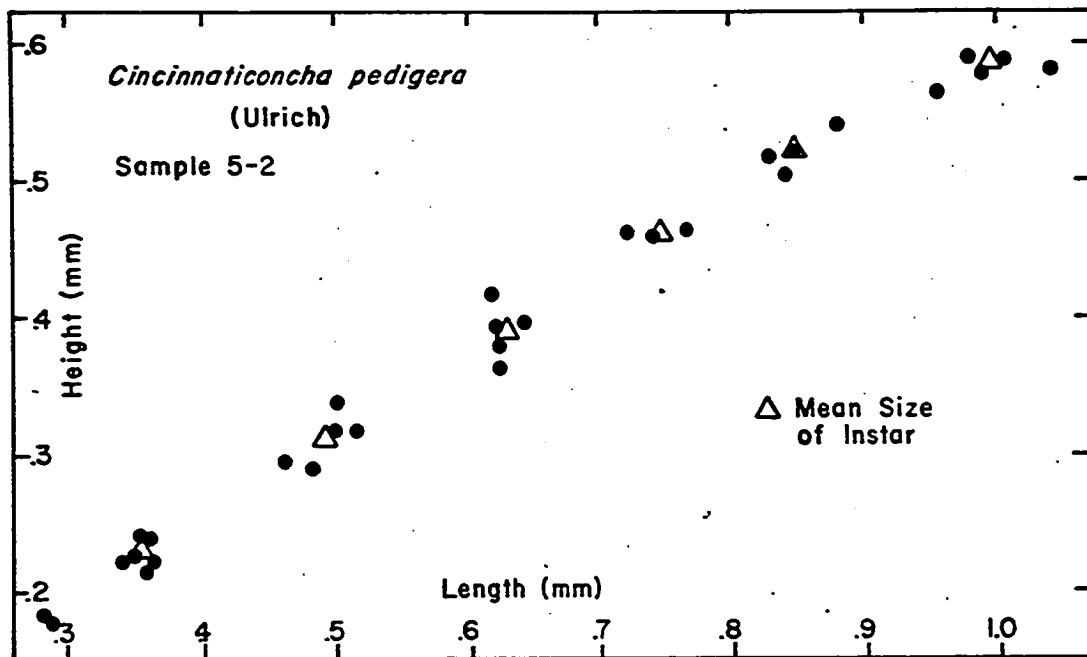
Table 24--Statistical summary of measurements for 30 specimens of Cincinnaticoncha pedigera from sample 5-2 (in mm).

Statistic	Adult	Adult-1	Adult-2	Adult-3	Adult-4	Adult-5	Adult-6
N L	5	4	3	5	5	6	2
\bar{X} L	.997	.852	.746	.627	.493	.355	.286
R L	.960-1.043	.835-.880	.722-.770	.620-.643	460-.518	.342-.363	.282-.290
s^2 L	.001	.000	.000	.000	.000	.000	-----
s L	.031	.019	.024	.009	.022	.010	-----
N H	5	4	3	5	5	6	2
\bar{X} H	.584	.521	.463	.390	.313	.227	.181
R H	.556-.600	.505-.543	.460-.467	.360-.420	.290-.340	.218-.242	.180-.182
s^2 H	.000	.000	.000	.000	.000	.000	-----
s H	.016	.015	.004	.022	.020	.010	-----
N H/L	5	4	3	5	5	6	2
\bar{X} H/L	.582	.612	.620	.621	.634	.640	.632
R H/L	.567-.592	.599-.619	.600-.637	.576-.677	.600-.677	.605-.666	.620-.645
s^2 H/L	.000	.000	.000	.001	.001	.001	-----
s H/L	.009	.009	.019	.037	.029	.026	-----

Adult-2, Adult-3, Adult-4, Adult-5 and the Adult-6. A perusal of the Height/Length ratios (Table 24) for the different instars of this species indicates, in addition to the expected change in absolute size, an ontogenetic change in relative size. In particular, C. pedigera displays a progressive decrease in the Height/Length ratio through ontogeny. Furthermore, the two smallest stages, the Adult-6 and the Adult-5, are amplete in outline and do not develop the post-plete condition of the Adult until the Adult-4 instar is attained. Likewise S2 migrates from a central position in the Adult-6 and Adult-5 to a more anterior local in the Adult-4. The peculiar "J" shaped ridge initiates in the Adult-6 as a unique, posteriorly directed adventral spine. No indication was observed of the anterior 50% of the structure. However, in the Adult-5 a wide curved swelling appears on the antero-dorsal, anterior and antero-ventral margins of the valve. This swelling can be considered the rudiment of the anterior "hook" portion of the ridge. A progressive increase in the definition of the anterior portion of the ridge can be observed from the Adult-4 through the Adult.

Discussion.--C. pedigera differs from all other species of ostracod by the possession of the "J" shaped ridge. However, see the discussion of Ambitella unispinifera for information regarding the similarity between C. pedigera and the juveniles of that species.

Ulrich (1890), in his original description of the species used an anterior-posterior orientation opposite to the one presently employed. However, a combination of characteristics such as the



Text Fig. 22—Size dispersion diagram of Cincinnaticoncha pedigera (Ulrich).

location of S2 and the inclination of the adventral spine indicates a reversed orientation. The only character in agreement with Ulrichs orientation is the posteriorly located greatest height.

Occurrence.--Found in 13 samples from Polythetic Range Zones A and B.

This species has also been reported from the following Upper Ordovician Formations, the Sheguiandah Shale of Manitoulin Island, Ontario (Bassler and Kellett, 1934) and the Lorraine of New York (Ruedemann, 1926).

Types.--Figured specimens

U.C.G.M. 40170

U.C.G.M. 40884

U.C.G.M. 40887

U.C.G.M. 40888

U.C.G.M. 40889

U.C.G.M. 40690

Measured specimens

U.C.G.M. 40891 (24 specimens on 1 slide)

Genus Primitiella Ulrich, 1894

"Primitiella" whitfieldi (Jones)

Pl. 2, Fig. 12

1890 Primitia whitfieldi Jones, T. R., Geol. Soc. London, Quart. Jour., 46:9, Pl. 3, Figs. 24 a-b.

Description.--The valves are equal in size and elongate-subovate in lateral view. Greatest height of the valves is anterior to the mid-length and the greatest length is at the mid-height. Greatest thickness is centrally located. Dorsal margin is straight and is approximately 60% of the greatest length. Ventral margin is slightly convex and oblique to the dorsal margin. The anterior margin is rounded in outline and the posterior margin is elliptical. Cardinal angles are obtuse and subequal. The posterior cardinal angle is approximately 150° and the anterior cardinal angle is approximately 140°. A shallow dorso-medial depression is occasionally present. When present the depression is representative of S2. No hingement was observed.

Measurements.--See table 25 for the measurements of 11 specimens from sample 2-1.

Discussion.--Ulrich (1894), in his original diagnosis of Primitiella, included P. whitfieldi in the genus. However, Guber and Jaanusson, 1964, have shown Primitiella to be a member of the Monotioleuroidae (see the discussion of the genus Pseudoprimitiella in this report). As P. whitfieldi displays no monotioleuroid characters, it therefore cannot be considered a true Primitiella. Investigations into the

Table 25—Measurements of 11 specimens of "Primitiella" whitfieldi
from sample 2-1 (in mm).

U.C.G.M. no.	Length	Height	Comments
40931	.720	.370	Left valve
40932	.890	.515	Left valve
40933	.900	.470	Right valve
40934	.710	.395	Left valve
40935	.578	.325	Left valve
40936	.700	.390	Left valve
40937	.740	.410	Left valve
40938	.800	.500	Carapace
40939	.555	.310	Right valve
40940	.710	.410	Left valve
40941	.695	.420	Left valve

true relationships of the species are severely hindered by the paucity of usable taxonomic characters. As presently understood, the exact systematic position of this and similar species (previously included in Primitiella but without monotiolepid characters) are obscure.

Primitiella paucisulcata Burr and Swain, 1965, is very similar to P. whitfieldi, including the occurrence of fine reticulation (Jones, 1890; Burr and Swain, 1965), and may in fact be conspecific. Unfortunately, poor preservation of the present material (none of the reticulation is preserved) makes a more critical comparison impossible.

A gross similarity does exist between P. whitfieldi and Aparchites minutissimus (Hall, 1871), for P. whitfieldi resembles an elongate version of the latter. However, P. whitfieldi does not seem to have the thickened marginal rim of A. minutissimus. Therefore, no relationship is currently being suggested.

Occurrence.--Found in 32 samples and occurs in Polythetic Range Zones A and B.

According to Bassler and Kellett (1934), this species also occurs in the uppermost Middle Ordovician of the Cincinnati area.

Types.--Figured specimen

U.C.G.M. 40177

Measured specimens

U.C.G.M. 40931

U.C.G.M. 40932

U.C.G.M. 40933

U.C.G.M. 40934

U.C.G.M. 40935

U.C.G.M. 40936

U.C.G.M. 40937

U.C.G.M. 40938

U.C.G.M. 40939

U.C.G.M. 40940

U.C.G.M. 40941

Order Podocopida Muller, 1884

Suborder Metacopina Sylvester-Bradley, 1961

Superfamily Healdiacea Harlton, 1933

Family Bairdiocyprididae Shaver, 1961

Genus Cytherellina Jones and Holl, 1869

Type species.--Beyrichia siliqua Jones, 1855

Discussion.--The specimens of Cytherellina described in this report are usually placed in the genus Bythocypris Brady, 1880. However, Bythocypris was originally based upon a recent ostracod and is defined, for the most part, by features not observable in Lower Paleozoic material. Some of the features used to define members of the genus are the soft parts, muscle scars and inner marginal structures (selvage, list and duplicature). As the inner marginal structures do not occur in the Edenian specimens, it is erroneous to include them in Bythocypris. For this reason, the following species have been included in Cytherellina, a Paleozoic genus more compatible with the present material.

"Cytherellina cylindrica" (Hall)

Pl. 7, Fig. 19; Pl. 8, Fig. 11

- 1871 Leperditia (Isochilina) cylindrica Hall, Hall, J., New York State Mus. Nat. Hist., 24th Ann. Rept., P. 231, Pl. 8, Fig. 12, 1872, (advance edition 1871, fide Bassler and Kellett, 1934). Hall, J., and Whitfield, R. P., 1875, Geol. Surv. Ohio, Rept., 2(2):10, Pl. 4, Fig. 5. Bassler, R. S., 1919,

- (as Bythocypris cylindrica), Maryland Geol. Surv., Cambrian and Ordovician Vol., P. 366, Pl. 55, Fig. 5.
- 1889 [NON]Bythocypris cylindrica (Hall), Ulrich, E. O., Geol. and Nat. Hist. Surv. Canada, Contrib. to the Micro-Paleontology of the Cambro-Silurian Rocks of Canada, (2):48, Pl. 0, Fig. 6.
- 1894 Bythocypris cylindrica (Hall), Ulrich, E. O., Geol. Minnesota, 3(2):687, Pl. 44, Figs. 29-35, 1897 (advance edition 1894, fide Bassler and Kellett, 1934).
- 1901 [NON]Bythocypris cylindrica (Hall), Ruedemann, R., New York State Mus. Bull. 49:86, Pl. 7, Figs. 26-28.
- 1924 Bythocypris cylindrica (Hall), Foerste, A. F., Geol. Surv. Canada, Mem. 138:255, Pl. 46, Fig. 2.
- 1951 Bythocypris cylindrica (Hall), Keenan, J. E., Jour. Paleont., 25:567, Pl. 78, Figs. 4, 8-13.
- 1957 [NON]Bythocypris cylindrica (Hall), Harris, R. W., Oklahoma Geol. Surv., Bull. 75:258, Pl. 10, Figs. 11a-c, 12.
- 1965 Bythocypris? cylindrica (Hall), Copeland, M. J., Geol. Surv. Canada, Bull. 127:45, Pl. 2, Figs. 2-4.
- 1970 "Bythocypris" cylindrica (Hall), Copeland M. J., Geol. Surv. Canada, Bull. 187:23, Pl. 4, Fig. 25.

Description.--The valves are reniform to subreniform in lateral view. They are unequal in size; the right valve overlaps the left valve around the entire free margin. Greatest height is anterior of the mid-length and the greatest length is approximately at the mid-height.

Greatest thickness is just posterior of the anterior margin. Dorsal margin is strongly to weakly convex. Ventral margin is strongly to weakly concave. Anterior and posterior margins are both convex, with the anterior being more bluntly convex than the posterior. A round adductor muscle scar is sub-centrally located. Surface of the valves is smooth. Hingement is peripheral, with a groove around the entire inner margin of the larger valve. The free margin of the smaller valve fits into the groove.

Measurements.--See table 26 for measurements of 12 specimens from sample 7-3.

Discussion.--The usual poor preservation (specimens either coarsely recrystallized or pyritized) of this species severely limits the array of usable taxonomic characters. Therefore, "Cytherellina cylindrica" has been used as an omnium gatherum for "bean shaped" Ordovician ostracods. Herein, several limitations have been set for the range of acceptable morphological variation. Firstly, "C. cylindrica" is restricted to valves with concave to sub-concave venters. Secondly, the anterior is higher and more inflated than the posterior. It is felt that these restrictions are close to Hall's original concept of the species based upon specimens from Cincinnati (whereabouts of the Holotype is unknown). Admittedly, even these restrictions are grossly generalized and probably include several different species. For this reason, "C. cylindrica" is still considered an omnium gatherum and has been so designated by the use of quotation marks.

Table 26--Measurements of 12 specimens of "Cytherellina cylindrica
from sample 7-3 (in mm).

U.C.G.M. no.	Length	Height	Comments
40798	1.060	.550	Left valve
40799	.941	.479	Left valve
40800	.840	.420	Left valve
40801	1.042	.498	Left valve
40802	.729	.392	Right valve
40803	.945	.502	Left valve
40804	1.024	.500	Right valve
40805	.740	.360	Left valve
40806	1.035	.540	Right valve
40807	.745	.400	Left valve
40808	.879	.468	Right valve
40809	.819	.419	Left valve

In 1889 Ulrich described specimens which he called Bythocypris cylindrica from the Richmondian of Stoney Mountain, Manitoba. These specimens are ventrally convex and dorsally inflated, and are not equivalent to "C. cylindrica" in the present restricted sense. It must be stated that Ulrich later (1894) realized the morphologic discrepancy between the Stoney Mountain material and "C. cylindrica"; even though Ulrich included his earlier work in the synonymy for specimens of Bythocypris cylindrica from the Trentonian of Minnesota, he did, in the discussion, explain his previous erroneous specific assignment for the Manitoba material.

Specimens figured by Ruedemann in 1901 and Harris in 1957 are likewise ventrally convex and therefore not equivalent to "C. cylindrica." The exact taxonomic position of Ruedemann's specimens is presently not known, although they seem to be related to "C. cylindrica." The material figured by Harris will be discussed with "C. granti."

Occurrence.--Found in 67 samples and occurs in Polythetic Range Zones A, B and C.

This species has also been reported from the Trentonian-Richmondian of the Cincinnati Area (Bassler, 1915; Bassler and Kellett, 1934), the Middle Ordovician Galena Shales near Cannon Falls, Minnesota (Ulrich, 1894; Kay, 1940), the Upper Ordovician Martinsburg Shale of the Pennsylvania and Maryland (Bassler, 1919), the Upper Ordovician Vaureal Formation of Anticosti Island (Bassler, 1927; Copeland, 1970), The Upper Ordovician Maquoketa Shale of Missouri

(Keenan, 1951) and the Middle Ordovician Liskeard Formation of Lake Timiskaming, Ontario (Copeland, 1965).

Types.—Figured specimens

U.C.G.M. 40178

U.C.G.M. 40798

Measured specimens

U.C.G.M. 40800

U.C.G.M. 40801

U.C.G.M. 40802

U.C.G.M. 40803

U.C.G.M. 40804

U.C.G.M. 40805

U.C.G.M. 40806

U.C.G.M. 40807

U.C.G.M. 40808

U.C.G.M. 40809

"Cytherellina granti" (Ulrich)

Pl. 8, Fig. 12

- 1894 Bythocypris granti Ulrich, Ulrich, E. O., Geol. Minnesota, 3(2):689, Pl. 44, Figs. 39-42.
- 1957 Bythocypris cylindrica (Hall), Harris, R. W., Oklahoma Geol. Surv., Bull. 75:258, Pl. 10, Figs. 11a-c, 12.
- 1957 [NON]Bythocypris sp. cf. B. granti Ulrich, Harris, R. W., Oklahoma Geol. Surv., Bull. 75:258, Pl. 10, Figs. 13a,b.
- 1965 Bythocypris granti Ulrich, Copeland, M. J., Geol. Surv. Canada, Bull. 127:45, Pl. 3, Figs. 14, 15.

Discussion.--"Cytherellina granti" is herein restricted to Ordovician Cytherellinid ostracods with convex venters and unequal extremities. The shape of the ventral margin is the one character separating "C. granti" from "C. cylindrica." In all other aspects, "C. granti" and "C. cylindrica" are quite similar. In addition, specimens of "C. granti" suffer from the same poor preservation as do specimens of "C. cylindrica." Therefore, the generalized form attributed to "C. granti" most probably represents a polyspecific array of undifferentiated ostracods. "C. granti" must then be considered an omnium gatherium.

In 1957 Harris figured several specimens of "Bythocypris" from the Middle Ordovician of Oklahoma. He assigned two of the specimens to B. cylindrica and the others to Bythocypris sp. cf. B. granti. The specimens attributed to B. cylindrica exhibit convex ventral outlines and therefore agree more closely with "C. granti." However, the specimen of B. sp. cf. B. granti is subrectangular in outline and

is attributable neither to "C. granti" nor to "C. cylindrica." The exact taxonomic position of this species is presently unknown.

Measurements.--See table 27 for measurements of 14 specimens from sample 1-57.

Occurrence.--Found in 76 samples and occurs in Polythetic Range Zones A, B and C.

This species has also been reported from the following Middle Ordovician Formations: the Decorah Shale of Minnesota (Ulrich, 1894; Kay, 1940), the Bromide and Tulip Creek of Oklahoma (Harris, 1957) and the Liskeard of Lake Timiskaming, Ontario (Copeland, 1965).

Types.--Figured specimen

U.C.G.M. 40810

Measured specimens (13 specimens on one slide)

U.C.G.M. 40811

Table 27--Measurements of 15 specimens of "Cytherellina granti"
from sample 1-57 (in mm).

U.C.G.M. no.	Box no.	Length	Height	Comments
40810	--	.842	.421	Right valve
40811	1	.525	.260	Carapace
40811	2	.493	.260	Carapace
40811	3	.657	.320	Carapace
40811	4	.662	.359	Carapace
40811	5	.480	.219	Carapace
40811	6	.488	.263	Carapace
40811	7	.490	.278	Carapace
40811	8	.586	.300	Left valve
40811	9	.321	.182	Carapace
40811	10	1.005	.445	Carapace
40811	11	.618	.320	Left valve
40811	12	.505	.298	Right valve
40811	13	1.055	.450	Carapace
40822	14	.482	.259	Left valve

Family Krausellidae Berdan, 1961

Genus Krausella Ulrich, 1894Krausella sp.

Pl. 2, Fig. 13

Discussion.--Seven poorly preserved specimens assignable to the genus Krausella were recovered during the present study. A modest degree of similarity exists between these specimens and the specimens of Krausella anticostiensis figured by Copeland in 1970 (Pl. 5). However, coarse recrystallization coupled with severe weathering of the valves makes a specific assignment nearly impossible. In addition, the posterior spine of the present material is wider and longer than the spine of K. anticostiensis.

Measurements.--The figured specimen is .621 mm in length and .285 mm in height.

Occurrence.--Found in 6 samples from Polythetic Range Zones A and B.

Types.--Figured specimen

U.C.G.M. 40892

Order indeterminate

Family indeterminate

Ostracod indet. A

Pl. 8, Fig. 14

Discussion.--This straight hinged, equivalved ostracod is quite common and appears abundantly in many samples. However, the inevitable mode of preservation, as a coarsely recrystallized carapace, makes critical study of this form impossible.

Measurements.--The figured specimen (from sample 5-19) is .618 mm in length and .240 mm in height.

Occurrence.--Found in 31 samples and occurs in Polythetic Range Zones A, B and C.

Types.--Figured specimen

U.C.G.M. 41320

Ostracod indet. B

Pl. 8, Fig. 17

Discussion.--Many poorly preserved specimens of this subelliptical species were recovered. The valves are equal ended and unequal in size. The larger valve overlaps the smaller one on the dorsal margin and the smaller valve overreaches the larger on the venter.

Measurements.--The figured specimen (from sample 1-32) is .437 mm in length and .260 mm in height.

Occurrence.--Found in 27 samples and occurs in Polythetic Range Zones A and B.

Types.—Figured specimen

U.C.G.M. 41321

Ostracod indet. C.

Pl. 8, Fig. 13

Discussion.—This species is very similar to ostracod indet. B but differs by having the valve overlap and overreach developed to a much greater degree. The valve orientation used herein is entirely subjective and may be erroneous. However, the proper orientation must await a better understanding of the species.

Measurements.—The figured specimen (from samples 2-8) is .415 mm in length and .282 mm in height.

Occurrence.—Found in 9 samples and occurs in Polythetic Range Zones A and B.

Types.—Figured specimen

U.C.G.M. 41322

Ostracod indet. D.

Pl. 8, Fig. 15

Discussion.—Coarse recrystallization and partial pyritization makes the identification of this form impossible. The shape does, however, grossly resemble a tumid, forshortened "Primitiella" whitfieldi Jones.

Examination of the contact margin reveals that the left valve overlaps the right valve on the dorsal margin. A question arises

in my mind as to whether or not the overlap is indicative of the natural condition of the valve or is an artifact of poor preservation.

Measurements.--The figured specimen (from sample 5-15) is .623 mm in length and .435 mm in height.

Occurrence.--Found in 10 samples and occurs in Polythetic Range Zones A, B and C.

Types.--Figured specimen

U.C.G.M. 41323

Ostracod indet. E

Pl. 8, Fig. 16

Discussion.--Seven free valves of this unknown species were recovered during the present sampling. Of these, five were fragmental and unusable. The two complete valves exhibit a sinuous dorsal outline, a long straight adductorial scar and a finely punctate surface. In addition, the general shape of the valves is somewhat leperditiod.

Measurements.--The figured specimen (from sample 7-3) is .732 mm in length and .460 mm in height.

Occurrence.--Found in 7 samples and occurs in Polythetic Range Zones A and B.

Types.--Figured specimen

U.C.G.M. 41324

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Explanation of Plate 1

(all figures 45X)

Figure	Page
1-5. <u>Bollia persulcata</u> (Ulrich).....	50
1. Lateral view of an Adult right valve. Sample 3-3. U.C.G.M. 41325. 2. Interior view of an Adult right valve. Sample 1-47. U.C.G.M. 40795. 3. Lateral view of a right valve of an Adult-1. Sample 1-47. U.C.G.M. 40796. 4. Later- al view of a right valve of an Adult-2. Sample 9-4. U.C.G.M. 40708. 5. Dorsal view of an Adult carapace exhibiting a slight gape along the ventral margin. Sample 9-4. U.C.G.M. 40794.	
6-9. <u>Warthinia nodosa</u> (Ulrich).....	59
6. Dorsal view of an Adult carapace exhibiting an extremely wide ventral gape. Sample 7-3. U.C.G.M. 40893. 7. Ventral view of an Adult carapace. Sample 2-7. U.C.G.M. 40166. 8. Dorsal view of an Adult carapace with a conical postero- dorsal node. Sample 2-7. U.C.G.M. 40165. 9. Lateral view of an Adult left valve. Sample 2-7. U.C.G.M. 40164	
10. <u>Parenthatia rabbithashensis</u> n. sp.....	67
Lateral view of the Holotype, an Adult left valve. Sample 5-23. U.C.G.M. 40897.	
11-13. <u>Jonesella crepidiformis</u> (Ulrich).....	75
11. Lateral view of an Adult left valve. Sample 2-7. U.C.G.M. 40167. 12. Lateral view of an Adult-2. Sample	

2-7. U.C.G.M. 40857.

14-17. Jonesella tumida n. sp..... 85

14. Lateral view of the Holotype, an Adult right valve.

Sample 1-40. U.C.G.M. 40873. 15. Lateral view of a

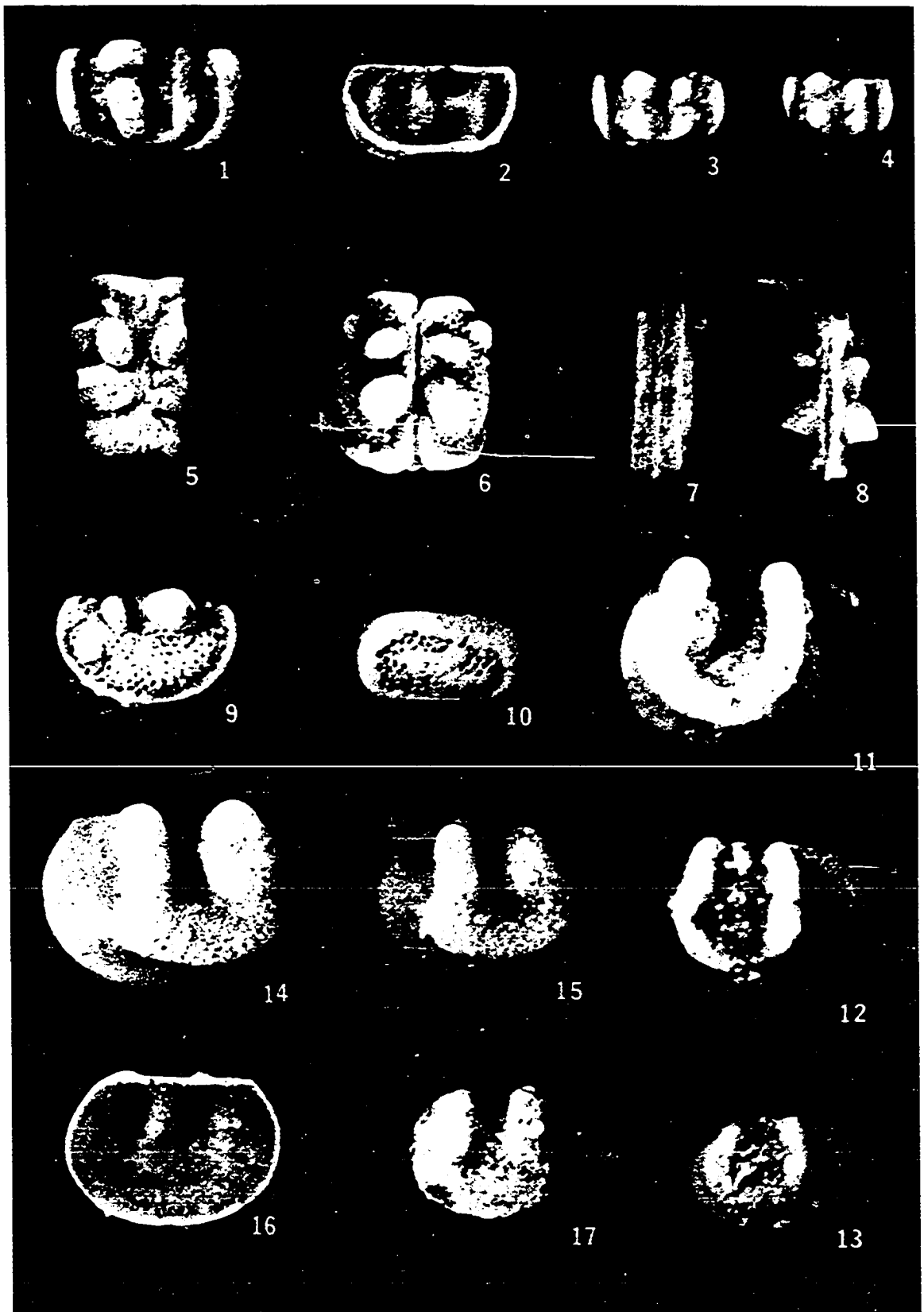
Paratype, the right valve of an Adult-1. Sample 1-34.

U.C.G.M. 40876. 16. Internal view of a Paratype, the

right valve of an Adult-1. Sample 1-34. U.C.G.M.

40874. 17. Lateral view of a paratype, the left valve

of an Adult-2. Sample 1-34. U.C.G.M. 40875



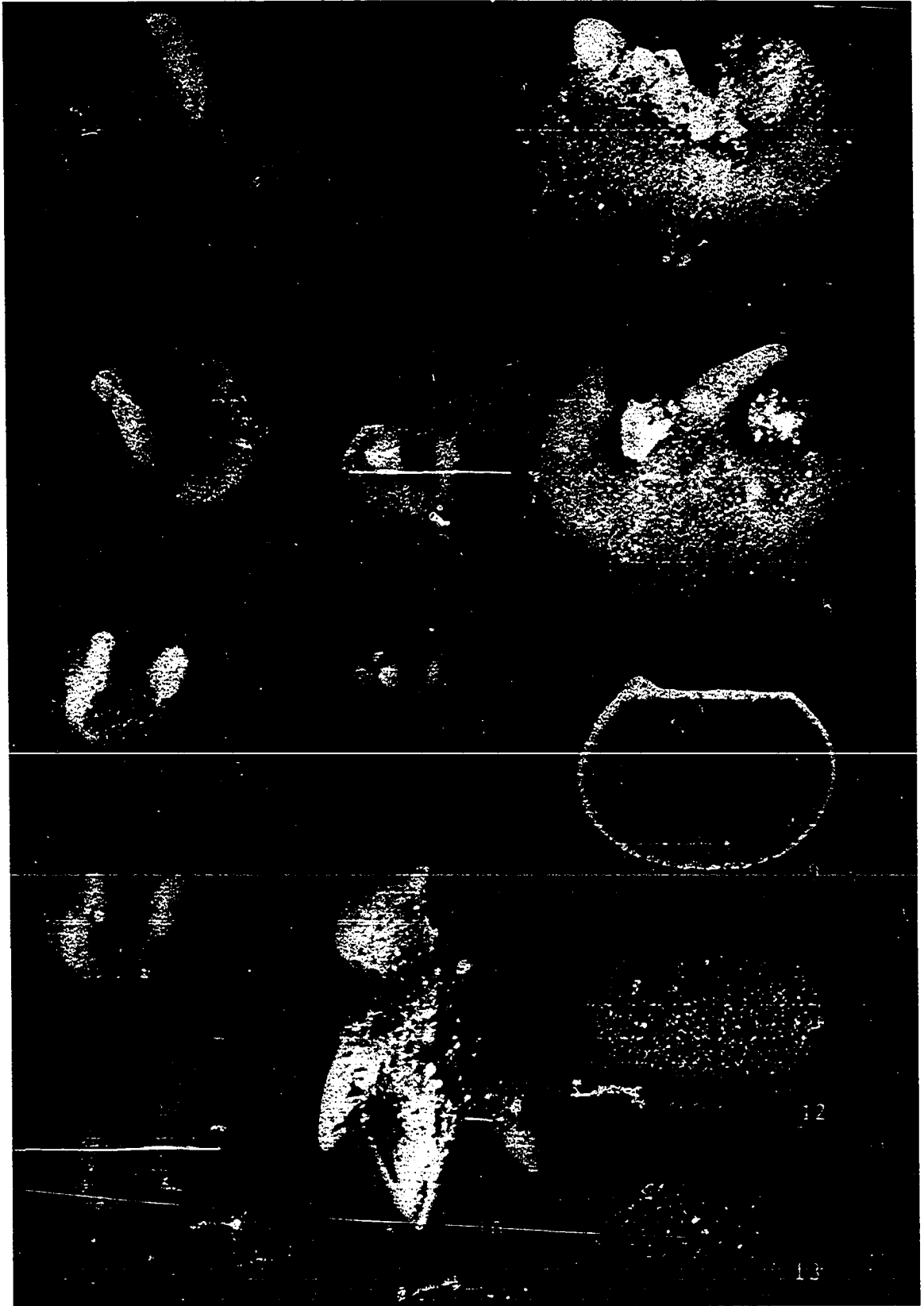
Explanation of Plate 2

(all figures 45X)

Figure	Page
1-6. <u>Jonesella interrupta</u> n. sp.....	80
1. Lateral view of the Holotype, an Adult right valve. Sample 2-1. U.C.G.M. 40168. 2. Lateral view of a Paratype, the right valve of an Adult-1. Sample 2-1. U.C.G.M. 40867.	
3. Lateral view of a Paratype, the recrystallized carapace of an Adult-2. Sample 2-1. U.C.G.M. 40863. 4. Lateral view of a Paratype, the left valve of an Adult-2. Sample 2-1. U.C.G.M. 40859. 5. Lateral view of a Paratype, the left valve of an Adult-2. Sample 2-1. U.C.G.M. 40858. 6. Lateral view of the right valve of a Paratype, the recrystallized carapace of a juvenile (instar unknown). Sample 2-1, U.C.G.M 40866.	
7-11. <u>Pseudulrichia byrnesi</u> (Miller).....	91
7. Lateral view of a Paralectotype, an Adult right valve. U.C. 8823B. 8. Lateral view of the Lectotype, an Adult left valve. U.C. 8823A. 9. Interior view of a Paralecto- type, an Adult right valve. U.C. 8823C. 10. Dorsal view of a recrystallized Adult carapace. Sample 9-4. U.C.G.M. 40895.	
11. Lateral view of the right valve of a recrystallized juvenile, instar unknown. Sample 9-4. U.C.G.M. 40896.	
12. " <u>Primitiella</u> " <u>whitfieldi</u> (Jones).....	184
Lateral view of a right valve. Sample 2-2. U.C.G.M. 40177.	

13. Krausella sp..... 196

Lateral view of the left valve of a recrystallized carapace. Sample 7-13. U.C.G.M. 40892.



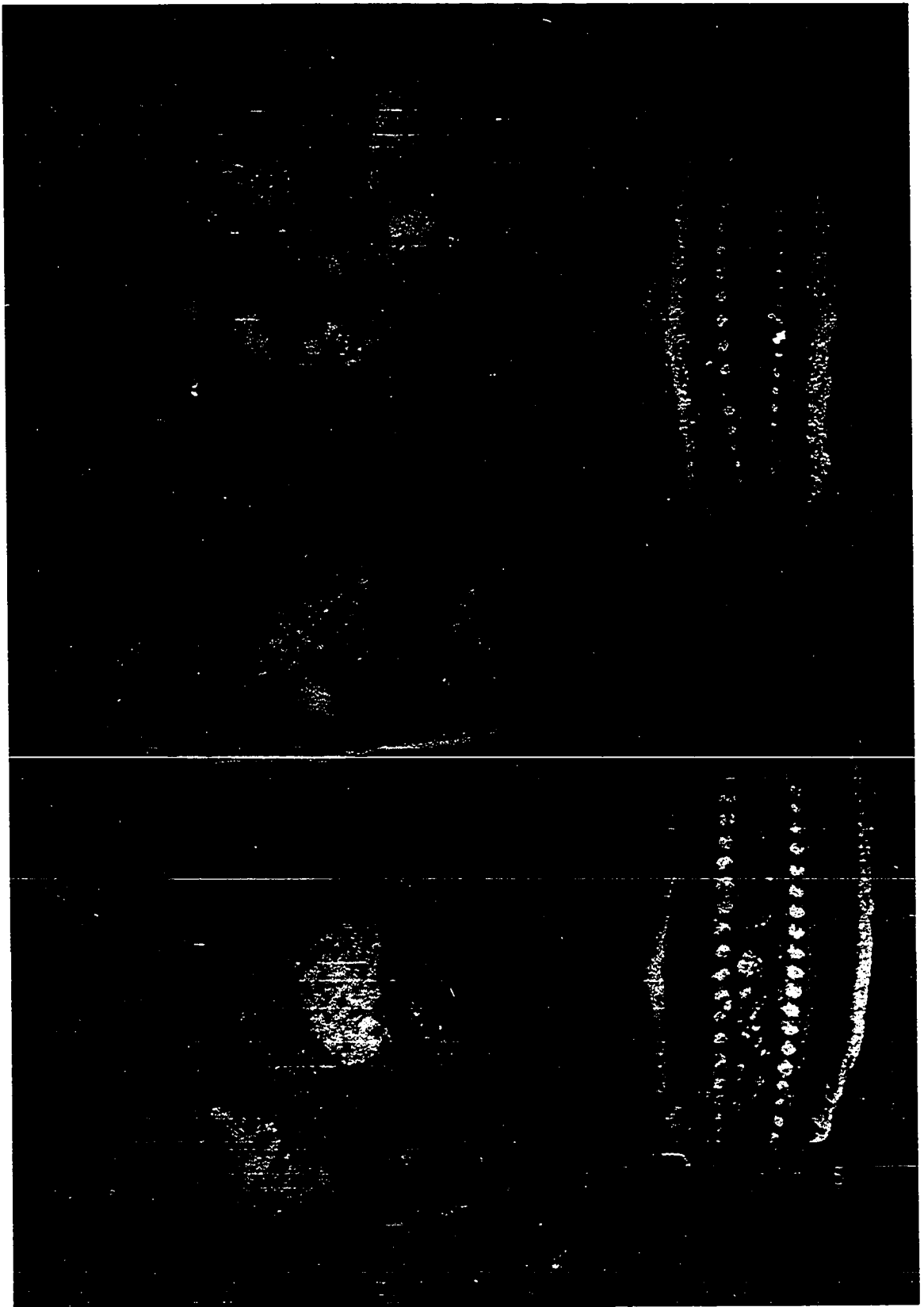
12

13

Explanation of Plate 3

(all figures 45X)

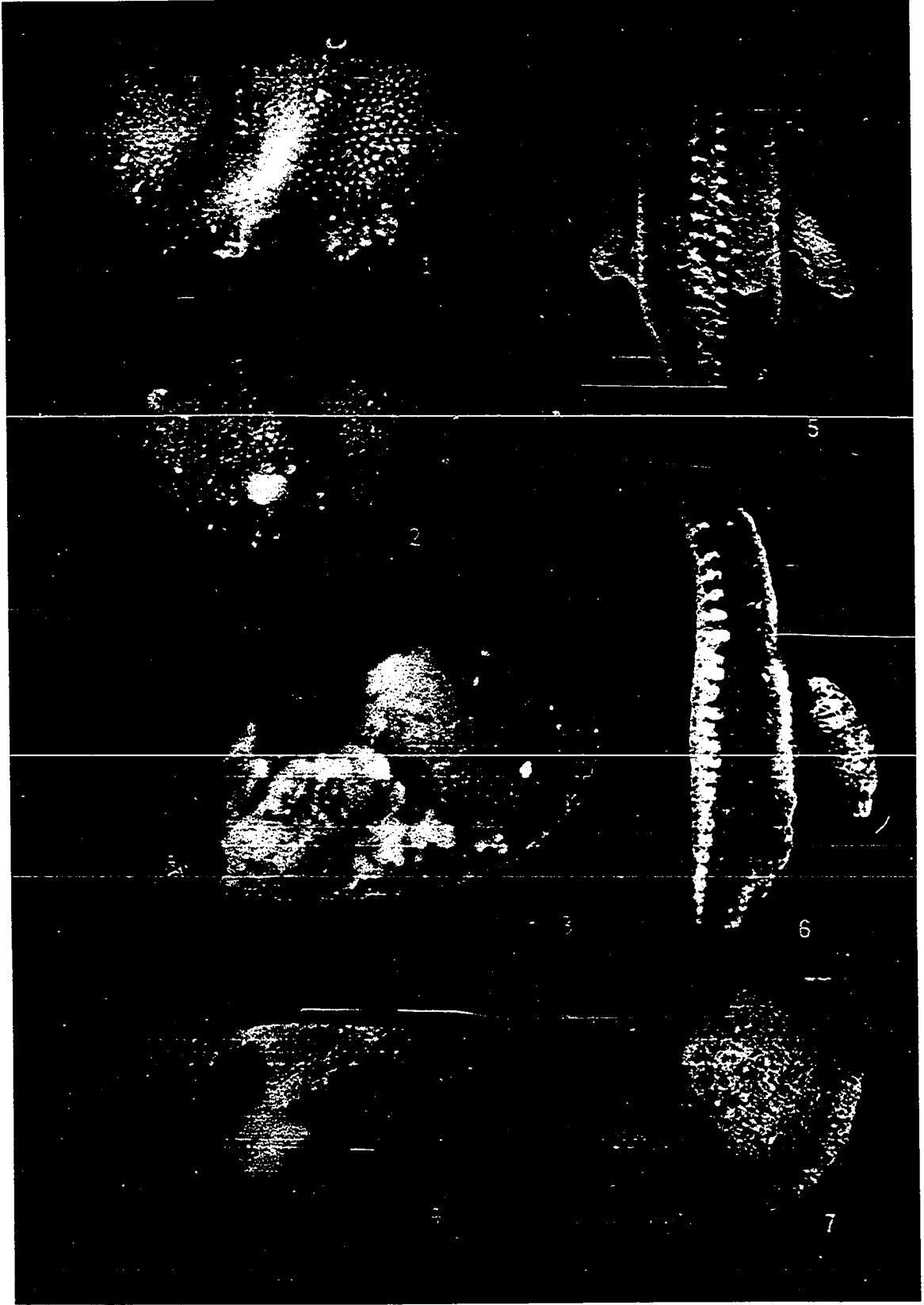
Figure	Page
1-5. <u>Ctenobolbina ciliata</u> (Emmons).....	102
1. Lateral view of the right valve of an Adult technomorph. Sample 12-1. U.C.G.M. 40843.	
2. Ventral view of the carapace of an Adult technomorph. Sample 12-1. U.C.M.G. 40838.	
3. Lateral view of the left valve of an Adult heteromorph. Sample 12-1. U.C.G.M. 40846.	
4. Lateral view of the right valve of an Adult heteromorph. Sample 12-1. U.C.G.M. 40839.	
5. Ventral view of the carapace of an Adult heteromorph showing infra-velar antrum. Sample 12-1. U.C.G.M. 40840.	



Explanation of Plate 4

(all figures 45X unless otherwise indicated)

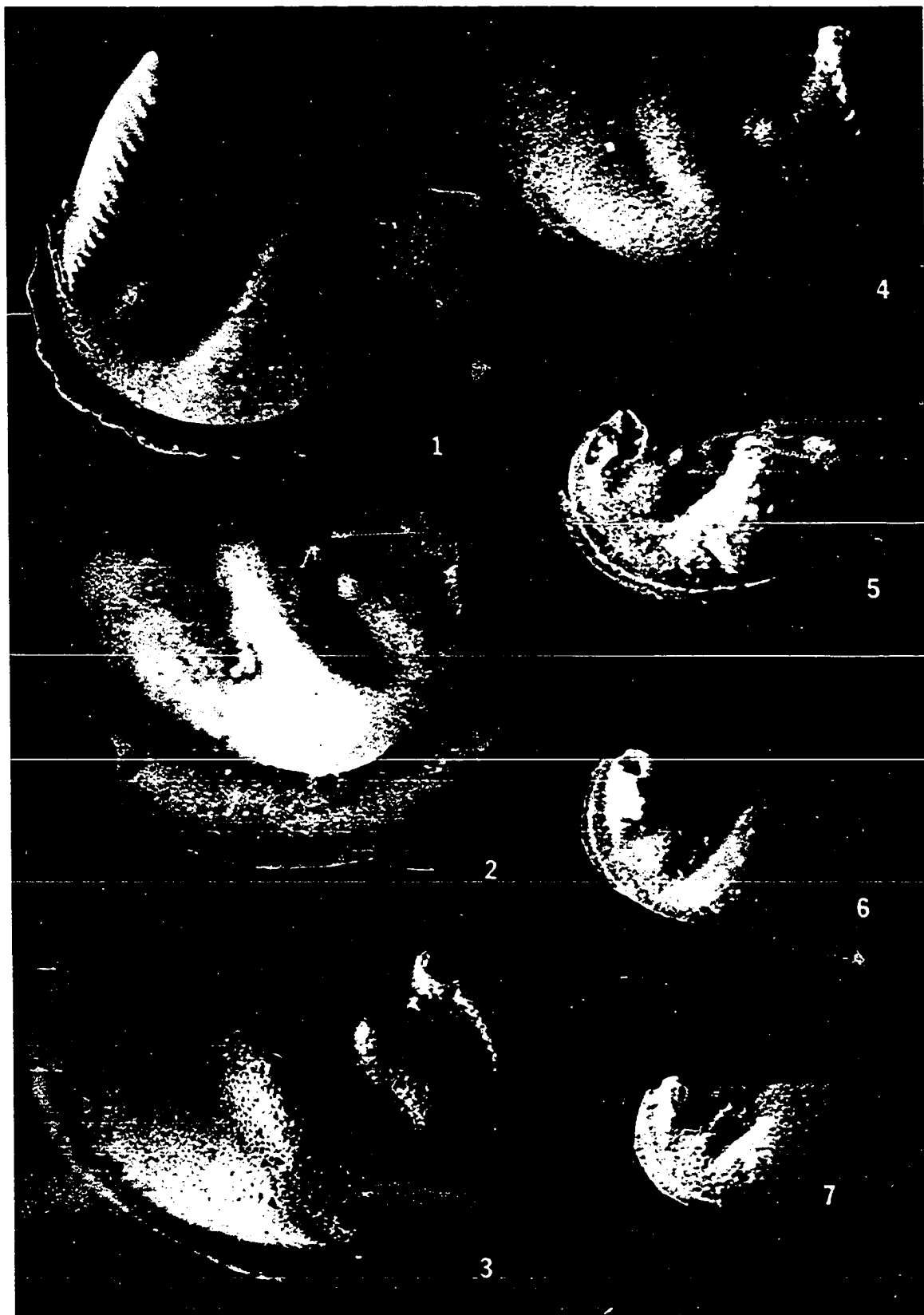
Figure	Page
1-3. <u>Ctenobolbina ciliata</u> (Emmons).....	102
1. Lateral view of the left valve of an Adult-2; note the two spine bases, one dorsal and the other lateral. Sample 12-1. U.C.G.M. 40848. 2. Lateral view of the right valve of an Adult-3. Sample 12-1. U.C.G.M. 40847. 3. Internal and marginal view of an Adult right valve; the material on the inside of the valve consists of non-ostracod fossil fragments. Sample 12-1. U.C.G.M. 40844.	
4-7. <u>Ctenobolbina</u> cf. <u>alata</u> Ulrich.....	112
4. Lateral view of the left valve of a Cotype, an Adult carapace (35X). Locality; excavation along Brown St. Cincinnati Ohio. U.S.N.M. 41489. 5. Ventral view of a Cotype (not the same specimen as fig. 4). An Adult heteromorphic carapace (35X). Locality; same as fig. 4. U.S.N.M. 41489. 6. Ventral view of a fragmental heteromorph. Sample 1-294. U.C.G.M. 40851. 7. Lateral view of an anterior fragment of a right valve. Sample 1-249. U.C.G.M. 40850.	



Explanation of Plate 5

(all figures 45X unless otherwise indicated)

Figure	Page
1-7. <u>Ceratopsis chambersi</u> (Miller).....	117
1. Lateral view of the left valve of an Adult technomorph (35X). Sample 3-2. U.C.G.M. 40171. 2. Lateral view of the right valve of an Adult Heteromorph (35X). Sample 12-1. U.C.G.M. 40812. 3. Lateral view of the right valve of an Adult-1 carapace. Sample 12-1. U.C.G.M. 40820. 4. Lateral view of the right valve of an Adult-2 carapace. Sample 12-1. U.C.G.M. 40819. 5. Lateral view of the left valve of an Adult-3 carapace. Sample 12-1. U.C.G.M. 40818. 6. Lateral view of the left valve of an Adult-4 carapace. Sample 12-1. U.C.G.M. 40817. 7. Lateral view of the left valve of an Adult-5 carapace. Sample 12-1. U.C.G.M. 40816.	

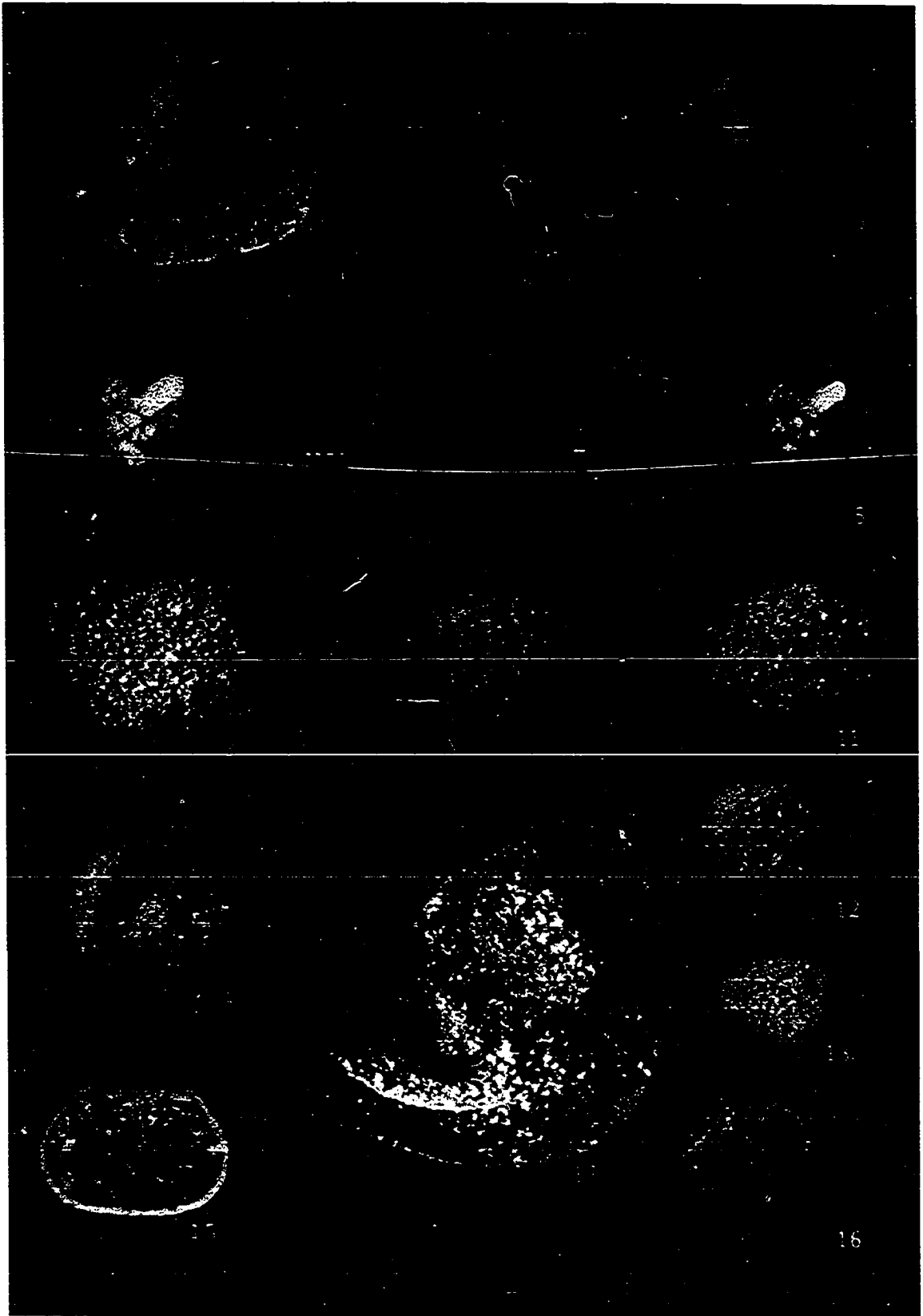


Explanation of Plate 6

(all figures 45X unless otherwise indicated)

Figure	Page
1,2. <u>Aechmina</u> sp. A.....	96
1. Lateral view of left valve. Sample 2-28. U.C.G.M. 40161.	
2. Dorsal view of recrystallized carapace. Sample 2-36. U.C.G.M. 40162.	
3. <u>Aechmina</u> sp. C.....	101
Lateral view of a right valve. Sample 7-3. U.C.G.M. 40774.	
4-6. <u>Aechmina</u> sp. B.....	100
4. Lateral view of a recrystallized juvenile carapace; Plane of focus on the far side of the specimen. Sample 7-3. U.C.G.M. 40773. 5. Same specimen as Fig. 4; Plane of focus on near side of the specimen. 6. Lateral view of a large specimen, questionably an Adult. Sample 2-10. U.C.G.M. 40772.	
7. <u>Euprimitia minuta</u> Keenan.....	113
Lateral view of a pyritized carapace. Sample 8-2. U.C.G.M. 40852.	
8. <u>Euprimitia</u> sp.....	115
Lateral view of recrystallized carapace. Sample 7-5. U.C.G.M. 40854.	
9-13. <u>Aparchites minutissimus</u> (Hall).....	128
9. Lateral view of an Adult left valve. Sample 2-2. U.C.G.M. 40173. 10. Lateral view of an Adult right valve. Sample	

- 2-2. U.C.G.M. 40788. 11. Lateral view of the left valve of an Adult-1. Sample 2-2. U.C.G.M. 40789. 12. Lateral view of the right valve of an Adult-2. Sample 2-2. U.C.G.M. 40790. 13. Lateral view of the right valve of an Adult-3. Sample 2-2. U.C.G.M. 40791.
- 14,15. Platamonaria bicava (Ulrich and Bassler)..... 166
 14. Lateral view of an Adult left valve. Sample 3-2. U.C.G.M. 40179. 15. Internal marginal view of an Adult valve; Note the groove along the dorsal margin. Sample 1-171. U.C.G.M. 40921.
16. Schmidtella claypolei (Jones)..... 162
 Lateral view of an Adult left valve. Sample 6-3. U.C.G.M. 40957.
17. Ceratopsis cf. intermedia Ulrich..... 127
 Lateral view of a right valve overgrown by secondary calcite (35X). Sample 7-7. U.C.G.M. 40821.

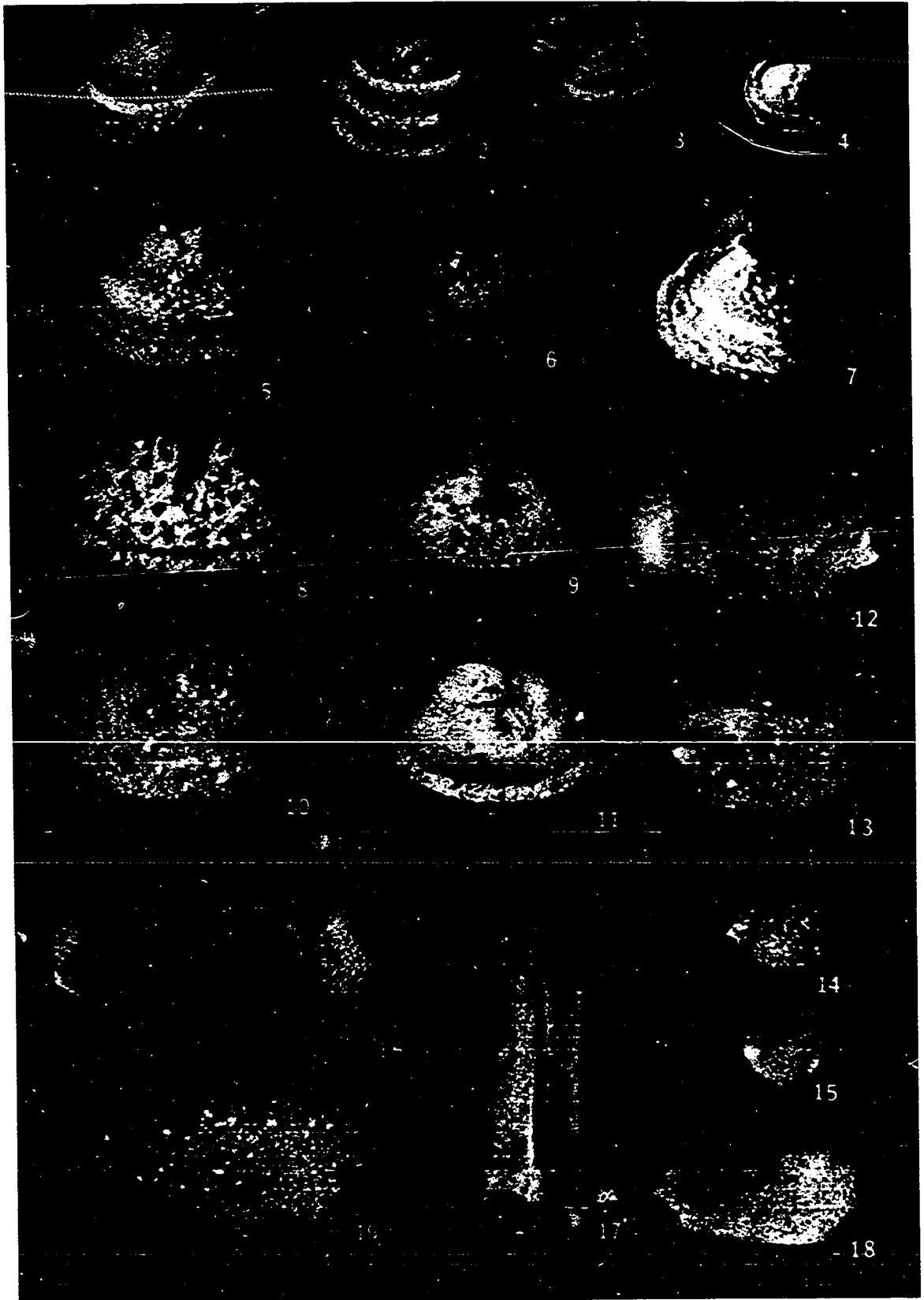


Explanation of Plate 7

(all figures 45X)

Figure	Page
1,2,4. <u>Americanoncha marginata</u> (Ulrich).....	135
1. Lateral view of a left valve retaining 2 instars. Sample 2-28. U.C.G.M. 40174. 2. Lateral view of a right valve retaining 3 instars. Sample 2-28. U.C.G.M. 40822. 4. Lateral view of the Holotype retaining 2 instars. U.S.N.M. 41364. Locality; Corryville Formation, Cincinnati Ohio.	
3. <u>Americanoncha multiannulata</u> (Levinson).....	
Lateral view of the Holotype. U.S.N.M. 116365. Locality; Waynesville Formation, Oxford Ohio.	
5-7. <u>Americanoncha</u> aff. <u>bifurcata</u> (Copeland).....	139
5. Lateral view of a right valve retaining 2 instars. Sample 1-40. U.C.G.M. 40831. 6. Lateral view of a juvenile retaining no instars. Sample 1-40. U.C.G.M. 40832. 7. Oblique view of dorsal margin of a recrystallized carapace retaining 3 instars. Sample 1-40. U.C.G.M. 40830.	
8,9. <u>Milleratia kopensis</u> n. sp.....	143
8. Lateral view of the Holotype, an Adult right valve. Sample 8-2A. U.C.G.M. 40175. 9. Lateral view of a Paratype, a juvenile right valve. Sample 8-3. U.C.G.M. 40942.	
10. <u>Milleratia rudis</u> (Ulrich).....	147
Lateral view of an Adult left valve. Sample 1-42. U.C.G.M. 40955.	

11. Milleratia shideleri (Levinson)..... 150
 Lateral view of an Adult right valve. Sample 2-13. U.C.G.M.
 40950.
- 12-15. Pseudoprimitiella unicornis (Ulrich)..... 153
 12. Lateral view of an Adult left valve. Sample 9-6.
 U.C.G.M. 40965. 13. Lateral view of a juvenile right valve,
 instar unknown. Sample 9-6. U.C.G.M. 40964. 14. Lateral
 view of a juvenile right valve, instar unknown. Sample
 9-6. U.C.G.M. 40967. 15. Lateral view of a juvenile right
 valve. sample 7-5. U.C.G.M. 40968.
- 16-18. Pseudoprimitiella reticulata n. sp..... 157
 16. Lateral view of a Paratype, an Adult right valve.
 Sample 7-3. U.C.G.M. 41310. 17. Dorsal view of the Holo-
 type, a recrystallized Adult carapace. Sample 1-32. U.C.G.M.
 41319. 18. Lateral view of a Paratype, a juvenile right
 valve.
19. "Cytherellina cylindrica" (Hall)..... 188
 Lateral view of a juvenile right valve. Sample 2-16.
 U.C.G.M. 40178.



Explanation of Plate 8

(all figures 45X)

Figure	Page
1-6. <u>Cincinnaticoncha pedigera</u> (Ulrich).....	178
1. Internal view of an Adult right valve. Sample 1-34. U.C.G.M. 40884. 2. Lateral view of an Adult right valve. Sample 2-2. U.C.G.M. 40170. 3. Lateral view of the right valve of an Adult-3. Sample 5-2. U.C.G.M. 40887. 4. Lateral view of the right valve of an Adult-4. Sample 5-2. U.C.G.M. 40888. 5. Lateral view of the left valve of an Adult-5. Sample 5-2. U.C.G.M. 40889. 6. Lateral view of the right valve of an Adult-6. Sample 5-2. U.C.G.M. 40890.	
7-10. <u>Ambitella unispinifera</u> n. sp.....	170
7. Lateral view of the Holotype, an Adult right valve. Sample 1-32. U.C.G.M. 40775. 8. Lateral view of a Paratype, the left valve of an Adult-1. Sample 1-32. U.C.G.M. 40776. 9. Lateral view of a Paratype, the left valve of an Adult-2. Sample 1-32. U.C.G.M. 40780. 10. Internal view of a Para- type, an Adult right valve. Sample 1-32. U.C.G.M. 40779.	
11. " <u>Cytherellina cylindrica</u> " (Hall).....	188
Lateral view of an Adult left valve. Sample 7-3. U.C.G.M. 40798.	
12. " <u>Cytherellina granti</u> " (Ulrich).....	194
Lateral view of an Adult right valve. Sample 1-57 U.C.G.M. 40810.	

13. Ostracod indet. C.....198
 Lateral view of a recrystallized carapace. Sample 2-8.
 U.C.G.M. 41322.
14. Ostracod indet. A.....197
 Lateral view of a recrystallized carapace. Sample 5-19.
 U.C.G.M. 41320.
15. Ostracod indet. D.....198
 Lateral view of a recrystallized carapace. Sample 5-15.
 U.C.G.M. 41323.
16. Ostracod indet. E.....199
 Lateral view of a left (?) valve. Sample 7-3.
 U.C.G.M. 41324.
17. Ostracod indet. B.....197
 Lateral view of a recrystallized carapace. Sample 1-32.
 U.C.G.M. 41321.