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Ostracoda of the Dubuque and Maquoketa Formations of Minnesota and Northern Iowa

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OSTRACODA OF THE DUBUQUE AND MAQUOKETA FORMATIONS OF MINNESOTA AND NORTHERN IOWA

J. H. Burr, Jr., and F. M. Swain

ABSTRACT

The ostracodes of the Dubuque Formation at Wubbles Ravine, Fillmore County, Minnesota and from the depauperate zone of the Maquoketa Formation at Bellevue State Park, Iowa comprise twelve genera and seventeen species, four of which are new.

On the basis of the ostracode data assembled here it is concluded that: (1) the Dubuque Ostracoda differ slightly from those of other Middle and Upper Ordovician rocks in the Mississippi Valley; (2) no equivalent of the Eden and Maysville Groups can at present be recognized in ostracode assemblages from Minnesota; (3) an unconformity exists between the Dubuque and Maquoketa Formations, recognizable on both faunal and lithologic grounds; and (4) the ostracode species of the depauperate zone of the Maquoketa Formation are not as a whole characterized by reduced dimensions of the shell as are some of the macrofaunal species.

INTRODUCTION

Ostracoda from the Dubuque and Maquoketa Formations of southern Minnesota and northern Iowa contribute to the solution of problems of Middle and Upper Ordovician stratigraphy. The purpose of this paper is to describe the ostracode species from one locality in the Dubuque and one in the Maquoketa and to evaluate the stratigraphic distribution of the species.

Collections were made by Burr from Wubbles Ravine where the Dubuque occurs as limestone intercalated with thin shaly layers, the latter generally less than 6 inches but locally as much as 22 inches thick. Samples were collected from each shale and limestone layer, dried, divided, and half treated with gasoline and half with acetic acid. The residues were washed through a 250-mesh screen and that fraction which remained on the screen was picked for Ostracoda. The shale residue contained a small number of specimens whereas the limestone residue contained none. We had hoped that the limestone might contain pyritized specimens, which are very common in the depauperate zone of the overlying Maquoketa Formation elsewhere. In order to insure that there were no microfossils in the limestone, hand specimens of the rock were examined carefully under a microscope.

The Maquoketa collections were obtained by both of us from Bellevue State Park, Iowa. The Bellevue section is a classic one in Ordovician stratigraphy, and provides a valuable addition to the collections from Minnesota. At that locality the depauperate zone is represented by 4 to 8 inches of light gray to dark gray shale containing a "dwarfed" molluscan fauna and abundant pyrite. Samples collected from Bellevue

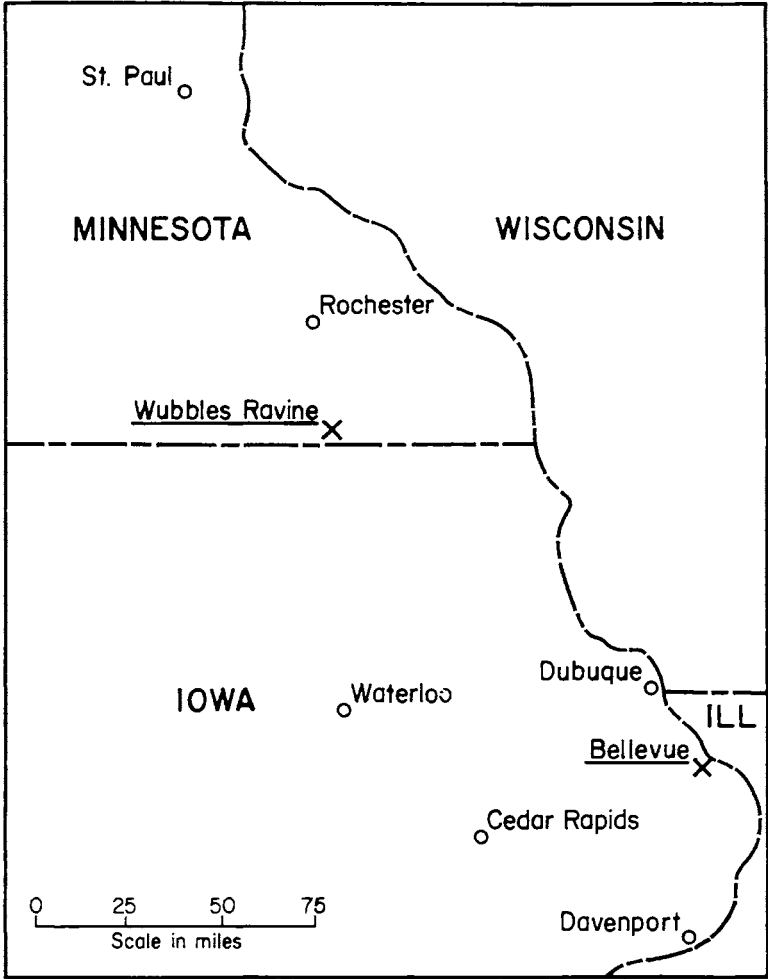


Figure 1—Map of southeastern Minnesota and adjacent areas showing location of areas studied.

were treated with hydrochloric acid, releasing many pyritized Ostracoda. A preliminary study of the specimens was made by E. J. Bolin.

Seventeen species are identified by us in this paper, of which four are new. The synonymy of each of the previously described species, descriptions of all species, and illustrations are given, together with brief descriptions of all genera. The specimens were photographed by Swain.

A table compiling results of the work of Kay, Cornell, Spivey, Keenan, Ulrich, Bassler, and us is also given. This tabulates the Ostracoda found in the Upper Ordovician rocks of the Mississippi Valley, as well as those of the Eden and Maysville Formations of Ohio and Kentucky.

Localities

The collections described herein were obtained from the following localities:

1. The Dubuque Formation at Wubbles Ravine; from a road cut along the town road in a ravine in the N½ Sec. 2, York Township (101 N, 12 W), Fillmore County, Minnesota. This section is described by Weiss (1953, p. 446).
2. The depauperate zone of the Maquoketa Formation, from the bank of Mill Creek, where it is crossed by the road leading south from Bellevue, at Bellevue State Park in Jackson County, Iowa. This section is described by Ladd (1929, p. 379).

ACKNOWLEDGMENTS

Edward J. Bolin provided his collection and prepared many of the depauperate zone specimens. We also wish to express our appreciation for the contributions of Dorothy Phillips Burr, K. A. Dickinson, D. R. Hoefl, and R. L. Buchheit.

REVIEW OF PREVIOUS WORK

Correlation of the Dubuque and Maquoketa Formations has been discussed by several writers and is reviewed herein. Among the problems are (1) correlation with other formations, (2) presence or absence of an unconformity between the Maquoketa and Dubuque, and (3) the possibility of Eden-Maysville correlatives in the Mississippi Valley.

The Dubuque is not regarded as a separate formation by all authors. Stauffer and Thiel (1941) considered the Dubuque in Minnesota as part of the Maquoketa Formation, Upper Ordovician, whereas other authors (Twenhofel, 1954) considered it as a part of the Galena Formation, Middle Ordovician. Since its introduction as a formal unit, the Maquoketa has been regarded as a separate formation.

Early workers considered the Galena Limestone to be part of the Silurian System, resting on the fossiliferous strata of Trentonian age. As more precise methods were employed, the classification of the Galena and Trenton beds was redefined. Ulrich (1911) considered the Stewart-

ville Member of the Galena Formation to be Middle Trenton in age and the Prosser Member to be equivalent to beds which underlie the Trenton Group in New York. The Prosser Member was thus judged to be of Hull (Black River) age. Ulrich (1930) correlated the Prosser with the Trenton Group and placed the Galena opposite the Eden and Maysville in his table, thus concluding that the Galena was post-Trenton in age. Kay (1935a) proved on the basis of stratigraphic evidence that the Stewartville was of Trenton age and younger than upper Hull. He found the fauna resembled that of the upper Cobourg Formation.

Ulrich (1911) classified the Dubuque as the oldest formation in the Richmond Group, which he placed in the lower part of the Medina Series of the Silurian. Ladd (1929) agreed with Ulrich that the Maquoketa Formation should be placed in the Silurian but pointed out that until more work was done it was probably best to leave it in the Ordovician. If the Stewartville is approximately equivalent to the upper Cobourg (Middle Trentonian) and the Maquoketa is Richmondian, the Dubuque Formation occupies a position somewhere between middle Trentonian and early Richmondian.

Hall and Sardeson (1892) originally included the Dubuque in the Maquoketa Formation, but Sardeson later recognized that it underlay that unit and referred to it as the *Oxoplecia* bed and Transition Formation. Even though he included the Dubuque in his Maquoketa or Hudson River Series he believed it to be older than Richmond and Utica correlatives (1897). Keyes (1931) agreed with Sardeson, pointing out that the faunal affinities of the Dubuque were, in his opinion, with the Maquoketa Formation above and not with the underlying Galena. Kay (1935a) classified the Dubuque as a member of the Galena Formation because it contained a typical Stewartville cephalopod, *Lambeoceras confertum* Foerste.

Most authors agree that the Stewartville and the overlying Dubuque Formations are conformable. However, the presence or absence of an unconformity between the Dubuque and the overlying Maquoketa Formation in the upper Mississippi Valley is debatable. The depauperate zone at the base of the Maquoketa contains many minute phosphatic invertebrates, commonly in a pyritiferous matrix. According to Agnew (1955) this zone represents a widespread sea, because the pyrite is recognized over a large area. He believed that the fossils of the middle Galena are Trenton in age whereas those of the upper part are similar to Richmond faunas. He also believed that the Maquoketa sea, especially in western Iowa, was continuous with that of the Galena. These concepts supported his opinion that there was no significant time break in the Galena-Maquoketa sequence in Iowa. The time interval of the Eden and Maysville deposits would probably be represented in the upper Galena or Dubuque rocks. The Eden and Maysville shaly-facies fauna would not necessarily have any similarity to the carbonate-facies fauna of the upper Galena (Weiss, 1953).

Ladd (1929) cited several kinds of evidence for an unconformity

between the Dubuque and Maquoketa Formations as a result of overlap. He pointed out that in addition to the absence of the Eden and Maysville Groups the presence of an unconformity was suggested by (1) the appearance of phosphatic beds, which commonly occur at stratigraphic breaks, in the depauperate zone at the base of the Maquoketa Formation, (2) the presence of carbonate pebbles, mechanically worn and pitted, probably by solution, (3) a distinct and sharp faunal change, the depauperate zone containing forty-odd species none of which is found in the lower rocks, (4) the occurrence of limonite which suggests exposure to the atmosphere in pre-Maquoketa times, and (5) the presence of an erosional unconformity beneath the Maquoketa Formation in Illinois and Missouri.

The study of the Ostracoda of the Dubuque and Maquoketa Formations contributes to the problem of the stratigraphic position and significance of the two formations but does provide unique solutions.

Table 1. Occurrence of Paleozoic Ostracoda in Ordovician sections

SPECIES	Depauperate Zone, Iowa	Maquoketa Fm., Iowa	Maquoketa Fm., Missouri	Eden-Maysville, Ohio, Ky.	Dubuque Fm., Minnesota	Decorah Fm., Minnesota	Decorah Fm., Iowa
	A	B	C	D	E	F	G
Aparchitidae							
<i>Aparchites barbatus</i> Keenan			x				
<i>Aparchites carinatus</i> Kay							x
<i>Aparchites chatfieldensis</i> Ulrich							x
<i>Aparchites ellipticus</i> Ulrich							x
<i>Aparchites fimbriatus</i> (Ulrich)						x	
<i>Bullatella granilabiatus</i> (Ulrich)						x	
<i>Aparchites macrus</i> (Ulrich)							x
<i>Aparchites minutissimus</i> (Hall)		x		x			
<i>Aparchites paratumida</i> Swain and Cornell							x
<i>Macronotella arcta</i> (Ulrich)							x
<i>Macronotella scofieldi</i> Ulrich						x	
<i>Byrsolopsina centipunctata</i> (Kay)						x	x
<i>Paraschmidtella irregularis</i> Keenan			x				
<i>Byrsolopsina normella</i> Swain and Hansen							x
<i>Byrsolopsina ovata</i> (Kay)						x	x
<i>Byrsolopsina planilateralis</i> (Kay)						x	x
<i>Paraschmidtella uphami</i> (Ulrich)							x
<i>Sacclatia angularis</i> (Ulrich)							x
<i>Sacclatia arcuamuralis</i> Kay						x	x
<i>Sacclatia arrecta</i> (Ulrich)						x	x
<i>Sacclatia bullata</i> Kay						x	x
<i>Sacclatia cletifera</i> Kay						x	x
Opikellidae							
<i>Opikatia emaciata</i> Kay						x	x
<i>Opikatia rotunda</i> Kay							x
Kloedenellidae							
<i>Eukloedenella richmondensis</i> Spivey		x					

Table 1 (continued)

SPECIES	A	B	C	D	E	F	G
Beyrichiidae							
<i>Beyrichia irregularis</i> Spivey		x					
<i>Parabolbina antecedens</i> Kay						x	
<i>Parabolbina carinifera</i> Kay							x
<i>Parabolbina stauferi</i> Kay							x
Ulrichiidae							
<i>Ulrichia nodosa</i> (Ulrich)		x		x	x		
<i>Ulrichia saccula</i> Burr and Swain, n. sp.	x						
Drepanellidae							
<i>Marattia</i> sp.						x	
<i>Marattia mara</i> Kay						x	
<i>Marattia micula</i> (Ulrich)						x	x
<i>Scofeldia bilateralis</i> (Ulrich)						x	x
Zygobolbidae							
<i>Zygobolboides calvini</i> Spivey		x					
<i>Zygobolboides grafensis</i> Spivey	x	x					
<i>Zygobolboides iowensis</i> Spivey		x					
<i>Zygobolboides thomasi</i> Spivey		x					
Bolliidae							
<i>Bollia persulcata</i> (Ulrich)				x		x	
<i>Bollia pulchra</i> Ruedemann				x			
<i>Bollia regularis</i> (Emmons)	x						
<i>Bollia ridicula</i> Keenan			x				
<i>Bollia ruthae</i> Spivey		x					
<i>Bollia simplex</i> (Ulrich)						x	x
<i>Bollia subaequata</i> Ulrich						x	x
<i>Parenthatia camerata</i> Kay						x	x
<i>Parenthatia punctata</i> (Ulrich)						x	x
Aechminidae							
<i>Aechmina cuspidata</i> Jones and Holl			x				
<i>Aechmina ionensis</i> Kay						x	x
<i>Aechmina maquoketensis</i> Keenan			x				
<i>Aechmina taurea</i> Keenan			x				
Tetradellidae							
<i>Bellornatia tricollis</i> Kay						x	x
<i>Ceratopsis chambersi</i> Miller				x		x	
<i>Ceratopsis humilinoda</i> Kay							x
<i>Ceratopsis oculifera</i> (Hall)				x			
<i>Ceratopsis quadrifida</i> (Jones)						x	x
<i>Ceratopsis trilobis</i> Keenan		x					
<i>Dicranella bicornis</i> Ulrich						x	x
<i>Dicranella marginata</i> Ulrich						x	x
<i>Dicranella spinosa</i> Ulrich							x
<i>Dilobella simplex</i> (Krause)						x	x
<i>Dilobella typa</i> Ulrich						x	x
<i>Dilobella lorrainensis</i> Reudemann				x			
<i>Raymondatia goniglypta</i> Kay						x	x
<i>Rigidella</i> sp.						x	
<i>Tetradella carinata</i> Keenan			x				
<i>Tetradella ellipsilira</i> Kay						x	x
<i>Tetradella septinoda</i> Keenan			x				
<i>Tetradella ulrichi</i> Kay						x	x
<i>Tetradella subquadrans</i> Ulrich					x		
<i>Thomasatia falcicosta</i> Kay						x	x
Sigmoopsidae							
<i>Ctenobolbina bispinosa</i> Ulrich			x				
<i>Ctenobolbina carinata</i> (Anderson)				x			
<i>Ctenobolbina duryi</i> (Miller)				x			
<i>Ctenobolbina emaciata</i> (Ulrich)		x					
<i>Ctenobolbina maquoketensis</i> Spivey		x					
<i>Kiesowia binoda</i> Keenan			x				
<i>Kiesowia insolens</i> Keenan			x				
<i>Kiesowia verrucosa</i> Kay		x				x	x
<i>Winchellatia initialis</i> (Ulrich)							x
<i>Winchellatia lansingensis</i> Kay						x	x
<i>Winchellatia longispina</i> Kay							x
<i>Winchellatia minnesotensis</i> Kay						x	x

Table 1 (continued)

SPECIES	A	B	C	D	E	F	G
Bassleratiidae							
<i>Bassleratia typha</i> Kay							x
Leperditellidae							
<i>Nodambichilina symmetrica</i> (Ulrich)						x	x
<i>Cryptophyllus sulcatus</i> Levinson						x	
<i>Cryptophyllus oboloides</i> (Ulrich and Bassler)							
<i>Eridococoncha elegantula</i> Keenan			x				
<i>Eridococoncha gibbera</i> (Ulrich)			x				
<i>Eridococoncha marginata</i> (Ulrich)	x		x				
<i>Eridococoncha punctata</i> Keenan			x				
<i>Eridococoncha rugosa</i> Ulrich and Bassler				x			
<i>Euprimitia floris</i> Keenan			x				
<i>Euprimitia labiosa</i> (Ulrich)						x	x
<i>Euprimitia linepunctata</i> (Kay)							x
<i>Euprimitia? celata</i> (Ulrich)							x
<i>Euprimitia minuta</i> Keenan			x				
<i>Euprimitia sanctipauli</i> (Ulrich)						x	x
<i>Hallatia convexa</i> Kay						x	x
<i>Hallatia? duplicata</i> (Ulrich)							x
<i>Hallatia partycylindrica</i> Kay						x	x
<i>Halliella magnapunctata</i> Kay							x
<i>Jonesella pedigera</i> Ulrich				x			
<i>Jonesites marginatus</i> (Ulrich)				x			
<i>Laccoprimitia centralis</i> (Ulrich)				x			
<i>Laccoprimitia fillmorensis</i> (Ulrich)							x
<i>Leperditella? dorsicornis</i> Ulrich			x				
<i>Leperditella fryei</i> Spivey		x					
<i>Leperditella macra</i> Ulrich							x
<i>Leperditella millepunctata</i> (Ulrich)							x
<i>Leperditella persimilis</i> Ulrich							x
<i>Leperditella sacceliformis</i> Keenan			x				
<i>Milleratia cincinnatiensis</i> (Miller)	x	x					
<i>Primitia gibbera</i> Ulrich		x					
<i>Primitia mammata</i> Ulrich					x	x	x
<i>Primitia rudis</i> Ulrich				x			
<i>Primitia spinata</i> Burr and Swain, n. sp.					x		
<i>Primitia tumidula</i> Ulrich	x				x	x	
<i>Primitia uphami</i> Ulrich							
<i>Primitiella belleuensis</i> Spivey		x					
<i>Primitiella carli</i> Spivey		x					
<i>Primitiella constricta</i> Ulrich						x	x
<i>Primitiella milleri</i> Spivey		x					
<i>Primitiella paucisulcata</i> Burr and Swain, n.sp.	x						
<i>Primitiella plattevilensis</i> Kay						x	
<i>Primitiella</i> sp.						x	
<i>Primitiella uniconis</i> (Ulrich)	x		x	x		x	
<i>Schmidtella affinis</i> Ulrich						x	x
<i>Schmidtella brevis</i> Ulrich						x	x
<i>Schmidtella incompta</i> Ulrich	x					x	x
<i>Schmidtella lacunosa</i> Burr and Swain, n.sp.	x					x	x
<i>Schmidtella latimarginata</i> Keenan			x				
<i>Schmidtella umbonata</i> Ulrich						x	x
<i>Pedomphalella intermedia</i> Swain and Cornell							x
<i>Pedomphalella subovata</i> Swain and Cornell							x
Eurychilinae							
<i>Eurychilina incurva</i> Ulrich (considered a dimorph, Kay 1940)							x
<i>Eurychilina minutifoveata</i> Kay						x	x
<i>Eurychilina partifimbriata</i> Kay						x	x
<i>Eurychilina reticulata</i> Ulrich						x	x
<i>Eurychilina subradiata</i> Ulrich						x	x
<i>Eurychilina ventrosa</i> Ulrich						x	x
<i>Bromidella depressa</i> Kay						x	x
<i>Bromidella rhomboides</i> Kay						x	x
<i>Tsitrella simplex</i> Swain and Hansen							
Primitiopsidae							
<i>Primitiopsis? bella</i> Kay							x

Table 1 (continued)

SPECIES	A	B	C	D	E	F	G
Entomidae							
<i>Elpe cincinnatiensis</i> (Meek)				x			
<i>Elpe irregularis</i> (Miller)				x			
<i>Elpe radiata</i> (Ulrich)				x			
Beecherellidae							
<i>Krausella arcuata</i> Ulrich							x
<i>Krausella curtispina</i> Kay							x
<i>Krausella inaequalis</i> Ulrich		x					
Barychilidae							
<i>Ellesmeria scobeyi</i> Spivey		x					
Cyprididae							
<i>Bythocypris batesi</i> Kay							
<i>Bythocypris? curta</i> Ulrich							x
<i>Bythocypris cylindrica</i> (Hall)			x	x		x	x
<i>Bythocypris furnishi</i> Spivey		x					
<i>Bythocypris granti</i> Ulrich							x
<i>Macrocypris kayi</i> Spivey		x					
Punctaparchitidae							
<i>Punctaparchites multipunctata</i> (Kay)							x
<i>Punctaparchites rugosus</i> (Jones)						x	x
<i>Punctaparchites splendens</i> (Keenan)							
<i>Macrocyproides clermontensis</i> Spivey	x		x				
<i>Macrocyproides trentonensis</i> (Ulrich)		x			x	x	x
Unknown family							
<i>Laddella insueta</i> Spivey		x					

Explanation for Table 1

- A. Depauperate zone of the Maquoketa Formation at Bellevue State Park, Iowa.
 B. Maquoketa Formation of Iowa at Dubuque, Graf, Fort Atkinson, Eldorado, and Clermont Township of Fayette County (Spivey, 1939).
 C. Maquoketa Formation of Missouri at Castlewood (Keenan, 1951).
 D. Eden and Maysville Formations from several locations in Ohio and Kentucky (Bassler and Kellett, 1934).
 E. Dubuque Formation at Wubbles Ravine in Fillmore County, Minnesota.
 F. Decorah Formation of Minnesota at Cannon Falls, Rochester, Sugar Creek, and St. Paul (Cornell, 1956).
 G. Decorah Formation of Minnesota, Wisconsin, and Iowa at: Church, Iowa; Ellsworth, Wisconsin; Cannon Falls, Minnesota; Glenwood Township, Winneshiek County, Iowa; and Allamakee County, Iowa (Kay, 1940).

DISCUSSION

The Ostracoda of the Dubuque Formation at Wubbles Ravine and the depauperate zone of the Maquoketa Formation at Bellevue State Park pose several stratigraphic problems. Those that will be discussed in this paper are (1) the correlation with other formations, (2) the presence or absence of an unconformity between the Dubuque and Maquoketa Formations, (3) the possibility of Eden-Maysville correlatives in the upper Mississippi Valley, and (4) the problem of "dwarfed" faunas. The significance of several length-height ratio diagrams will also be discussed.

Correlation

At first glance the Dubuque ostracode fauna appears to be markedly different from that of other formations of the Minnesota Ordovician.

The species found in the Dubuque section at Wubbles Ravine are: *Macrocyproides trentonensis*, *Warthinia nodosa*, *Tetradella subquadrata*, *Primitia mammata*, *Primitia spinata* n. sp., and *Primitia tumidula*. An examination of table 1 shows that only *T. subquadrata* and *P. spinata* are restricted to the Dubuque Formation. The others are found in the Decorah and/or the Maquoketa Formations. Moreover *T. subquadrata* has been reported in the Trenton Group, Trenton Falls, N.Y. Among those species encountered elsewhere in the upper Mississippi Valley, *M. trentonensis* has been reported in the Decorah and Maquoketa, *W. nodosa* in the Maquoketa, *P. mammata* in the Decorah, and *P. tumidula* in the Decorah and Maquoketa.

We are treating the identification of *W. nodosa* as questionable because of the close similarity of the genera *Ulrichia*, *Kiesowia*, and *Warthinia*. *Ulrichia nodosa* has been cited as fairly common in the Eden and Maysville beds. It is believed that *U. nodosa* and *W. nodosa* may be conspecific but a definite comparison must await redescription of the type of *U. nodosa*.

Although the ostracode fauna of the Dubuque does not resemble that of any other known formation, there are relatively few species on which to base this conclusion. A logical conclusion would be that the data do not allow the correlation of the Dubuque ostracodes with those of any other Ordovician formation, but whether this be due to age difference or to facies variation is yet to be determined.

Unconformity Between Dubuque and Maquoketa Formations

Although the present collection from the depauperate zone of the Maquoketa Formation differs somewhat from that of the remainder of the formation, only a few of the species are common to the underlying Ordovician rocks. Only 11 percent of the Maquoketa species have been recorded from older rocks of the Minnesota-Iowa-Missouri area. Moreover, only 5.5 percent of the Decorah species carry over into the Maquoketa. The ostracode data would therefore not detract from evidence for an unconformity beneath the Maquoketa.

Eden-Maysville Correlation

The Eden-Maysville Ostracoda are generally different from those of either the Dubuque or the Maquoketa Formations. Only three species or 16 percent of the Eden-Maysville species are common to the Maquoketa and only four or 21 percent are common to the Dubuque; furthermore, two of the species are common to all three units. Therefore, little direct evidence exists for correlating the Dubuque Formation of the Mississippi Valley with the Eden and Maysville beds in Ohio and Kentucky. Present knowledge of Ostracoda of the Eden-Maysville (19 species) indicates that the Dubuque has a much different fauna and probably is not of the same age. However, it should be pointed out that very little recent work has been published on the Ostracoda of the Ohio-Kentucky area. The late Professor William H. Shideler is said to have made extensive collections

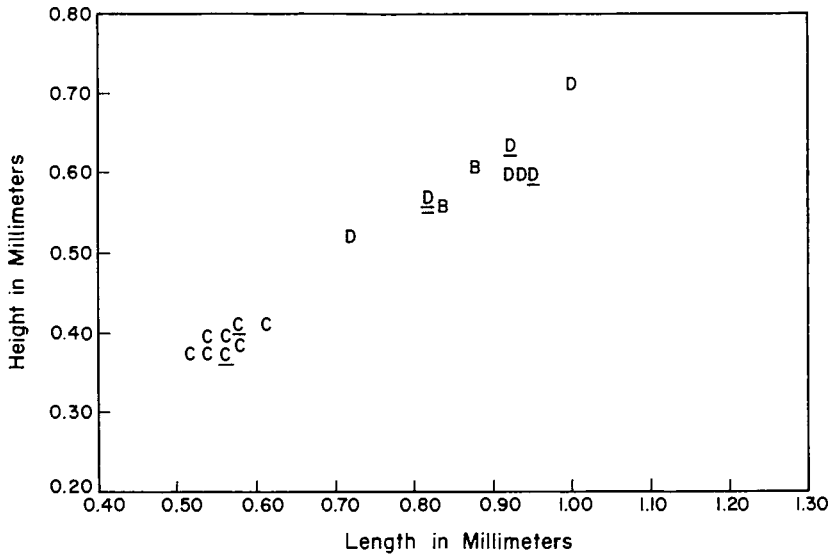


Figure 2—Length-height ratio of *Primitia tumidula* Ulrich. D, Du-buque, Wubbles Ravine; B, Maquoketa, Bellevue State Park; C, Decorah, Cornell (1956). Underlining indicates more than one specimen.

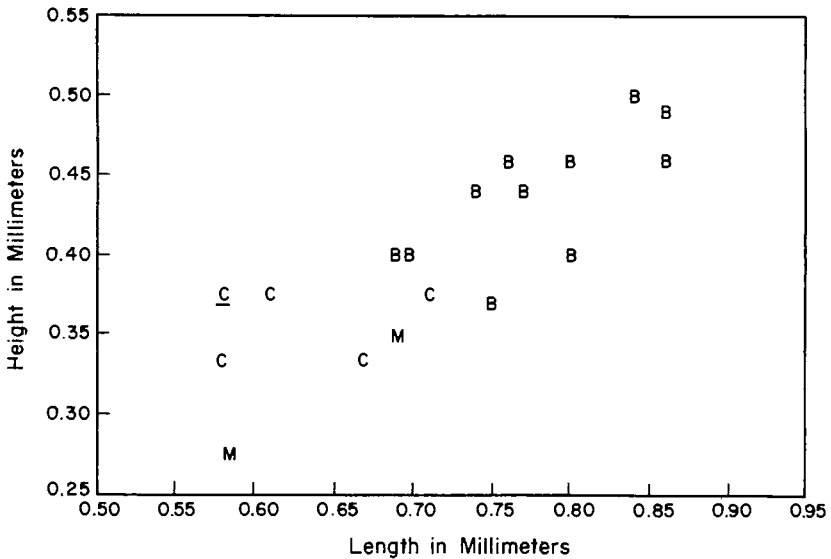


Figure 3—Length-height ratio of *Primitiella unicornis* (Ulrich). B, Maquoketa, Bellevue State Park; C, Decorah, Cornell (1956). M, Maquoketa, Keenan (1951). Underlining indicates more than one specimen.

from that area but his findings have not been presented. The results of such a study should prove enlightening. The possibility exists that the Eden-Maysville Ostracoda were taken from a different facies, or from deposits of a separate basin of deposition, from that in which the fauna of the Dubuque accumulated, so that age equivalence would be difficult to recognize.

“Dwarfed” Fauna

The depauperate zone at the base of the Maquoketa Formation has a fauna which has been termed “dwarfed” by Ladd (1929) and Kay (1935b). Examples of other “depauperate” faunas are given by Tasch (1953). To date, the only fossils that have been described as being dwarfed species are macrofossils (Tasch, 1953; Ladd, 1929). Many of the ostracodes recovered from the depauperate zone by us were found to be smaller than normal for adults, notably *Schmidtella incompta*. Figure 4 shows an overall decrease in length-height ratio of *S. incompta* from the Decorah to the Maquoketa depauperate zone. It is possible that the identification of *S. incompta* in either the Decorah or Maquoketa is incorrect. Some specimens, however, reached their normal dimensions perhaps in no more than a normal molt: adult ratio. Perhaps as a result of unfavorable seasonal bottom conditions individuals of some species (i.e. *Eridoconcha marginata*) died before attaining adulthood, rather than being stunted. The high content of pyrite and phosphate attests to unusual sea water composition. It should be emphasized, however, that whatever caused the diminution of the macrofossils had little effect on some species of Ostracoda, for example *Primitiella unicornis* (figure 3) and *Primitia tumidula* (figure 2) and *Macrocyproides trentonensis* (figure 4).

We conclude from the general size as well as the length-height ratio that the Ostracoda of the depauperate zone are not dwarfed. Furthermore, from the fact that forty-odd species are found in the depauperate zone, none of which is reported in older rocks, we conclude that the entire fauna of the depauperate zone was neither dwarfed nor environmentally inhibited.

Agnew's contention (1955) that the depauperate zone represents a widespread deepened stagnant sea seems unlikely from the number and variety of ostracode species as well as by their increased size. Ostracoda typically are excluded from deep stagnant sea bottoms or occur only in limited numbers of species and individuals in such environments.

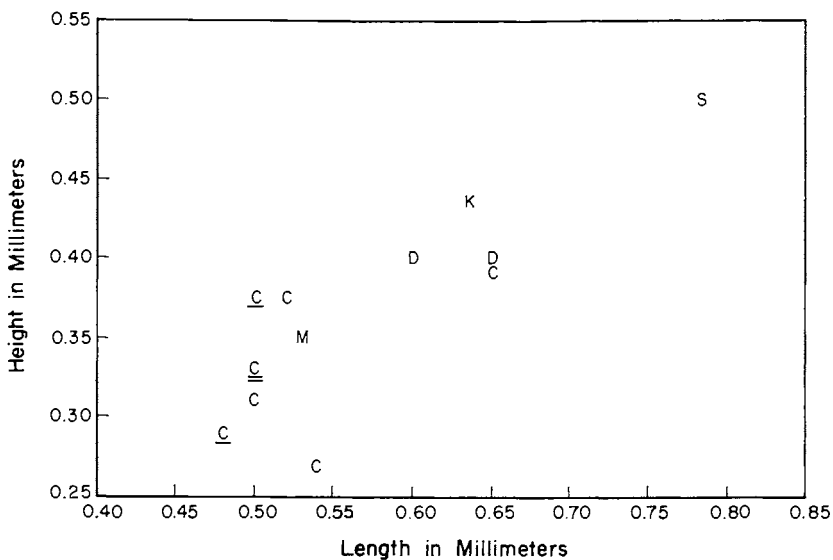


Figure 4—Length-height ratio of *Macrocyproides trentonensis* (Ulrich). C, Decorah, Cornell (1951); D, Dubuque, Wubbles Ravine; K, Decorah, Kay (1940); S, Maquoketa, Spivey (1939); M, Maquoketa, Keenan (1951). Underlining indicates more than one specimen.

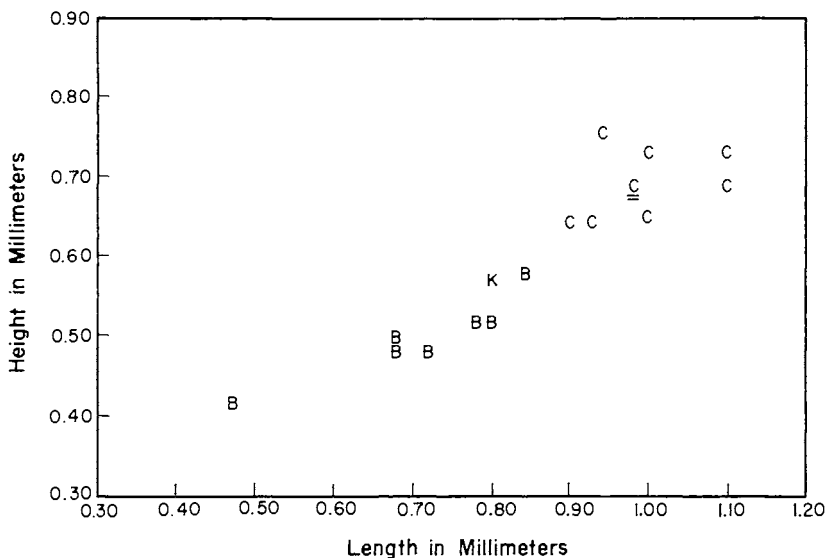


Figure 5—Length-height ratio of *Schmidella incompta* Ulrich. B, Maquoketa, Bellevue State Park; C, Decorah, Cornell (1956); K, Decorah, Kay (1940). Underlining indicates more than one specimen.

SYSTEMATIC DESCRIPTIONS

Order Palaeocopida Henningsmoen, 1953

Suborder Beyrichicopina Scott, 1961

Superfamily Drepanellacea Ulrich and Bassler, 1923

Family Bolliidae Bouček, 1936

Genus *Bollia* Jones and Holl, 1886

Bollia Jones and Holl, 1886, *Annals and Mag. Nat. Hist.*, ser. 5, 17, p. 360.

Carapace oblong or somewhat rounded; valves subequal; ends rounded and nearly equal; hinge straight. Surface punctate or smooth; large horseshoe-shaped ridge in ventral and median portions; angular or rounded marginal ridge, rarely coalescing with inner ridge; ends of horseshoe ridge may be bulbous while connecting portion is relatively low and thin. Ridges hollow as seen interiorly.

Genotype. *Bollia bicollina* Jones and Holl.

Geologic range. Middle Ordovician-Upper Devonian.

Bollia regularis (Emmons)

Plate 4, Figures 7, 11

Beyrichia regularis Emmons, 1855, *Am. Geologist*, v. 1, pt. 2, p. 219, text fig. 74b; Walcott, 1884, *U. S. Geol. Survey Mon.* 8, p. 88; Lesley, 1889, *Pa. Geol. Survey Rept. Prog.* 4, p. 91, text fig.; Jones, 1890, *Geol. Soc. London Quart. Jour.*, v. 46, p. 13.

Bollia regularis (Emmons) Ulrich, 1894, *Final Rept. Minn. Geol. Nat. Hist. Survey*, v. 3, pt. 2, p. 669; Ulrich and Bassler, 1908, *U. S. Nat. Mus. Proc.*, v. 35, p. 288, text figs. 12-14; Bassler, 1915, *U. S. Nat. Mus. Bull.*, v. 92, p. 129; Foerste, 1918, *Ottawa Nat.*, v. 31, p. 124.

Bollia permarginata (Foerste) Bassler and Kellett, 1934, *Geol. Soc. America Special Paper* 1, p. 219.

Tetradella regularis (Emmons) Hussey, 1926, *Univ. Mich. Mus. Geol. Contr.*, v. 2, no. 8, p. 131, pl. 2, figs. 14-15.

Subovoid in outline; hinge line and dorsum straight or nearly so; ventral edge more or less uniformly rounded; maximum width equal to about two-thirds of maximum length. Three prominent ridges and one less well-developed ridge posteriorly; two medial lobes joined ventrally to form a horseshoe ridge. Lobes hollow as seen internally. Length varies from 0.60 to 0.67 mm.; width varies from 0.40 to 0.47 mm.

Remarks. *B. regularis* as described by Ulrich differs from that of Emmons in that the medial horseshoe ridge overlaps the dorsal margin in the former and not in the latter. *Beyrichia regularis* Emmons shows a centrally located horseshoe ridge, which is not present in the specimens of Ulrich; in which it is located slightly toward the posterior margin. The classification of *Tetradella regularis* is also doubtful, owing to incomplete

description and illustration of Hussey's species. The writers have tentatively classified *T. regularis* as conspecific with *B. regularis*.

Occurrence. Depauperate zone at the base of the Maquoketa Formation at Bellevue State Park, Iowa. Also found in Waynesville Formation of Ohio, Indiana and northern Michigan.

Genus *Ulrichia* Jones, 1890

Ulrichia Jones, 1890, Geol. Soc. London Quart. Jour., v. 46, p. 543.

Warthinia Spivey, 1939, Jour. Paleontology, v. 13, no. 2, p. 167.

Shell small equivalved, subquadrate, surface reticulate and with distinct marginal rim; two prominent dorsomedian nodes which, unlike *Bollia*, are not united ventrally.

Genotype. *Ulrichia conradi* Jones.

Geologic range. M. Ordovician-M. Devonian.

Ulrichia nodosa (Ulrich)

Plate 4, Figures 2a-b, 3

Primitia nodosa Ulrich, 1890, Cincinnati Soc. Nat. Hist. Jour., v. 13, p. 134, pt. 10, figs. 11a-12b.

Ulrichia nodosa (Ulrich) Ulrich, 1891, Cincinnati Soc. Nat. Hist. Jour., v. 13, p. 203; Grabau and Shimer, 1910, North American Index Fossils, p. 346, text fig. 1658, o, o'; Bassler, 1915, U. S. Nat. Mus. Bull., v. 92, p. 1311; 1927, Geol. Surv. Canada Mem. 154, p. 345.

Warthinia nodosa (Ulrich) Spivey, 1939, Jour. Paleontology, v. 13, p. 167-168.

Kiesowia nodosa (Ulrich) Kay, 1940, Jour. Paleontology, v. 14, p. 234; Keenan, 1951, Jour. Paleontology, v. 25, p. 569.

Semicircular in outline; equivalved; greatest length in dorsal third; greatest thickness in posterior third; very narrow marginal ridge; hinge straight, about 0.7 of total length of valve. Well defined node just anterior to center of carapace, overlapping dorsal margin; somewhat less well defined node on anterodorsal margin with dorsal overlap; poorly defined node or swelling on anteroventral margin at about midheight; surface finely punctate. Interior not visible. Length and width are 0.49 mm. and 0.25 mm. respectively.

Remarks. The writers did not observe a prominent spine but rather a rounded, blunted spine anterior to the center of the valve. Similar specimens have been figured by other authors as *Primitia nodosa* Ulrich (1890, p. 134), *Ulrichia nodosa* (1891, p. 203), and *Kiesowia nodosa* (Ulrich) Kay (1940, p. 234).

Occurrence. In the upper twelve feet of Dubuque Formation at Wubbles Ravine in Fillmore County, Minnesota. Also found in Maquoketa Formation at Graf and Eldorado, Iowa.

Ulrichia saccula, Burr and Swain, n. sp.

Plate 4, Figures 4, 5, 8

Carapace semicircular to subovate in outline; greatest thickness in ventral third; greatest length in dorsal third; greatest width just anterior to midlength; hinge straight, about 0.8 of total length of valve; relatively wide and thick marginal ridge. Short straight sulcus of shallow depth slightly posterior to midlength, extending approximately two-fifths of width of carapace from dorsal border; large, broad swelling just anterior to sulcus, slightly overlapping dorsal margin; well defined swelling or node posterior to sulcus, somewhat elongate in form; one or two broad swellings visible on posteroventral margin, not reaching marginal border; entire external surface of carapace coarsely punctate except for marginal border; nodes or swelling somewhat more finely punctate than remainder of valve. Swellings hollow as seen internally; punctuation not visible there. Length varies from 0.56 to 0.65 mm.; width varies from 0.32 to 0.36 mm.; thickness equals about 0.07 mm. (one valve).

Remarks. *U. saccula* differs from other species of *Ulrichia* in that the nodes have become rather broad swellings, lacking any resemblance to spines. The punctuation here is also much coarser than in any other described species. The present specimens are smaller than others of the genus, a difference which may or may not be due to the age, development, and preservation of the specimens.

Occurrence. Depauperate zone at the base of the Maquoketa Formation at Bellevue State Park, Iowa.

Superfamily Hollinacea Swartz, 1936

Family Quadrijugatoridae Kesling and Hussey, 1953

Genus *Zygobolboides* Spivey, 1939

Zygobolboides Spivey, 1939, Jour. Paleontology, v. 13, p. 169.

“Tri-lobed, emaciated-appearing *Zygobolbinae*, somewhat smaller than the average of that subfamily. The lobes have broad bases, which are surmounted by thin crest-like ridges. Typically, the bases of the anterior and median lobes are indistinctly united ventrally” (Spivey, 1939, p. 169).

Genotype. *Zygobolboides grafensis* Spivey.

Geologic range. Upper Ordovician.

***Zygobolboides grafensis* Spivey**

Plate 4, Figures 10, 12-15, 18-20

Zygobolboides grafensis Spivey, 1939, Jour. Paleontology, v. 13, p. 169.

Subquadrate in outline; anterior end slightly thicker than posterior; hinge straight, 0.75 of total length of valve; ventral margin nearly straight but not parallel to hinge; greatest thickness at median lobe in approxi-

mate center of valve. Anterior lobe subparallel to anterior margin; bases of anterior and median lobes broadly united ventrally, but crests not joined; posterior sulcus broad and deep, broadening toward center; median sulcus deeper than posterior sulcus, narrowing ventrally. Length varies from 0.81 to 0.94 mm.; width varies from 0.41 to 0.61 mm.

Remarks. Four species of *Zygobolboides* have been described from the Maquoketa Formation. The writers, however, conclude that only *Z. grafensis* Spivey is present in the depauperate zone.

Occurrence. Depauperate zone at the base of the Maquoketa Formation at Bellevue State Park, Iowa. Also found in Maquoketa Formation at Graf and Dubuque, Iowa.

Family Tetradellidae Swartz, 1936

Genus Tetradella Ulrich, 1890

Tetradella Ulrich, 1890, Cincinnati Soc. Nat. Hist. Jour., v. 13, p. 112-114.

Carapace oblong or subquadrate; hinge straight. Surface somewhat depressed with a narrow ridge arising from the free margins and running nearly parallel to them, terminating at the anterodorsal and posterodorsal angles. In enclosed area two narrow ridges traverse the valve in vertical or oblique directions. All ridges merge in the ventral part of the shell.

Genotype. *Beyrichia quadrilirata* Hall and Whitfield.

Geologic range. Ordovician-Devonian.

Tetradella subquadrans Ulrich

Plate 3, Figures 1-10

Plate 5, Figures 24-26

Tetradella subquadrans Ulrich, 1890, Cincinnati Soc. Nat. Hist. Jour., v. 13, p. 115, text figs. 2a-c; *T. subquadrans* Ulrich; Ulrich and Bassler, 1908, U. S. Nat. Mus. Proc., v. 35, p. 307, pl. 39, figs. 1-3; Bassler, 1915, U. S. Nat. Mus. Bull., v. 92, p. 1264.

Subquadrate, slightly elongate in outline; posterior end almost vertical in upper half; anterior end broadly rounded; hinge fairly straight; greatest length at midheight; greatest height posterior to midlength; greatest thickness ventromedian. Three distinct ridges, two posterior and one anterior; short lobelike ridge extends from posterior side of anterior ridge; all ridges united ventrally; large ridges extend beyond dorsal margin; posterior two curve slightly forward; wide concave border extends around entire free margin. Length and width average 1.36 mm. and 1.00 mm. respectively (including border or "frill").

Remarks. Kay (1934, p. 339) mentions that several specimens of *T. ellipsilira* Kay have small projections normal to the marginal ridge along the ventral border. The writers have noted a small spine-like projection at the base of the anteromedian ridge on some specimens. It does not ap-

pear that the latter projection is the same as that discussed by Kay, nor does it seem advisable to separate the varieties with and without these projections as all intermediate forms are present.

Occurrence. Throughout the lower two-thirds of the Dubuque Formation at Wubbles Ravine in Fillmore County, Minnesota. Also found in Trenton Group, Trenton Falls, New York.

Superfamily Leperditellacea Ulrich and Bassler, 1906

Family Leperditellidae Ulrich and Bassler, 1906

Genus Leperditella Ulrich, 1894

Leperditella Ulrich, 1894, Final Rept. Minn. Geol. and Nat. Hist. Survey, v. 3, pt. 2, p. 636.

Carapace elongate, subovate, or oblong in outline; left valve slightly larger than the right, overlapping it, especially along the ventral margin; hingement effected by shallow groove of right valve, resulting in a slight projection or dorsal overlap of right valve beyond that of the left. A broad, shallow, more or less obscure depression is generally present in the central part of the dorsal half. Shell generally does not exceed 3 mm. in length.

Genotype. *Leperditia inflata* Ulrich.

Geologic range. Ordovician.

***Leperditella* ? sp.**

Plate 6, Figure 14

Carapace elongate, subovate in outline; greatest thickness in posterior third; greatest length at midheight; greatest width posterior to midlength; hinge relatively straight, extending about 0.7 of total length; left valve overlaps right ventrally; right valve extends a short distance beyond left on posterodorsal margin, but may be due to preservation and compression. Left valve of figured specimen has a pit in the approximate center which is due to the growth of a calcite crystal; slight indentation on right valve in approximate center may be muscle scar area; right valve has broad swelling on posterior portion; surface fairly smooth. Length, width, and thickness are 0.57 mm., 0.37 mm., and 0.09 mm., respectively.

Occurrence. Upper two feet of the Dubuque Formation at Wubbles Ravine in Fillmore County, Minnesota.

Genus Eridoconcha Ulrich and Bassler, 1923

Eridoconcha Ulrich and Bassler, 1923, Md. Geol. Survey, Silurian Vol., p. 297.

“Carapace small, subovate, umbonate with subtriangular inflation or bilobed extension above dorsum, if lobate; posterior swelling larger than

anterior; hinge moderately long, straight; cardinal angles equal, venter parallel to hinge, slightly convex, ends broadly rounding to cardinal angles; convexity of surface increases from marginal area to dorsal umbo, greatest thickness at umbo; dorsal sulcus short or elongate; one or more narrow, concentric ridges parallel the lower margins, the most ventral of the ridges always lies a short distance from the ventral margin, if more than one ridge present, they converge at dorsum, ridges separated from one another by a U-shaped trough. Carapace equivalved" (Levinson, 1951, p. 556).

Genotype. *Eridoconcha rugosa* Ulrich and Bassler.

Geologic range. Ordovician-Devonian.

Eridoconcha marginata (Ulrich)

Plate 5, Figures 6-20, 22-23

Placentula marginata Ulrich, 1890, Cincinnati Soc. Nat. Hist. Jour., v. 13, p. 124, pl. 10, figs. 13a-c; Grabau and Shimer, 1910, North American Index Fossils, v. 2, p. 351, fig. 1666 d, d', p. 360; Bassler, 1915, U. S. Nat. Mus. Bull., v. 92, p. 982.

Eridoconcha rugosa (Ulrich) Ulrich and Bassler, 1923, Md. Geol. Survey, Silurian Vol., p. 296, 297, fig. 14 (9).

Jonesites marginata (Ulrich) Bassler and Kellett, 1934, Geol. Soc. America Special Paper 1, p. 349.

Eridoconcha marginata (Ulrich) Keenan, 1951, Jour. Paleontology, v. 25, p. 566.

Subovate in outline; greatest length at midheight; greatest width just posterior to midlength; straight hingement. Wide, short sulcus extending downward from dorsal margin; sulcus divided into two parts at lower extremity; two parts do not rejoin as in *E. elegantula* Keenan; series of one or more retained molts are apparent on all specimens. Presence of sulcus and molts visible on interior. Length in specimens at hand varies from 0.38 to 0.86 mm.; width varies from 0.28 to 0.60.

Occurrence. Depauperate zone at the base of the Maquoketa Formation at Bellevue State Park, Iowa. Also found in Maquoketa Formation of Missouri.

Genus *Milleratia* Swartz, 1936

Milleratia Swartz, 1936, Jour. Paleontology, v. 10, pl. 86, p. 567-568.

"Small, strongly unisulcate Ostracoda, each valve with a strong asymmetrical dorsal hump or swelling, highest posteriorly; carapace consequently heart-shaped in end view. Hingement apparently simple; overlap lacking or inconspicuous. Surface without knobs, ridges, or marginal rim, although the free edges may be a little expanded. Anterior cardinal

angle more recessive than the posterior. Sexual dimorphism unknown" (Swartz, 1936, p. 567).

Genotype. *Beyrichia cincinnatiensis* Miller.

Geologic range. Upper Ordovician.

Milleratia cincinnatiensis (Miller)

Plate 4, Figures 16-17, 21-23

Plate 5, Figures 1-5, 21

Beyrichia cincinnatiensis Miller, 1875, Cincinnati Quart. Jour. Sci., v. 2, p. 350, text fig. 25.

Primitia cincinnatiensis Miller, 1889, North American Geology and Paleontology, p. 561, text fig. 1045; Ulrich, 1890, Cincinnati Soc. Nat. Hist. Jour., v. 13, p. 132, pl. 10, figs. 5, 6; Cummings, 1908, Dept. Geol. Nat. Hist. Res. Indiana 32d Ann. Rept., p. 345, figs. 11-11d; Ulrich and Bassler, 1923, Md. Geol. Survey, Silurian Vol., p. 299, text fig. 15; Bassler and Kellett, 1934, Geol. Soc. America Special Paper 1, p. 440.

Milleratia cincinnatiensis Swartz, 1936, Jour. Paleontology, v. 10, p. 568, pl. 86.

Subovate in outline; thickest just posterior to middle; maximum width equal to about one-third of greatest length; valves strongly convex; hinge straight and short, about one-half of total length; prominent backward swing on posterior end. Subtriangular sulcus just anterior of middle; does not extend to ventral border; posterior lobe overhangs posterior part of hinge; anterior lobe well-defined. Sulcus readily visible interiorly. Length varies from 0.68 to 0.87 mm.; width varies from 0.47 to 0.57 mm.; thickness varies from 0.38 to 0.47 mm. (both valves).

Occurrence. Depauperate zone at the base of the Maquoketa Formation at Bellevue State Park. Also found in Lorraine Shales, Clarksville, Ohio.

Genus Primitia Jones and Holl, 1865

Primitia Jones and Holl, 1865, Annals and Mag. Nat. Hist., ser. 3, v. 16, p. 415.

Carapace small; variable outline, but generally subovate; hinge straight; equivalved, no overlapping; generally has a narrow border. Well marked pit or sulcus near the middle of the dorsal half; pit either rounded or drawn out vertically from dorsal margin; on one or both sides of sulcus, surface commonly raised into low, rounded or ridge-shaped swellings; surface of valves may be reticulated, punctate, or unornamented.

Genotype. *Beyrichia mundula* Jones.

Geologic range. Cambrian-Permian.

Primitia spinata Burr and Swain, n. sp.

Plate 6, Figures 11, 13, 16-17, 19-24

Carapace subovate in outline; valves moderately convex; greatest length slightly above midheight; greatest width posterior to midlength; greatest thickness slightly posterior and dorsal to center of shell; posterior end slightly higher and more broadly rounded than anterior; hinge straight, about two-thirds of total length of valve. Short straight sulcus anterior to midlength, about one-third of total width; poorly defined swelling anterior to sulcus; well defined spine-like node posterior to sulcus, extending back and over dorsal margin. Interior not visible. Length varies from 0.63 to 0.72 mm.; width varies from 0.40 to 0.46 mm.; thickness varies from 0.07 to 0.09 mm. (excluding spine).

Remarks. *P. spinata* seems to be somewhat transitional between the genera *Primitia* and *Aechminaria* (Coryell and Williamson, 1936). The spine is readily apparent but at the same time the sulcus is distinct. The backward swing of *Aechminaria* is not in every case prominent so this is not a limiting factor. The transition from a sulcus to a broad or poorly defined pit would be relatively simple.

Occurrence. Fairly common from 3 to 20 feet above base of the Du-
buque Formation at Wubbles Ravine.

Primitia mammata Ulrich

Plate 6, Figure 18

Primitia mammata Ulrich, 1894, Final Rept. Minn. Geol. and Nat. Hist. Survey, v. 3, pt. 2, p. 652, pl. 43, figs. 78, 79, 81; Bassler, 1915, U. S. Nat. Mus. Bull., v. 92, p. 1031; Bassler and Kellett, 1934, Geol. Soc. America Special Paper 1, p. 447; Kay, 1940, Jour. Paleontology, v. 14, p. 248, pl. 30, fig. 22.

Small Ostracoda with similar valves; suboval in outline; greatest length at midheight; greatest width just anterior to midlength; greatest thickness in centrodorsal area; hinge fairly straight, about one-half of total length of shell; back somewhat arcuate; anterior and posterior ends regularly and similarly curved; surface rises sharply from dorsal margin, gently from ventral. Short, weak, but well defined, sulcus at dorsal margin posterior to midlength, extending about one-fourth of total width; low, poorly defined swellings on both sides of sulcus. Length, width, and thickness are 0.66 mm., 0.32 mm., and 0.16 mm. (one valve) respectively.

Occurrence. Twelve feet to 20 feet below the top of the Dubuque Formation at Wubbles Ravine in Fillmore County, Minnesota; also found in Decorah Formation at Minneapolis, Minnesota.

Primitia tumidula Ulrich

Plate 4, Figures 1, 6

Plate 6, Figures 25-32, 34

Primitia tumidula Ulrich, 1894, Final Rept. Minn. Geol. and Nat. Hist. Survey, v. 3, pt. 2, p. 655, pl. 43, figs. 62-65; Ulrich and Bassler, 1908, U. S. Nat. Mus. Proc., v. 35, p. 303; Grabau and Shimer, 1910, North American Index Fossils, p. 345, text fig. 1658 m, m', n; Wade, 1911, Geol. Soc. London Quart. Jour., v. 67, p. 452; Bassler, 1915, U. S. Nat. Mus. Bull., v. 92, p. 1033; Ladd, 1931, Iowa Geol. Survey Ann. Rept., v. 34, p. 395.

Valves subovate in outline; greatest thickness in posterior portion of carapace; greatest length and width are medial; valves strongly convex; anterior end more rounded than posterior. Sulcus, just anterior to center in dorsal half of shell, has slight forward swing; lobes or swelling evident on both sides of sulcus; posterior swelling slightly more prominent; slight dorsal overlap by posterior swelling; wide border evident on ventral margin which extends parallel to the margin. Length varies from 0.78 to 0.86 mm.; width varies from 0.63 to 0.68 mm.

Occurrence. Upper fifteen feet of the Dubuque Formation at Wubbles Ravine and in the depauperate zone of the Maquoketa Formation at Bellevue State Park. Also found in Decorah Formation at Cannon Falls, Minnesota; Maquoketa Formation at Spring Valley, Minnesota; Maquoketa Formation of Missouri.

Genus Primitiella Ulrich, 1894

Primitiella Ulrich, 1894, Final Rept. Minn. Geol. and Nat. Hist. Survey, v. 3, pt. 2, p. 647.

Generally oblong carapace; equivalved, moderately convex Ostracoda; surface either smooth or finely punctate; dorsal slope contains broad, shallow, and rather undefined depression which may represent undeveloped medial sulcus; hinge straight; posterior end more broadly rounded than anterior.

Genotype. *Primitiella constricta* Ulrich.

Geologic range. Middle Ordovician-Upper Devonian.

Primitiella paucisulcata Burr and Swain, n. sp.

Plate 2, Figures 3, 5-7, 9-11, 13, 20

Carapace oblong in outline; long straight hinge; greatest length at midheight; greatest width in posterior third; generally uniform thickness; posterior margin more gently rounded than anterior. Faint, poorly defined depression or sulcus anterior to midlength, seen best from interior. Surface smooth. Length varies from 0.84 to 0.94 mm.; width varies from 0.48 to 0.56 mm.; thickness varies from 0.36 to 0.38 mm. (two valves).

Remarks. This species bears a marked similarity to *P. unicornis* (Ulrich) in most shell features but lacks a spine or node on the posteroventral margin. Figure 20, Plate 2, shows bertillon ornamentation but such ornamentation is rarely preserved.

Occurrence. Depauperate zone at the base of the Maquoketa Formation at Bellevue State Park, Iowa.

Primitiella unicornis (Ulrich)

Plate 2, Figures 21-25

Plate 6, Figures 1-10

Leperditia unicornis Ulrich, 1879, Cincinnati Soc. Nat. Hist. Jour., v. 2, p. 10, pl. 7, fig. 4.

?*Aparchites unicornis* Ulrich, 1889, Contr. Canadian Micropaleontology, pt. 2, p. 50.

?*Primitia unicornis* Jones, 1890, Geol. Soc. London Quart. Jour., v. 46, p. 7.

Primitiella unicornis Ulrich, 1894, Final Rept. Minn. Geol. and Nat. Hist. Survey, v. 3, pt. 2, p. 649, pl. 43, figs. 75-77; Shimer and Shrock, 1944, Index Fossils of North America, p. 665, pl. 281, figs. 5-7; Keenan, 1951, Jour. Paleontology, v. 25, p. 568, pl. 78, fig. 5, pl. 79, figs. 38, 39.

Carapace oblong; most convex just posterior to center of valve but generally of uniform thickness; long straight hinge line; posterior dorsal angle more gently rounded than anterior angle. Faint, poorly defined sulcus or depression on the dorsal slope just anterior to the center of the carapace; a spine or node occurs along outward mid-posterior margin. Spine or projection hollow as seen internally. Length in present specimens varies from 0.60 to 0.82 mm.; width varies from 0.40 to 0.50 mm.; thickness averages about 0.18 for one valve.

Remarks. The spine on Ulrich's (1894, p. 649) specimens is on the posteroventral margin, but he does not mention that the spine is restricted in its location. Most of the writers' specimens had their spines somewhat more dorsal in position.

Occurrence. Depauperate zone at the base of the Maquoketa Formation at Bellevue State Park, Iowa; also in upper Trenton group at Cincinnati, Ohio; Canajoharie and Whetstone Formations of New York; Decorah Formation of St. Paul, Minnesota; Maquoketa Formation of Missouri.

Genus *Schmidtella* Ulrich, 1892

Schmidtella Ulrich, 1892, Am. Geologist, v. 10, p. 269.

Carapace small (2 mm. or less in length), subovate, subcircular to subelliptical; dorsal margin convex, umbonate, right valve slightly larger than left; hinge margin straight, short, and with weakly rabbeted articulation of valves; internal low dorsomedian ridge represents sulcus in ani-

mal; surface smooth ventrally with submarginal furrow in some species marking position of edge of earlier molt.

Genotype. *Schmidtella crassimarginata* Ulrich.

Geologic range. Ordovician-Silurian.

Schmidtella incompta Ulrich

Plate 2, Figures 1, 2, 4, 8, 12, 14-15, 17

Schmidtella incompta Ulrich, 1894, Final Rept. Minn. Geol. and Nat. Hist. Survey, v. 3, pt. 2, p. 642, pl. 45, figs. 27, 32, 33; Kay, 1940, Jour. Paleontology, v. 14, pl. 29, figs. 5-6; Swain and others, 1961, Jour. Paleontology, v. 35, p. 361, pl. 48, figs. 6a-g.

Carapace ovate to subovate in outline; valves moderately convex; ventral margin regularly curved; anterior and posterior ends nearly equally rounded; greatest length at midheight; greatest width at midlength; greatest thickness median or slightly posteromedian; hinge straight to slightly convex, about one-half of length of valve. Faint depression slightly anterior to midlength most easily recognizable on valve interior. Length in present specimens varies from 0.68 to 0.84 mm.; width varies from 0.42 to 0.58 mm.; thickness of single valve varies from 0.10 to 0.14 mm.

Occurrence. Depauperate zone at base of Maquoketa Formation, Bellevue State Park, Iowa. The species also occurs in the Decorah Formation of Minnesota, Wisconsin and Iowa.

Schmidtella lacunosa Burr and Swain, n. sp.

Plate 2, Figures 16, 18-19

Carapace subovate in outline; greatest length, width, and thickness at midheight, midlength, and middle, respectively; ventral margin regularly curved; anterior end somewhat extended and less broadly rounded than posterior; hinge straight, about half of length of valve. Very faint depression anterior to midlength, lies on interior surface anteriorly; entire surface of shell covered by small punctae. Length of specimens at hand varies from 0.60 to 0.73 mm.; width varies from 0.40 to 0.48 mm.; thickness of single valve varies from 0.09 to 0.13 mm.

Remarks. This species bears a close resemblance to both *Leperditella millepunctatus* (Ulrich) and *Byrsolopsina centipunctata* (Kay). The chief distinctions are the anterodorsal depression and the uniformly punctate surface.

Occurrence. Depauperate zones at base of Maquoketa Formation, Bellevue State Park, Iowa.

Order Podocopida Müller, 1894

Suborder Uncertain

Family Punctaparchitidae Swain, Cornell and Hansen, 1961

Genus Punctaparchites Kay, 1934

Shell small to medium-sized, subovate in side view, highest in posterior half; dorsal margin strongly convex with steep posterior, and gentler anterior slope; ventral margin slightly concave; posterior margin broadly rounded; anterior margin much more narrowly rounded, strongly extended below. Valves not strongly convex; complete shell not seen but right valve is believed to be larger and to extend beyond left. Surface smooth or punctate. Articulation of valves consists of a grooved right valve into which fits edge of left; midventrally, edges of valves turned inward in a typical podocopid fashion. Muscle scar a rounded dorso-medial spot. Ordovician, central United States.

Genotype. *Macronotella multipunctata*, Kay, 1940.

Geologic range. Ordovician.

Punctaparchites splendens (Keenan)

Plate 4, Figure 9

Bythocypris splendens Keenan, 1951, Jour. Paleontology, v. 25, no. 5, pl. 78, figs. 24-28, p. 567.

Carapace subpyriform in outline, greatest length at midheight, greatest height in posterior third, greatest thickness in posterior third; hinge about one-half of total length. Dorsal margin strongly convex, sloping gently behind position of greatest height; ventral margin concave anteromedially; anterior margin narrowly rounded, strongly extended below, posterior margin broadly rounded. Right valve larger than left, overlapping it on all margins. Interior of right valve not visible. Length, width, and thickness are 0.66 mm., 0.40 mm., and 0.10 mm. respectively.

Occurrence. Thirteen feet below the top of the Dubuque Formation at Wubbles Ravine in Fillmore County, Minnesota. Also found in Maquoketa Formation of Missouri.

Genus Macrocyproides Spivey, 1939

Macrocyproides Spivey, 1939, Jour. Paleontology, v. 13, p. 165.

Shell subovate in side view, highest anteromedially, dorsal margin strongly convex, sloping steeply behind and much more gently in front; ventral margin nearly straight; anterior margin narrowly rounded, extended to bluntly angulated below; posterior margin much more broadly rounded, typically extended above, truncate below. Right valve larger than left, but posterodorsally, edge of left valve over-reaches right. Valves moderately convex. Surface smooth. Hinge simple.

Type species. *M. clermontensis* Spivey.

Geologic range. Middle and Upper Ordovician.

Macrocyproides trentonensis (Ulrich)

Plate 6, Figures 12, 15, 33

Aparchites minutissimus trentonensis Ulrich, 1894, Final Rept. Minn. Geol. and Nat. Hist. Survey, v. 3, p. 646, pl. 43, figs. 18-20; Bassler, 1915, U. S. Nat. Mus. Bull., v. 92, p. 54; Bassler & Kellett, 1934, Geol. Soc. America Special Paper 1, p. 159; Spivey, 1939, Jour. Paleontology, v. 13, p. 165, pl. 21, figs. 26, 27.

Aparchites trentonensis Kay, 1940, Jour. Paleontology, v. 14, p. 244, pl. 29, fig. 33.

Macrocyproides trentonensis (Ulrich) Swain and others, 1961, Jour. Paleontology, v. 35, p. 371, pl. 48, fig. 11, pl. 50, figs. 5a-d, text fig. 21.

Carapace small, suboval in outline; greatest length slightly above midheight; greatest width in posterior third; greatest thickness in center of valve; hinge fairly straight, about two-thirds of length of shell; both anterior and posterior margins smoothly rounded but posterior more broadly rounded. Surface tumid and unornamented. Length, width, and thickness are 0.60 mm., 0.40 mm., and 0.07 mm. (one valve) respectively.

Occurrence. Upper third of the Dubuque Formation at Wubbles Ravine in Fillmore County, Minnesota. Also found in Decorah Formation at Cannon Falls, Minnesota; Maquoketa Formation of Missouri.

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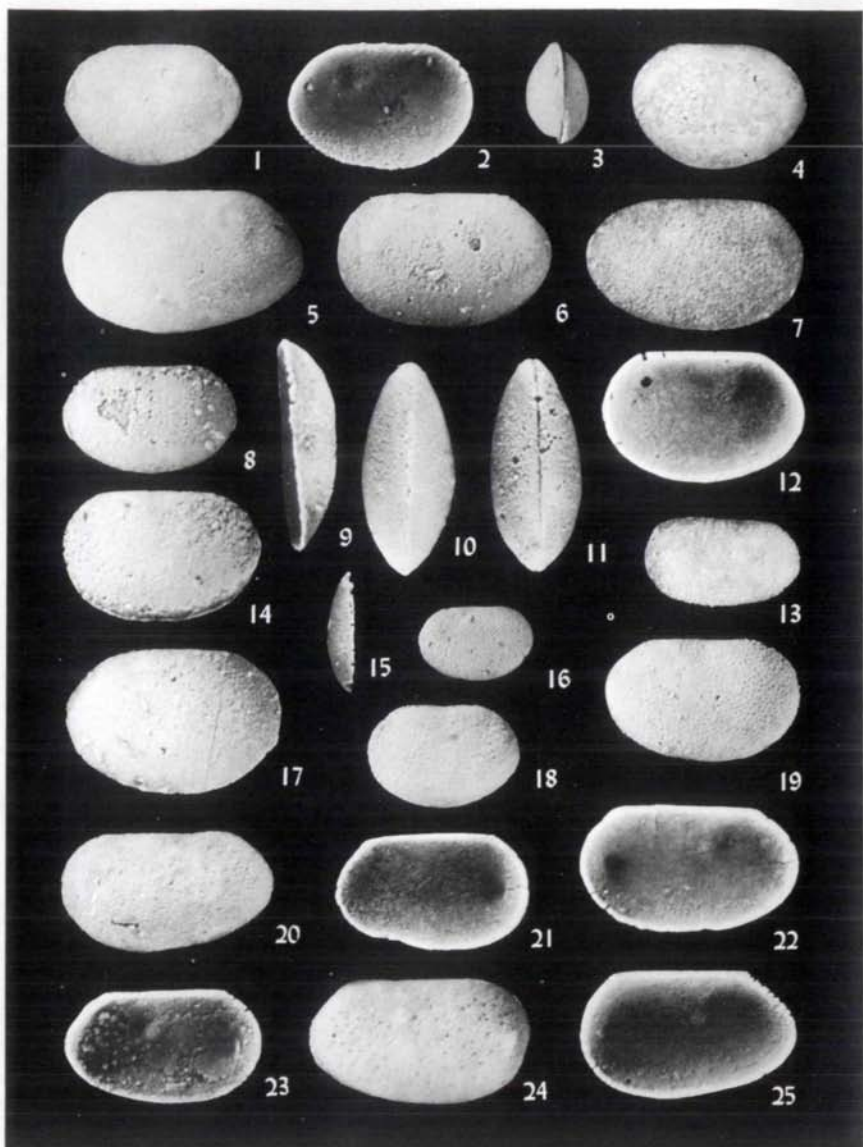


Plate 2

Figures

1. *Schmidtella incompta* Ulrich.
1. Exterior of a right valve; X33. UMPC 9120
2. *Schmidtella incompta* Ulrich.
2. Interior of a right valve; X33. UMPC 9121
3. *Primitiella paucisulcata*, Burr and Swain, n. sp.
3. Whole specimen; anterior end view; X33. UMPC 9122
4. *Schmidtella incompta* Ulrich.
4. Exterior of a right valve; X33. UMPC 9123
5. *Primitiella paucisulcata*, Burr and Swain, n. sp.
5. Exterior of a right valve; X33. UMPC 9124
6. *Primitiella paucisulcata*, Burr and Swain, n. sp.
6. Exterior of a right valve; X33. UMPC 9125
7. *Primitiella paucisulcata*, Burr and Swain, n. sp.
7. Exterior of a left valve; X33. UMPC 9126
8. *Schmidtella incompta* Ulrich.
8. Interior of a left valve; X33. UMPC 9127
9. *Primitiella paucisulcata*, Burr and Swain, n. sp.
9. Dorsal view of left valve; X33. UMPC 9128
10. *Primitiella paucisulcata*, Burr and Swain, n. sp.
10. Whole specimen; ventral view; X33. UMPC 9129
11. *Primitiella paucisulcata*, Burr and Swain, n. sp.
11. Whole specimen; ventral view; X33. UMPC 9130
12. *Schmidtella incompta* Ulrich.
12. Exterior of a right valve; X33. UMPC 9131
13. *Primitiella paucisulcata*, Burr and Swain, n. sp.
13. Exterior of poorly developed right valve; X33. UMPC 9132
14. *Schmidtella incompta* Ulrich.
14. Exterior of a right valve; X33. UMPC 9133
15. *Schmidtella incompta* Ulrich.
15. Dorsal view of a left valve; X33. UMPC 9134
16. *Schmidtella lacunosa*, Burr and Swain, n. sp.
16. Exterior of a left valve; X23. UMPC 9135
17. *Schmidtella incompta* Ulrich.
17. Exterior of a left valve; X33. UMPC 9136
18. *Schmidtella lacunosa*, Burr and Swain, n. sp.
18. Exterior of a right valve; X33. UMPC 9137
19. *Schmidtella lacunosa*, Burr and Swain, n. sp.
19. Exterior of a left valve; X33. UMPC 9138
20. *Primitiella paucisulcata* Burr and Swain, n. sp.
20. Exterior of a right valve; X33. UMPC 9139
21. *Primitiella unicornis* (Ulrich).
21. Interior of a right valve; X33. UMPC 9140
22. *Primitiella unicornis* (Ulrich).
22. Interior of a left valve; X33. UMPC 9141
23. *Primitiella unicornis* (Ulrich).
23. Interior of a left valve; X33. UMPC 9142
24. *Primitiella unicornis* (Ulrich).
24. Exterior of a left valve; X33. UMPC 9143
25. *Primitiella unicornis* (Ulrich).
25. Interior of a left valve; X33. UMPC 9144

Figures 1-25 are from depauperate zone of Maquoketa Formation, Bellevue State Park, Iowa.

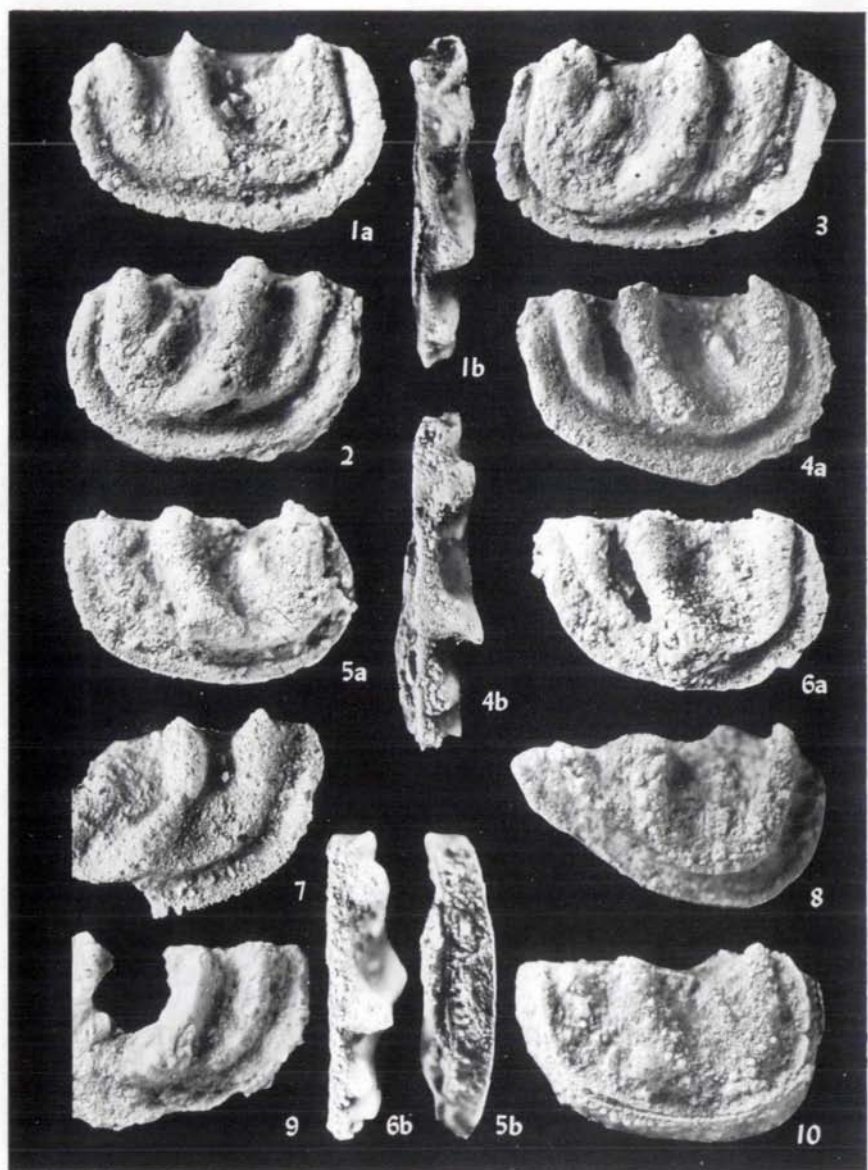


Plate 3

Figures

1. *Tetradella subquadrans* Ulrich.
 - 1a. Exterior of a right valve; X23. UMPC 9146
 - 1b. Dorsal view of a right valve; X23. UMPC 9147
2. *Tetradella subquadrans* Ulrich.
Exterior of a left valve; X23. UMPC 9148
3. *Tetradella subquadrans* Ulrich.
Exterior of a left valve; X23. UMPC 9149
4. *Tetradella subquadrans* Ulrich.
 - 4a. Exterior of a right valve; X23. UMPC 9150
 - 4b. Dorsal view of a right valve; X23. UMPC 9151
5. *Tetradella subquadrans* Ulrich.
 - 5a. Exterior of a right valve; X23. UMPC 9152
 - 5b. Ventral view of a right valve; X23. UMPC 9153
6. *Tetradella subquadrans* Ulrich.
 - 6a. Exterior of a right valve; X23. UMPC 9154
 - 6b. Dorsal view of a right valve; X23. UMPC 9155
7. *Tetradella subquadrans* Ulrich.
Exterior of an incomplete left valve; X23. UMPC 9156
8. *Tetradella subquadrans* Ulrich.
Exterior of a male ? right valve; X23. UMPC 9157
9. *Tetradella subquadrans* Ulrich.
Exterior of a broken incomplete left valve; X23. UMPC 9158
10. *Tetradella subquadrans* Ulrich.
Exterior of a poorly preserved right valve; X23. UMPC 9159

Figures 1-10 are from Dubuque Formation, Wubbles Ravine, Fillmore County, Minnesota.

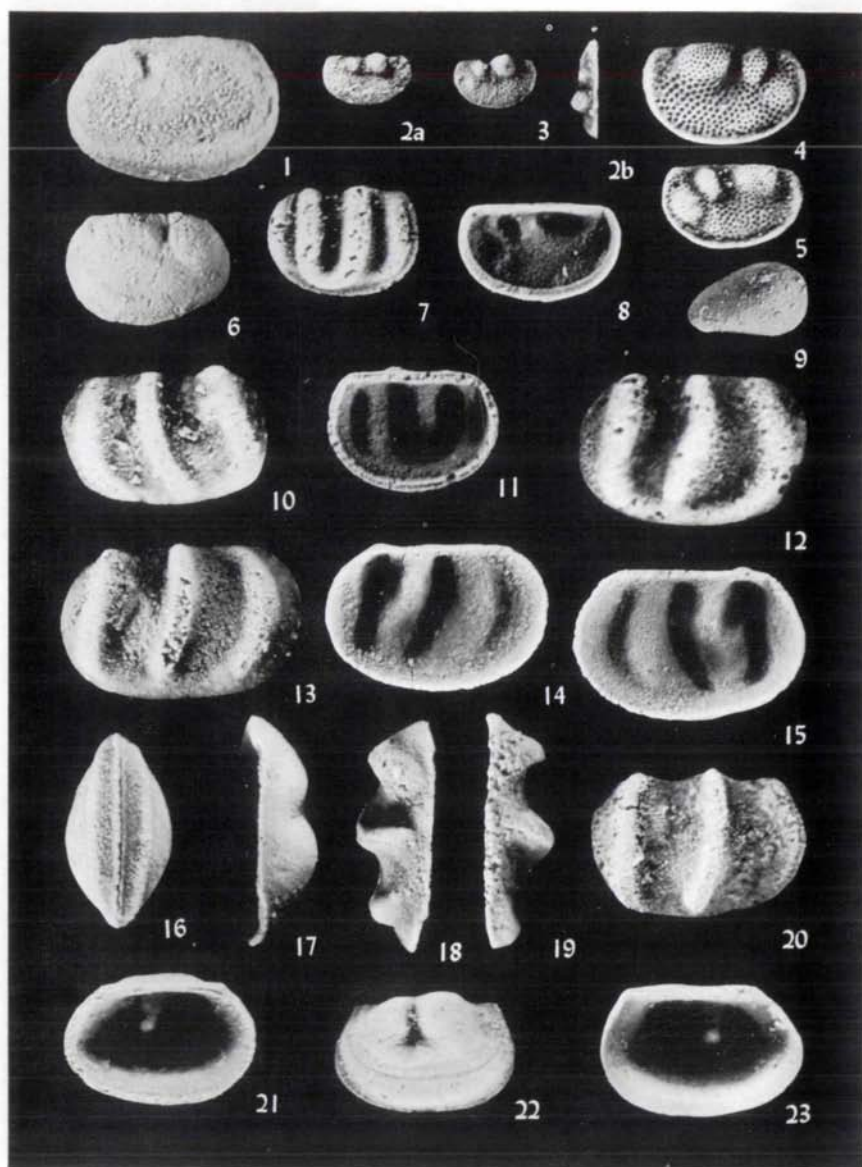


Plate 4

Figures

1. *Primitia tumidula* Ulrich
1. Exterior of a left valve; X33. UMPC 9160
2. *Ulrichia nodosa* (Ulrich)
2a. Exterior of a right valve; X23. UMPC 9161
2b. Dorsal view of a right valve; X23. UMPC 9162
3. *Ulrichia nodosa* (Ulrich)
3. Exterior of a right valve; X23. UMPC 9163
4. *Ulrichia saccula* n. sp.
4. Exterior of a left valve; X33. UMPC 9164
5. *Ulrichia saccula* n. sp.
5. Exterior of a right valve; X33. UMPC 9165
6. *Primitia tumidula* Ulrich
6. Exterior of a right valve; X23. UMPC 9166
7. *Bollia regularis* (Emmons)
7. Exterior of a left valve; X33. UMPC 9167
8. *Ulrichia saccula* n. sp.
8. Interior of a left valve; X33. UMPC 9168
9. *Punctaparchites splendens* (Keenan)
9. Exterior of a right valve; X23. UMPC 9169
10. *Zygoboloides grafensis* Spivey
10. Exterior of a right valve; X33. UMPC 9170
11. *Bollia regularis* (Emmons)
11. Interior of a left valve; X33. UMPC 9171
12. *Zygoboloides grafensis* Spivey
12. Exterior of a left valve; X33. UMPC 9172
13. *Zygoboloides grafensis* Spivey
13. Exterior of a left valve; X33. UMPC 9173
14. *Zygoboloides grafensis* Spivey
14. Interior of a right valve; X33. UMPC 9174
15. *Zygoboloides grafensis* Spivey.
15. Interior of a left valve; X33. UMPC 9175
16. *Milleratia cincinnatiensis* (Miller)
16. Whole specimen, ventral view; X33. UMPC 9176
17. *Milleratia cincinnatiensis* (Miller)
17. Dorsal view of a right valve; X33. UMPC 9177
18. *Zygoboloides grafensis* Spivey
18. Dorsal view of a left valve; X33. UMPC 9178
19. *Zygoboloides grafensis* Spivey
19. Ventral view of a left valve; X33. UMPC 9179
20. *Zygoboloides grafensis* Spivey
20. Exterior of a left valve; X33. UMPC 9180
21. *Milleratia cincinnatiensis* (Miller)
21. Interior of a right valve; X33. UMPC 9181
22. *Milleratia cincinnatiensis* (Miller)
22. Exterior of a left valve; X33. UMPC 9182
23. *Milleratia cincinnatiensis* (Miller)
23. Interior of a left valve; X33. UMPC 9183

Figures 1, 4, 5, 7, 8, 10-23 are from depauperate zone of Maquoketa Formation, Bellevue State Park, Iowa.

Figures 2, 3, 6, 9 are from Dubuque Formation, Wubbles Ravine, Fillmore County, Minnesota.

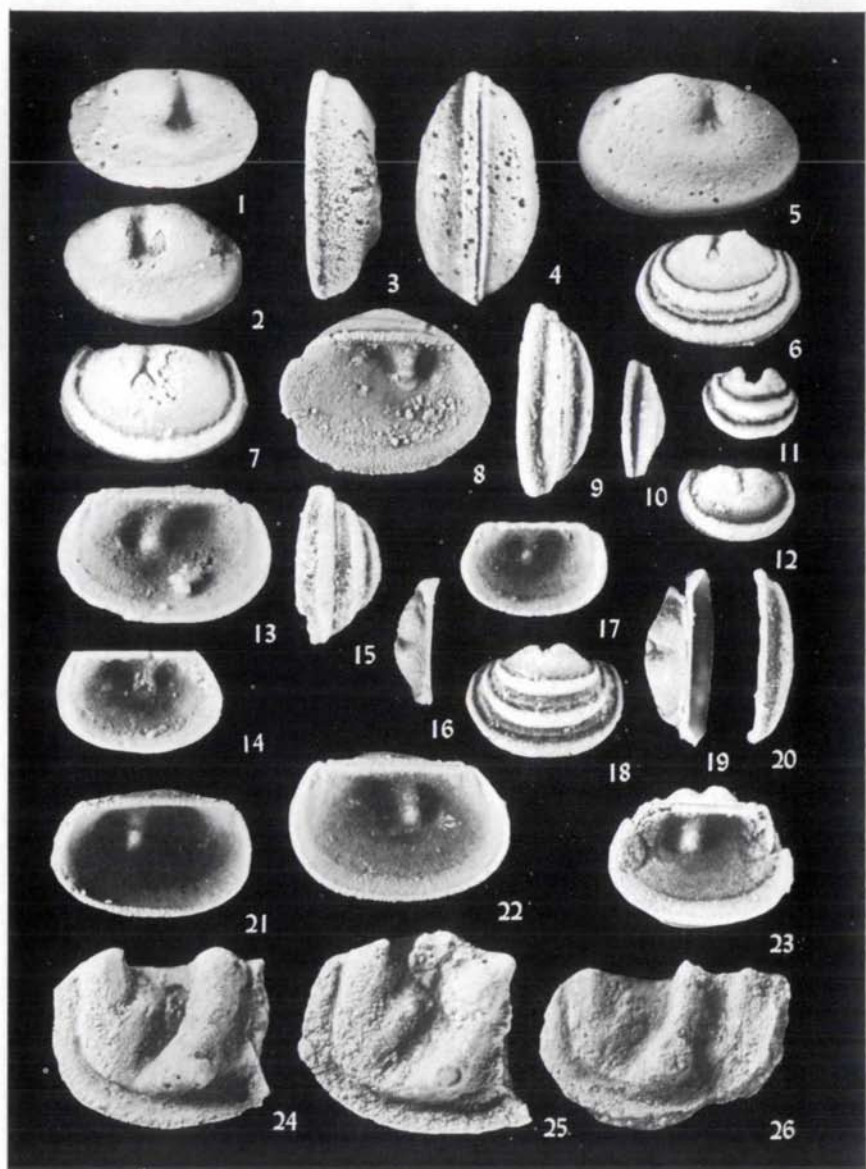


Plate 5

Figures

1. *Milleratia cincinnatiensis* (Miller).
1. Exterior of a right valve; X33. UMPC 9184
2. *Milleratia cincinnatiensis* (Miller).
2. Exterior of a left valve; X33. UMPC 9185
3. *Milleratia cincinnatiensis* (Miller).
3. Ventral view of a left valve; X33. UMPC 9186
4. *Milleratia cincinnatiensis* (Miller).
4. Whole specimen; ventral view; X33. UMPC 9187
5. *Milleratia cincinnatiensis* (Miller).
5. Exterior of a right valve; X33. UMPC 9188
6. *Eridoconcha marginata* (Ulrich)
6. Exterior of a left valve; X33. UMPC 9189
7. *Eridoconcha marginata* (Ulrich)
7. Exterior of a left valve; X33. UMPC 9190
8. *Eridoconcha marginata* (Ulrich)
8. Interior of a left valve; X33. UMPC 9191
9. *Eridoconcha marginata* (Ulrich)
9. Ventral view of a left valve; X33. UMPC 9192
10. *Eridoconcha marginata* (Ulrich)
10. Ventral view of a left valve; X33. UMPC 9193
11. *Eridoconcha marginata* (Ulrich)
11. Exterior of a right valve; X33. UMPC 9194
12. *Eridoconcha marginata* (Ulrich)
12. Exterior of a right valve; X33. UMPC 9195
13. *Eridoconcha marginata* (Ulrich)
13. Interior of a right valve; X33. UMPC 9196
14. *Eridoconcha marginata* (Ulrich)
14. Interior of a left valve; X33. UMPC 9197
15. *Eridoconcha marginata* (Ulrich).
15. Ventral view of a left valve; X33. UMPC 9198
16. *Eridoconcha marginata* (Ulrich).
16. Dorsal view of a left valve; X33. UMPC 9199
17. *Eridoconcha marginata* (Ulrich)
17. Interior of a right valve; X33. UMPC 9200
18. *Eridoconcha marginata* (Ulrich).
18. Exterior of a left valve; X33. UMPC 9201
19. *Eridoconcha marginata* (Ulrich).
19. Dorsal view of a left valve; X33. UMPC 9202
20. *Eridoconcha marginata* (Ulrich).
20. Ventral view of a left valve; X33. UMPC 9203
21. *Milleratia cincinnatiensis* (Miller).
21. Interior of a right valve; X33. UMPC 9204
22. *Eridoconcha marginata* (Ulrich).
22. Interior of a left valve; X33. UMPC 9205
23. *Eridoconcha marginata* (Ulrich).
23. Interior of a right valve; X33. UMPC 9206
24. *Tetradella subquadrans* Ulrich.
24. Exterior of a left valve; X23. UMPC 9207
25. *Tetradella subquadrans* Ulrich.
25. Exterior of a left valve; X23. UMPC 9208
26. *Tetradella subquadrans* Ulrich.
26. Exterior of a left valve; X23. UMPC 9209

Figures 1-23 from depauperate zone of Maquoketa Formation, Bellevue State Park, Iowa.
Figures 24-26 from Dubuque Formation, Wubbles Ravine, Fillmore County, Minnesota.

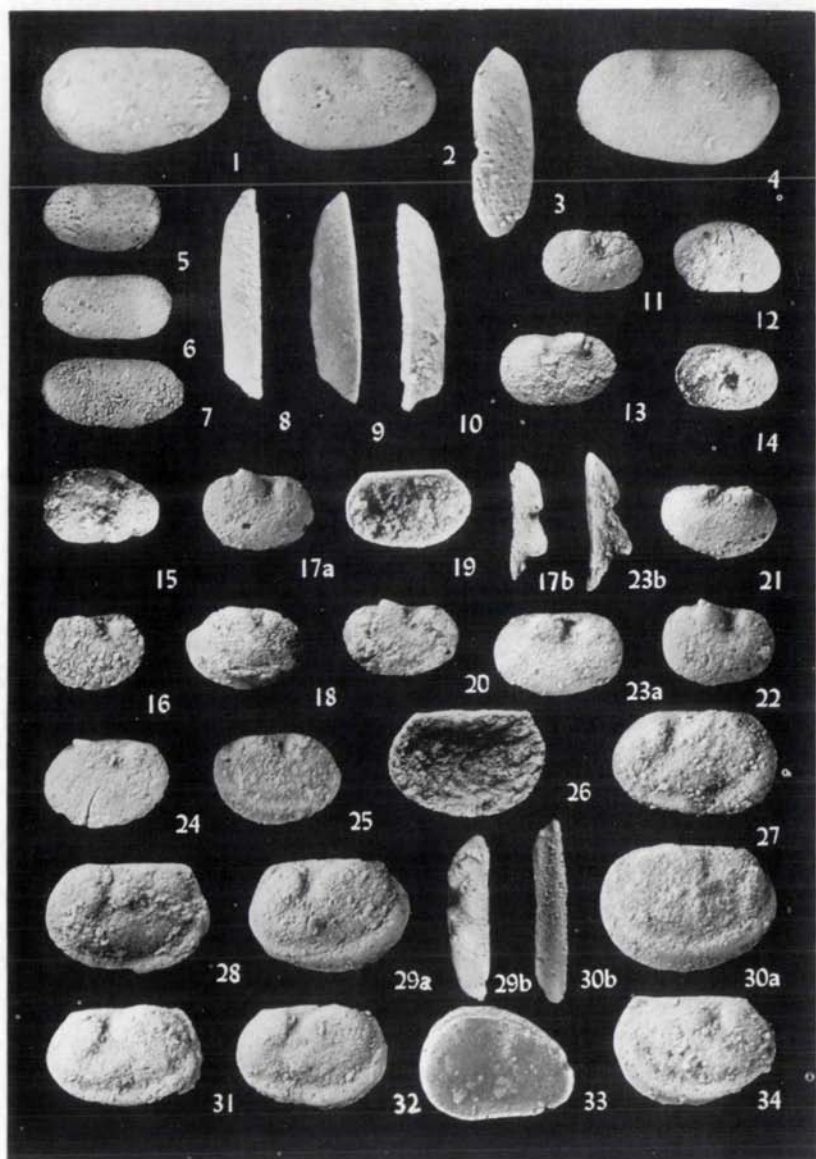


Plate 6

Figures

1. *Primitiella unicornis* (Ulrich).
 1. Exterior of a right valve; X33. UMPC 9210
2. *Primitiella unicornis* (Ulrich).
 2. Exterior of a right valve; X33. UMPC 9211
3. *Primitiella unicornis* (Ulrich).
 3. Dorsal view of a right valve; X33. UMPC 9212
4. *Primitiella unicornis* (Ulrich).
 4. Exterior of a left valve; X33. UMPC 9213
5. *Primitiella unicornis* (Ulrich).
 5. Exterior of a left valve; X23. UMPC 9214
6. *Primitiella unicornis* (Ulrich).
 6. Exterior of a left valve; X23. UMPC 9215
7. *Primitiella unicornis* (Ulrich).
 7. Exterior of a right valve; X23. UMPC 9216
8. *Primitiella unicornis* (Ulrich).
 8. Ventral view of a right valve; X33. UMPC 9217
9. *Primitiella unicornis* (Ulrich).
 9. Ventral view of a right valve; X33. UMPC 9218
10. *Primitiella unicornis* (Ulrich).
 10. Ventral view of a left valve; X33. UMPC 9219
11. *Primitia spinata* Burr and Swain, n. sp.
 11. Exterior of a right valve; X23. UMPC 9220
12. *Macrocyproides trentonensis* (Ulrich).
 12. Exterior of a right valve; X23. UMPC 9221
13. *Primitia spinata* Burr and Swain, n. sp.
 13. Exterior of a left valve; X23. UMPC 9222
14. *Leperditella* ? sp.
 14. Exterior of a right (?) valve; X23. UMPC 9223
15. *Macrocyproides trentonensis* (Ulrich).
 15. Exterior of a right valve; X23. UMPC 9224
16. *Primitia spinata* Burr and Swain, n. sp.
 16. Exterior of a right valve; X23. UMPC 9225
17. *Primitia spinata* Burr and Swain, n. sp.
 - 17a. Exterior of a right valve; X23. UMPC 9226
 - 17b. Dorsal view of a right valve; X23. UMPC 9227
18. *Primitia mammata* Ulrich.
 18. Exterior of a right valve; X23. UMPC 9228
19. *Primitia spinata* Burr and Swain, n. sp.
 19. Interior of a right valve; X23. UMPC 9229
20. *Primitia spinata* Burr and Swain, n. sp.
 20. Exterior of a right valve; X23. UMPC 9230
21. *Primitia spinata* Burr and Swain, n. sp.
 21. Exterior of a left valve; X23. UMPC 9231
22. *Primitia spinata* Burr and Swain, n. sp.
 22. Exterior of a right valve; X23. UMPC 9232
23. *Primitia spinata* Burr and Swain, n. sp.
 - 23a. Exterior of a right valve; X23. UMPC 9233
 - 23b. Dorsal view of a right valve; X23. UMPC 9234
24. *Primitia spinata* Burr and Swain, n. sp.
 24. Exterior of a right valve; X23. UMPC 9235
25. *Primitia tumidula* Ulrich.
 25. Exterior of a right valve; X23. UMPC 9236
26. *Primitia tumidula* Ulrich.
 26. Interior of a right valve; X23. UMPC 9237

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Figures

27. *Primitia tumidula* Ulrich
27. Exterior of a left valve; X23. UMPC 9238
28. *Primitia tumidula* Ulrich.
28. Exterior of a left valve; X23. UMPC 9239
29. *Primitia tumidula* Ulrich.
29a. Exterior of a left valve; X23. UMPC 9240
29b. Dorsal view of a left valve; X23. UMPC 9241
30. *Primitia tumidula* Ulrich.
30a. Exterior of a right valve; X23. UMPC 9242
30b. Ventral view of a right valve; X23. UMPC 9243
31. *Primitia tumidula* Ulrich.
31. Exterior of a left valve; X23. UMPC 9244
32. *Primitia tumidula* Ulrich.
32. Exterior of a left valve; X23. UMPC 9245
33. *Macrocyproides trentonensis* (Ulrich)
33. Interior of a left valve; X33. UMPC 9246
34. *Primitia tumidula* Ulrich.
34. Exterior of a right valve; X23. UMPC 9247

Figures 1-10 from depauperate zone of Maquoketa Formation, Bellevue State Park, Iowa.
Figures 11-32, 34 from Dubuque Formation, Wubbles Ravine, Fillmore County, Minnesota.
Figure 33 from Decorah Shale 5.5-7.5 feet above base, Cannon Falls, Minnesota.

